

Research Application Summary

Microbiological Safety and Nutritional Quality of Street Vended Ready-to-Eat Foods in Bukavu, Eastern DR Congo

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Abstract

Ready-to-eat foods sold by street vendors play a significant role in urban diets worldwide, offering accessible, affordable, and diverse options. However, concerns about food safety due to inadequate handling practices have raised questions about their consumption. This study addresses the quality and safety of street-vended ready-to-eat foods in Bukavu, South Kivu Province, Democratic Republic of Congo (DRC). The socio-economic profiles of vendors and the nutritional and microbial attributes of five major food types were investigated. A comprehensive survey was conducted involving 120 street food vendors from four prominent hotspots in Bukavu. Cataloging the available foods and understanding vendor demographics provided critical context. Most vendors were male (62.32%), single (65.94%), and had limited formal education (60.14%). Makeshift, unsheltered facilities were common (75.36%). The primary food categories included meat (43%), snacks (36%), and fish (14%). Samples of the major food types were collected for microbiological and physicochemical analyses. Microbial load and nutritional content varied substantially among foods. Processed beef exhibited the highest total mesophilic aerobic flora (TMAF) load (4.11 cfu/g), whereas salty fried fish displayed the lowest (1.4 cfu/g). Boiled pork and fresh fried fish showed distinct levels of *Salmonella* contamination (3.9 cfu/g and 1.21 cfu/g, respectively). *Listeria* prevalence was highest in fresh fried fish (3.81 cfu/g) compared to potato-based (1.49 cfu/g) and plantain-based snacks (1.56 cfu/g). Processed pork had the highest total coliforms (TC) count (2.10 cfu/g), while potato-based snacks showed the lowest (0.91 cfu/g). Nutritional analysis revealed variations across foods. Salted fried fish demonstrated high mineral content (1.77%) and protein content (36%), while lipid-rich snacks (23%) based on plantains had the highest lipid content (30%). Processed pork had the highest carbohydrate content (21.9%), and a near-neutral pH (6.5) was consistent across all foods. This study underscores the need for targeted training programs to enhance food safety practices among vendors. The findings provide a baseline for designing interventions that mitigate risks associated with foodborne pathogens and improve food safety management systems. By addressing the concerns surrounding ready-to-eat street foods in Bukavu, this research contributes to the enhancement of nutritional and public health outcomes in the region.

Keywords: Beef, Chicken, DR Congo, Pork, Salads, Public Health, ready to eat foods, South Kivu, Ready to eat foods

