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Eating to Live or Eating to Damage One's Health: Microbiological Risks Associated with Street-Vended Foods in a Subtropical Urban Setting (Yaoundé-Cameroon)

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Abstract

Background: The wide variety of foodborne diseases is the most important concern about food quality. It is known that enteric pathogens are not normal flora in the human intestine but transmitting through contamination of water and foods. During the past few years, streets of numerous urban settings have become an attraction to many customers who eat from street vendors selling raw, cooked and processed foods. While street foods are an important source of ready-to-eat nutritious, low-cost meals for the urban poor, the health risk posed by such foods may outweigh their benefits.

Objective: In the present article we evaluate the microbial quality of streets-vended foods in the Yaoundé metropolis in order to gain an understanding on the safety of these street vended foods.

Methods: A cross-sectional study was conducted in different streets and open places samples obtained from three different locations in Yaoundé to determine the microbial quality of foods/beverages on sale. A total of 50 foods samples were randomly collected from a variety of mobile and stable vendors. Standard microbiological methods were used to trace the presence of organisms and opportunistic pathogens indicative of fecal and non- fecal contamination.

Results: The microbiological contamination levels of aerobic mesophilic bacteria ranged from 1.71 to 3.71*105cfu/g, while the level of total coliforms ranged from 1.73 to 4.10*103cfu/g. Bacteria (such as *Staphylococcus aureus, Escherichia coli, Shigellaflexneri*), Parasites (such as *Entamoebahistolytica; Giardia intestinalis; Cryptosporidium parvum*), and viruses likeHepatitis A; Noroviruswere detected in foods and beverages samples; most of them found to be enterotoxin producers.

Conclusion: Taken together, these results indicate that tested street foods/beverages samples are of low microbiological quality, that their consumption may pose a risk of foodborne disease, and that good hygienic practices should be required to ensure public health.

Keywords: Microbiological risks; Foodborne diseases; Pathogens; Street-vended foods; Yaoundé

Abbreviations: NASBA: Nucleic Acid Sequence Based Amplification; EPEC: Enteropathogenic *Escherichia Coli*; NTS: Non-Typhoidal *Salmonella Enterica*; IFORD: Institute of Population and Research Studies; AMC: Aerobic mesophilic count; TCC: Total Coliform Count.

Introduction

Since the pioneering epidemiology in the 1850's, whereby the English physician John Snow established that cholera was waterborne, there is a sound understanding of the transmission of various pathogens that cause diseases via drinking water and food. Diseases caused by consumption of such a contaminated food are known as foodborne diseases. In fact foodborne disease is a pervasive problem and more than 200 pathogens are associated with it, such as bacteria, parasites, toxins, and viruses. Despite efforts to investigate foodborne disease, less than 50% of all outbreak causes are identified, usually because of limited diagnostic capabilities. From an epidemiological point of view, it is reported that in the United States (using FoodNet data from 2000-2010), there were 47.8 million foodborne illnesses per year (16,000 cases for 100,000 inhabitants) with 9.4 million of these caused by 31 known identified pathogens [1]. In France, 750,000 cases that is 1210 per 100,000 inhabitants were reported, slightly as in Switzerland [2,3]; whereas a study by the Australian National University, found in 2010 that there were an estimated

4.1 million cases of foodborne gastroenteritis acquired in Australia on average each year [4]. In Africa and Asia where the phenomenon is underreporting, it is reported that foodborne diseases are of great magnitude since foodborne and waterborne diarrhoeal diseases kill an estimated 2.2 million people annually, most of whom are children [5]. The above facts and figures illustrate that foodborne diseases of microbial origin are an international health problem associated to food safety, since worldwide, 18 million DALYs were attributed to foodborne diarrhoeal disease agents, particularly NTS and enteropathogenic Escherichia coli (EPEC) [5]. Cultural and demographic factors, as well as change in consumption lifestyle, have resulted in major epidemiologic shifts in foodborne disease during recent decades. Whereas family picnics or dinners and home-canned foods were the typical sources for the outbreaks, today, many more people dine outside the home and resort more extensively to fast food or ready-to-eat foods [6]. As a result, more than 80% of foodborne disease cases occur from exposures outside the home, namely from street-vended foods.

Street-vended foods or street foods are those foods and beverages that are prepared and/or sold by vendors on the street and in other public places for immediate consumption or for consumption at a later time without further processing or preparation [7]. Street- vended foods are appreciated for their flavors, accessibility, low cost, convenience and for the role they play in the cultural and social heritage of societies [8]. They have also become important for maintaining nutritional status of populations as they provide some nutrients to consumers, namely low-income groups in the developing countries [9]. However they are sometimes considered unsafe due to unacceptable handling practices of food servers. Street foods are mostly prepared and distributed in mobile and temporary shelters that lack major facilities and infrastructure required to ensure safe preparation of the foods [10]. The proliferation of street-food vendors is increasing because the business requires very low capitalization and then is very profitable [11]. However, many reports have shown that street vendors lack knowledge of food hygiene, thus they are unaware of basic food-safety issues [7,12]. Street-vended foods are frequently associated with diarrhoeal diseases due to their improper handling and serving practices. In fact, it has been reported that those foods sold by street vendors are in most cases contaminated with pathogens, then becoming a major public health problem [13,14]. From the initial contamination of raw foods with pathogenic bacteria to subsequent contamination by vendors themselves during preparation, there are many factors that should be considered when analyzing hazards due to street foods [15,16]. Vendors can be carriers of pathogens like *E. coli,* Salmonella, Shigella, Campylobacter and *S. aureus* who eventually transfer these food borne hazards to consumers [17]. In some cases, the surrounding environment is the source of risk. Street foods pose major public health risk due to lack of basic infrastructure and services, difficulty in controlling the large numbers of street food vending because of their diversity, mobility and temporary nature.

