Heliyon 7 (2021) e07780

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Evaluation of sanitary risks associated with the consumption of street food in the city of Yaoundé (Cameroon): case of braised fish from Mvog-Ada, Ngoa Ekélé, Simbock, Ahala and Olézoa

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ARTICLE INFO

Keywords:
Street food
Braised fish
Carp
Good Hygiene and Manufacturing Practices
Microbiological quality

ABSTRACT

An investigation was performed to evaluate the braising fish practices and the level of hygiene of the sellers in the city of Yaoundé. Thereafter, five braised carp samples were collected from each of the five selected sites and their microbiological quality assessed. The results showed that all the braising sites do not satisfy the Good Hygiene and Manufacturing Practices. Pathogenic microorganisms such as coliforms (2.17 ± 0.08 to 5.94 ± 0.38 Log cfu/g), *E. coli* (3.71 ± 0.20 to 6.21 ± 0.48 Log cfu/g) and *Salmonella* spp. were found in braised carp samples at levels higher than the microbiological criteria of the European Commission which are 1, 1 and 0 Log cfu/g, respectively. Spoilage microorganisms such as yeasts (2.39 ± 0.18 to 3.09 ± 0.23 Log cfu/g) and moulds (2.30 ± 0.10 to 2.92 ± 0.18 Log cfu/g) as well as spore-forming (3.02 ± 0.18 to 4.86 ± 0.35 Log cfu/g) and anaerobic (3.74 ± 0.28 to 4.52 ± 0.38 Log cfu/g) bacteria were also found at higher levels. The study highlights the poor microbiological quality of braised fish sold in the city of Yaoundé.

1. Introduction

Street food can be defined as any ready to eat food or beverage sold especially in streets and other similar places and sometimes prepared in outdoor public spaces by vendors and handlers or cooks on the move (hawkers) or stationary, from an outlet with or without indoor space to accommodate consumers (Marras et al., 2016). They are intended for immediate consumption or at a later time without further processing or preparation. Street food represents an important part of the daily consumed food in urban areas by poor and low-income people living in Africa (FAO, 2007). A study conducted by the Food and Agriculture Organization (FAO, 2007) revealed that over 2.5 billion people eat street food every day. For a large number of persons, the main reasons are their low prices, their accessibility and availability, as well as their diversity (Oranusi and Braide, 2012; Tavonga, 2014). In Africa, street food was mostly developed due to many factors such as low incomes, migration to the cities, the demographic growth in town associated with urbanization, the high cost of affordable, tasty and nutritious meals sold close to workplaces, and long commuting distances between the workplace and home (Adjrah et al., 2013; Sambo, 2014; Marras et al., 2016). However, many insalubrity factors can be observed in the preparation and selling sites of street food. These factors include the poor arrangement of the site, improper food handling, the poor quality of water, the presence of rodents like flies and rats/cockroaches, the proximity of selling sites to garbage containers and others (Nguendo Yongsi, 2014; Okojie and Isah, 2014; Alamo-Tonelada et al., 2018). These insalubrity factors have as consequence the distribution of food with poor microbiological quality responsible for foodborne infections (Adu-Gyamf and Nketsia-Tabiri, 2007). Cases of gastroenteritis due to consumption of street food were reported in the literature. Meng and Doyle (2002) and Adu-Gyamf and Nketsia-Tabiri (2007) highlighted street food as vehicles of bacterial agents responsible for food safety problems, especially gastroenteritis. Outbreaks of diarrhea diseases in developing countries linked to consumption of street food were noticed by Mensah et al. (2002) and

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https://doi.org/10.1016/j.heliyon.2021.e07780
Received 24 November 2020; Received in revised form 24 February 2021; Accepted 10 August 2021

Tambekar et al. (2009). In a study conducted by Mohammadou (2016), they noticed digestive troubles and diarrhea in primary school children in the city of Yaoundé, Cameroon due to the consumption of street food. The main incriminated germs in that food poisoning outbreak were *Staphylococcus aureus*, *Salmonella* sp., *E. coli*, and *Bacillus cereus*. Nguendo Yongsi (2018) also pointed out the low microbiological quality of street food/beverage samples in the city of Yaoundé, Cameroon and suggested that their consumption may present a risk of foodborne disease.

In Cameroon, the most sold and consumed street foods are bread, fritters, chips, fruit juices, cassava derived products, peanut products, roasted beef and braised fish (Edima et al., 2014). Braised fish is one of the most popular and widely consumed food in the whole population due to its highly appreciated organoleptic quality, and its nutritional value. It is food obtained after seasoning with a spicy soup and then braised on charcoal fire. The braising process varies from one region to another and the species of braised fish depends on its availability and the consumer's preferences. Hence, the braising fish process is traditional and there is not a standard process. Due to its composition (nutrients and water contents), braised fish is a favorable environment for microbial growth (Danikuu et al., 2015) and is thus a highly perishable food. Besides, braised fish is generally sold near street corners and is exposed to dust, microorganisms and insects, and this sometimes in a poor sanitary environment. This alters its quality and constitutes a major risk of contamination leading to foodborne toxi-infections. Based on this, braised fish like other street foods is potentially a large public health concern particularly with the increase in out-of-home feeding (Danikuu et al., 2015; Alamo-Tonelada et al., 2018). Previous works carried out on street braised fish sold in the city of Douala, Cameroon showed the poor microbiological quality of that food (Nkah, 2017). Another study carried out by Achondi (2018) on the contamination factors of braised mackerels sold in some modern braising fish sites in the city of Douala reported that the level of hygiene is insufficient to guarantee a good microbiological quality of the finished product. However, there are few studies carried out on braised fish in Cameroon and most of these studies were performed in the city of Douala. Therefore, it appears interesting to expand the study to another Cameroonian city like Yaoundé. Nowadays, to satisfy the increasing consumers' demands regarding the sanitary quality of braised fish, there is an emergence of modern braising fish points. Modern braising fish points are places developed and well-adjusted, where it is possible to find at least 4 braised fish vendors with chairs and tables fit up for customers. Hence, to contribute to the improvement of the sanitary quality of braised fish sold in Cameroon, the present research was carried out based on the following objectives: 1) to diagnose the braised fish production system in the city of Yaoundé, Cameroon and 2), to assess the microbiological quality of braised fish sold in the city of Yaoundé.