Résumé

Les aliments prêts à manger vendus par les vendeurs de rue jouent un rôle important dans les régimes alimentaires urbains à travers le monde, offrant des options accessibles, abordables et diversifiées. Cependant, des préoccupations concernant la sécurité alimentaire due à des pratiques de manipulation inadéquates ont soulevé des questions sur leur consommation. Cette étude aborde la qualité et la sécurité des aliments prêts à manger vendus dans la rue à Bukavu, dans la province du Sud-Kivu, en République Démocratique du Congo (RDC). Les profils socio-économiques des vendeurs et les attributs nutritionnels et microbiologiques de cinq types principaux d'aliments ont été étudiés. Une enquête exhaustive a été menée auprès de 120 vendeurs de rue de quatre points chauds de Bukavu. L'inventaire des aliments disponibles et la compréhension des caractéristiques démographiques des vendeurs ont fourni un contexte critique. La plupart des vendeurs étaient des hommes (62,32 %), célibataires (65,94 %) et avaient une éducation formelle limitée (60,14 %). Des installations de fortune et non abritées étaient courantes (75,36 %). Les principales catégories d'aliments comprenaient la viande (43 %), les collations (36 %) et le poisson (14 %). Des échantillons des principaux types d'aliments ont été collectés pour des analyses microbiologiques et physico-chimiques. La charge microbienne et la teneur nutritionnelle variaient considérablement parmi les aliments. Le bœuf transformé présentait la charge la plus élevée de flore aérobie mésophile totale (TMAF) (4,11 cfu/g), tandis que le poisson frit salé affichait la plus basse (1,4 cfu/g). Le porc bouilli et le poisson frit frais présentaient des niveaux distincts de contamination par *Salmonella* (3,9 cfu/g et 1,21 cfu/g, respectivement). La prévalence de *Listeria* était la plus élevée dans le poisson frit frais (3,81 cfu/g) par rapport aux collations à base de pommes de terre (1,49 cfu/g) et aux collations à base de plantains (1,56 cfu/g). Le porc transformé avait la plus haute teneur en coliformes totaux (TC) (2,10 cfu/g), tandis que les collations à base de pommes de terre montraient la plus basse (0,91 cfu/g). L'analyse nutritionnelle a révélé des variations entre les aliments. Le poisson frit salé présentait une teneur élevée en minéraux (1,77 %) et en protéines (36 %), tandis que les collations riches en lipides (23 %) à base de plantains avaient la plus haute teneur en lipides (30 %). Le porc transformé avait la plus haute teneur en glucides (21,9 %), et un pH quasi-neutre (6,5) était constant parmi tous les aliments. Cette étude souligne la nécessité de programmes de formation ciblés pour améliorer les pratiques de sécurité alimentaire parmi les vendeurs. Les résultats fournissent une base pour concevoir des interventions visant à atténuer les risques associés aux agents pathogènes d'origine alimentaire et à améliorer les systèmes de gestion de la sécurité alimentaire. En répondant aux préoccupations entourant les aliments de rue prêts à manger à Bukavu, cette recherche contribue à l'amélioration des résultats nutritionnels et de santé publique dans la région.

Mots-clés: Bœuf, Poulet, RDC, Porc, Salades, Santé publique, aliments prêts à manger, Sud-Kivu

Introduction

Ready-to-eat foods sold in the streets or in mobile markets are popular due to their accessibility, affordable price, variety, and nutritional value, even though they often have a reputation for being unsafe due to sellers' inadequate handling and hygiene practices (Manguiat and Fang, 2013). Most foods are prepared and distributed in mobile and temporary facilities that lack the necessary basic tools and equipment to ensure safe food preparation. Furthermore, previous research has shown that street vendors are generally unaware of basic food safety issues, lack knowledge of food hygiene, and have limited education, both in general and specifically in the field of food technology (Gadaga *et al.*, 2008; Roger *et al.*, 2015). Across the world, the proliferation of street food vendors continues to increase as this activity is

highly profitable and requires very low initial capital. In the South Kivu province of the Democratic Republic of Congo, there are many types of ready-to-eat foods that are typically sold by street vendors in different popular neighborhoods and hotspots of cities and towns. As in many developing and underdeveloped countries, these ready-to-eat foods are an integral part of urban life due to high unemployment rates, low wages, limited job opportunities, and restricted social programs (Sobukola *et al.*, 2010). Street vendors provide an essential service to people of all economic levels by selling complete meals, refreshing beverages, and snacks. In Bukavu, these street foods are an important economic factor as they provide a source of inexpensive and nutritious meals for a large number of people. Economic operators in this sector significantly contribute to providing food for large segments of the residents living in the city center, suburbs, and slums of Bukavu.

In Bukavu, ready-to-eat foods sold in the streets are commonly based on chicken, pork, and goat. Salads and vegetables are generally based on potatoes, onions, and peppers, while beverages typically include locally produced milk, juices, and beers. As for meats, vendors commonly use sensitive parts such as blood, anal base, feet, neck, head, skin, heart, liver, and gizzard. These parts are inherently unclean and require additional thorough cleaning procedures to be suitable and safe for human consumption. To date, little information is available regarding the quality and microbiological safety of these foods in Bukavu.

