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BACTERIOLOGICAL QUALITY OF STREET FOODS VENDED IN BUKAVU CITY: POTENTIAL HEALTH RISKS TO CONSUMERS OF SOUTH KIVU PROVINCE, EASTERN D.R. CONGO

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ABSTRACT

Foods vended in roadsides of our African cities is a reality and constitute a major problem of public health starting the multiplicity and diversity of microbial flora that they carry. To address these challenges, this study was performed to control the hygienic quality of street foods vended in urban zones of Bukavu city in South Kivu province, DR Congo and assess the potential health risks to consumers. This prospective study was conducted among street vending food from vendors in three urban zone of Bukavu city. A total of 80 food samples compressing boiled meat (16), roast fish (18), sausages (21), fresh milk (13) and loaf (12) from 320 vendors were purchased and analyzed. Standard microbiological methods NF ISO 7218: 1996 were used for isolation, enumeration and identification of bacteria. Investigations into the point of sale and microbiological test results revealed the presence of a perpetual contamination risk by vendor categories. All street food samples tested are contaminated to varying degrees by bacteria, including: FMAT, total coliforms with *Escherichia coli*, *Staphylococcus* sp. with *Negative Staphylococci Coagulase* and *Staphylococcus aureus* and *salmonella* with species *Salmonella enterica*, represent a great risk of street food poisoning for over 350 consumers per month. The mean bacterial counts in these foods expressed to CFU/10g of each food collected exceed the standards set by the Codex Alimentarius, significant and highly statistically significant according different categories of vendors and sampling sites ($p<0.0001$). Samples collected from vendors in Kadutu urban zone (the most popular and unhealthy in the city) are more contaminated. Dishes that are not subjected to heating during preparation have the highest microbial load. This is the case of fresh milk where the total mesophilic flora is of order of 10^6 CFU/10g. This is also the case of street food which, after cooking are exposed for a long time at room temperature: boiled meat and sausages contain an uncountable amount of bacteria. Total coliforms, and *Salmonella* sp. are more loaded in boiled meat, fresh milk and sausages. Many *Staphylococcus* sp. are in the loaf. Much (77%) contaminated dishes are from ambulant vendors than other distributors, followed by semi-stationary and stationary vendors respectively ($p<0.001$). Contamination of street food in Bukavu is multifactorial and hygiene vendors contribute significantly to contamination factor, including unhygienic managers, dirty environment and poor water quality. Hence, sustainable development of communities through good hygiene practices in street foods handling. The government should thus strengthen health checks at street food and ensure their hygienic quality before consumption by the population in order to prevent these diseases and improve health of consumers.

Keywords: street foods, bacteriological quality, consumers health risk, Bukavu city

INTRODUCTION

Street foods are foods and beverages ready to eat prepared and/or sold by ambulant or stationary vendors, especially in streets and other similar places. They are an important part of the daily urban food consumption of million consumers in low or middle income **(FAO, 1989; OIT, 1972).** For many people with limited resources, street food is often the cheapest and most accessible to get a meal nutritionally balanced out of the house **(FAO, 1997; 2007; 2009).**
According to some researchers, this phenomenon affects all layers of the large cities of black African population: students, civil servants, married, single, etc. easy to eat and easily outside the home and relatively low cost **(Canet and Ndiaye, 1996; Chauliac *et al.*, 1998; Barro and Traore, 2002).** But unfortunately these foods undergo in the process of manufacturing and selling unhygienic operations resulting mostly to microbial contamination and/or toxigenic **(Manzilima, 2011; Kama, 2014; Baba-Moussa *et al.*, 2012).**
Indeed, preparing and selling food on the streets can cause big problems for consumer health. Various studies on food streets in Africa argue that hypothesis, such is the case for Kenya by **Gitahi (2012)**, Burundi by **Noel (2013),** Nigeria by **(Okojie and Isah, 2014; Chibundu *et al.*, 2012; Okonko *et al.* , 2009),** Ghana by **(Mensah *et al.*, 2012, 1999, 2002; Feglo and Nkansah, 2010),** Benin by **Baba-Moussa *et al.* (2012),** Burkina Faso **(Barro *et al.*, 2002),** Dakar **(Diallo, 2010; Dione, 2000; Soumare, 1997),** Cameroon **(Ngabet Njassap 2001),** Madagascar **(Rakotondramanana 1998; Ravaonindriana *et al.*, 1999)** and also in countries around the world: India **(Chirag *et al.*, 2013),** Philippines **(Dexter *et al.*, 2014);** etc. to not only mention it. These works showed cases of food-borne infections such as microbial agents. Which constitutes a major risk to public health **(WHO, 1996).**
In fact, Bukavu city is not safe by this scourge, like all cities of the Democratic Republic of Congo it is under pressure due to rapid urbanization, high population due to rural migration, but also knows a degrading situation of employment, housing and nutrition, but also new profitable activities **(FAO, 1998).** However, to deal with these challenges, another phenomenon is dispersal in our streets, the central market where utilities: this is street food, known as "Malewa" in Congolese language; which is a social reality in Bukavu. It is found everywhere in the vicinity of the streets and in markets where the food safety status is not guaranteed **(Ranaivoarimanana, 2006).** This appears to meet the food needs of Bukavu population as was the case for Kisangani and Kinshasa city **(Manzilima, 2011; Kama, 2014).**
The safety of street food depends on several factors such as the quality of different materials to use and good practice of preparation. In most cases this security is not guaranteed and street food often becomes epidemic sources and gastrointestinal diseases such as gastroenteritis and diarrhea of microbial origin **(Adams and Motarjemi, 1999; Barro and Traore 2002; Tjoa *et al.*, 1977; Owhe-Ureghe *et al.*, 1993; Umoh and Odoba, 1999).**
Several studies have shown that street food is exposed to severe environmental conditions such as the presence of insects, flies and air pollution **(Sobel *et al.*, 1998).** Until today, most street vendors ignore good food hygiene practices. They expose the food in poor conditions creating cross-contamination and failures in food preservation **(Ekanem, 1998).**
It is in this context that we propose to control the bacteriological quality of some consumer street food in Bukavu city urban zones and health risks to consumers from Bukavu where cases of food poisoning caused by street foods have been observed and reported in the past three years. In addition, cholera, also called disease of dirty hands, which caused the death of hundreds of people in urban

health zones of South Kivu and also some deaths in Bukavu between 2000 and 2015, is worrying consumers food vended on the street. Our study investigate the microbiological quality (hygienic) and assessment of potential health risks to consumers of these foods by discovering the risk of infection by study site according to vendors' categories.