In short, numerous reports have revealed the risks associated with consuming contaminated street-vended foods that have high levels of enteric pathogens [18,19]. In addition, the exposure to the above micro-organisms could contribute to the increased prevalence of multi-drug resistance in these organisms posing a real danger to the public health of the general population [20]. A general lack of factual knowledge about the epidemiological significance of many street-vended foods, poor knowledge of street vendors in basic food safety measures and inadequate public awareness of hazards posed by certain foods has severely hampered the deployment of a precise scientific approach to this serious problem [16]. In Cameroon, illnesses and deaths from diseases caused by unsafe foods are a constant threat to public health security as well as socio-economic development throughout the world. The full extent of the burden and cost of foodborne diseases associated with pathogenic bacteria, viral and parasitic microorganisms, and food contaminated by chemicals is still unknown but is thought to be substantial. This study was undertaken to develop an understanding of the microbiological problems associated with street vended foods, because we assume that knowing the microbiological quality of street-vended foods is important factor to appreciate the safety problems related to street foods so that concerned authorities may take appropriate measures to improve safety and sanitation with respect to this economic sector.

Material and Methods

Conceptual framework

Foodborne disease is a pervasive problem caused by consumption of contaminated food and beverages. Despite efforts to investigate foodborne disease, less than 50% of all outbreak causes are identified, usually because of limited diagnostic capabilities [21]. Viruses are likely the most common cause of foodborne disease but are seldom investigated and confirmed because of the short duration and self-limited nature of the illness. In addition, the inherent difficulty of laboratory investigation and subsequent cost of viral studies lead to a lack of clinician investigation and therefore overall underreporting [22]. Bacteria are the most common documented cause. Then, using polluted water in food preparation may result in outbreak of infections. Recognition that unsafe food was a source of pathogenic microorganisms was made in the late 1800's [23]. Almost any food can be a source of foodborne disease. Some foods are more commonly associated with particular organisms. Salmonella has traditionally been associated with poultry and eggs, Campylobacter with chicken and unpasteurized milk, and STEC O157:H7 with ground beef [24]. The pathogenic agents implicated consist of bacteria, viruses, toxins and parasites. However, the most commonly identified pathogens are *Campylobacter spp.,*

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Salmonella spp., Shigella spp., Listeria spp, STEC O157:H7, Cryptosporidiumspp, Cyclospora, Giardialamblia and *Vibrio spp*. These organisms have evolved and now have greater cold, heat, and acid tolerance, as well as resistance to multiple antibiotics. The most common microorganisms are total coliform bacteria, fecal coliforms and *Escherichia coli (E. coli)*. All of these infectious agents are associated with diseases like Campylobacteriosis, Cryptosporidiosis, *Escherichia coli* O157:H7 Infection, Giardiasis, Listeriosis, Norovirus Infection, Salmonellosis, ameabiasis, hepatitis and typhoid fever, severe and sometimes fatal diarrheas. Though foodborne diseases are common, only a fraction of these illnesses are routinely reported. It has then beens estimated that in 2014, thirty-one foodborne hazards causing 32 diseases were included, being 11 diarrhoeal disease agents (1 virus, 7 bacteria, 3 protozoa), 7 invasive infectious disease agents (1 virus, 5 bacteria, 1 protozoan), 10 helminths and 3 chemicals. Together, the 31 hazards caused 600 million foodborne illnesses and 420,000 deaths world-wide [5]. The most frequent causes of foodborneillness were diarrhoeal disease agents, particularly norovirus, Salmonella Typhi, Taenia solium, hepatitis A virus and Campylobacterspp. Foodborne diarrhoeal disease agents caused 230,000 deaths, particularly non-typhoidal Salmonella enterica (NTS) which causes diarrhoeal andinvasive disease; from which 40% was among children under five years of age. To control food safety, the following microbiological parameters can be recommended:

i. Samples should not contain any coliform organisms in 100ml.

ii. No sample should contain *E.Coli* in 100ml.

iii. No sample should contain more than 10 coliform organisms per 100ml.

iv. Coliform organisms should not be detectable in 100ml [25].

Due to the interactions between exposure to enteric pathogens via unsafe foods, and also lack of inadequate hygiene of vendors, data resolving the foodborne component is not generally available, particularly in developing regions where there is a higher rate of endemic gastrointestinal disease and pathogen concentrations in food [26,27]. Hence, this paper is an attempt to fill the gap by assessing the microbiological quality of streets-vended food in a city of one of those developing countries.

Study design and area

A cross-sectional study was conducted from February to May, 2013 in Yaoundé. In fact, Yaoundé is one of the two Cameroonian metropolis situated in Central Africa between latitudes 3° 47' and 3° 56' North and 11° 10' and 11° 45' East (Figure 1). She displays the classical Equatorial climate (regular and abundant rainfall of more than 1,600 mm per annum, and a fairly high average annual temperature of 23 °C. Like many sub-Saharan African cities, Yaoundé is currently experiencing very rapid urbanization. With an estimated annual growth rate of 4.5 per cent since 1980, its population has grown from 812,000 inhabitants in 1987 to 1,500, 000 inhabitants in 2000, and to about 2, 500, 000 inhabitants nowadays. Thus, like many metropolises, Yaoundé is in the grip of sudden and unprecedented urban growth with an increase in the size of the city's labour force. Consequently, the demand for non-traditional services has increased and there has been a surge in service-oriented activities that are not part of the formal economic system. As the population pressure in the inner city grows, many people settle in suburbs and distant areas, and daily commuting has become a way of life. Dwellers like civil servants who are subject to the 8 to 4 working day (with short lunch break) have been forced to change their schedules, tastes and attitudes towards food consumption, by resorting to street-vended foods (Figure 1).

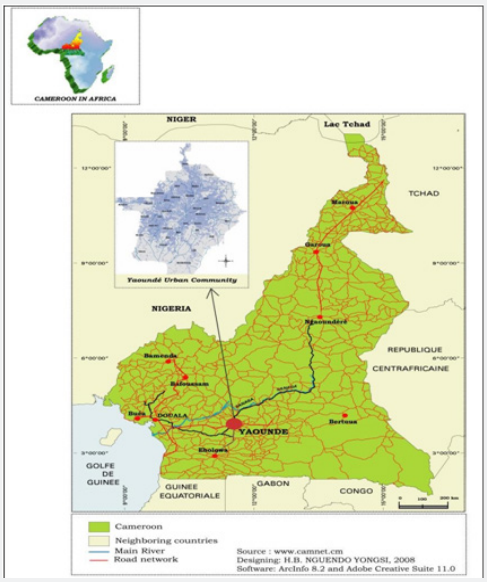

Figure 1: Map of Cameroon showing the location of the urban community of Yaoundé.