2. Materials and methods

2.1. Study area

The study was conducted in the city of Yaoundé, the Center region of Cameroon from March to July 2019. A preliminary investigation was performed to identify the different modern braising points where braised fish is sold every day.

2.2. Survey

An investigation was performed to diagnose the braised fish production system of the vendors in the city of Yaoundé. Sampling was performed in modern braising fish points in the city of Yaoundé using the convenient sampling method. A semi-structured questionnaire was used. The questionnaire was pre-tested with some of the braised fish operators who were not included as respondents of the study. Each braised fish operator was interviewed at their working place. The study was carried out according to the guidelines for human experimental models as stated by the Cameroon Ministry of Public Health. Besides, the ethical and administrative clearances for this study were issued by the institutional ethic committee of the University of Douala-Cameroon (CEI-UDo) under reference number CEI-UDo/692/11/2016/T of 24th November 2016. Only volunteer *braised fish* vendors who signed an informed consent form for their participation were enrolled.

A total of 30 vendors of modern braising fish structures responded to the questionnaire. The questionnaire administered sought information concerning the respondents' socio-demographic profile (such as their gender, age, marital status, educational background…) and respondents' braising fish practices.

To evaluate the level of hygiene of the different braised fish operators, an observation checklist established following the guide of Good Hygiene and Manufacturing Practices was used (Bonne et al., 2005). This observation was conducted on persons who work on each fish braising site as well as on the vending sites in order to assess the environmental sanitation. The checklist contained close-ended questions about the 5-M (Environment, Manpower, Material, Method, Raw material). The 5-M method was used to describe the braising activity (preparation and the selling processes) as it naturally occurs in the environment through observation and record in a checklist. The checklist was structured in five groups corresponding to the 5-M (Environment, Manpower, Material, Method, Raw material). Environment refers to the location and surroundings of the braising site in comparison with reference for such activity. Manpower refers to the behavior of people involved in the braising process in comparison with the reference. Materials refer to the braising equipment which must be used following the references and intended use for which it is destined. Methods refer to the braising process, the cleaning conditions, the waste management and storage, the identification and traceability policies. Raw materials refer to the collection, transportation and storage of the food matrix that will be transformed following the reference methods. It includes fish and ingredients used to season fish as well as to prepare the accompanying spicy soup. Globally, observations were recorded as either satisfactory, partially satisfactory or non-satisfactory, concerning Good Hygiene and Manufacturing Practices (Bonne et al., 2005).

2.3. Microbiological analysis of braised fish samples

2.3.1. Sampling procedure

Braised fish samples were collected from the volunteer vendors responding to the survey. The most braised fish species was chosen for microbiological analysis. In each site, a braised fish vendor was randomly chosen and five braised fish of approximately 500 g each, together with its seasoning ingredients were bought. Samples were labelled, placed into an icebox and transported directly to the laboratory for microbiological analyses.

2.3.2. Sample processing

Samples were processed following the method ISO 6887-2 (2017). For microbiological analysis, 500 g of each sample (braised fish + seasoning ingredients) were aseptically weighed, crushed and 25 g were introduced into a sterile Erlenmeyer containing 225 mL of sterile peptone water (LiofilChem, Italy). The mixture was homogenized and left at room temperature for 30 min to allow microbial resuscitation. Thereafter, serial decimal dilutions (10^{-1} to 10^{-6}) of the suspension were carried out. These different dilutions were used to inoculate Petri dishes for cell enumeration.

2.3.3. Inoculation and culture conditions

The pour plate method was used for the enumeration of the total aerobic mesophilic counts as well as the total anaerobic mesophilic counts (ISO 4833-1, 2013). In this method, 1 mL of each dilution was introduced into Petri dishes followed by the addition of 20 mL of sterile Plate Count Agar (PCA, LiofilChem, Italy). The plates were homogenized and left for gelification at room temperature. Then the plates were incubated aerobically at 37 °C for 48 h for the total aerobic mesophilic

counts and anaerobically in the same conditions for the total anaerobic mesophilic counts. For the total spore count, the different dilutions were heated at 80 °C for 10 min, then cooled rapidly on ice, and 1 mL of each dilution was introduced into Petri dishes. 20 mL of sterile PCA were added and the plates were homogenized, left for gelification at room temperature and incubated at 37 °C for 48 h (Watterson et al., 2014).

Spread-plate method on specific culture media was used for the enumeration of total coliforms, fecal coliforms, *E. coli*, *Staphylococcus* spp., yeasts and moulds. Total coliforms, fecal coliforms and *E. coli* counts of the different samples were assessed according to the protocol of the norm ISO 4832 (2006). 0.1 mL of the different dilutions was surface inoculated on Mac Conkey agar (LiofilChem, Italy) followed by incubation of Petri dishes for 48 h at 37 °C and 44 °C, respectively for total coliforms and fecal coliforms. Regarding *E. coli*, 0.1 mL of the different dilutions was surface inoculated on Eosin Methylene Blue agar (EMB, LiofilChem, Italy) and the plates were incubated at 44 °C for 48 h. *Staphylococcus* spp. counts was determined by spreading 0.1 mL of the different dilutions on Mannitol Salt Agar (MSA, LiofilChem, Italy) followed by incubation of Petri dishes at 37 °C for 24–48 h (ISO 6888-2, 1999). For yeasts and moulds, the normalized method ISO 21527-1 (2008) was used. Briefly, 0.1 mL of the different dilutions was spread at the surface of Sabouraud agar supplemented with chloramphenicol (LiofilChem, Italy). The Petri dishes were incubated at 25 °C for 72 h for the enumeration of yeasts and for 120 h for moulds enumeration.