MATERIALS AND METHODS

Study areas and types of vendors

The food samples were collected in public procurement and in crowded areas of three urban zones constituting Bukavu city (including Bagira, Kadutu and Ibanda). Vendors were grouped into three categories according to the study sites and methods of sale: ambulant vendors cooking at home and not having a fixed point of sale; semi-stationary vendors preparing and selling outdoors along the road or under trees in the street and stationary vendors with dining facilities. During the collection, special attention was paid to the immediate environment of vendors and their hygiene practices. Thus, attention has been paid to the presence of solid or liquid waste, to the nearby waste water drains, unpleasant odor, utensils, food handling and dishwater.

Sampling

The range of street food available in Bukavu reflects ethnic and cultural richness of various inhabitants of South Kivu province. Collection was carried out for 4 months from April to July 2015. A minimum of 320 study participants were required for the study. However, in this study a total of 330 respondents were interviewed to provide the 320 required for the research. The response rate in the study was therefore 97 %.
A pre-selection of dishes was made in advance because of the higher risk or lower contamination and their high consumption frequency. Food samples were collected at different times and according to their shelf life. The samples were taken immediately from a total of 80 food samples compressing boiled meat (16), roast fish (18), sausages (21), fresh milk (13) and loaf (12) from 320 vendors, whose one food sample for 5 vendors (sampling interval k=5) were evaluated: after cooking, when vendors have tidy utensils and more or less clean; at the time of the service and by the end of sale. The same food samples were selected from the same vendor categories. They are placed in sterile plastic bags containing ice and sent to the Microbiological Laboratory of Bukavu Institute of Higher Education in Medical Techniques "ISTM-Bukavu" for analysis within 2 hours. Many sample copies were taken by site and vendor category each day of field visit.
The materials and equipment used for these analyzes are standard and comply with the standard **NF ISO 7218: 1996** on general rules for microbiological examinations **(AFNOR, 1996).** Standard microbiological methods were used for isolation, enumeration and identification of bacteria.

Search of microorganisms

Among microorganisms responsible of food poisoning, *enterobacteria* coliforms, *Staphylococcus aureus, Yersinia enterocolitica, Clostridium difficile, Salmonella, Shigella*, yeasts and fungi as well as *streptococci* prominently. The bacterial count was made from different foods mentioned above by the method described by Speck **(Speck, 1976).** It consists in the stock solution 1:10 by taking 10g of the sample which will be ground and dissolved in 90 ml of buffered peptone water (BPW). Different seeds were determined on specific media by morphological criteria. Biochemical criteria complement the morphological observations. So:
- *Staphylococci* were identified on Chapman manity medium after 48 hours of incubation at 37°C. The yellow colonies underwent tests of coagulase and catalase.
- Spores and clostridia have been identified in the Bryan and Burkey broth after heating for 5 min at 80°C to destroy vegetative forms.
- *Coliform enterobacteriaceae* are identified on eosin methylene blue medium. The presumptive identification of *Escherichia coli* is made by Mackenzie test. For gas producing coliforms is lactose bile broth brilliant green that was used.
- Incubation lasts 48 hours at 37°C.
- *Salmonella* and *Shigella* are sought on MacConkey medium after incubation at 37°C for 24 hours.
- The total mesophilic flora FMAT was determined after plating 0.1 ml of the 10-1 and 10-3 dilutions of the samples on petri dishes containing nutrient agar and incubated for 48h at 37°C.

These steps were repeated two times to calculate the average number to consider. Results of bacterial load are presented in CFU/10 g of food tested.

Statistical data analysis

The procedure of Generalized Linear Models (Proc GLM) of SAS (Statistical Analysis System, version11 (2013) USA, which is well suited to analyzing data with variables complex in distribution terms was used for analysis of variance. Cross-tabulations were made of the levels of the various bacteria tested and the responses obtained in the interviews. The significance of any observed differences was determined using χ^2 test and Student's t-test. The comparison of means was made through the ANOVA One-way test. Statistical significance was set at $P \leq 0.05$. In order to determine the effect of the knowledge and practices of vendors on the microbial quality of street foods, we calculated confidence intervals after factors and levels of contamination were cross-tabulated.