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Sources of data and sampling method

Data used in this work come from a cross-sectional study carried out on the town in 2013 by the Geospatial Land & Health Research Group of Institute of Population and Research Studies (IFORD). Although the whole city constituted the basis of our sampling because of the proliferation of street-food vendors, a double strata sample was carried out. First, 3 main representative locations were chosen out of the multiple ones that cover the town as they appear to be where city-dwellers congregate, that is the City-center with its public offices and ministries, the Mokolo market which is the biggest one in Yaoundé, and the Ngoa Ekelle university campus with its faculties and higher schools. Secondly, 837 food vendors were selected from these 3 locations on the basis that they sell food items that are consumed directly or food items that need to cook before consumption (Figure 2).

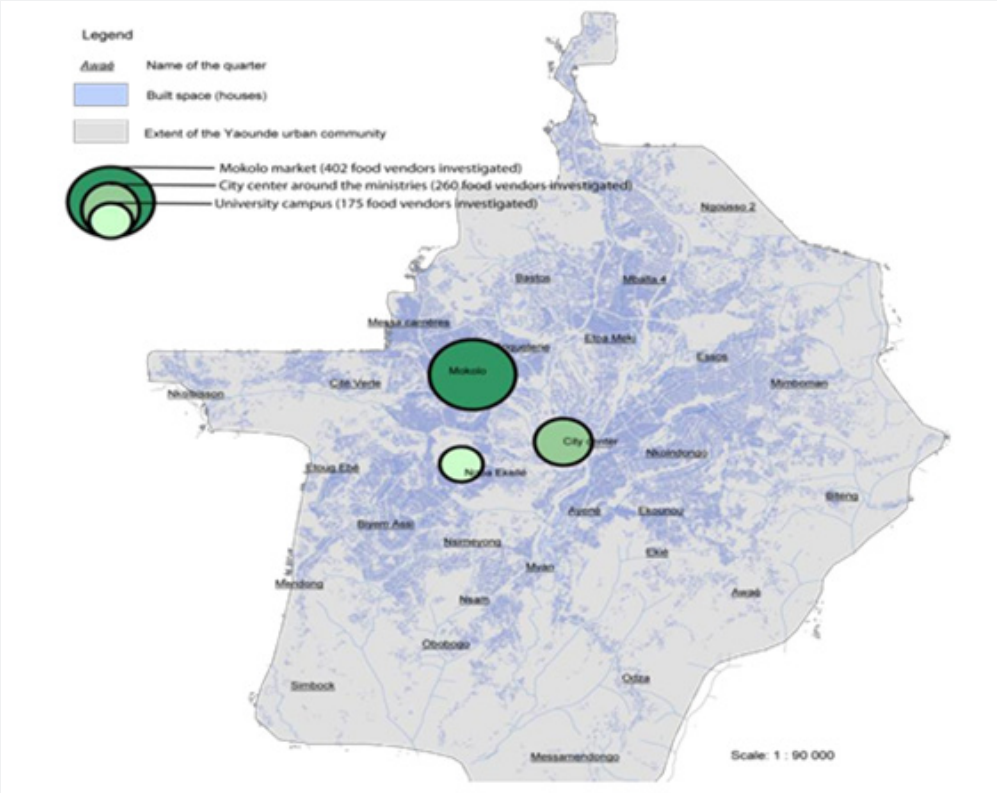

Figure 2: Sampling sites.

After noticing that street-vended food undergo different degrees of processing, they were classified into three categories: unprocessed foods, semi processed foods and processed foods. Unprocessed food is foods which have not undergone any heat treatment; semi processed food includes foods where the preparation includes ingredients which are processed as well as added raw to the final preparation; and processed food which have been completely processed and subjected to high temperature treatment (Table 1).

Table 1: Local street foods found in Yaoundé.

Food Category	Food Items	Ingredients/ Components	Method of Cooking
Unprocessed foods	Lettuce/Cabbage	no	Ready mixing of raw ingredients
	Carrot/salad	no	Ready mixing of raw ingredients
	Avocados/pineaple/mangoes	no	Ready mixing of raw ingredients
Semi processed food beverages	Kossam beverage	Non-pasteurized milk, sugar, water	Mixing of ingredients and chilling
	Folere beverage	Sorrel leaves, sugar, water	Mixing of ingredients and chilling
	Ginger beverage	Ginger, sugar, water	Mixing of ingredients and chilling
	Jus de fruit	Fresh fruits, ice, sugar, water	Mixing of ingredients only

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	Poisson braisé	Fresh fish, oil, salt, onion, spices	Steaming
	Pouletbraisé	Chicken, oil, salt and spices	Steaming
	Shawarma	Meat, cereal, vegetables oil, salt and spices	Mixing of ingredients and heating
	Pain chargé	Bread, corned beef, bologna, sardines	Ready mixing of raw ingredients
	Sausage/meatballs	Pork or beef meat, oil, and seasonings	Mixing of ingredients and steaming
	Oeuf boulli	Eggs and other seasonings	Boiled egg and mixing of ingredients
Processed food	Riz-sauce d'arachide	Rice, roasted peanuts, salt, oil, tomato, other spices	Boiled rice, served with chopped roasted peanuts mixed with spices and meat or fish
	Ndole	Biter leaves, fresh groundnuts, salt and other spices, crawfish	Mixing of ingredients and steaming
	Kondre	Green plantain, oil, meat, other	Mixing of ingredients and
	Sauce jaune	spices Dasheen, muskox skin, spices	steaming Mixing of ingredients and steaming
	Fufu and Eru	Cassava, eru leaves, muskox skin, palm oil	Pounded fresh cassava served with boiled leaves immersed in oil, spices and muskox skin
	Okok	Okok leaves, vegetables, palm oil, peanuts	Slurry okok leaves immersed in grounded roasted peanut
	Pommes pilées	Irish potato, beans, salt, spices	Slurry pounded potato with beans
	Soya	Beef meat, oil, salt and spices	
	Sanga	Fresh maize, cassava leaves, salt or sugar, water	Mixing of ingredients and steaming
	Beignet-haricot	Flour, salt, beans, oil, spices	Sauteing and frying

Those different varieties of local street-vended food were then classified according to the seven modified FAO food groups (Table 2) suggested by the FAO [28]. Two samples from each of the food items were collected under aseptic conditions from street food spots to assess their microbiological quality; that is a total of 50 samples.

