Advances in Infectious Diseases, 2025, 15(1), 171-183
https://www.scirp.org/journal/aid
ISSN Online: 2164-2656
ISSN Print: 2164-2648

Prevalence, Antimicrobial Susceptibility Pattern, and Associated Health Risks of Foodborne Pathogens in Street Foods Sold in Elementary Schools, Yaounde, Cameroon

Mary Nkongho Tanyitiku[1,2*], Wilson Agwanande[3], Exodus Akwa Teh[4], Royas Mawe Laison[5], Igor Casimir Njombissie Petcheu[2]

[1]Food and Markets Department, Natural Resources Institute, University of Greenwich, London, United Kingdom
[2]Women's Network for Biodiversity and Food Science, Yaounde, Cameroon
[3]Department of Process Engineering, National School of Agro-Industrial Sciences, University of Ngaoundere, Ngaoundere, Cameroon
[4]Department of Animal Biology, University of Dschang, Dschang, Cameroon
[5]Department of Anaesthesiology, AIC Mission Hospital Kijabe, Nairobi, Kenya
Email: *Mary.Tanyitiku@greenwich.ac.uk

How to cite this paper: Tanyitiku, M.N., Agwanande, W., Teh, E.A., Laison, R.M. and Petcheu, I.C.N. (2025) Prevalence, Antimicrobial Susceptibility Pattern, and Associated Health Risks of Foodborne Pathogens in Street Foods Sold in Elementary Schools, Yaounde, Cameroon. *Advances in Infectious Diseases*, **15**, 171-183.
https://doi.org/10.4236/aid.2025.151014

Received: January 10, 2025
Accepted: March 22, 2025
Published: March 25, 2025

Abstract

Objectives: Street foods are an affordable source of nutrition in Cameroon; however, their association with microbial pathogens poses significant risk to public health. **Methods:** We investigated 160 street food samples sold within elementary schools for the presence of foodborne pathogens and also the antimicrobial resistance of cultured-confirmed bacteria isolates using the agar disk diffusion method. **Results:** The total viable count of seven (bread, spaghetti, fish, peanuts, eggs, beef, pepper) of the eight street foods examined (except beans sauce) were >10^5 cfu/g and indicated unsatisfactory levels for human consumption. In addition, 16 bacteria pathogens with at least one in each street food were identified: *E. coli* was the most prevalent 47.50% (76/160), followed by *Staphylococcus aureus* 39.37% (63/160) in foods such as beef 80% (16/20) and bread 85% (17/20). *Salmonella* spp. 32.50% (52/160), *Campylobacter* spp. 14.37% (23/160) and *Shigella* spp. 23.75% (38/160) were largely isolated in eggs 60% (12/20), 35% (7/10), and pepper 40% (8/20) sauces, respectively. Furthermore, except *E. coli*, all bacteria isolates were highly susceptible to ciprofloxacin. *Yersinia enterocolitica* was the most susceptible to ciprofloxacin 90.90% (10/11), tetracycline 81.81% (9/11), gentamicin 81.81% (5/11), and chloramphenicol 90.09% (10/11). *Staphylococcus aureus*, *Campylobacter* spp., and *E. coli* were highly resistant to chloramphenicol 90.47% (57/63), tetracycline 82.60% (19/23), gentamicin 81.57% (62/76), and vancomycin 64.47% (49/76), respectively. **Conclusion:** The findings strongly indicated that preventable foodborne diseases of resistance to a wide range of antibiotics could be occurring among food handlers and young children in street food vending settings. In particular, the presence of coliforms in all street food samples indicated poor hygiene and sanitary practices in street food activities. It thus recommends effective implementation strategies to improve food safety and hygiene practices in street food vending within elementary schools in Cameroon.

Keywords

Street Food, Young Children, Foodborne Diseases, Foodborne Pathogens, Antimicrobial Resistance, Microbial Contamination, Public Health Risk, Cameroon