The presence of *Salmonella* spp. in the samples was assessed following the normalized method ISO 6579-1 (2017). Briefly, the initial suspension of braised fish in sterile peptone water was incubated for 16 h at 37 °C. 1 mL of the pre-enrichment broth culture was introduced into sterile test tubes containing 10 mL of Selenite Cystine broth (LiofilChem, Italy). The tubes were incubated for 24 h at 37 °C and a loopful of each enrichment broth culture was streaked onto Salmonella Shigella agar (SS, LiofilChem, Italy) Petri dishes. The dishes were incubated for 24 h at 37 °C and colorless colonies with the black center considered as *Salmonella* spp.

2.3.4. Colony counts

After incubation, colonies appearing on the Petri dishes were counted. Only Petri dishes containing colonies between 30 and 300 were considered. All experiments were carried out in triplicate and the mean counts were calculated. The final results were expressed as colony-forming units per gram of braised fish.

2.4. Statistical analysis

The data gathered from the survey (questionnaire) were analyzed using Sphinx V5 Lexica (Sphinx Plus^2 - Edition Lexica-V5, Chavanod, France). Descriptive statistics through the percentage and frequency count method were used. Information obtained from the checklist was used to calculate the percentage of satisfaction of each of the 5M assessed. The statistical software Statgraphic centurion XV version 16.1.18 (StatPoint Technologies, Inc., Virginia, USA) was used to perform Analysis of variance on the microbiological data and the Duncan Multiple Range test was performed to compare means at $p < 0.05$. Correlation analysis was performed between the 5M parameters and the microbial loads of braised fish using SPSS version 20.0 (Armonk, IBM Corporation, New York, USA).

3. Results

3.1. Socio-demographic profile of the studied population

The 30 braised fish operators involved in the present study were distributed in 5 modern braising fish sites in the city of Yaoundé. These sites were Mvog-Ada, Ngoa Ekélé, Simbock, Ahala and Olézoa. In these sites, braising fish was exclusively carried out by women (100 %). These women were housewives (100 %) and 3.3 % had a primary level of education, 80 % a secondary level, 13.3 % a university level while 3.3 % had no formal education (Figure 1A). 70 % of these women aged were between 30 and 50 years and 30 % between 19 and 29 years (Figure 1B).

3.2. Braising fish practices of the studied population

Results gathered from the survey showed that braising fish was a daily activity carried out in the different sites. 37.17 % of braised fish vendors included in this study were from Ngoa Ekélé and 34.28 % were from Mvog-Ada (Figure 2A). The others were from Ahala (11.34 %), Simbock (11.43 %) and Olézoa (5.71 %). As shown in Figure 2B, the braised fish vendors were trained by other braised fish vendors (43.3 %). Some of them were taught in hostelry schools (30 %) while others acquired their knowledge as assistant of braised fish vendors called masters (26.7 %). They were working as an employee for these masters. Fishes were mainly bought at fish shops (50 %) and markets (46.7 %). These fishes were transported to braising points in bowls (40 %), plastic packages (40 %), cartons (16.7 %) and basins (3.3 %). During transportation, the fishes were not always held at low temperature for a long period. As presented in Table 1, carp was the most braised fish species (96.7 %). The choice of this fish species is due to consumer's preference and availability. Based on the data collected from the different braised fish vendors involved in the present study, a general flow diagram of braising fish process showing the different unitary operations was drawn (Figure 3).

Raw fishes were often stored at home at room temperature. At the selling time, they were transported to the selling sites where a well-organized chain was set up. In that chain, there were persons responsible for cleaning, braising and service. Fish cleaning consisted of scaling and evisceration. After cleaning, the next step was washing. In all cases running water at that unit operation was not available at vending sites. Table 1 shows that water used for cleaning was collected in containers mainly from boreholes (43.3 %) and tap (76.7 %). Once fishes were prepared, they were drained and kept at room temperature into a basin. From the basin, they were collected and introduced into another small basin containing the brining solution by 96.7 % of the vendors (Table 1). The salt concentration of the brine was at the proportion required to salt fish in order to improve its taste. The objectives of vendors were not to reduce the water content of fish and avoid its spoilage. The duration of the brining process was approximately 5 min. For few proportions of vendors (3.7 %), fish were directly salted with NaCl crystals and braised (Table 1). In some cases, fishes were also spiced (33.3 %) and left at room temperature for approximately 5 min. The braising fish duration which depends on the species and the size of fish varied from 10 to 30 min and more for other operators. Braised fish were sold with an accompanying spicy soup mainly composed of onions (83.3 %), white pepper (83.3 %), *Monodora myristicia* commonly called African nutmeg (83.3 %) and garlic (76.7 %). These spices were cleaned, ground and seasoned with salt (73.3 %) and sodium glutamate (73.3 %). Then the mixture was cooked and stored in small pots (70 %) or plastic jars (36.7 %). Furthermore, braised fish was served to customers in dishes accompanied with potato or plantain chips, and in some cases, with “bobolo” a cassava derived product. The duration between fish braising and its consumption was not determined since it varied from one selling day to another. According to vendors, during affluence periods the product spent 1–45 min before being sold. Sometimes, it may spend 4–7 h. However, in all cases, the products were heated again for few minutes before being served to consumers.