Regarding preparation methods, most of these foods are either boiled in water of unknown quality or fried in poor-quality or second-hand oils, often reused multiple times. In terms of equipment and unit operations used, hygiene is generally lacking in the majority of cases, and cooking or frying temperatures are almost never guaranteed to prevent the formation of undesirable compounds. Lastly, these foods are not effectively protected against dust and flies, which can harbor foodborne pathogens, and maintaining safe storage temperatures appears to be challenging. Thus, there are potential health risks associated with initial contamination of raw foods by pathogenic bacteria, as well as subsequent contamination by vendors during preparation and handling after cooking. It is therefore important to gather data that provide information on the microbial and food safety risks present in this category of foods sold in public places in Bukavu. The objective of this study was to investigate the safety and quality of ready-to-eat foods provided by street vendors, locally produced and collected from several typical vendors around the main hotspots of Bukavu, South Kivu Province, Democratic Republic of Congo. Specifically, this study wanted to (i) establish the socio-economic profile of street food vendors as well as the catalog of ready-to-eat foods available in Bukavu, and (ii) determine the nutritional value and the microbiological quality of the 5 major ready-to-eat foods sold in Bukavu city, Eastern DR Congo. The results of risk assessments will serve as a basis for the development of scientific interventions aimed at controlling hazards and implementing and improving food safety management systems in the street food vending sector.

Materials and Methods

Study area. This study took place in Bukavu (Figure 1), located in the Eastern part of the Democratic Republic of Congo. This area is characterized by an average temperature of 24°C and is located between 2°30'55" South latitude and 28°50'42" East longitude. Data collection was conducted at a hotspot in each municipality of the city: Ibanda municipality (Essence), Kadutu municipality (Carrefour), and Bagira municipality (Brasserie). The analyses were performed in the microbiology laboratories (for microbiological analyses) and the soil laboratory (for physicochemical analyses) of the

Faculty of Agronomic and Environmental Sciences at the Université Evangélique en Afrique (UEA).