RESULTS AND DISCUSSION

Bacteriological quality of street foods vended in Bukavu city

The enumeration of total flora (mesophilic aerobic bacteria) and specific flora (all pathogens and toxigenic) samples collected in Bukavu city gave the results shown in Tables 1 and 2. All street food samples collected are contaminated to varying degrees by isolated and identified bacteria including: FMAT, total coliforms with *Escherichia coli*, *Staphylococcus* species with Negative Staphylococci Coagulase and *Staphylococcus aureus* and *salmonella* with the species *Salmonella enterica.* The quantities of bacteria obtained by CFU/10g of each food exceed the standards established by Codex Alimentarius, significant and highly statistically significant according to vendors categories and sampling sites ($p<0.0001$). This is consistent with the study of **Feglo and Sakyi (2012), Feglo and Nkansah (2010)** in Kumasi, Ghana, which reveals that most ready-to-eat foods in Kumasi were contaminated with enteric bacteria and other potential food poisoning organisms (*Coagulate negative staphylococci, Staphylococcus aureus, Escherichia coli, Salmonella enterica, Enterobacter cloacae*, etc.) with bacterial counts higher than the acceptable levels. In his study, **Mensah *et al.* (2012, 2002, and 1999)** exhibits the presence of mesophilic bacteria in the majority of samples (69.7%): *Bacillus cereus* was isolated in 28 of them (5.5%), and *Staphylococcus aureus* in 163 (31.9%). He said, hundred seventy-two samples (33.7%) contained *enterobacteria*.
The following tables of this study show that dishes that are not subjected to heating during preparation have highest microbial load. This is the case of fresh milk where the total mesophilic flora is of the order of 10^5 CFU/10g and varies to sampling sites. Is 102.10^4 CFU/10g in fresh milk collected in Bagira urban zone, 11.10^5 in Kadutu and 12.10^4 in Ibanda urban zone. But also more interesting, it is 10^5 CFU/10g in fresh milk collected at Brasserie market and 2.10^5 CFU/10g at Muhanzi, markets of Kadutu urban zone. These outcomes are similar to those obtained by **Baba-Moussa *et al.*, (2006),** which noted a high level of contamination in the street food that are not subjected to heating during preparation sold in Benin, Cotonou city.
This is also the case of foods selected in this investigation that, after preparation are exposed for a long time at room temperature: boiled meat and sausages contain an uncountable amount of FMAT bacteria in dishes taken from Brasserie market and roasted fish which have a total mesophilic flora 2.10^5 CFU/10g in Bagira and order of 10^6 CFU/10g roasted fish collected in Kadutu urban zone, the most popular and unhealthy city. The presence of unacceptable levels of mesophilic flora in meat and fish may suggest inadequate handling during the display (**Babe *et al.*, 2018**) of fish before sale by the vendors. In this Nairobi location 50% of stalls were dusty and had houseflies suggesting inadequate sanitation **(Gitahi, 2012)**.
But street foods like loaf has a total mesophilic flora equal to 657.10^2, 435.10^3 and 765.10^2 CFU/10g in Bagira, Kadutu and Ibanda urban zone respectively. Total coliforms, *Staphylococcus* sp and *Salmonella* sp are more numerous in boiled meat, fresh milk and sausages. The presence of *Staphylococcus aureus* and *Salmonella* sp. was also reported in previous studies on street food by **Okonko *et al.* (2008b, c)** and in sausages vended in Abeokuta and Benin-city, Nigeria in a study by **Oluwafemi and Simisaye (2005).** According **Oluwafemi and Simisaye (2005)** most of the sausage being sold as ready-to-food pose health risk to consumers, making it imperative to institute not only sanitary measures during its production and sales bit for retailers selling raw of preprocessed foods to have a steady source of power supply.
Note that, all analyzed foods contain salmonella *(Salmonella enterica* and other *Salmonella)* in the order of 10^2 and 10^4 CFU/10 g of food. *Escherichia coli* and

Staphylococcus aureus are present at relatively high rates. The presence of *Staphylococcus auerus*, a pathogenic organism of public health concern and significance in these street foods might have contaminated from source as a result of handling by processors. Improper handling and improper hygiene might lead to the contamination of ready-to-eat food and this might eventually affects the health of the consumers **(Dunn *et al.*, 1995; Adebolu and Ifesan, 2001, Omemu and Bankole, 2005; Okonko *et al.*, 2008b, c).** It was reported that counts of 10^7 cells/g for B. *cereus* **(ICMSF, 1974)**, and 10^6 cells/g for enterotoxigenic S. *aureus* **(Bergdoll, 1979)** are required to present a risk of intoxication. It is therefore suggested that street food vendors should be educated on the adverse effect of using untreated or polluted water for processing as these could serve as sources of fecal contamination. However, the vendors/handlers should observe strict hygienic measures so that they will not serve as source of chance inoculation of microorganisms and contamination of these street foods. Incidences of *E. coli, Enterobacter aerogenes* and other index of poor sanitary quality found in this study are in agreement with those of **Trevett *et al.* (2005)** and **Hogue *et al.* (2006)**.

As for staphylococci they are present in significant numbers in roast fish and loaf, but virtually low in fresh milk collected, but worrying in Bagira, Kadutu and Ibanda urban zone (Table 2). **Gitahi (2012)** in his study on the microbial quality, strain and distribution of selected food enterotoxigenicity terminal pathogens in relation to the hygienic practices in industrial area, Nairobi, Kenya discovered that the presence of *Escherichia coli* and *Staphylococcus aureus* in street food samples selected was qualitatively isolated in 3 food samples. *Escherichia coli* and *Staphylococcus aureus* in street food samples selected was qualitatively isolated in 3 food samples.

Table 1 Quantity variation of bacteria in some street foods collected from different categories of Bukavu vendors

Groups	Species	Samples collected					χ^2-test
		Boiled meat	Roasted fish	Sausages	Fresh milk	Loaf	
Ambulant vendors							
Global contamination (FMAT)	-	344.10^2	455.10^2	344.10^4	605.10^3	5.10^5	8837963**
Total coliforms	*Escherichia coli*	324.10^2	176.10^3	238.10^3	288.10^3	198.10^3	198111**
	Others *Enterobacteria*	234.10^3	189.10^3	365.10^3	237.10^2	343.10^2	486389**
Staphylococci	Negative Staphylococci coagulase	321.10^2	31.10^3	15.10^4	166.10^3	21.10^4	226953**
	Staphylococcus aureus	554.10^3	620.10^3	163.10^2	219.10^3	2.10^5	812693**
Salmonella	*Salmonella enterica*	866.10^3	543.10^3	435.10^3	321.10^3	34.10^3	843808**
	Others *Salmonella*	134.10^3	343.10^3	324.10^3	534.10^4	244.10^4	126789**
Semi-stationary vendors							
Global contamination (MTAF)	-	354.10^3	657.10^3	876.10^3	659.10^3	9.10^5	280962**
Total coliforms	*Escherichia coli*	546.10^2	6.10^3	209.10^3	43.10^4	237.10^3	599633**
	Others *Enterobacteria*	548.10^3	779.10^3	329.10^3	93.10^4	856.10^3	353790**
Staphylococci	Negative Staphylococci coagulase	324.10^2	3.10^5	543.10^3	86.10^4	23.10^4	1032460**
	Staphylococcus aureus	327.10^3	356.10^3	234.10^3	886.10^3	54.10^4	569968**
Salmonella	*Salmonella enterica*	546.10^3	768.10^3	657.10^3	869.10^2	998.10^3	745181**
	Others *Salmonella*	435.10^3	756.10^2	553.10^3	867.10^2	657.10^2	891659**
Stationary vendors							
Global contamination (FMAT)	-	987.10^3	10^4	354.10^3	953.10^2	765.10^2	2136641**
Total coliforms	*Escherichia coli*	546.10^3	435.10^3	867.10^2	657.10^2	888.10^3	1163814**
	Others *Enterobacteria*	876.10^2	987.10^2	132.10^2	2.10^4	897.10^2	111818**
Staphylococci	Negative Staphylococci coagulase	645.10^2	443.10^2	129.10^3	10^5	987.10^4	37525141**
	Staphylococcus aureus	234.10^2	325.10^2	657.10^2	276.10^2	879.10^2	66748**
Salmonella	*Salmonella enterica*	325.10^2	$154.6.10^2$	768.10^2	$.10^4$	324.10^2	82399.2**
	Others *Salmonella*	657.10^2	567.10^3	876.10^2	435.10^2	768.10^3	1488162**