Table 2: Sampled food according to FAO groupings. Source: (FAO, 2011).

Consumed Food	Food Samples
Vegetables	Salads, cabbages, carrots, avocados
Meat	Stewed beef/pork, shawarma, grilled chicken/fish
Mix dishes	Eru, kondrè, ndolè, Rice & peanut sausage
Cereals/fresh fruits	Maize, pineaple, mangoes
Legumes and starch food	Boiled peanuts, steamed beans, pounded irish potato
Flour and meat based	Beignet-haricot, Oeufboulli, Pain chargé
Beverages	Kossam, Folerè, Ginger

Sample collection

The survey was conducted by nurses and professional investigators from the Institute of Population and Research Studies (IFORD) under our coordination. After four days of theoretical and practical training, they visited targeted food vendors to collect food and beverages samples. All the samples were aseptically collected in sterile containers, were maintained in chilled state using coolants (ice pack), and transported to the laboratory (Laboratoire du Centre) and were stored at a temperature of 4° Celsius and analyzed within 1-2hours of collection. Contents were examined microscopically for parasites and/or bacteria following direct wet mount preparations in normal saline and iodine solution [29].

Microbiological analysis

For the microbiological assay, 25g of food samples were taken and 100g of beverages were taken to the laboratory where direct smear method and formol ether concentration methods were used as described by W.H.O [30]. In fact, each of the specimens was checked for its label, quantity and procedure of collection

For bacteria

Enumeration of bacterial load in each sample was done by statistical process control method where the colony forming units (CFUg-1 /CFUml-1) of the food samples were determined. 1g (for solid food) or 1ml (for beverage) of the food sample

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was measured and added to 9ml of sterilized saline (0.85% NaCl), mixed well to make a dilution of 10 fold. From the 10-1 dilution further dilutions of 10-2, 10-3, 10-4, 10-5 and 10-6 were prepared. A spread plate of each dilution was done on plate count agar plates and incubated at 37 °C for 16-18h. After incubation, the plates were analyzed and CFUs were counted for appropriate plates. For isolating the bacteria, enrichment culture was done by inoculating 0.5g (for solid samples) or 0.5ml (for liquid samples) of the food sample in 4.5ml peptone water broth and incubated for 6 to 8h at 37 °C. The growth in the medium was depicted as turbidity in the broth. Aloopful from broth was streaked on nutrient agar, eosin methylene blue agar, MacConkey agar, Mannitol salt agar, Cetrimide agar and deoxycholate citrate agar plates were incubated at 35-37 °C for 24h and pure cultures of isolated bacteria were obtained. Microscopic examination and biochemical characterisation of the isolates was carried out as per the standard laboratory protocol [31,32] and the isolates were identified using Bergey's manual of determinative bacteriology, (9th edn).

For viruses detection

Since we were interesting in hepatitis virus-causing, combined techniques based on direct flocculation methods and Nucleic Acid Sequence Based Amplification (NASBA) were used [33].

For parasites

The diagnosis was made on direct wet mount, formalin-ether concentration, and with confirmation of positive stool specimens on Ziehl- Neelsen and Trichrome stained slides. A portion each of the food samples was processed with a direct microscopic technique to detect cysts, trophozoites, eggs and larva of intestinal parasites immediately. The remaining part of the samples was transported to research laboratory. Samples examinations were performed using the formol-ether concentration technique. Both the 10× and 40× objectives were used for detection of eggs and larvae of helminths and cysts and trophozoites of protozoan parasites. Iodine solution was used to detect and identify cysts of protozoan parasites. Presence of faecal coliforms were determined using Brilliant Green Lactose Bile broth (44.50C/48hrs.), followed by confirmation of gas positive tubes using Eosin methylene Blue agar.

Data analysis

Computer programmes used were Epi info (recording raw data, verifying and validating the data collected), SPSS 10.0 (statistical analysis and tabulation). Chi-square method was used to test for significance in proportions. P-values <0.05 were taken as statistically significant association. Quantitative data on the microbial counts obtained from the experiment were subjected to the analysis of variance (ANOVA). Observed differences among the mean values of samples were compared using Duncan Multiple Test using SPSS 20 for windows (SPSS Inc., Chicago, Illinois). Results of enumeration were expressed as mean ± standard deviation log10cfu/g for all food samples.

Ethical considerations

Informed written consent was obtained from each study participants after explaining the objective of the study. All the information about the study participants kept confidential.

Results

Routine examination of foods for the complete range of pathogenic micro-organisms is almost unrealistic. In order to assess the microbiological safety of foodborne pathogens, indicator organisms are often used which indicate the presence of pathogens of intestinal origin as a result of direct or indirect faecal contaminations. In the present study, the identification criteria for indicator organisms have been done in three methods to determine the contaminating conditions to which foodstuffs are exposed to: aerobic mesophilic count, total coliform count, and enteric indicator pathogens (isolated germs or species). Results of analyses obtained from Aerobic mesophilic count (AMC) and Total Coliform Count (TCC) of various food groups are presented on Table 3. With regard to the mean bacteriological count of street foods, the table shows that high aerobic mesophilic count ranged from 1.71-3.71*105CFU/g to 1.67-4.10*103CFU/g coliform. The bacteriological count of organisms was more in the vegetables, fresh fruits and beverages, whereas for Total coliform count, the organisms were more fresh fruits, beverages and legumes.

Table 3: Microbial count of street foods from various food groups collected in Yaoundé.