Leftovers braised fishes were stored refrigerated (26.7 %) or frozen (6.7 %) to be resale the next day if they were not eaten by the vendors themselves or taken back to their families. The ones that are intended for consumption by vendor families were kept at room temperature. Upon arrival at home, these leftovers braised fishes were mostly consumed without any heat treatment. This observation suggests that there are at high risk of foodborne diseases. Leftovers braised fishes were preserved for 1 or 2 days refrigerated or frozen. Up to that period, vendors declared that braised fish lost its taste and flavor and could not be sold. However, in some sites like Ahala, there was no leftover because customers could

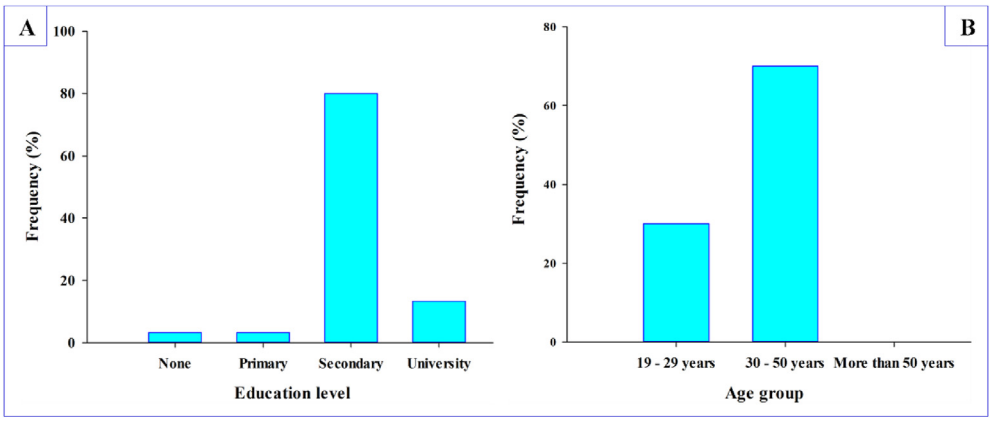

Figure 1. Distribution of the studied population according to their education level (A) and their age group (B).

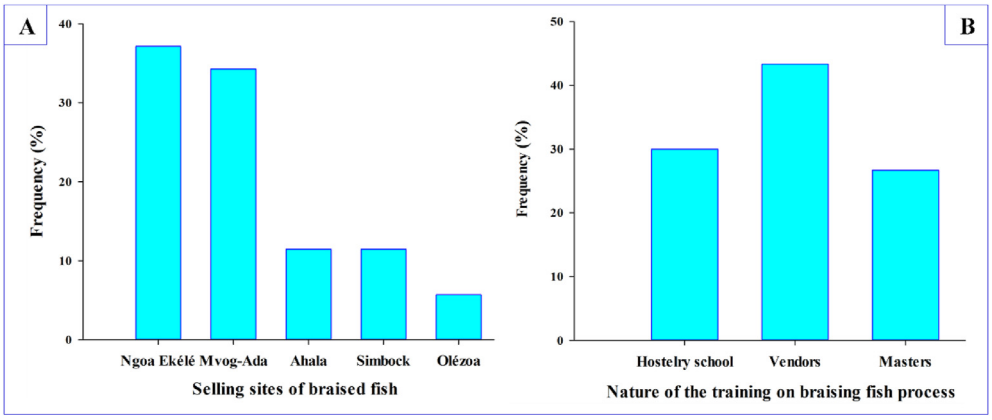

Figure 2. Braising fish practices: selling sites of braised fish (A) and nature of the training on braising fish process (B).

choose live fish from an aquarium to be braised. The main difficulties faced by the braised fish operators were competition (33.3 %), high cost of fish as well as ingredients used for seasoning (13.3 %) and insecurity because, they mostly end their commercial activities late in the night (3.3 %).

3.3. Fish braising conditions of the studied population

Table 2 summarizes the level of hygiene of the braising fish vendors and their surrounding environment assessed through the 5-M method. Globally, the satisfaction levels were very low independently of the sites (0–16.66 %). In the Mvog-Ada site, the levels of satisfaction were 9.13 % for Environment, 8.07 % for Manpower, 9.52 % for Materials, 2.8 % for Method and null for raw materials. Most of the 5-M parameters assessed were either partially satisfying or non-satisfying with regards to Good Hygiene and Manufacturing Practices. Ahala and Olézoa were the worst sites as the levels of satisfaction of the 5-M parameters were null and void. In the site of Simbock, Manpower and Raw materials scored respectively 10.72 and 16.66 % of satisfaction while for the other M (Environment, Method, Materials), the levels of satisfaction were null. Apart from Manpower which scored 4.02 % of satisfaction in the site of Ngoa Ekélé, the rest of the parameters were null and void. The main reasons being the weak satisfaction levels of hygiene of the braised fish vendors as well as the sanitary conditions of their surrounding environment.

3.3.1. Environment

The level of satisfaction was null and void for some sites and weak for others. The walls and ground were dirty and un-washable. Garbage containing wastes were near the braising furnace and the bench. Wastewater was thrown on the ground surrounding the site. In some sites, the presence of flies, rats/cockroaches were noticed. In these conditions, the risks of cross-contamination might increase.

3.3.2. Manpower

Globally, it was observed that a healthy labour policy was absent in the different sites. The braised fish vendors had no health certificate and no personal protective equipment like aprons and headcovers. Employees with open injuries were not excluded from fish braising operations. On some sites, there was only one person who performed the fish cleaning, braising and customer services.

3.3.3. Materials

Generally, a weak level of satisfaction was recorded for materials in Mvog-Ada while for the rest of the sites, the scores were null and void. Utensils used to prepare and serve braised fish were cleaned into basins containing water and that water was not always changed. The knives used in raw fish preparation also served to turn fish during the braising process and cut onion deposited on braised fish served to customers. The same brush was used to collect the spicy soup and season fish before, during and after the braising process.

3.3.4. Method

Regarding the method, the level of satisfaction was null and void in some sites and weak in others. The main cause recorded in the different sites was the absence of standardized procedures. Braised fish vendors used their own experience to ensure the reproducibility of their products. The formulation of ingredients used to prepare the accompanying spicy soup varied from one producer to another.