Legend: *FMAT: Flora Mesophilic Aerobic Total; NSC: Negative Staphylococci Coagulase; CFU: Colony Forming Units, DF= 4; different significance levels of the X^2- test variable association *p<0.05; **p<0.001; otherwise it is not significant when the value obtained in X^2 is followed by no asterisk (p>0.05). Others: undetermined species.*

He adds that vegetables had unacceptable contamination levels of coliforms and *Staphylococcus aureus,* while meat (fish) from Nanyuki road had unacceptable levels of *coliforms.*

When an analysis of contamination vendor category, majority of products sampled and analyzed (Table 1), we note that ambulant vendors have mostly much contaminated dishes than other distributors (p<0.001). Among these walking the load in total mesophilic flora is very high in loaf 5.10^5 CFU/10g, sausages 344.10^4 followed by fresh milk 605.10^3 and roast fish 455.10^2 CFU/10g as well as total coliform bacteria (*Escherichia coli* and others), staphylococci (Negative Staphylococci Coagulase NSC and *Staphylococcus aureus*) and Salmonella *(Salmonella enterica* and others Salmonella) which are of the order of 10^2 and 10^3, in others street foods analyzed. But *Staphylococcus aureus* and NSC 2.10^5 and 21.10^4 and CFU/10g respectively are many in bread. Milk have an important microbial load in Salmonella 534.10^4 CFU/10g (Table 1). Mesophilic aerobic bacteria are present in foods in favor of a time/temperature favorable to their growth. All food (foodstuff) ready to eat may have been kept in too high temperature and/or too long **(SCAV, 2007).** According to the hygienic order, this also involves the cooked food (tolerance: 1 million per gram) than the mixed products (tolerance 10 million per g). From 100 million cells/g of food, it is considered corrupted and unhealthy for consumption.

Pathogens account for 77% of ambulant vendors against 33% and 26% respectively for semi-stationary and stationary sellers. Almost 61% contain coliforms. As for pathogenic E. *coli*, it is present to 83% in foods collected from the street. Similarly sulphite-reducing anaerobes are also found in these foods to 66% (Table 3). Note that, pathogenic E. *coli* bacteria normally found in the intestines of livestock. It is transmitted to humans through direct contact with infected feces, or by indirect contact, such as when we eat meat or fresh milk that came into contact with the bacteria during slaughter or treatment.

In semi-stationary vendors, only fresh milk has a large load in FMAT and coliforms, *Salmonella* sp. and *Staphylococcus* sp. exceeding the standards established by the Codex Alimentarius. The comparison of the three vendor categories shows that as microbial loads sample selected among stationary vendors contain anaerobic mesophilic aerobes and sulphite-reducing exceeding significant prescribed standards. This is in agreement with those of **Baba-Moussa *et al.* (2006)** in Benin, Cotonou city who notes in his study that street vendors have mostly much contaminated dishes than other distributors. This can be explained by the fact that food usually transported on the head are poorly covered and are subject to air pollution, given the density of car and motorcycle taxis in the city of Bukavu. These street vendors are usually forced to walk to the edge and along the roads that still resemble most aerosol products for mobile devices. More street vendors very often lack of water to rinse utensils with which they provide service. This is an aggravating factor of contamination. Also we note that in stationary vendors all samples contain mesophilic aerobic microorganisms and anaerobic sulphite-reducing exceeding the prescribed standards. This is explained by the presence of sidewalks,

sewage and garbage discarded in nearby streets pollutant of sale and the environment sellers with pathogens.

The heavy load foods *Salmonella* ssp. analyzed in all vendor categories exposes consumers to food poisoning. The presence of *Salmonella* sp. in street food threatens food security of the population. However, microbial loads observed for aerobic mesophilic flora, beyond June 10^6 germs set by **AFNOR** (French Association for Standardization), shows a significant level of contamination of street food vended in Bukavu city.

Table 2 Quantity determination of bacteria (CFU/10g) in some street foods collected by sampling sites

Bacteria (CFU/10g of food)	**Samples collected**	**Names of sampling sites**					**χ^2-test**
FMAT		**Bagira**	**Brasserie**	**Muhanzi**	**Kadutu**	**Ibanda**	**χ^2**
	Boiled meat	12.10^4	uncountable	348.10^2	28.10^4	265.10^3	61991306**
	Roasted fish	2.10^5	58.10^3	219.10^2	10^6	5.10^4	2604018**
	Sausages	349.10^4	uncountable	32.10^4	9.10^4	90880	267332207**
	Fresh milk	102.10^4	10^5	2.10^5	11.10^5	12.10^4	2016693**
	Loaf	657.10^2	768.10^3	987.10^2	435.10^3	765.10^2	1322772**
Total coliforms							
	Boiled meat	10^5	29.10^4	109.10^4	19.10^4	256.10^3	153503**
	Roast fish	17.10^4	2.10^4	10^3	29.10^4	265.10^3	484737**
	Sausages	19.10^4	129.10^3	176.10^3	165.10^3	176.10^3	12791.9**
	Fresh milk	123.10^3	209.10^3	10^5	176.10^3	234.10^3	75707.8**
	Loaf	657.10^3	987.10^3	546.10^3	866.10^2	908.10^3	796901**
Staphylococci							
	Boiled meat	234.10^2	128.10^3	287.10^3	29980	276.10^2	521814**
	Roast fish	17.10^4	1739.10^2	165.10^3	67.10^4	574.10^3	713705**
	Sausages	187.10^3	276.10^3	286.10^3	269.10^3	248.10^3	24703**
	Fresh milk	2554	5477	$37.6.10^2$	4538	7688	3121.45**
	Loaf	768.10^3	879.10^3	987.10^3	87.10^3	546.10^2	1452646**
Salmonella							
	Boiled meat	18.10^4	10^5	9807	6579	9870	389843**
	Roasted fish	98.10^3	298.10^3	254.10^2	435.10^2	29.10^3	536535**
	Sausages	23.10^3	287.10^3	38.10^4	254.10^3	65.10^3	457992**
	Fresh milk	76.10^3	64.10^3	69.10^3	98.10^3	231.10^2	45098.6**
	Loaf	987.10^2	876.10^4	98.10^4	547.10^2	987.10^3	1533501**