Food Groups	Aerobic Mesophilic Count (CFU/g)	Total Coliform Count(CFU/g)
Vegetable	3.71*105	2.91*103
Meat/fish	2.47*105	1.73*103
Mix dishes	1.71*105	1.67*103
Cereals//fresh fruits	3.70*105	4.10*103
Legumes and starch food	2.89*105	3.81*103
Flour and meat based	2.96*105	2.42*103
Beverages	3.21*105	3.48*103

Street-vended foods were analyzed for microbiological examinations from three different locations of Yaoundé metropolis, and it appears that food samples taken from Mokolo market area with 3.81*105CFU/g of Aerobic Mesophilic Count and 2.58*103CFU/g of total coliform was the most contaminated street food vending site (Figure 3).

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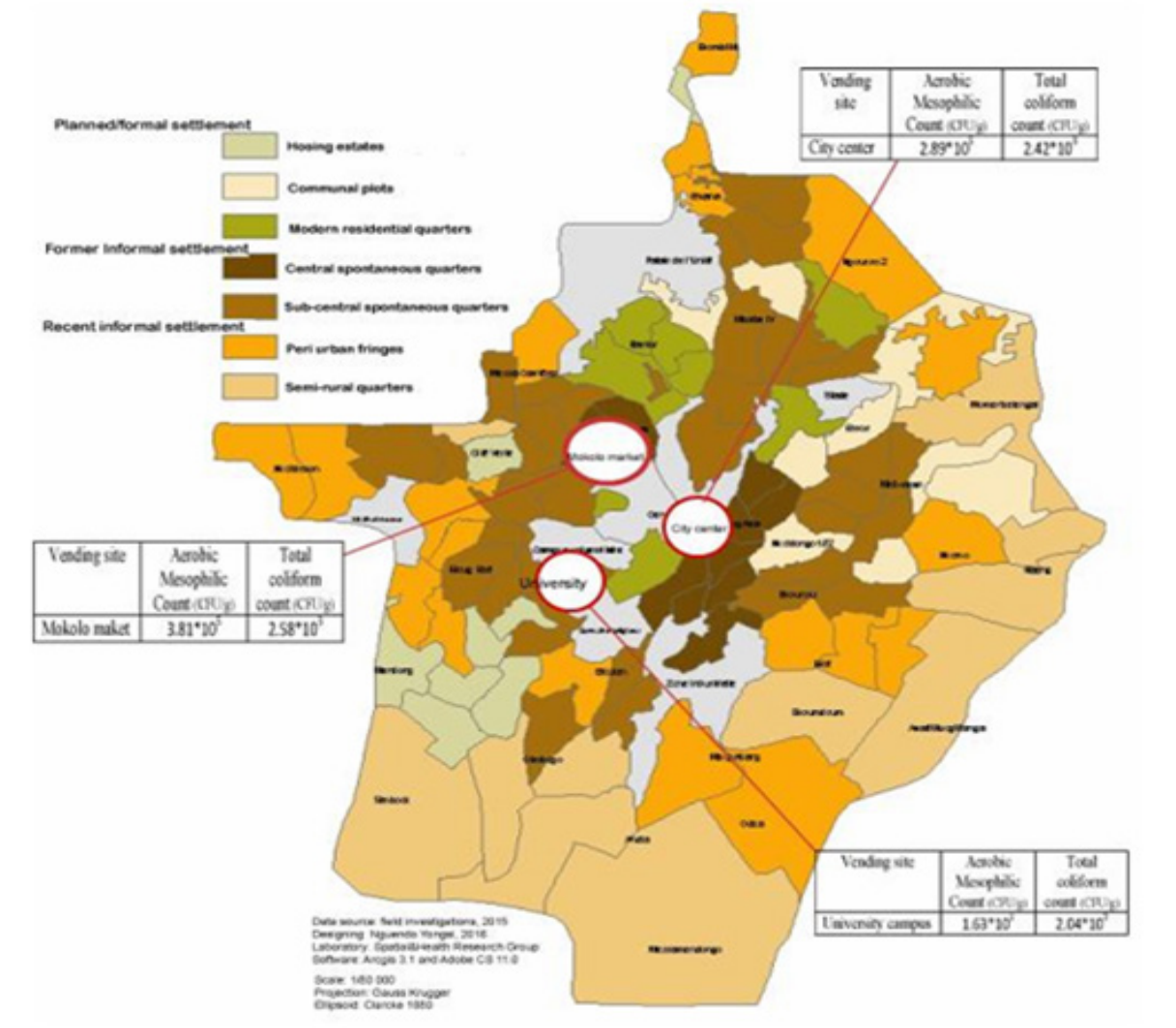

Figure 3: Microbial count of street foods from the three sites in Yaoundé.

From the fifty water samples of foods and beverages analyzed for presence of pathogens, the study revealed pathogenic microbial contamination as viable counts in all the samples were beyond the recommended Microbiological standards for any food and beverage sold [7]. Based on the growth on selective and differential media and biochemical tests, various isolates were identified as bacteria pathogens *(Escherichia coli, Staphylococcus aureus, Klebsiella sp., Pseudomonas sp., Shigella, Citrobacter and Salmonella spp)*, parasitic germs *(Entamoebahistolytica, Giardia intestinalis, Cyclosporacayetanensis, Cryptosporidiumparvum)* (Table 4).

Table 4: Enumeration of pathogenic micro-organisms (*104cfu g^{-1}) found in street foods in Yaoundé.