1. Introduction

Globally, the consumption of unsafe food is estimated to cause 420,000 deaths and 33 million DALYs (disability adjusted life years) each year [1] [2]. Among those affected, children under the age of five years are at high risk due to less developed immune systems to combat pathogenic infections [2]. Specifically, an estimated 1.7 billion cases of childhood diarrhoea occur each year, leading to about 30% of childhood deaths in developing countries [2] [3]. Diarrhoea is an intestinal tract infection, commonly caused by bacterial pathogens such as *Escherichia coli*, *Salmonella* spp., *Shigella* spp., *Campylobacter* spp., *etc*. [2] [3]. Infected children could experience 2 - 3 episodes of diarrhoea annually, and each episode can lead to nutrient deprivation, malnutrition, and eventually death [3]. In Cameroon, there is scarcity of data on diarrhoea morbidity and mortality among children, however, epidemiological studies indicate a community-based prevalence of 16 to 23% with common symptoms including stomach ache/cramps, fever, vomiting, and loss of appetite [4]. In fact, the risk of foodborne diarrhoea is high in many African communities, and about 94% of these cases of diarrhoea are attributed to the environment, which includes risk factors such as unsafe drinking water, poor food handling, and hygiene practices [4]-[6].

Street foods are considered nutritious and readily affordable foods that provide a source of income for many people in developing countries [7]. Although they can be consumed by all age groups and are appreciated for their unique characteristics (flavours, taste, convenience, and affordability), their association with microbial pathogens remains a serious threat to public health [8]-[13]. Street foods are prepared and sold under unregulated food safety conditions in public places, including streets, local markets, bus stations, schools, work, and healthcare facilities [13]. In particular, food handling and hygienic practices of these foods across their supply chain, from acquiring raw ingredients, transportation, storage, food preparation, to vending (at the roadside and/or hawking) remain questionable [13]-[15].

In Cameroon, several studies [7] [11] [16]-[19] have highlighted the poor microbiological quality of street foods to include food safety indicators (fecal coliforms, yeast and mould, *E. coli*, *Salmonella*, coagulase-positive staphylococci, *Bacillus cereus*, among others), which could contribute to foodborne diseases. Indeed, on 2 May 2003, the Centre Pasteur du Cameroun (CPC, Cameroon) was notified of a cluster of diarrhoeal illnesses among 90 individuals, who were involved in a party held on 1 May 2003 in Yaounde and included some street food (cold fish and hard boiled eggs with mayonnaise) [20]. This resulted in suspected food contamination with *Plesiomonas shigelloides*, a rare causative agent in foodborne disease outbreaks [20]. Despite this, the food safety risks of street foods sold within elementary schools that generally enrol children from infants to primary school age have been completely ignored. Foodborne diarrhoea in such settings can be mitigated and even prevented when microbial exposure routes are identified and acted upon [21] [22].

To understand the risk of exposure of vulnerable young children to foodborne pathogens, the purpose of this study was to investigate the prevalence and antibiotic susceptibility patterns of foodborne pathogens in street foods sold within elementary schools in Yaounde, Cameroon.

2. Materials and Methods

2.1. Sample Collection and Preparation

The study was carried out between September and December 2022 in Yaounde. Yaounde is the political capital of Cameroon, and due to socioeconomic conditions (poverty, busy work schedules, changes in tastes and food preferences), several households have been found to primarily consume street foods [7] [11] [16] [17]. In total, 160 samples (n = 20 per street food) were purchased weekly from street vendors who sold these foods within 20 elementary school premises. Of the 5031 elementary schools in the region, these 20 schools were randomly selected based on observed overcrowded and cosmopolitan nature of its pupil's population [23] [24]. In Cameroon, the education system is divided into two distinct subsystems: the French and the British colonial model. Although studies in French were popular in the past, English courses are becoming more popular due to the increasing influence of globalisation [24]. In these settings, its education system is made up of two optional years of pre-school (ages 3 - 5), six compulsory years of primary school (ages 6 - 11), and seven years of secondary education (ages 12 - 18) [24]. In this study, we sampled schools that enroled preschool-age children to primary-age children in both the French and the British colonial model. Notably, Nguendo Yongsi [25] isolated at least one pathogenic microorganism among these age groups living within the sampled population; that is, in 59.5% (260/437) of children's stools with diarrhea. We were interested in two staples (bread, spaghetti) and six sauces (beans, fish, peanuts, eggs, beef, and pepper), based on their availability in all selected schools and since more than 50% of street vendors sold these street foods in Cameroon [17]. These foods were prepared from individual homes either prior to or on the same day and transported to vending school facilities. Upon purchase from street vendors, street food samples were placed aseptically in sterile polythene bags, transported to the laboratory in a cool box between 2˚C and 8˚C, and analysed within one hour.