Table 1. Some technologic parameters of the braising fish process in the city of Yaoundé.

Parameters		Frequency (%)
Species of fish commonly braised	Carp (*Cyprinus carpio*)	96.70
	Mackerel (*Scomber scombrus*)	86.70
	Tilapia (*Oreochromis niloticus*)	36.70
	Dicentrarchus labrax	56.70
	Arius heudolotii	30.00
Water source supply	Boreholes	43.30
	Tap water	76.70
	Wells and springs	0.00
Pre-seasoning before braising	Pickling into brine	96.70
	Spicing	33.30
	Salting with NaCl crystal	3.30
	None	0.00
Spices used for seasoning	Onion	83.33
	White pepper	83.33
	African nutmeg (*Monodora myristica*)	83.33
	Garlic	76.70
	Aridan (*Tetrapleura tetraptera*)	63.33
	Leek	60.00
	Manketti nut or Zambezi almond (*Rhicinodendron heudelotii*)	50.00
	Country onion	30.00
	Celery	23.33
	Sweet pepper	10.00
Conditioning of the spicy soup	Pot	70.00
	Plastic boxes	30.00
Braising duration	10 min	23.30
	15 min	90.00
	20 min	70.00
	30 min	33.33
	>30 min	23.33
Preservation temperature of leftovers braised fish	Refrigerator	26.70
	Freezer	6.70
Duration of the preservation of leftovers braised fish	Not conserved	20.00
	1–2 days	16.70
	>2 days	0.00

3.3.5. Raw materials

There was no control procedure for raw materials. The only control was performed on raw fish at purchasing was by unaided eyes. Spices bought from markets were not sorted and sometimes not properly washed before being used. Only onion, garlic and leek were superficially washed. The cleaned raw fish were stored at room temperature before being braised.

3.4. Microbiological quality of braised fish

Table 3 presents the mean microbial load (Log cfu/g) obtained per site. It comes from Table 3 that the total aerobic count obtained ranged significantly ($p < 0.05$) from 4.01 ± 0.31 (at Simbock) to 6.66 ± 0.48 Log cfu/g (at Ahala). The most contaminated samples were from Ahala and Mvog-Ada while the least ones were from Simbock, Olézoa and Ngoa Ekélé.

Microorganisms that indicated fecal contamination of the samples were assessed. Total and fecal coliforms were found at loads ranging respectively from 2.17 ± 0.08 (Ngoa Ekélé) to 5.94 ± 0.38 Log cfu/g (Mvog-Ada) and from 3.63 ± 0.23 (Ngoa Ekélé) to 6.11 ± 0.40 Log cfu/g (Mvog-Ada) in samples collected. Total and fecal coliforms were absent in the Ahala site.

E. coli, the major indicator of fecal contamination was absent in samples from Ahala, and present in the samples from the other sites with a load ranging significantly ($p < 0.05$) from 3.71 ± 0.20 (Simbock) to 6.21 ± 0.48 Log ufc/g (Mvog-Ada). Correlation analysis showed that this parameter was positively and significantly associated to materials used by vendors ($r = 0.995$, $p = 0.001$) and to the handling method ($r = 0.995$, $p = 0.001$). *Salmonella* spp., another index germ was screened for its presence in the different samples. It comes from Table 3 that *Salmonella* spp. the germ index of the safety quality of fish was present in all braised carp samples. Microorganisms that indicated the level of hygiene of the braised fish operators were assessed. The results showed that *Staphylococcus* spp. were present in all the samples with loads between 3.33 ± 0.18 (Ngoa Ekélé) and 6.47 ± 0.00 Log cfu/g (Mvog-Ada). These loads were significantly ($p < 0.05$) different from one site to another. *Staphylococcus* spp. count of the samples was positively correlated to the non-respect of the environment ($r = 0.999$, $p = 0.001$), the poor quality of materials used in the site ($r = 0.997$, $p = 0.001$) and methods applied by braised fish vendors ($r = 0.995$, $p = 0.001$).

Some microorganisms can resist to heat treatment due to their ability to sporulate. The total spore count of the samples was assessed and Table 3 presents the results. The sporulated flora was found in all samples at loads varying significantly ($p < 0.05$) from 3.02 ± 0.18 (Simbock) to 4.86 ± 0.35 Log cfu/g (Mvog-Ada). Among the sporulated flora, moulds were analyzed and results obtained show that they were present in samples from Simbock, Mvog-Ada and Ngoa Ekélé with respective loads of 2.30 ± 0.10, 2.74 ± 0.18 and 2.92 ± 0.18 Log cfu/g.