Food Groups	Bacteria								Parasites				Viruses	
	Ec	Sa	Ks	Ps	Sf	Cf	Ea	Se	Eh	Gi	Cp	Cc	HA	Nv
Vegetable	1.36	0.20	0.73	0.60	1.00	1.45	0.76	10.6	1.47	3.06	0.82	1.77	3.11	0.05
Meat/fish	0.70	0.69	0.90	0.05	0.03	0.01	0.03	6.02	0.84	1.00	0.00	0.00	0.03	0.00
Mix dishes	0.58	0.05	0.03	0.03	0.46	0.27	0.01	1.04	0.07	0.04	0.45	0.53	0.14	0.00
fresh fruits	1.08	0.87	1.00	0.03	1.62	1.24	1.36	3.68	1.58	1.05	0.87	0.92	0.67	0.20
Legumes and starch food	0.14	0.60	0.05	0.82	0.58	0.20	0.75	1.10	0.54	0.91	0.46	0.33	0.42	0.14
Flour/& meat based	0.09	0.20	0.85	0.06	0.67	0.43	0.20	2.85	0.67	0.04	0.00	0.12	0.02	0.00
Beverages	1.16	2.81	1.31	2.90	6.07	8.30	8.02	10.8	3.02	1.56	0.67	0.74	1.33	0.74

Ec: *Escherichia coli;* Sa: *Staphylococcus aureus*; Ks: *Klebsiellasp*; Ps: *Pseudomonas sp.*; Sf: *Shigellaflexneri*; Cf: *Citrobacterfreundi*; Ea: *Enterobacteraerogenus*; Ss: Salmonella entritis; Eh: *Entamoebahistolytica*; Gi: *Giardia intestinalis*; Cp: *Cryptosporidiumparvum*; Cc: *Cyclosporacayetanensis*; HA: Hepatitis A; Nv: Norovirus

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Discussion

Overall study indicated that majority of samples were contaminated with variety of pathogens. The presence of aerobic mesophilic count in all the samples varied between 1.71*105 and 3.71x105CFU/g. The observed differences reported in the aerobic mesophilic count of mix dishes, fruits and vegetables may be attributedto the fact that the street-vended foods were served in unhygienic conditions, hence resulting in contamination from serving utensils [34]. The reported presence of aerobic mesophilic count in the vegetables and fresh fruits as seen in the result of the study meant that they did not meet the microbial standards of below 6.00log10cfu/g. The high amount of microbial contamination in those food items can be attributed to increase in microbial load during sprout, exposure of leaves to soil, as well as trapped dirt in leaf folds [35]. As stated in Figure 3, aerobic mesophilic count was significantly high in the cereals/fruits and vegetables prepared at Mokolo market due mainly to the fact that they are served in unhygienic conditions and contaminated serving utensils, as also reported in India by Das et al. [36]. When compared to other locations, Mokolo market is found to be in an overcrowded environment where foods are processed in an open space and exposed to contamination from gaseous emissions and atmospheric gases such as oxygen which supports the growth of aerobic microorganisms [37].

With regard to Total Coliform Counts of street-vended food samples, the presence of total coliforms in food groups can be linked to contamination resulted from inappropriate processing, incomplete heating, use of contaminated water during preparation and washing or secondary contamination via skin infections and nose nares of food handlers and via contact with contaminated equipments such as chopping boards, knives, and serving wares [38]. Results obtained from this study differ from the study of Thembanani et al. [39], but are close to the study conducted by Gitahi et al. [40] which recorded the results of 3.27 log10cfu/g in cereals, 3.32 log10cfu/g in mixed dishes, and 4.63log10cfu/g in vegetables. Differences in microbial enumeration obtained from both studies could be attributed to contamination of foods by street vended food sellers during handling, processing and vending [17]. Across the locations, no significant difference was observed in the food samples examined. Vegetables which are most parts of unprocessed foods taken as breakfast were contaminated with coliforms and almost all the pathogens. Lack of awareness n requirement for basic safety issues by street-vendors add up the microbial loads. Unhygienic practices such as use of rudimentary stands and carts, non availability of running water for washing, extended preservation without refrigeration, and airborne dust have resulted in severe contamination [41].

Escherichia coli were detected in about 24.6% of the food samples. This detection rate was consistent with previous studies [26,31], which have reported finding of *E. coli* in 36 to 41% of all food samples The presence of Escherichia coli which is widely accepted as faecal contamination of water showed the possible presence of enteric pathogens. Their substantial numbers in foods such as meat, mixed dishes might be attributed to the heat processing failure or post-processing contamination and also suggest lack of hygiene and cleanliness in handling and improper storage [42]. The presence of *Staphylococcus aureus* in the food samples were less than 5% with a range of 0.20-0.87*104cfu g-1 (beverages excluded) these results were lower than those of a study conducted by Suneetha [37]. The highest detection of *S. aureus* was found in fresh fruits and legumes and their presence is an indication of contamination from the skin, mouth or nose of food handlers through coughing and sneezing, during handling, processing or vending [43]. In this study Salmonella enteritidis was detected and has been associated with beef, meat based products, milk poultry and eggs. Vegetables and beverages were highly contaminated and this could be due to the method of handling and preparation: these street food items are either unprocessed foods or cooked for short periods. And it is known that when the steak is not thoroughly cooked to an adequate internal temperature, the microorganisms survive and illness occur after consumption. Whereas vegetables (carrots, cabbage and lettuce) are handled excessively during transport, storage and sale, beverages are prepared in boiling water for a few minutes and add cold water after, then stored in used plastic bottles and exposed for sale. This could be the means of contamination [44]. As for the other species (Shigella, Pseudomonas, Citrobacter), they could have been introduced by the unwashed hands of food handlers who are themselves infected. Also, in this study one of the risk factors for the contamination of street vended foods was storage of left over foods for consumption. It has been noticed that those leftover foods for 2 days and more by vendors were contaminated with pathogenic bacteria.

Viruses are reported to be the most common cause of waterborne illness, indeed. However Hepatitis A virus and Nor virus have been the two most commonly viral sources of foodborne disease identified in our study. This should not be surprising because the city has experienced in recent months, outbreaks of gastroenteritis due to nor viruses. Those outbreaks occurred in informal spontaneous quarters close to Mokolo market and to the city center where overcrowding, poor sanitation, disruption of water supplies, and floods are closely linked to infectious diseases. Hepatitis A virus is one of the most frequent causes of foodborne infection, and epidemics related to contaminated food or water can erupt explosively. Hepatitis A viruses persist in the environment and can withstand food-production processes routinely used to

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inactivate and/or control pathogens [45]. In Yaoundé, it was associated with shellfish and infected food handlers. Whereas Norovirus outbreaks occur in the food service settings like street eating-slots where infected food workers are frequently the source of the outbreaks, often by touching ready-to-eat foods, such as raw fruits and vegetables with their bare hands before serving them. However, Norovirus outbreaks can also occur from foods, such as oysters, fruits and vegetables which are contaminated at their source, that is any food served raw or handled after being cooked [46].