2.2. Microbiological Analyses of Street Food Samples

Each sample was thoroughly mixed, and 25 g was homogenised in 225 mL of maximum recovery diluent. Serial dilutions were prepared, and then 50 µL of each diluent was plated and incubated on the respective agar and growth conditions. Total viable count (TVC) and total coliforms (TC) were plated on plate count agar and violet red bile agar, respectively, and incubated at 30˚C for 48 h. Yeast and mould on Dichloran Rose-Bengal Chloramphenicol agar and incubated at 25˚C for 5 days. Skirrow Campylobacter selective agar with SR0069 as a supplement was used for *Campylobacter* spp. and incubated at 42˚C for 48 h, under microaerophilic conditions. For *E. coli*, *Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus aureus* and *Yersinia enterocolitica*, Eosin Methylene Blue, xylose lysine desoxycholate, Palcam, Baird Parker, and MacConkey agars were used, respectively, and incubated at 37˚C for 24 h. Other Enterobacteriaceae were qualitatively identified using the RapID™ ONE System (Thermofisher, USA), according to the manufacturer's guidelines. Growth colonies were presumptively identified by Gram staining, catalase, oxidase tests, and using API 20E and API Listeria kits (Biomerieux, France), to characterise *Enterobacteriaceae*, *Listeria*, *Staphylococcus*, *Campylobacter*, non-fermenters, and anaerobes.

2.3. Antibiotic Susceptibility Testing for Selected Bacterial Pathogens

Antibiotic susceptibility tests were carried out based on Kirby-Bauer agar disk diffusion method, to determine which antimicrobials could inhibit the growth of the bacteria isolates. Here, 3 - 5 of the cultured-confirmed bacteria isolates were transferred to 3 mL of nutrient broth, mixed, and then adjusted to 0.5 McFarland standards using normal saline. The suspension was spread uniformly on solidified Mueller-Hinton agar. For fastidious bacterial isolates, 5% defibrinated sheep blood was supplemented [26]. Subsequently, five broad-spectrum antibiotic-impregnated discs, namely, ciprofloxacin (5 µg), tetracycline (30 µg), gentamicin (30 µg), chloramphenicol (30 µg) and vancomycin (30 µg), were placed aseptically in agar media, and sterile discs impregnated with 50 µL distilled water served as negative control. The plates were incubated at 37˚C for 18 h, and the results were interpreted as susceptible, intermediate, or resistant according to the CLSI breakpoint criteria [26]. All growth media and antibiotic-impregnated discs were obtained from Oxoid Limited, United Kingdom.

2.4. Statistical Analysis

All experiments were carried out in triplicate and analysed using SPSS (v26). The results were expressed as mean ± standard deviation and one-way ANOVA was used to compare the means. Duncan's multiple range test was used, where the mean difference was considered significant at $p < 0.05$. Additionally, we calculated the percentages of bacteria prevalence in each type of street food.

3. Results

The total viable count for the bread and spaghetti staples, as well as for the fish and beef sauces, was not statistically different ($p > 0.05$) (**Table 1**). Also, total coliforms, yeast and mould counts were high, and ranged between 1.77 $\log_{10}$cfu/g (spaghetti) and 6.42 $\log_{10}$cfu/g (pepper sauce), and 1.27 $\log_{10}$cfu/g (beef) and 7.28 $\log_{10}$cfu/g (bread), respectively.

Table 1. Total viable count and total coliforms ($\log_{10}$cfu/g) of street food samples.

Street food	Total viable count	Total coliforms	Yeast and mould
Bread	7.89 ± 0.02^{a}	2.04 ± 0.02^{d}	7.28 ± 1.61^{a}
Spaghetti	8.21 ± 0.90^{a}	1.77 ± 0.04^{e}	4.32 ± 1.08^{b}
Beans	3.70 ± 0.02^{f}	3.56 ± 0.04^{c}	2.44 ± 0.00^{b}
Fish	6.42 ± 0.03^{b}	5.63 ± 0.02^{a}	5.61 ± 0.12^{b}
Peanut	5.83 ± 0.02^{c}	4.44 ± 0.04^{b}	2.89 ± 0.00^{d}
beef	6.55 ± 0.77^{b}	5.56 ± 0.24^{a}	1.27 ± 0.88^{d}
Eggs	5.34 ± 0.08^{d}	5.84 ± 0.99^{a}	1.69 ± 0.61^{d}
Pepper	5.25 ± 0.04^{e}	6.42 ± 0.31^{a}	3.79 ± 0.51^{c}
Mean	**6.13 ± 0.64**	**4.40 ± 0.50**	**3.64 ± 1.11**

cfu: colony forming units, n = 20 per street food, results are expressed in mean ± standard deviation of three replicates, different superscripts (a, b, c….) within the same column are significantly different at $p < 0.05$.