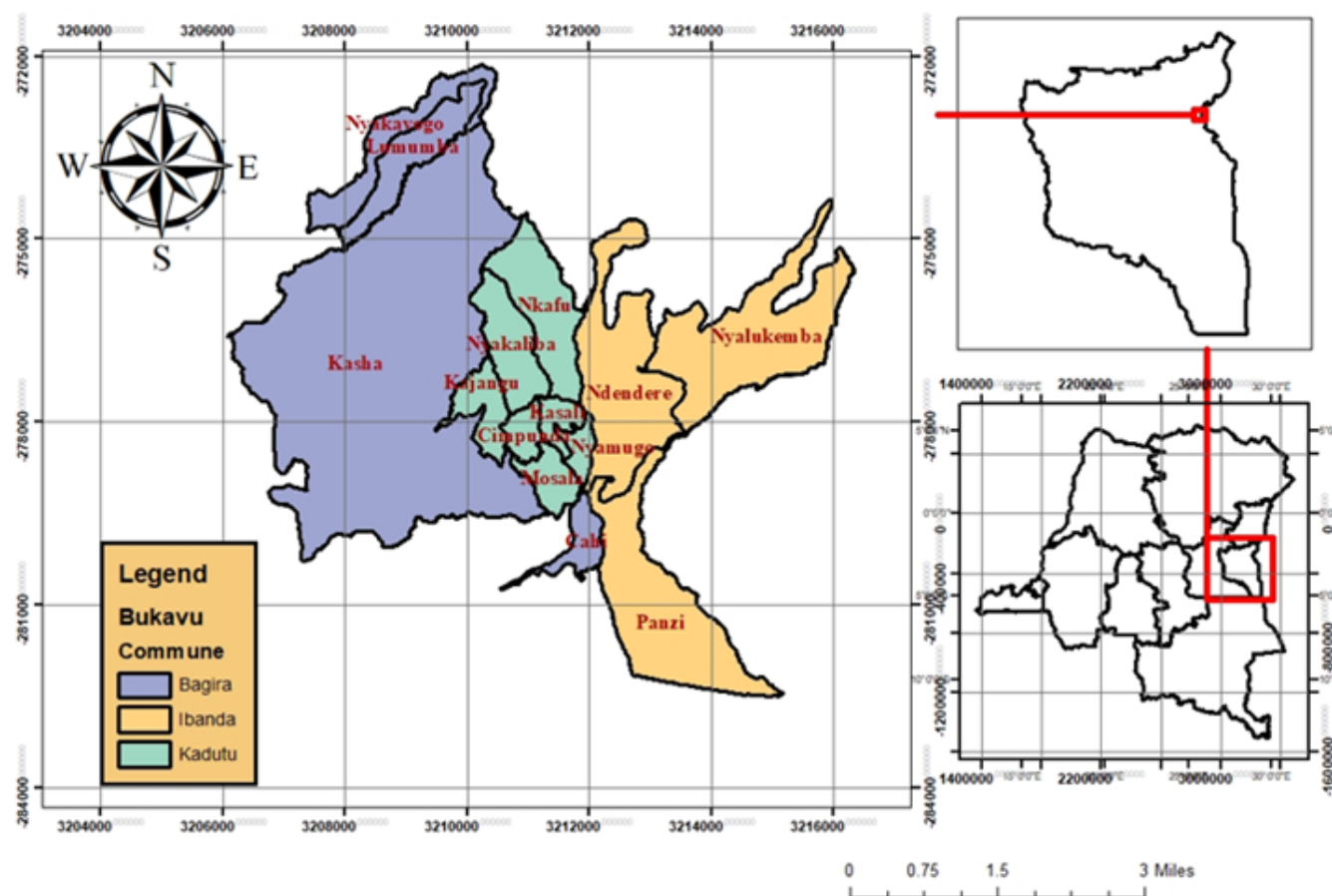


Figure 1. Area of study, Bukavu

Sample collection, treatments and data analysis. In each selected hot spot in Bukavu, street vendors of ready-to-eat food were subdivided into three categories according to their mode of sale (World Health Organization, 2018): (1) mobile food vendors (MFS) are those who prepare food at home and then transport it for sale, (2) stationary food vendors without shelter (SFS) who prepare their food in an open place under a tree or by the side of the road and sell on the spot and (3) stationary food vendors with shelter (SFS) who prepare complete meals under makeshift shelters and serve them on tables in stalls as in restaurants. A sample of 10 vendors per category was selected from each site to complete the survey questionnaires. A total of 120 street food vendors operating in four prominent locations in Bukavu were surveyed. Vendors' socio-economic characteristics, including age, gender, educational background, marital status, and location of operation, were recorded using structured questionnaires. Samples of meat, fish and snacks prepared and sold in the street were collected from each vendor after the survey. Only samples with a temperature below 45°C were collected, as some street foods are always cooked and stored at high temperatures. Samples of approximately 250 g of each ready-to-eat food were taken using the vendor's utensils and transferred to sterile jars. All samples were kept on ice during transport to the laboratory for analysis the same day. After investigation in the hot spots of three communes (Brasserie, Feu Rouge, Essence and Carrefour) in Bukavu.

A total of 30 samples, including boiled, fried and processed pork and beef; fried fresh and salted fish; and fried potato and Plantain banana snacks, were collected from the vendors who were interviewed during the survey.

In each commune, 10 samples were taken from these vendors and stored in a jar in an icebox before being sent to the laboratories for analysis.

Microbiological analyses were conducted carried out to assess the microbial quality of the selected street-vended foods. Samples were collected in sterile plastic containers and transported to the laboratory under refrigeration conditions. Total mesophilic aerobic flora (TMAF), Salmonella, Listeria, and total coliforms (TC) counts were determined using standard procedures. Results are presented as colony-forming units per gram (cfu/g) of the sample. Physico-chemical analyses were performed to assess the nutritional quality of the street-vended foods. Parameters measured included pH, moisture content, ash content, protein content, lipid content, and carbohydrate content. Statistical analyses were performed using IBM SPSS Statistics version 25. One-way Analysis of Variance (ANOVA) followed by the Least Significant Difference (LSD) test was used to determine significant differences ($p < 0.05$) among the means.