Table 3 Percentage of bacteria affecting consumer health for different vendor categories of Bukavu city

Vendor categories	**Pathogens bacteria (%)**	**Toxicogenic bacteria (%)**
Ambulant	77	75
Semi-stationary	33	60
Stationary	26	20

Epidemiological profile on the consumption of street food in Bukavu city

The figure 1 results exhibits the number of disease cases in people who have eaten street food register in Bukavu General Reference Provincial Hospital (HPGR-Bukavu) between 1992 and 2015. The last three years (2013- 2015) prevalence of people having eaten street food in Bukavu city is growing, it was 300 cases in September 2013, 350 cases in May 2014 and more than 380 cases in April 2015. This prevalence was almost the same between 2004 and 2006 but a decreasing manner (Figure 1), the worrying numbers for the city and public health.

Household surveys in developing countries have shown that the householder takes on average a meal out of the household. As indicated in the above tables that the quality of street food eaten outside the home is questionable, the consequences in terms of poverty are enormous. Indeed, the head of household, main breadwinner for the family has to take meals outside the home for various reasons. If the head of household was infected with a pathogen, consequences are immediate and harmful to his family. Thus, the quality of food consumed should be a priority for the fight against poverty **(Gohou, 2005).**

Most people who consumed these foods contaminated with Salmonella for example, show up at the hospital with symptoms of diarrhea, sometimes with blood in the stool; abdominal cramps; nausea; vomiting (sometimes); fever; chills; headache. Symptoms usually appear 6 to 72 hours after consumption of contaminated food. The symptoms usually last 3 to 7 days. There are several strains of E. *coli* bacteria and while most are harmless, some of them can lead to health problems more often, we talk of food poisoning (severe gastroenteritis), but also urinary tract infections observed in Bukavu city. Staphylococcus also causes a range of diseases mild skin infections such as boils, pimples, impetigo and cellulitis, more serious illnesses such as food poisoning, bacteremia (blood infection), Syndrome toxic shock and pneumonia (microbiologist **Claude Wakeka,** personal communication). Prevalence of 22% in *Staphylococcus aureus* mastitis were also detected in isolates in Turkey by **Murat *et al.* (2009).**

As noted in the document by **Mensah *et al.* (2012)**, well-coordinated surveillance data on foodborne diseases in Africa after consumption of street food is lacking. There are, however, data on a number of homes, as well as epidemiological studies in infants and the youth children suffering of diarrhea.

An outbreak of bloody diarrhea caused by *Escherichia coli* 0157 infections occurred in southern Africa with a prevalence of 42% among 778 residents who were studied. The consumption of meat, juice and fresh milk and untreated water were predisposing factors. According **Mensah *et al.* (1999)** in Accra, vendors were carriers of a variety of bacterial enteropathogens, including *Salmonella*. Defective personal hygiene can facilitate the transmission of these pathogens via food to humans. The serving stage is a critical point in the street food industry. Enteropathogens can survive on the hands for three hours or longer. Diarrhea pathogens on the hands of mothers can be transmitted to infants **(Mensah, 1997)**.

E. coli 0157: NM was recovered seven affected households having consumed street food vended in Swaziland and South Africa. Isolates from 27 of the 31 samples from patients and the environment was indistinguishable from gel electrophoresis patterns in pulsed field. Important factors that contributed to the outbreak have been droughts and wind causing the increased transport *E. coli* O157 by food sold on the street, heavy rain and contaminated surface water **(Effler *et al.*, 2001).**

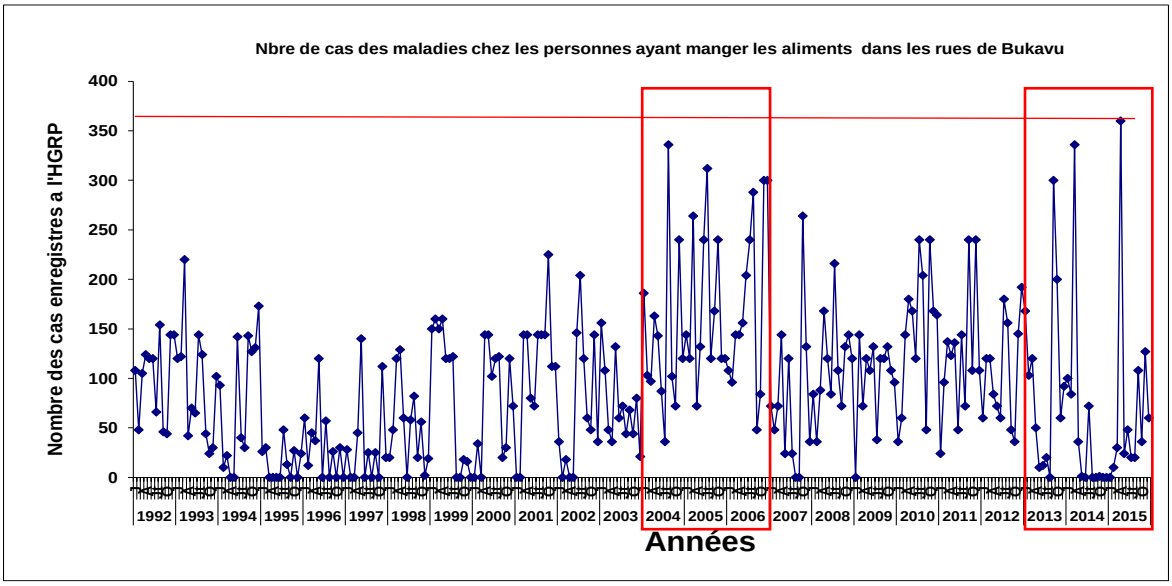

Figure 1 Number of illness cases recorded in Bukavu General Hospital between 1992 and 2015 for people who have eaten street foods in Bukavu city