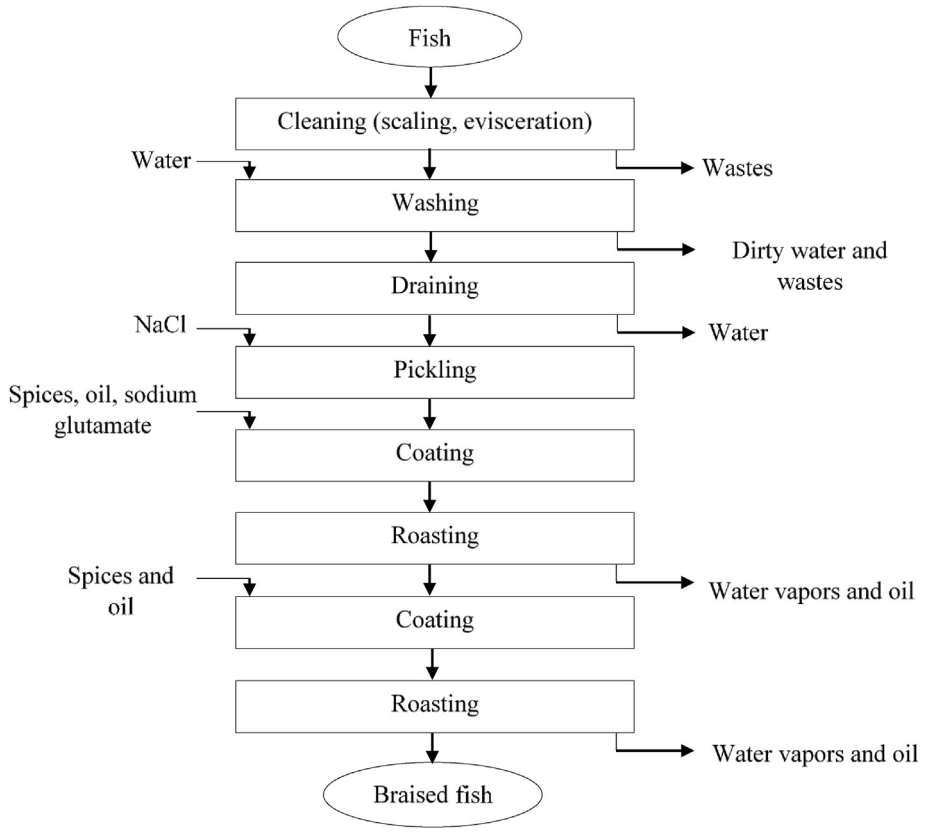

Figure 3. General flow diagram of braising fish process in the city of Yaoundé.

Table 2. Level of satisfaction of the 5-M in the main modern braising fish sites in the city of Yaoundé.

Braising fish sites	Status	Level of satisfaction (%)				
		Environment	Manpower	Material	Method	Raw material
Mvog-Ada	Satisfying	9.13	8.07	9.52	2.80	0.00
	Non-Satisfying	26.98	51.86	22.02	21.90	50.00
	Partially Satisfying	63.89	40.08	66.23	75.71	50.00
Ngoa Ekélé	Satisfying	0.00	4.02	0.00	0.00	0.00
	Non-Satisfying	58.40	63.05	53.85	20.25	78.20
	Partially Satisfying	41.31	31.9	46.15	79.74	22.07
Simbock	Satisfying	0.00	10.72	0.00	0.00	16.66
	Non-Satisfying	24.99	32.14	25.00	16.66	50.00
	Partially Satisfying	74.99	57.14	75.00	83.33	33.33
Ahala	Satisfying	0.00	0.00	0.00	0.00	0.00
	Non-Satisfying	66.66	66.66	66.66	33.33	50.00
	Partially Satisfying	33.33	33.33	33.33	66.66	50.00
Olézoa	Satisfying	0.00	0.00	0.00	0.00	0.00
	Non-Satisfying	22.22	43.65	16.66	20.00	50.00
	Partially Satisfying	77.77	56.35	83.33	80.00	50.00

Spoilage microorganisms such as yeasts were found in the different samples analyzed except those coming from Olézoa. Their loads varied significantly ($p < 0.05$) from 52.39 ± 0.18 (Mvog-Ada) to 3.09 ± 0.23 Log cfu/g (Ahala). Anaerobic total count was also assessed in this study and results gathered showed that they were present in all samples with loads ranging significantly ($p < 0.05$) from 3.74 ± 0.28 (Ahala) to 4.52 ± 0.38 Log cfu/g (Simbock).

Generally, statistical analysis showed that the most contaminated samples of braised carps were those collected from the Mvog-Ada site while the least contaminated samples were those from Ahala.

4. Discussion

Street vended food represent a growing sector of activities in several cities of developing countries. However, these products are not always of good quality (Tambekar et al., 2009; Nguendo Yongsi, 2018). In order to valorize street foods, the practice of food hygiene which makes it possible to obtain healthy and valid food was set as one of the main alternatives. In a study performed on skewered meat sold in N'Djamena-Chad, Tidjani et al. (2013) demonstrated the suitability and efficiency of the 5-M method to record information about the hygiene practices in the meat

Table 3. Mean microbial loads (Log cfu/g) of the different samples of braised carp sold in the modern braising fish sites in the city of Yaoundé.

Parameters	Braising fish sites					Norms
	Mvog-Ada	Olézoa	Ngoa Ekélé	Simbock	Ahala	
Total aerobic mesophilic count	6.32 ± 0.41^{b}	4.32 ± 0.32^{a}	4.38 ± 0.38^{a}	4.01 ± 0.31^{a}	6.66 ± 0.48^{b}	6
Staphylococcus spp.	6.47 ± 0.00^{e}	4.01 ± 0.30^{c}	3.33 ± 0.18^{a}	4.56 ± 0.24^{d}	3.86 ± 0.18^{b}	2
Total coliforms	5.94 ± 0.38^{e}	4.81 ± 0.28^{d}	2.17 ± 0.08^{b}	3.85 ± 0.26^{c}	0.00 ± 0.00^{a}	1
Fecal coliforms	6.11 ± 0.40^{d}	4.75 ± 0.34^{c}	3.63 ± 0.23^{b}	3.74 ± 0.27^{b}	0.00 ± 0.00^{a}	1
E. coli	6.21 ± 0.48^{e}	5.25 ± 0.40^{d}	4.50 ± 0.34^{c}	3.71 ± 0.20^{b}	0.00 ± 0.00^{a}	1
Yeasts	2.69 ± 0.18^{c}	0.00 ± 0.00^{a}	3.09 ± 0.23^{d}	2.39 ± 0.18^{b}	2.84 ± 0.21^{c}	2
Moulds	2.74 ± 0.18^{c}	0.00 ± 0.00^{a}	2.92 ± 0.18^{c}	2.30 ± 0.10^{b}	0.00 ± 0.00^{a}	2
Total spore count	4.86 ± 0.35^{d}	4.21 ± 0.28^{c}	3.35 ± 0.15^{b}	3.02 ± 0.18^{a}	3.30 ± 0.00^{b}	
Total anaerobic count	4.47 ± 0.20^{b}	4.31 ± 0.28^{b}	3.79 ± 0.26^{a}	4.52 ± 0.38^{b}	3.74 ± 0.28^{a}	
Salmonella spp.	+	+	+	+	+	-