Results and Discussion

Socio-economic characteristics of street food vendors. The socio-economic characteristics of street food vendors are summarized in Figure 2. The results show that 62.32% of these vendors are men and only 37.68% are women. The majority of these vendors are single (65.94%) and have only studied up to primary school (60.14%). The results also showed that most of these vendors use makeshift facilities without shelter (75.36%). Few are mobile (13.77%) and only a minority sell their products under a sheltered structure (10.87%). This corroborates the findings of previous studies on street food, particularly those by Oyunga-Ogubi *et al.* (2009). These studies had already suggested that this economic activity is carried out by men and women with a relatively low level of education and that it requires relatively little capital, given that it is carried out without recourse to imposing and sophisticated infrastructures.

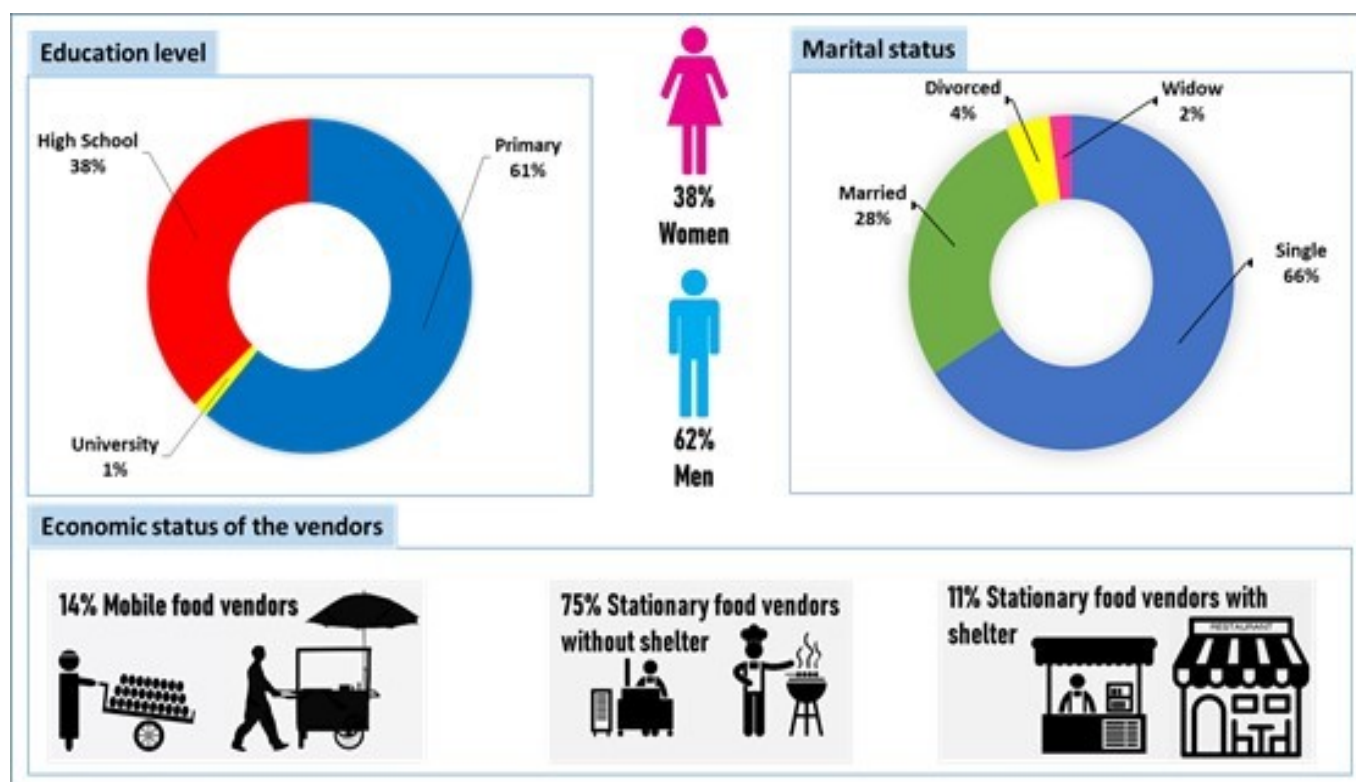


Figure 2. Socio-economic characteristics of street food vendors

Types of street food sold in Bukavu. Figure 3 summarizes the types of food commonly sold in Bukavu. The results show that meat (43%) and snacks (36%) followed by fish (14%) are the most common street foods in Bukavu. Salads (6%) and drinks (1%) are in the minority. Among meats, pork (58%) is the most common, alongside beef (24.69%) and goat (13.58%).

Poultry meat, particularly chicken, accounts for only 3.7% of the market. As for fish, it is either fresh (37%), salted (37%), or fretins (26%). Snacks, for their part, are mainly made from potato-based products (66.67%) and plantain (21.74%). Similar results were obtained by (Maroko, 2016) in his study of food prepared in hot spots in Kenyan towns and cities. The use of these types of food is justified by the fact that they are cheap, available, easy to prepare and an integral part of consumers' eating habits.