In **Table 2**, at least one bacteria pathogen was identified in each street food. Fish sauce was the most contaminated, containing 13 of the 16 bacteria isolates, and pepper sauce was the least contaminated, with six of the 16 bacteria pathogens. Furthermore, *E. coli* was the most prevalent 47.50% (76/160) in all street food samples, particularly in beef sauce 80% (16/20), bread 65% (13/20), and pepper sauce 55% (11/20). *S aureus* was the second most prevalent bacteria pathogen 39.37% (63/160) and was largely isolated in bread 85% (17/20), fish sauce 55% (11/20), and peanut sauce 40% (10/20). Other bacterial pathogens such as *Salmonella* spp. 32.50% (52/160), *Shigella* spp. 23.75% (38/160), *Campylobacter* spp. 14.37% (23/160) and *E. aerogenes* 14.37% (23/160) were highly prevalent in beans 75% (15/20), pepper 40% (8/20), eggs 35% (7/20) and beef 60% (12/20) sauces, respectively. *E. cloacae* 20.62% (33/160) was highly isolated in fish, beef, and pepper sauces at 40% (8/20). In all food samples, *P. penneri* 5% (8/160) and *C. freundii* 3.12% (5/160) were the least identified.

Table 2. Prevalence of bacterial pathogens in street food samples.

Bacterial pathogens	Bread n (%)	Spaghetti n (%)	Beans n (%)	Fish n (%)	Peanut n (%)	Beef n (%)	Eggs n (%)	Pepper n (%)	Overall prevalence N (%)
E. coli	13 (65)	4 (20)	10 (50)	7 (35)	9 (45)	16 (80)	6 (30)	11 (55)	76 (47.50)
Salmonella spp.	7 (35)	5 (25)	15 (75)	8 (40)	0	2 (10)	12 (60)	3 (15)	52 (32.50)
Campylobacter spp	1 (5)	0	2 (10)	5 (25)	0	5 (25)	7 (35)	3 (15)	23 (14.37)
L. monocytogenes	4 (20)	3 (15)	0	2 (10)	2 (10)	4 (20)	0	2 (10)	17 (10.62)
Y. enterolitica	2 (10)	3 (10)	5 (25)	0	0	1 (35)	0	0	11 (6.87)
S. aureus	17 (85)	5 (25)	1 (5)	11 (55)	8 (40)	9 (45)	5 (25)	7 (35)	63 (39.37)
Y. pseudotuberculosis	1 (5)	7 (35)	0	7 (35)	0	4 (20)	3 (15)	8 (40)	30 (18.75)
E. aerogenes	2 (10)	2 (10)	0	2 (10)	1 (5%)	12 (60)	4 (20)	0	23 (14.37)
E. cancerogenus	0	0	1 (10)	4 (20)	0	5 (25)	3 (15)	0	13 (8.12)
E. cloacae	0	0	2 (10)	8 (40)	7 (35)	8 (40)	0	8 (40)	33 (20.62)
Shigella spp.	4 (20)	7 (35)	7 (35)	6 (30)	5 (25)	0	1 (5)	8 (40)	38 (23.75)
K. pneumoniae	1 (5)	5 (25)	0	3 (15)	2 (10)	0	0	2 (10)	13 (8.12)
P. penneri	0	0	4 (20)	1 (5)	3 (15)	0	0	0	8 (5)
P. oryzihabitans	2 (10)	6 (30)	0	4 (20)	1 (5)	5 (25)	0	0	18 (11.25)
P. luteola	1 (5)	0	0	0	4 (20)	0	1 (5)	3 (15)	9 (5.62)
C. freundii	0	0	2 (10)	0	0	1 (10)	3 (15)	0	5 (3.12)

0 = not detected in street food samples.

Table 3. Antibiotic resistance pattern of foodborne pathogens.