+ = present; - = absent; Values with same superscript letters on a same raw are not significantly different at $p < 0.05$, Norms = Microbiological criteria of fish products established by European Commission Regulation (EC, 2005).

establishment. The 5-M method was applied in this study and it has enabled a methodic assessment of the level of hygiene of the braised fish vendors. The braising fish practices and conditions observed in the different sites were not adequate in respect to the good hygiene and manufacturing practices as reported by Bonne et al. (2005). This lack of good hygiene and food preparation practices by the vendors might arise from their low education level (80 %). A positive influence of education on the vendors' level of knowledge of food safety and thus the respect of good hygiene practices was highlighted by Rheinländer et al. (2008). Dun-Dery and Addo (2016) also pointed out that vendors aware of food hygiene, respected good hygiene practices. Singh and Thakur (2018) reported that street food vendors with elementary education level should undergo basic training on food hygiene and suggested the need for health education to improve their knowledge on hygiene practices and food safety. The observations made in this study suggested a hypothesis of the presence of microorganisms in braised fish sold in the different sites. The total aerobic count obtained in braised fish samples from Simbock, Olézoa and Ngoa Ekélé were of good microbiological quality according to the microbiological criteria of the European Union which states that the total aerobic count must be less than 6 Log cfu/g (EC, 2005). However, the total aerobic count of braised fish samples from Ahala and Mvog-Ada were higher than the values specified by the microbiological criteria of the European Commission (6 Log cfu/g) (EC, 2005), thus, suggesting a poor microbiological quality of these foods and a potential health risk. The total aerobic count was also noticed in the literature by Cenci-Goga et al. (2005) as a good indicator of food safety. The high contamination observed in this study could result from the poor sanitary quality of the raw materials. In fact, 50 and 78.20 % of raw materials were non-satisfying in these two sites. Moreover, the insufficiency of hygiene during the braising process and the high cross-contamination possibilities observed in these sites could also justify the high contamination. Indeed, during the braising process, raw fish is generally daubed on the grill with spicy soup and refined oil using a brush. However, the same brush without being cleaned is again introduced in the spicy soup to daub other braised fish. In these conditions, cross-contamination might occur leading to the contamination of the spicy soup with pathogens from the raw fish and the contamination of braised fish through the use of a contaminated spicy soup.

The duration of braised fish in air exposed at room temperature before being sold (1 min–7 h) could favor the proliferation of microorganisms. In fact, once fish was braised, it was left on a part of grill which is not heated, or left uncovered on the bench for potential sale up to 7 h in high ambient temperatures, ideal conditions that favor microbial proliferation. A reheating for few minutes applied to these previously cooked fish before being served to consumers later in the day might not be sufficient to eliminate pathogens. Furthermore, ingredients such as carrots, onions, and celery added to braised fish during service to customers could be a source of contamination if their preparation and storage conditions were considered (Beuchat, 2002). A total aerobic count higher than the norm was also reported by Nkah (2017) with braised mackerels sold in the city of Douala, Cameroon.

Concerning *Staphylococcus* spp., its presence in the different samples analyzed at levels higher than 2 Log cfu/g as recommended by the microbiological criteria of the European Commission (EC, 2005) suggests poor hygienic practices of the braising operators. It was observed during the investigation that, in some sites, the same operator braised fish, discussed with customers, received money and served customers. Moreover, the presence of *Staphylococcus* spp. in the braised fish samples was attributed to the poor sanitary environment, the materials used by vendors and the braised fish handling methods as demonstrated in the present study. Food handlers were noticed as the most common mode of transmission of *Staphylococcus* spp. by Bezirtzoglou et al. (2000) and Alfred et al. (2019). Moreover, braised fish operators with open wounds, dust that crumble on fish during the braised fish exposition, saliva emitted during the discussion with customers, and sweat derived from perspiration could also explain the contamination observed in this study. Burt et al. (2003) established that *Staphylococcus* spp. contamination of street food could result from man's respiratory passages, skin and superficial wounds which are its common sources. Nkah (2017) and Achondi (2018) also pointed out high contamination with *Staphylococcus* spp. (loads ranging from 3 to 5 Log cfu/g) of braised mackerels sold in some quarters of the city of Douala. In other studies conducted in the city of Yaoundé, Nguendo Yongsi (2014) pointed out the low personal hygiene of a majority of street-food vendors and Nguendo Yongsi (2018) noticed the low microbiological quality street food/beverage samples sold in three locations of that city.

According to consumer's reports, consumption of braised fish is sometimes associated with gastro-enteritidis. In this study, except Ahala, enterobacteria like total coliforms, fecal coliforms and *E. coli* were found in the braised carps collected from the other sites at levels higher than 1 Log cfu/g recommended by the norm (EC, 2005). According to the safety criteria of the European Commission Regulation (EC, 2005), *Salmonella* spp. another enterobacterium must be absent in 25 g of samples analyzed. In this study, *Salmonella* spp. were found in all braised carp samples. This suggests doubt about the safety status of the braised fish. The presence of these enterobacteria could be attributed to the non-respect of good hygiene and manufacturing practices at one or more stages of preparation or from the materials used. The poor quality of water used to clean the braising and service utensils, to reduce flame intensity during the braising process, and the use of the same utensils to handle raw fish as well as braised fish could therefore explain the contamination observed. Moreover, it was observed that these water containers (plastic cans of 20 L) were difficult to clean and consequently, represent a favorable environment to the growth of microorganisms such