Parasites may be present in food or in water and are therefore identified as causes of foodborne or waterborne illness. Foodborne disease caused by parasites may have a variety of presentations that include gastrointestinal symptoms, neurologic manifestations, or both. Numerous parasites can be transmitted by food including many protozoa and helminths. In Yaoundé, the most common foodborne parasites we found were protozoa such as *Cryptosporidium parvum, Giardia intestinalis, Cyclosporacayetanensis, and Entamoebahistolytica*. Though many of these organisms can also be transmitted by soil or person-to-person contact, in our study, we found that they were occasionally transmitted in foods such as undercooked fish and crabs, undercooked chicken and pork meat, and raw vegetables and fresh fruits that have been contaminated by human or animal feces. However, some foods such as mixed dishes and meat-based food may have been contaminated by food service workers who practice poor hygiene or who were working in unsanitary facilities.

Talking of beverages in particular, there are various kinds of drinks sold at the streets or from roadside shops, including carbonated soft drinks, tea, coffee, fruit juices and non-pasteurized milk. But the major beverages sold by the street vendors in Yaoundé and found to consume by the people at the street are various kinds of fruit juices, kossam and Folere. During summer season (November to May) a huge section of the population of all income and age groups consumes these three beverages. Fresh pressed and squeezed mangos/papayas/pineapple fruits juices and unpasteurized milk are preferred by the consumers because of the "fresh flavor" attributes and low cost. They are simply prepared by mechanically squeezing fresh fruits (fresh juice), or by mixing powder milk with sugar and water (kossam), or by mixing boiled sorrel leaves with sugar and water (Folere). The final product is an unfermented, clouded, untreated drink, ready for consumption. Consumption of these beverages is increasing day by day. In addition to their increasing popularity in consumption patterns, they have also become increasingly important vehicles in foodborne disease statistics [47]. In fact, there are several reports of illnesses due to the foodborne diseases associated with the consumption of such beverages at several places around the globe [48,49]. From our study, it has appeared that most of the juices, kossam milk and folere drink contain a significant amount of microorganisms. The average total viable count (microbial load) showed the presence of microbes in all the drinks analyzed in this study (3.21*105cfu/ml as for Aerobic Mesophilic Count and 3.48*103 for the Total coliform count). The analyses have shown that Kossam milk was the most contaminated with a count of 5*105cfu/ml, whereas the microbial load of fruit juice was 2.55*105cfu/ml, and that of Folere drink of 1.98*105cfu/ml. The presence of total coliforms in all drinks implied a negative relation with food quality and safety, since the isolates identified in the samples are recognized to be harmful for human health (Table 4). The presence of these pathogenic microorganisms can be linked to a number of risk factors such as improper handling and processing, use of contaminated water during washing and dilution, cross contamination from rotten fruits, or the use of dirty processing utensils like knife, flies and trays which were so relevant with the study of Parveen et al. [50] and Rashed et al. [51]. This might also implicate the processing and rinsing water as possible sources of contamination of drinks and beverages sold by street vendors [52]. The ice and water added during preparation are also likely to provide possible sources of additional contamination of total coliforms, fecal coliforms, and fecal streptococci [53]. Furthermore, these fruit juices are left in ambient temperature which may have led to the proliferation of contaminating bacteria resulting in increased bacterial counts. In short, prevalence of unhygienic conditions has substantially contributed to the entry of pathogens in drinks.

This study also revealed that there was a spatial variation in the contamination levels of Aerobic Mesophilic Count and of the Total coliform count. Among vending sites, food samples from - Mokolo area was more contaminated than food from the other locations. Observational studies have shown that Mokolo area is part of the informal spontaneous fabric (Figure 4). She is overcrowded and the mobility of people is high because it is one of the areas where taxi/car stations and market place are found. There are many street-food vendors and consumers in Mokolo. But the street-foods are displayed and sold openly at very dirty surrounding on the road side. Food can easily be contaminated by dust, insects, and hands of intending consumers. From interview and observations, supply of tap water is not available. Therefore street food vendors who are from the area or who come from surrounding informal neighborhoods typically do not have clean water supply for drinking, cleaning and cooking. They are obliged to store water, often using for this purpose wide-mouth storage vessels that permit the introduction of hands and utensils. In addition they use water from unsafe sources such as wells and surface water consequent contamination of water [54].