Two other outbreaks occurred in Ghana in 2001. In the first forty-six Ghanaians who attended a funeral eaten apapransa (toasted corn flour dish with soup palm, fish and crabs) were admitted to hospital with diarrhea and vomiting. in the second home, about 20 people who ate rice dumplings with soup dumplings palm or corn with okra stew were admitted to hospital with diarrhea and vomiting. The likely cause of both outbreaks was not identified **(Ghanaweb, 2001).** E. *coli* was detected also in hand washings of high-income and low-income mothers in India at levels of 7.0 + 4.2 log10 CFU/ml and 9.0 + 5.7 log10 CFU/ml, respectively **(Mathur and Reddy, 1983)**. In Peru, E. *coli* was detected in 11 of 78 mothers' hand washings **(Black *et al.*, 1989)**. In Thailand, enterotoxigenic E. *coli* (ETEC) was detected in 6 of 42 mothers' hands and in 50 of 37 children's hands. The samples were from homes where children were suffering from ETEC diarrhea. In most instances the type isolated from diarrhea cases corresponded to that isolated from hands **(Echeverria *et al.*, 1987)**. During cholera epidemic in Mali in 1984, there were 1793 cases and 406 deaths. Case-control studies have identified three transmission routes: consumption of street food, drinking water the biggest village well and eat millet left in the drought-affected area in Mali **(Tauxe *et al.*, 1988).** Cholera is endemic in most countries, its transmission through food is appreciated, there is evidence to show that preparation and food handling by infected persons and physicochemical characteristics of growth of the food aid *Vibrio* sp. - high moisture content, a neutral/alkaline pH, the absence of competing bacteria allow transmission of *Vibrio cholerae.* There were 578 cases of *Shigella flexneri* in 2001, which have been associated with corn flour vended on public roads in South Africa. In 2002, botulism type A cause of canned fish contaminated tomato sauce is also two deaths in South Africa. A large outbreak of acute *aflatoxicosis* due to contaminated maize consumption took place in 2004 **(Nyikal *et al.*, 2004).** This affected more than 317 people and has a fatality rate is estimated at 39% around.

In 2008, an unprecedented number of street food-related events were reported to the Regional Office. These included anthrax in Zimbabwe; Typhoid fever and botulism in Uganda; beans and maize seed contaminated by chemicals in Kenya and Nigeria; poisoning by pesticides cabbage and other vegetables in Senegal; and *salmonellosis* due to the mouse fish in Mauritius. Others are poisonous mushrooms in Algeria; associated diarrhea Gala Dinner Meals in Nigeria; bromide poisoning in Angola and food poisoning in Nigeria, Madagascar, Angola, Kenya, Mauritius, Côte d'Ivoire, Benin, Congo, Ethiopia, Burkina Faso and Botswana. There were outbreaks of diarrhea in the Congo, Kenya, Madagascar, Burundi, Comoros, Uganda, Kenya, Botswana and Mozambique due to the consumption of street food. Fewer cases of foodborne outbreaks occurred in 2009. These keys were *shigellosis* in Malawi, Kenya and acute aflatoxicosis konzo DRC and Angola **(Mensah *et al.*, 2012)**.

Environmental and social characteristics of street food vendors in Bukavu city

Environment vendors

The results of estimating linear model (GLM, Table 4) exhibit there twelve variables statistically significant influent on the quality of the immediate vendors environment and their hygiene practices on microbiological quality of street food, it results in the exposure of food to houseflies (GLM: Z=1.27, p<0.05), the presence of stalls and improvised structures located along the sidewalks being the place of sale of street food (GLM: Z=7.22; p<0.001). The food vendors share the sidewalk with many other street vendors selling clothes, toys and especially sewage and garbage is discharged into the nearby streets of sale (GLM: Z=-5.35, p< 0.001). The presence of houseflies implies probable lack of adequate sanitation. This agreed with **(Muinde and Kuria, 2005)** who found houseflies in most of the street food stalls in Nairobi. **Mwadime, 2001** noted houseflies in 54.8% of the vending stalls. This implies that food contamination is most likely to occur despite efforts to keep the vending area clean. In a study conducted in Ghana by **Annan-Prah *et al.* (2011)**, food items were sold in the open-air which was dusty, near drainage gutters and some near garbage bins. **Paulson (1994)** reported that outbreaks are generally caused by foods due to poor personal hygiene of the vendors and that have been mishandled or mistreated during preparation or storage. Unhygienic surroundings like sewage, improper waste disposal system, and inadequate water supply attract flies and houseflies which further increases food contamination **(Chumber *et al.*, 2007).**

After cooking, foods are arranged on tables often even the floor (GLM: Z=-2.47, p<0.05) and briefly covered close to busy streets (GLM: Z=-1.91, p<0.05) and are reheated before being served for most of the time (GLM: Z=-2.99, p=0.003). The food cooking ahead of time, exposure to flies, and makes handling food on the floor and hand were identified as potential contamination factors of street food in Ghana **(Mensah *et al.*, 2002). Muinde and Kuria (2005)** reported about 85 % of the vendors prepared their foods in unhygienic conditions given that garbage and dirty waste were close to the vending stalls. Majority of the vendors left the food cool naturally which could lead to multiplication of microorganisms present in the food at the time of storage (**Gitahi, 2012)**.