Bacteria isolates		Ciprofloxacin n (%)	Tetracycline n (%)	Gentamicin n (%)	Chloramphenicol n (%)	Vancomycin n (%)
Salmonella spp. (n = 37)	S	21 (56.75)	7 (18.91)	28 (75.67)	31 (83.78)	4 (10.81)
	I	16 (43.24)	11 (27.72)	4 (10.81)	6 (16.21)	10 (27.02)
	R	0	19 (51.35)	5 (13.51)	0	23 (62.16)
Campylobacter spp. (n = 23)	S	16 (69.56)	3 (13.04)	18 (78.26)	12 (52.17)	3 (13.04)
	I	7 (30.43)	1 (4.34)	5 (21.73)	11 (47.82)	11 (47.82)
	R	0	19 (82.60)	0	0	9 (39.13)
L. monocytogenes (n = 17)	S	13 (76.47)	8 (47.05)	7 (41.17)	2 (11.76)	15 (88.23)
	I	4 (23.52)	5 (29.41)	1 (5.88)	4 (23.53)	2 (11.76)
	R	0	3 (13.63)	9 (52.94)	11 (64.70)	0
S. aureus (n = 63)	S	55 (87.30)	33 (52.38)	28 (44.44)	0	62 (98.41%)
	I	7 (11.11)	19 (30.15)	15 (23.80)	6 (9.52)	1 (1.58)
	R	1 (1.58)	11 (30.56)	20 (31.74)	57 (90.47)	0
Y. enterocolitica (n = 11)	S	10 (90.90)	9 (81.81)	5 (81.81)	10 (90.09)	0
	I	1 (9.09)	3 (27.72)	5 (45.45)	1 (9.09)	2 (18.18)
	R	0	0	1 (9.09)	0	9 (81.81)
E. coli (n = 76)	S	53 (69.73)	36 (47.36)	1 (1.31)	11 (14.47)	17 (22.36)
	I	16 (21.05)	27 (35.52)	13 (17.10)	35 (46.05)	30 (39.47)
	R	7 (9.21)	13 (17.10)	62 (81.57)	10 (13.15)	49 (64.47)

S = Susceptible, I = Intermediate, R = Resistant.

Furthermore, **Table 3** presents the antimicrobial susceptibility pattern of six bacteria pathogens, namely, *Salmonella* spp., *Campylobacter* spp., *Listeria monocytogenes*, *Staphylococcus aureus*, *Yersinia enterocolitica E. coli*. All bacteria isolates were resistant to at least one antibiotic and highly susceptible to ciprofloxacin. With the exception of *Campylobacter* spp. and *Salmonella* spp., all other bacteria isolates were largely susceptible to *tetracycline*. Specifically, *Yersinia enterocolitica* was the most susceptible to ciprofloxacin 90.90% (10/11), tetracycline 81.81% (9/11), gentamicin 81.81% (5/11), and chloramphenicol 90.09% (10/11). *E. coli* was the most resistant, particularly to gentamicin 81.57% (62/76), and vancomycin 64.47% (49/76). *Staphylococcus aureus* and *Campylobacter* spp. were highly resistant to chloramphenicol 90.47% (57/63) and tetracycline 82.60% (19/23), respectively.

4. Discussion

The results showed that all street foods were contaminated with various levels of microorganisms and only the bean sauce (total viable count = 3.70 $\log_{10}$cfu/g) was within acceptable limits (total viable count <10^5 cfu/g) for human consumption [27]. Similarly, total coliforms were apparent in all food samples examined. Djoulde *et al.* [16] and Zokou *et al.* [28] respectively reported a similar unsatisfactory bacterial count ranging between 5.1 and 7.3 $\log_{10}$cfu/g, and 2.56 and 4.48 $\log_{10}$cfu/g in street-vended meat and egusi pudding sold in Cameroon. Although total coliforms might not mean that the street food samples were a potential risk to human health, their presence (including fecal coliforms and *E. coli*) indicated some exposure to animals and/or human faeces, thus, suggesting contamination with enteric pathogens. Within the same studied population in Yaounde, several unhygienic street food practices were reported [7] [11], such as the use of dirty utensils and hands to prepare and/or serve food, and the use of plastic packaging that was opened by blowing with the mouth. Moreover, the poor food safety quality and microbial contamination of street food in this research could have occurred at any point, for example, from uncontrolled temperatures during cooking and food storage and the fact that food was sold unpackaged, and stalls did not have protective coverings against environmental contaminants (dusts, flies, rodents, dirt, and soil debris). Similarly, Compaore *et al.* [29] reported that street foods (bread, pasta, rice with sauce, beans and milk) in five different localities in Burkina Faso were sold in related retailing conditions; on pushcarts, bicycles, baskets or balance poles, and stalls that do not have four permanent walls.