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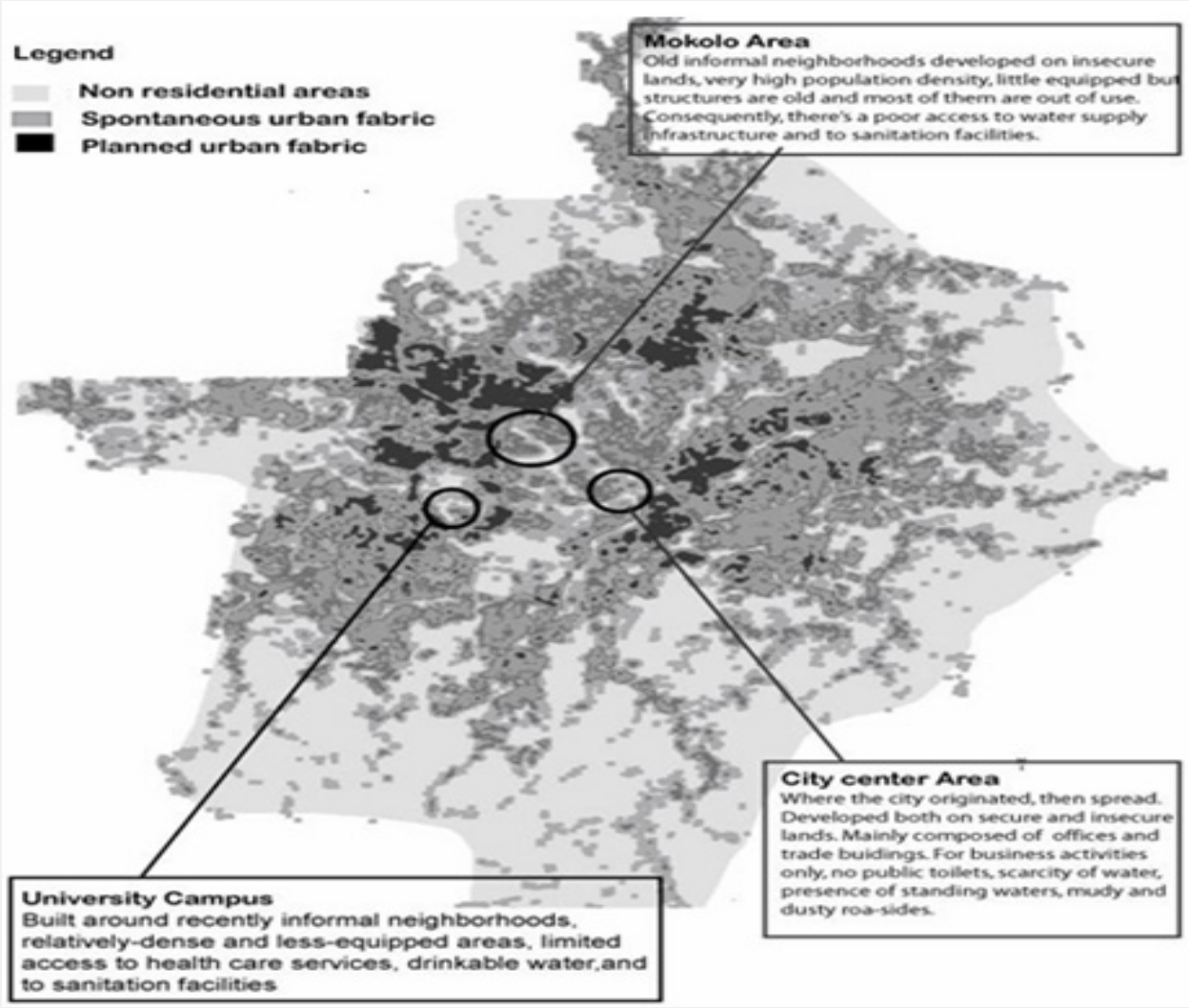

Figure 4: Main socio-health characteristics of the investigated sites.

The city center was moderately contaminated. The city center is made up of the administrative and trading areas. Though they are both areas where the city originated, sewage and water supply networks are old, degraded or inexistent. Absences of piped borne water and of improved toilets have led to a precarious environment. Due to crowded buildings and road-sides, street-foods are either handled in unclean shelters or are displayed and sold openly in ambient temperature favorable to species like Norovirus which is able to survive a wide range of temperatures and in many different environments. Mostly that the virus can spread quickly, especially in places where people are in close proximity like here [55]. Pathogenic microorganisms found on mixed dishes, flour and meat based and unprocessed foods are then suspected to have been transmitted through the environment, contaminated surfaces, water, fomites, aerosols, and flies.

The University campus of Yaoundé I were less contaminated. The prominent isolates were *Salmonella enteritis, Shigellaflexneri, Cryptosporidium parvum, Cyclosporacayetanensis*, and *Entamoebahistolytica* found in unprocessed and semi- processed foods such as vegetables, boiled eggs, and meat/fish based food. Though piped borne water and of improved toilets exist, the campus is invaded with vegetation and standing waters which serve as habitat for many pathogens. And since foods are displayed and sold openly, they are easily contaminated through flies and fomites. However, a number of microorganisms have been traced to fresh fruits and vegetables that were processed under less than sanitary conditions. Presence of these microorganisms show that the quality of water used for washing and chilling the produce is critical. Using water that is not clean can contaminate many boxes of produce. Further observations show that other foodborne microbes could have been introduced from infected food vendors with poor and inadequate personal hygiene [17].

Conclusion

Studies in developing countries have shown that up to 20-25% of household food expenditure is incurred outside the home, and some segments of the population depend entirely

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on street foods. This is one of the consequences of rapid urbanization with millions.

i. People having no access to a kitchen or other cooking facilities,

ii. Workers or floating population who move in and out of the city for work who largely depend upon street foods for their daily sustenance [56].

In many developing countries, street food vendors are an important component of the food supply chain. Being reasonably priced and conveniently available, street food satisfies a vital need of the urban population. These ready-to-eat foods and beverages are prepared and/or sold by vendors or hawkers mainly in streets or other convenient public places such as around places of work, schools, hospitals, railway stations, and bus terminals [57]. But, ready-to-eat foods and beverages raise concern with regard to the potential hazards due to microbiological contamination and poor environmental sanitation and hygiene involved in their preparation and processing. In fact, those foods are generally prepared and sold under unhygienic conditions, with limited access to safe water, sanitary services, or garbage disposal facilities. Hence street foods pose a high risk of foodborne diseases. Foodborne diseases encompass a wide spectrum of illnesses and are a growing public health problem worldwide. They are the result of ingestion of foodstuffs contaminated with microorganisms or chemicals. The contamination of food may occur at any stage in the process from food production to consumption ("farm to fork") and can result from environmental contamination, including pollution of water, soil or air. A majority of the street-vended foods analyzed for microbial contamination from all three different locations did not met the microbiological standards of ready-to-eat foods. The enumerated Aerobic Mesophilic Count and of Total coliform count values obtained in this study for unprocessed, semi-processed and processed foods and beverages samples were not within the specifications set by the WHO Standards which indicates that cooked food should contain less than log106.00cfu/g. This implies that street-food vendors in Yaoundé do not apply standard hygiene practices in the processing and preparation of street- vended ready-to-eat foods. Therefore, presence of Coliforms and other parasites and viruses is an indication those street-vended foods in Yaoundé are unsafe for human consumption. As street-vended foods prepared and sold in the streets of Yaoundé have shown to be unsafe for human consumption, regular trainings on ways of maintaining and increasing food safety, hygiene levels and environmental sanitation is needed for the food handlers and vendors. This is paramount to ensure that food safety measures are regularly put in place in guaranteeing that standards are constantly maintained in the preparation of street-vended foods. This will ensure that street- vended foods are not vehicles for pathogens or the transmission of diseases to people who depend on them for their survival and nutritional needs [58,59].

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