as *E. coli* and *Salmonella*. Adjrah et al. (2013) highlighted a high level of contamination with coliforms of street food (ready-to-eat salads) in Lomé which resulted from a lack of hygienic practices. Nkah (2017) also indicated in their study on braised mackerels sold in some quarters of the city of Douala that coliforms and *Salmonella* spp. were present at levels higher than the norm. However, the results observed in this study is contrary to those of Achondi (2018) and Adjrah et al. (2013) who showed that *Salmonella* spp. were absent in street braised mackerels and ready-to-eat salads, respectively. In the literature, poor environmental, personal and food hygiene practices were also reported as being responsible for the high rate of foodborne illness in developing countries (Danikuu et al., 2015). The results observed in this study underline the potential of braised carp sold in the city of Yaoundé to induce foodborne diseases. Surprisingly, there are no reports of foodborne diseases incriminating braised fish despite its poor microbiological quality. The main reasons for the apparent lack of reporting of any foodborne illness are low awareness of food poisoning in general, poverty, self-medication and limited enforcement of food safety laws, as highlighted by Datta et al. (2012). As a result, the number of foodborne diseases is underestimated and the economic losses underestimated (Abayneh et al., 2014).

Yeasts and moulds were found in samples from Mvog-Ada, Ngoa Ekélé, Simbock and Ahala at a level higher than 2 Log cfu/g recommended by the microbiological criteria of the European Commission (EC, 2005). However, at Ahala braised fish were not exposed. On that site, customers chosen fish in an aquarium, from where it is directly captured and braised. The presence of spore-forming microorganisms in braised fish samples could result from contamination through exposition to dust which may harbor microbial spores (Rane, 2011; Alfred et al., 2019). Unpaid braised fishes were left for a longer duration at room temperature which is favorable to microbial growth. When these latter were finally sold, they were just reheated for a few moments and served to the customers. In these conditions, spore-forming microorganisms such as *Bacillus cereus* might be present in the braised fish and its consumption might lead to foodborne infection. Moreover, the consumption of these air-exposed braised fish later by the vendors or their families might lead to foodborne infection as the product was not heated before being eaten. The presence of spores in the braised carp samples also pointed out a pre- or post-contamination of these samples giving that these microorganisms may be able to resist to heat treatment. Regarding the pre-contamination, it is important to highlight that raw fishes were often stored at home at room temperature until the selling time. In these conditions, microbial proliferation can occur leading to the high load of spore-forming bacteria observed in braised carp samples. These results suggest the necessity to improve the construction of these modern braising fish sites and the use of transparent glass to protect the braised fish.

It was also observed that leftover braised fish at the end of the day and intended for resale the next day were mostly stored refrigerated (26.7 %). However, it is possible that the reheating process the next morning could stimulate germination of spores, which were in the leftover braised fish. Such germination followed by bacterial growth could result in toxin production with a risk of foodborne diseases (Jessberger et al., 2020).

Anaerobic microorganisms were found in all samples analyzed in the present study. This contamination with anaerobic microorganisms could be justified by the possible contamination of fish during the evisceration process. Anaerobic microorganisms such as *Clostridium* spp. are found in the fish gastrointestinal tract (Wang et al., 2018). Abdelsalam (2017) also reported that fish slime, gills and intestines were subjected to contamination with anaerobic bacteria such as *C. botulinum, C. perfringens* and *C. bifermentans,* or *Actinomyces* and *Eubacterium tarentallus.* Hence, this study pointed out the poor evisceration practices of braised fish vendors and also the inefficiency of the washing operation after evisceration. There are no reports on the anaerobic microflora of braised fish despite their high pathogenicity. Hence, it therefore appears interesting to study the profile of these anaerobic microorganisms in the leftovers braised fishes without any further heat treatment.

Globally, braised fish samples analyzed in this study were of poor microbiological quality. This observation is worrisome as it was shown that vendors family mostly consumed the leftovers braised fishes without any heat treatment. Indeed, the braising fish practice allows vendors who were mainly women and housewives to supplement their husbands' lower wages. A similar observation was noticed by Njaya (2014). Hence, vendors training and sensibilization on hygiene practices and food safety regulations should be emphasized.

5. Conclusion

The present study showed that the main braised and consumed fish species in the city of Yaoundé is carp. The fish braising practices and conditions are responsible for the contamination of braised fish samples sold in these sites. Pathogenic microorganisms such as coliforms, *Salmonella* spp., *Staphylococcus* spp. as well as spoilage microorganisms such as yeasts and moulds were found in braised carps sold in the city of Yaoundé at loads higher than the threshold values recommended by the European Commission. Thus, suggesting a non-satisfying safety and hygienic quality of these braised fishes. The most contaminated braised carp samples were those collected from the site Mvog-Ada. The limitations arising from this study were sampling and analyses of braised fish air-exposed for 7 h before being sold as well as the leftovers braised fish. The results of this study indicated that attention must be paid to this street vended food. The minimal quality of braised carp could hinder its opening to a significant part of the markets, reduce working time and increase sanitary costs. Therefore, urgent measures need to be taken by the government to educate braised fish sellers on good hygiene and manufacturing practices. In addition, prospective studies on the genomic identification of braised carp pathogens should be conducted to further characterise the risk. A mastery sanitary plan must be proposed to the braised fish operators, implemented and frequently evaluated.

Declarations

Author contribution statement

Stephanie Tchigui Manga Maffouo: Performed the experiments; Analyzed and interpreted the data.

Hippolyte Tene Mouafo: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

Raymond Simplice Mouokeu: Conceived and designed the experiments.

Linda Manet: Performed the experiments.

Alex Kamgain Tchuenchieu, Boris Noutsa Simo: Analyzed and interpreted the data.

Huguette Tchuitcheu Djeuachi: Conceived and designed the experiments; Wrote the paper.

Gabriel Nama Medoua, François Tchoumbougnang: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

Authors acknowledge the cooperation of the braised fish vendors who took part in this investigation. They also acknowledge the Director of the Institute of Medical Research and Medicinal Plant Studies for providing necessary facilities for the successful completion of this project.

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