Additionally, the results indicated significant public health concerns in street food consumption, as at least one foodborne pathogen was isolated in each street food. Specifically, credible outbreaks of foodborne diarrhoea have been reported among related street food handlers and schoolchildren in Ghana [30] and Indonesia [15]. In the same region, our previous published investigations [31] [32] reported a high prevalence of *Listeria* spp. (86%), *Campylobacter* spp. (75%), *Yersinia* spp. (71%), *Salmonella* spp. (69%), and Shiga toxin-producing *E. coli* (57%) in edible land snails, and STEC (20%), *Yersinia enterolitica* (13%), *Campylobacter* spp. (21%), *Listeria monocytogenes* (15%), and *Salmonella* spp. (15%) in locally consumed leafy vegetables. Ngueugang *et al.* [17] also enumerated *S. aureus* (93.3%), *Salmonella* spp. (60.7%), *Shigella* spp. (57.4%) *Citrobacter freundii* (23.4%), *E. coli* (18.0%), *Enterobacter aeruginosa* (5.2%) and *Klebsiella pneumoniae* (6.6 %) in street foods sold in Douala, Cameroon. Likewise, Nicholas *et al.* [18] identified *E. cloacae* (31.57%), *Salmonella* spp (10.52%), *C. freundii*, and *K. pneumonia* (15.78%) in street-vended pepper sauces in Buea, Cameroon. Although Enterobacteriaceae are typically a normal flora in the human intestinal tract, their presence at high levels (>10^4 cfu/g) in cooked foods is an indicator of several risks factors resulting from cross-contamination, and inadequate cooking. In addition, Enterobacteriaceae could indicate an increased risk of the presence of foodborne pathogens as well as the potential formation of histamine in scombroid fish (scombrotoxin) [27] [33]. For example, the presence of *E. coli* in street foods indicated poor hygiene or faecal contamination [33], and *C. freundii* indicated mild to severe foodborne infections. In particular, *C. freundii* contamination of green butter was reported to cause 152 cases of gastroenteritis and eight haemolytic uremic syndromes among nursery school pupils in Germany [34].

Furthermore, antimicrobial resistance (AMR) of bacteria isolates in street foods could be devastating to public health, and its associated health risks have been emphasized in spoiled vegetables [35] and healthy pigs [36]. In 2019, Cameroon was rated the 31st highest age-standardized mortality rate per 100,000 population worldwide, due to 5600 attributable and 24,600 associated deaths from AMR [37]. Specifically in Yaounde, Cameroon, antibiotic susceptibility testing over a three-year period demonstrated high resistance of Gram-negative bacteria such as *E. coli* (30.5%) and *K. pneumoniae* (24.2%), to penams and cephems, and low resistance to carbapenems [38]. Recognising that AMR is a natural process primarily due to antibiotic overuse, other contributing socioeconomic determinants, such as poor community hygiene, poor infection control in hospitals and clinics, and the accumulation of antibiotics in the environment due to mishandling, could further lead to fatal diseases [36]. The high prevalence of *S. aureus*, 39.37% (63/160), especially in beef sauce at 45% (7/20), indicated a high risk of enterotoxin production [27] [32] [39], and, as shown, the isolates were highly resistant to chloramphenicol 90.47% (57/63) and gentamicin 31.74% (20/63). In the United States, for example, the five main isolated enteric pathogens in this research caused 291,162 illnesses in children under five years of age, which resulted in 102,746 physician visits, 7830 hospitalisations, and 64 deaths [39]. In these foodborne disease outbreaks, non-typhoidal Salmonella was the most prevalent (42%), followed by *Campylobacter* spp. (28%), *Shigella* spp. (21%), *Y. enterocolitica* (5%) and *E. coli* O157 (3%) [40]. Among the studied population, Nguendo Yongsi [25] isolated foodborne-related microorganisms in children aged 6 - 59 months, particularly *Enteric adenovirus* (2.7%), *Salmonella* spp. (9.6%), *Campylobacter* spp. (8.8%), *E. coli* enteropathogenic (4.2%), *Shigella* spp. (7.3%), *Ascaris lumbricoides* (17.8%), *Giardia lamblia* (13.2%), *Trichuris Trichiura* (10.7%), and *Entamoeba* (8.4%). Moreover, it should be noted that foodborne diseases are not only limited to gastroenteric symptoms (diarrhoea, vomiting), but also short-to-long term systemic infections [38]. As such, the presence of *Campylobacter* spp. and *Y. enterocolitica* that were highly resistant to tetracycline 82.60% (19/23) and vancomycin 81.81% (9/11) indicated bloody and chronic diarrhoea that could develop into Guillain-Barré syndrome [41], Graves' disease, and reactive arthritis [42], respectively.