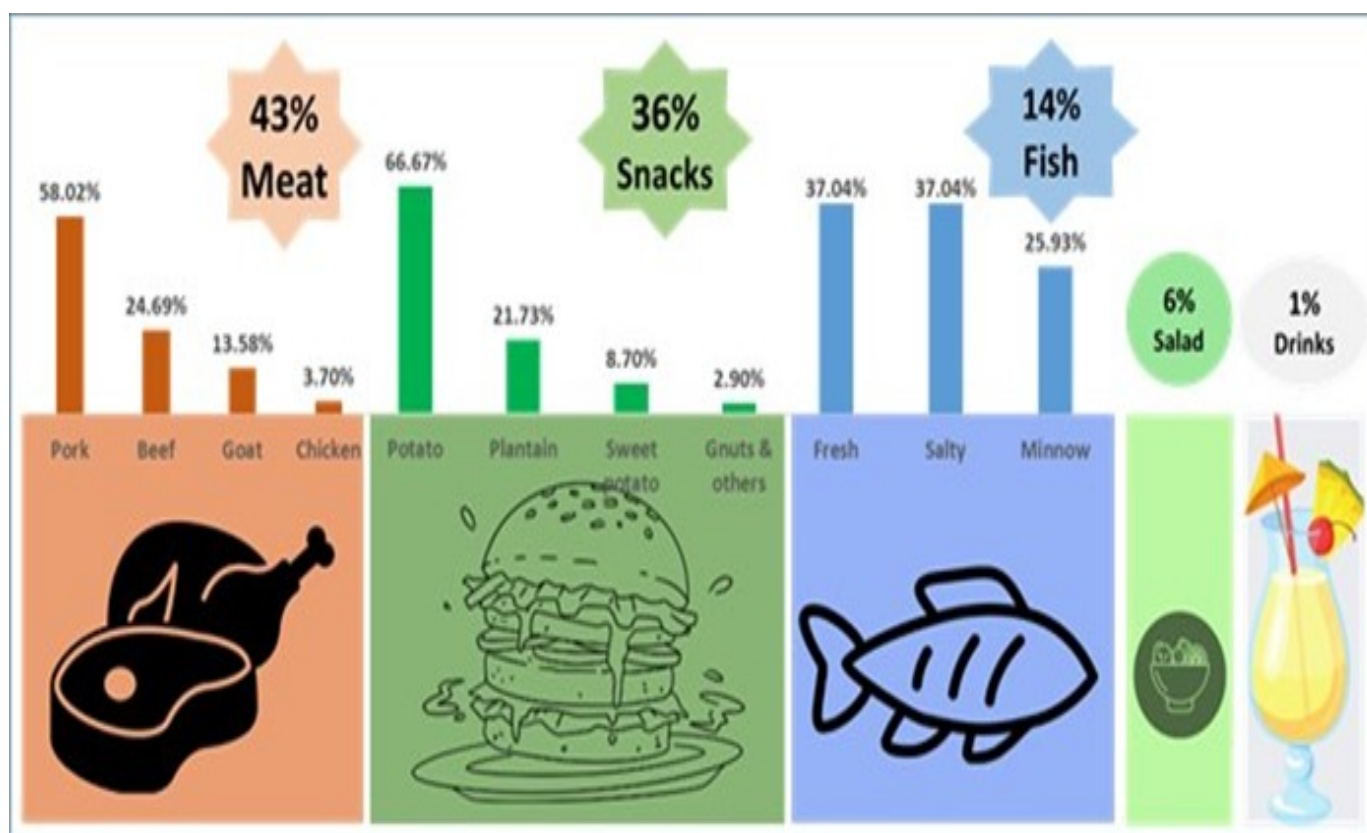


Figure 3. Types of street food sold in Bukavu

Method of preparation of street food. The results on the method of preparation of food sold in the streets of Bukavu are summarised in Figure 4. These results show that frying is the most common method of preparation (39.13%) among vendors of food sold in the streets of Bukavu. Other foods were boiled (28.99%), processed or smoked, such as sausages (17.39%) or grilled (14.49%). This predominance of frying as a preparation method could be attributed to the improved sensory properties that frying confers on food, but also to its ability to eliminate pathogenic elements thanks to the temperatures involved in the frying process (Oke *et al.*, 2018).

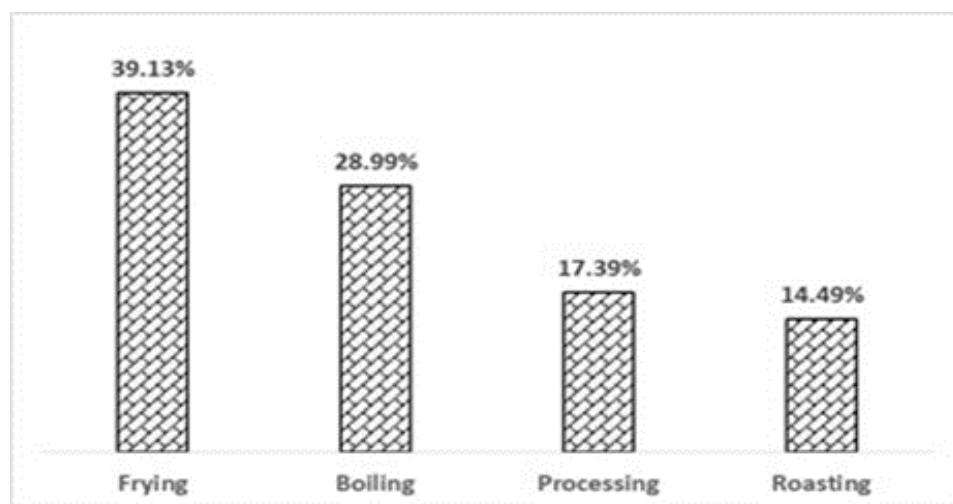


Figure 4. Preparation methods of street food in Bukavu

Microbiological quality of food sold in the streets of Bukavu. Table 1 summarises the results on the microbiological quality of foods commonly sold and consumed in the streets of Bukavu. These results show that there are significant variations between the different products in terms of their microbial load. In terms of total aerobic mesophilic flora (TAMF), processed beef recorded the highest load (4.11 cfu/g) while fried dirty fish had the lowest score (1.4 cfu/g). This could be attributed to the microbiological qualities of meat in general and beef in particular (Kotzekidou, 2016). Compared with fish, which live in anaerobic conditions in water, foodstuffs and meat in particular, produced on land, live in symbiosis or parasitism with aerobic microorganisms. The latter are the first to colonise the animal's body once it has been slaughtered. Salmonella were abundant in boiled pork (3.99 cfu/g) and less so in fresh fried fish (1.21 cfu/g). Similar results were obtained by (Syne *et al.*, 2013).