Table 4 Generalized Linear Model (GLM) testing influence of independent factors (vendors quality and their environment hygienic practices) on the microbiological quality of street food vended (dependent variable) in urban zone of Bukavu city

GLM: *Gaussian identity model*						
Environmental quality	**Coef.**	**OIM Std. Err.**	**Z**	**P>|z|**	**[95% Conf. Interval]**	
Presence of sidewalks	.2917397	.0404132	7.22	**0.000**	.2125312	.3709481
Food wrapping nature	-.0821282	.0410271	-2.00	**0.045**	-.1625398	-.0017167
Selling food along street	-.0409156	.0428148	-0.96	0.339	-.1248311	.0429998
Presence of sewage and garbage	-.5120828	.0957703	-5.35	**0.000**	-.6997892	-.3243764
Spread food	-.0105502	.0042713	-2.47	**0.014**	-.0189217	-.0021787
Cooking foods before serving	-1.667467	.5585333	-2.99	**0.003**	-2.762172	-.5727623
Urban zone	-.0603794	.0316646	-1.91	**0.037**	-.1224409	.001682
Year to work	-.0241399	.0136762	-1.77	0.078	-.0509447	.0026649
Food proxy place vended	-.0115558	.0388798	-0.30	0.766	-.0877589	.0646473
Packaging type	-.0590675	.0434543	-1.36	**0.017**	-.1442362	.0261013
Food protection against insects	.000962	.0515662	0.02	0.985	-.1001058	.1020298
Work-related problem	.0322824	.015205	2.12	**0.034**	.0024811	.0620838
Hygiene service passage	.0004151	.0520125	0.01	0.994	-.1015275	.1023576
Exposing food to insects	.0868986	.0682821	1.27	**0.020**	-.0469319	.2207291
Handling food	.0107749	.0687665	0.16	**0.005**	-.124005	.1455548
Provision dishwater	-.0963449	.0594317	-1.62	**0.015**	-.212829	.0201391
Tools for serving food	.0010743	.0114172	0.09	**0.025**	-.0213029	.0234516
Constant	.2378941	.192922	1.23	0.021	-.1402261	.6160143

Other statistics : *Number of observations=333; Log likelihood = -377.7840824; AIC (Akaike's Information Criterion)= 1.37425 ; BIC (Schwarz's Bayesian Criterion) = -3421.5*

We see when tracking sales transactions that ambulant vendors and semi-stationary do not have enough water for dishes (GLM: Z=-1.62, p<0.05). The dish washing waters were sometimes the contamination source of street food vended with unacceptable levels (above 10^2) of different bacteria such as, coliforms and *Staphylococcus aureus* (P<0.05) **(Barro *et al.*, 2006)**. In addition the status and type of packaging used are poor (GLM: Z=-1.36, p<0.05) and are made of waste paper, moldy, inadequate plastic bags, cement bags of paper.

According **Gitahi (2012)** in industrial area of Nairobi, Kenya a total of 69% of vendors dump their wastes into Nairobi city council waste bins, while 79% use the Nairobi city council sanitary facilities. 87% of vendors used polythene bags for packaging take away rations. Majority of these vendors serve food with their hands (GLM: Z=0.09, p=0.025). **Carl *et al.* (2013)** states that some production and handling practices expose consumers to substantial health risks in Nairobi. The passage of health service on sale point has a positive influence on improving hygienic quality of the street food sellers environment, but not statically significant (p>0.05) (Table 4).

I terms of medical certificates none vendors (ambulant, semi-stationary and stationary) had food handlers' medical certificate. These results are very different from those obtained by **Gitahi (2012)** in Nairobi, were 24% (7/29) vendors had food handlers' medical certificate. And the levels noted in the streets of Accra Ghana (40%) by **Ackah *et al.* (2011)**. **Annan-Prah *et al.* (2011)** observed that 45% of street food vendors in Cape coast Ghana were not certified medically to handle food. As highlighted in the standard newspaper, Kenya of September 13, 2011, there is a need to ensure food handlers are immunized or treated against typhoid and other food borne illnesses. According **Mensah *et al.* (2012)** emphasizes that in the WHO African region, human factors including: unhygienic practices and deliberate contamination, environmental factors, such as unsafe water, unsafe waste disposal and exposure of food to insects and dust, undercooked food, and prolonged storage of cooked food without refrigeration are the main predisposing factors for street foods contamination.

Social characteristics of street food vendors

Table 5 summarizes results obtained in the survey on the social characteristics of vendors. We can see that the vast majority of street vendors (84%) are women, a Congolese national, South Kivu Province which generally comes from the outskirts of Bukavu. This result is not surprising for an African country like DRC in general and the South Kivu province in particular where sociologically food cooking is reserved for women. It is similar to the 71.22% obtained in Burkina by **Barro *et al.*, (2002),** similar to that of **Baba-Moussa *et al.* (2006)** in Benin, Cotonou city, but different from that obtained by **Khairuzzaman *et al.* (2014)** in Bangladesh, which states in its study both males and females, married and unmarried operate as street food vendors.

Indeed, it is true that women play a very vital role in the street food sector through their direct and/or indirect involvement in the business. Additionally a significant number of street vendors are woman-headed households **(Ackah *et al.*, 2011; WIEGO, 2014)**. The women engage in the sale of food because it is an activity that does not require at least in our African countries to have a high intellectual level or even be literate. It is not possible to suit the absolute number of street food vendors in Bukavu city, as was also the case in Dhaka by **Benjamin (2011),** India by **Bhowmik (2010).** 44% of these vendors are ambulant, 30% are semi-stationary, and 26% stationary. Nearly 78% are illiterate and most (60%) received no training for sale. By cons, in Ouagadougou city only 50% are illiterate, 3.57% achieved the top level **(Barro *et al.*, 2002).** The level of education achieved by the street food vendors in Bangladesh is comparatively low and in the case of a majority, education levels varied between grades 5 and 8 **(Khairuzzaman *et al.*, 2014)**. This lack of education has consequences for the ignorance of the basic rules of hygiene and sanitation in these sellers. Our study shows that only 8% of the saleswomen wear caps and aprons but many of them are clean (73%). Unfortunately (80%) of them serve food with their hands. Also, at the same time they serve food they handle currency money which are for the dirtiest and germ carriers. This practice can lead to bacterial contamination inherent to the safety of food. Hands carry most of the fecal contamination of germs time (E. *coli*, other heat resistant) which are often responsible for diarrheal diseases and gastroenteritis.