Although salmonellosis is common in foods such as meat, eggs, and milk; however, foodborne diseases have also been reported in bread [43] [44] and peanut butter [45]. *Salmonella* spp. in ready-to-eat foods and its resistance to tetracycline and vancomycin are considered harmful to health regardless of their level of contamination, especially in children where irritable bowel syndrome could develop later in life [27] [34]. In the study area, high levels of *Salmonella* spp. were previously attributed to inadequate refrigeration due to constant power shortages, and the ancestral practice of insufficient heating or reheating of food in Cameroon [17]. In fact, *Salmonella* spp. and *Listeria monocytogenes* in the selected street foods (25g of food) should be considered capable of causing disease [33].

5. Conclusion

This research examined the presence of foodborne pathogens in street foods sold within elementary school facilities in Yaounde, Cameroon. At least one foodborne pathogen was present in each street food examined (bread, beans, fish, peanut butter, eggs, minced meat, pepper, and spaghetti). The findings indicated that street food handlers and vulnerable young children are significantly at risk of foodborne diseases in such local food handling, vending and consumption practices. Although further research could be carried out to 1) investigate the genomic virulence gene profiles of these isolates to reveal bacterial strains that are not associated with foodborne diseases, 2) determine the different routes of street food contamination between street vendors and elementary schools, and 3) establish any incidence of foodborne disease outbreak among the studied population, there is an urgent need to mitigate these identified health risks, such as through local government initiatives and effective food safety implementation programmes in nursery and primary schools across Cameroon.

Acknowledgements

The authors thank placement students at the Wonet-bioscience laboratory of the Women's Network of Biodiversity and Food Science, Yaounde, Cameroon, for their assistance with sample collection.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Pires, S.M., Desta, B.N., Mughini-Gras, L., Mmbaga, B.T., Fayemi, O.E., Salvador,

E.M., *et al.* (2021) Burden of Foodborne Diseases: Think Global, Act Local. *Current Opinion in Food Science*, **39**, 152-159. https://doi.org/10.1016/j.cofs.2021.01.006

[2] Kirk, M.D., Angulo, F.J., Havelaar, A.H. and Black, R.E. (2016) Diarrhoeal Disease in Children Due to Contaminated Food. *Bulletin of the World Health Organization*, **95**, 233-234. https://doi.org/10.2471/blt.16.173229

[3] WHO (2024) Diarrhoeal Disease. https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

[4] Troeger, C.E., Khalil, I.A., Blacker, B.F., Biehl, M.H., Albertson, S.B., *et al.* (2017) Quantifying Risks and Interventions That Have Affected the Burden of Diarrhoea among Children Younger than 5 Years: An Analysis of the Global Burden of Disease Study. *The Lancet Infectious Diseases*, **20**, 37-59.

[5] Havelaar, A.H., Kirk, M.D., Torgerson, P.R., Gibb, H.J., Hald, T., Lake, R.J., *et al.* (2015) World Health Organization Global Estimates and Regional Comparisons of the Burden of Foodborne Disease in 2010. *PLOS Medicine*, **12**, e1001923. https://doi.org/10.1371/journal.pmed.1001923

[6] Machava, N.E., Mulaudzi, F.M. and Salvador, E.M. (2022) Household Factors of Foodborne Diarrhea in Children under Five in Two Districts of Maputo, Mozambique. *International Journal of Environmental Research and Public Health*, **19**, Article 15600. https://doi.org/10.3390/ijerph192315600

[7] Edima, H., Nnam, R., Enama, T., Biloa, D. and Ndjouenkeu, R. (2014) Street Food Sector in the Metropolitan Areas of a Cameroonian City, Yaounde. *International Journal of Current Microbiology and Applied Sciences*, **3**, 740-751.