In terms of listeria, fresh fried fish had the highest microbial load (3.81 cfu/g), while there were fewer in potato-based snacks (1.49 cfu/g) and plantain-based snacks (1.56 cfu/g). Studies on the microbial flora of foods have already shown that fish products have a higher *Listeria* microbial load than livestock products and field foods (Ramos *et al.*, 2013). For total coliforms (TC), processed pork recorded the highest microbial load (2.10 cfu/g) while potato-based snacks had the lowest score (0.91 cfu/g). The proximity of pork to faecal matter and a lack of adequate hygiene could explain this finding (Roger *et al.*, 2015). These results are in agreement with the findings of (Manguiat and Fang, 2013) on the microbiological qualities of ready-to-eat foods sold on the streets.

Conclusion

This study examined the characteristics of ready-to-eat street food in Bukavu, South Kivu Province, Democratic Republic of Congo. It revealed that street food vendors in Bukavu typically have low education levels and are mainly men. They often operate in makeshift facilities without proper shelter, making street vending accessible as an economic activity. The most commonly sold street foods were meat and snacks, with pork being the predominant meat choice due to affordability, availability, and ease of preparation. Frying was the most common method of food preparation among vendors, likely due to its sensory appeal and pathogen-eliminating potential at high temperatures. However, the study highlighted concerns about food safety and hygiene practices during preparation due to microbial risks. Microbiological analysis showed varying contamination levels among different food items,

emphasizing the need for improved food safety measures. Nutritional analysis revealed diverse nutritional compositions, with fish being rich in minerals and proteins, and snacks, especially plantain-based ones, high in lipids due to frying. The study recommends interventions to enhance vendor education, food preparation techniques, and hygiene standards to ensure the safety and quality of street foods, benefiting both vendors and consumers in Bukavu and similar urban areas worldwide.

Table 1. Microbiological quality of food sold in the streets of Bukavu

Type of products	TAMF	Salmonella	Listeria	Total coliforms
Boiled beef	2.40±1.46 ^{bcd}	2.14±0.55 ^{bcd}	3.25±0.14 ^b	1.88±0.36 ^{ab}
Fried beef	3.62±1.76 ^{ab}	1.87±0.14 ^d	2.06±0.09 ^{de}	2.09±0.81 ^{ab}
Processed beef	4.11±0.60 ^a	1.95±0.08 ^d	2.61±0.21 ^c	1.55±0.57 ^{de}
Fried fish	1.71±0.07 ^d	1.21±0.04 ^e	3.81±0.16 ^a	1.71±0.38 ^{abc}
Fried salted fish	1.40±0.08 ^d	1.35±0.04 ^e	2.66±0.10 ^c	1.88±0.14 ^{abc}
Boiled pork	3.44±0.18 ^{abc}	3.99±0.14 ^a	2.22±0.16 ^{cd}	1.58±0.32 ^{cde}
Fried pork	2.36±1.17 ^{bcd}	2.48±0.08 ^{bc}	2.31±0.57 ^{cd}	1.54±0.12 ^{bcd}
Processed pork	4.12±0.36 ^a	2.31±0.08 ^{bcd}	2.29±0.07 ^{cd}	2.10±0.42 ^a
Plantain based snack	2.46±0.65 ^{abcd}	2.65±0.85 ^b	1.56±0.43 ^{ef}	1.59±1.21 ^e
Potato based snack	1.72±0.43 ^{cd}	2.03±0.35 ^{cd}	1.49±0.51 ^f	0.91±0.36 ^e
P-value	0.01019**	1.051e ^{-7***}	3.85e ^{-7***}	6.75e ^{-4***}

FAMT: Total Mesophilic Aerobic Flora. Values are expressed as averages in CFU/G (colony-forming units). Means in the same column with the same letter are not significantly different.

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