This has already been proven in several studies: **FAO/WHO (1990),** in Lebanon, **Harakeh *et al.*, (2005)** results showed that the meat-based fast food were contaminated with *Salmonella paratyphi* (serogroup A) and *Shiga Toxin* (Stx)-producing E. *coli* (STX-EC) and in Nigeria **Tjoa *et al.*, (1977)**, **Owhe-Ureghe *et al.*, (1993)** report the case. The selling part is very safe. Sewage and garbage is discarded in nearby streets selling places, attracting so as disease vectors. The consumption service and Veterinary **(SCAV, 2007)**-Neuchâtel, **Khairuzzaman *et al.*, (2014)** for Bangladesh and **Okonko *et al* (2009)** for Nigeria, confirmed that contact with equipment and utensils not washed or disinfected; the use of multi-use hand towels; handling of foodstuffs with unwashed hands; inadequate cooking; too slow cooling before storage; too high temperature or too long conservation are street food contamination modes aerobic mesophilic bacteria (FMAT).

In South Kivu, Bukavu city as in most African cities sub-Saharan informal food sector is an important source of employment in urban areas, particularly for people who do not have a high level of education and which would have had trouble finding a skilled job. This sector generates annual daily business of several million Congolese francs in a country like the DRC. This street food is cheaper and allows households to save on their daily income, for the same meal would cost 3 to 5 times more than in a traditional restaurants (formal sector), or even at home. But can we say that these people really are saving? The question needs to be asked because this power sometimes has adverse effects on the economy arising from medical expenses caused by food toxi-infections, work absences and can even generate casualties.

An international workshop was held in Ouagadougou on 22-24 November, 1999 on the theme, "the food industry for a healthy nutrition in West Africa." One of the sub theme was "street/new foods to food production, marketing summons, quality and health effects." Several papers under this theme showed that the street food sector is growing while the products offered are not always of good

quality **(Umoh and Odoba, 1999).** And one of the recommendations of this workshop was to improve the nutritional, hygienic and organoleptic quality of food produced by small units of transformations to provide the populations of urban centers healthy and balanced products.

Table 5 Social characteristics of vendors

Characteristics of vendors	N=320	Proportion (%)
	Gender	
Men		16
Women		84
	Vendor categories	
Ambulant		44
Semi-stationary		30
Stationary		26
	Level of education	
Illiterate		78.67
Primary/Literate		18.67
Secondary/Higher		2.67
	Types of training	
Technical		3.33
On the job		36
Without level		60.67

CONCLUSION

This study aimed to control the hygienic quality of street foods vended in urban zones of Bukavu city and assess the potential health risks to consumers in South Kivu province, DR Congo in general. This prospective study was conducted among street vending food from 320 vendors in three urban zones of Bukavu city. From April to July, 2015, a total of 80 food samples compressing boiled meat (16), roast fish (18), sausages (21), fresh milk (13) and loaf (12) from 320 vendors were purchased and analyzed. Standard microbiological methods were used for isolation, enumeration and identification of bacteria.

Investigations on the sales premises and microbiological test results revealed the presence of a perpetual risk of contamination as study sites and vendors 'categories. The results of this study indicate that all street food samples tested are contaminated to varying degrees by isolated and identified bacteria including: FMAT, Total coliforms with *Escherichia coli, Staphylococcus* species with Negative Staphylococci coagulase and *Staphylococcus aureus* and *Salmonella* species with *Salmonella enterica.*

The quantities of bacteria obtained by CFU/10g of each food taken exceed the standards established by the Codex Alimentarius, very important and significant for different vendors categories and sampling sites ($p<0.0001$). Food samples collected from vendors in Kadutu urban zone (the most popular and unhealthy city) are more contaminated. The foods that are not subjected to heating during the preparation have the highest microbial load. This is the case where fresh milk the total mesophilic flora is of the order of 10^5 and varies the sampling sites. This is also the case of the foodstuff after cooking are exposed for a long time at room temperature: boiled meat and sausages contain an uncountable number of bacteria. But products like loaf has a total mesophilic flora equal to 657.10^2, 435.10^3 and 765.10^2 CFU/10g in Bagira, Kadutu and Ibanda urban zones respectively. Total coliforms, *Staphylococcus* sp, and *Salmonella* sp. are more numerous in the boiled meat, fresh milk and sausages.

When had a contamination analysis by vendor category, the majority of products sampled and analyzed, we see that ambulant vendors have mostly dishes much more contaminated than other distributors ($p<0.001$). They are followed by semi-stationary and stationary vendors respectively. It was found also that the contamination of street food is multifactorial and vendors' hygiene contribute significantly to contamination factor, including unhygienic managers, dirty surroundings and poor water quality.

Epidemiological findings show that the prevalence of diseases recorded in Bukavu General Hospital "HPGR", people having eaten street food in Bukavu city is growing for the last three years (2013-2015), it was 300 cases in September 2013, 350 cases in May 2014 and more than 380 cases in April 2015. This prevalence was almost the same between 2004 and 2006 but a decreasing manner. These results are part of an approach similar to those for other cities in black Africa and including Kisangani by (**Kama, 2014; Manzilima, 2011)** for Nigeria by **Oranusi *et al.* (2003), Okonko *et al.* (2008a, b, c),** and a few years ago **Mensah *et al.* (2012).**

In general, interventions and programmes can only be successful if they do not focus on one aspect alone. Tackling only food quality, for instance, cannot ensure that street food vendors play the most positive role in realizing food security of the urban population. It is important not to forget that the street foods constitute a very heterogeneous sector and the interventions need to be carefully planned by keeping different aspects such as gender, secondary audience, and local customs into consideration. It is also necessary to differentiate between vendors selling freshly prepared food on the spot or hawking dishes prepared earlier at home, with the second practice being much more risky in terms of foodborne pathogen and spores. Needless to say, general education levels also play an important role in ensuring safe street foods. The more both vendors and patrons will be educated and the more they will know about issues such as nutrition and food safety, the more they will be interested in having the business as clean and the products as healthy as possible.

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