[8] WHO (2022) Food Safety Is Everyone's Business in Street Food Vending. https://www.who.int/publications/i/item/WHO-HEP-NFS-AFS-2022.4

[9] Kok, R. (2014) Street Food Vending and Hygiene Practices and Implications for Consumers. *Journal of Economics and Behavioral Studies*, **6**, 188-193. https://doi.org/10.22610/jebs.v6i3.482

[10] Rakha, A., Fatima, M., Bano, Y., Khan, M.A., Chaudhary, N. and Aadil, R.M. (2022) Safety and Quality Perspective of Street Vended Foods in Developing Countries. *Food Control*, **138**, Article ID: 109001. https://doi.org/10.1016/j.foodcont.2022.109001

[11] Yongsi, H.B.N. (2018) Eating to Live or Eating to Damage One's Health: Microbiological Risks Associated with Street-Vended Foods in a Subtropical Urban Setting (Yaoundé-Cameroon). *Nutrition & Food Science International Journal*, **6**, 1-13. https://doi.org/10.19080/nfsij.2018.06.555695

[12] FAO (1996) Essential Safety Requirements for Street-Vended Foods (Revised Edition). https://apps.who.int/iris/handle/10665/63265

[13] Mengistu, D.A. and Tolera, S.T. (2020) Prevalence of Microorganisms of Public Health Significance in Ready-To-Eat Foods Sold in Developing Countries: Systematic Review and Meta-Analysis. *International Journal of Food Science*, **2020**, Article ID: 8867250. https://doi.org/10.1155/2020/8867250

[14] Kharel, N., Palni, U. and Tamang, J.P. (2016) Microbiological Assessment of Ethnic Street Foods of the Himalayas. *Journal of Ethnic Foods*, **3**, 235-241. https://doi.org/10.1016/j.jef.2016.01.001

[15] Lubis, N.D.A., Amelia, S., Arrasyid, N.K. and Rozi, M.F. (2019) Modelling of Risk Factors Associated with Foodborne Disease among School-Aged Children in Medan, Indonesia. *Open Access Macedonian Journal of Medical Sciences*, **7**, 3302-3306. https://doi.org/10.3889/oamjms.2019.721

[16] Djoulde, R., Bayoï, J. and Daoudou, B. (2015) Microbiological Quality and Safety of

Street Meat-Food Sold in Soudano Sahelian Zone of Cameroon. *International Journal of Current Microbiology and Applied Sciences* (*IJCMAS*), **4**, 441-450.

[17] Laure Wounang Ngueugang, A., Tientche, B., Asaah, S., Lucien Fouamno Kamga, H. and Bsadjo Tchamba, G. (2021) Microbiological Assessment of Ready-to-Eat Food Sold in Urban Primary Schools, Douala, Littoral Region, Cameroon. *International Journal of Food Science and Biotechnology*, **6**, 36-44. https://doi.org/10.11648/j.ijfsb.20210602.13

[18] Nicholas, T., Emlah, N., Nyasa, R., Meriki, H., Mbino, T. and Kamdep, Y. (2020) Microbial Analysis and Factors Associated with Contamination of Ready-To-Eat Chili Pepper Sauce in Buea Municipality, Cameroon. *African Journal of Food Science*, **14**, 366-372.

[19] Tchigui Manga Maffouo, S., Tene Mouafo, H., Mouokeu, R.S., Manet, L., Kamgain Tchuenchieu, A., Noutsa Simo, B., *et al.* (2021) Evaluation of Sanitary Risks Associated with the Consumption of Street Food in the City of Yaoundé (Cameroon): Case of Braised Fish from Mvog-Ada, Ngoa Ekélé, Simbock, Ahala and Olézoa. *Heliyon*, **7**, e07780. https://doi.org/10.1016/j.heliyon.2021.e07780

[20] Wouafo, M., Pouillot, R., Kwetche, P.F., Tejiokem, M., Kamgno, J. and Fonkoua, M. (2006) An Acute Foodborne Outbreak Due to *Plesiomonas shigelloides* in Yaounde, Cameroon. *Foodborne Pathogens and Disease*, **3**, 209-211. https://doi.org/10.1089/fpd.2006.3.209

[21] WHO (2021) Estimating the Burden of Foodborne Diseases: A Practical Handbook for Countries: A Guide for Planning, Implementingand Reporting Country-Level Burden of Foodborne Disease.

[22] WHO (2016) Estimating the Burden of Foodborne Diseases. https://www.who.int/activities/estimating-the-burden-of-foodborne-diseases

[23] Tanyi, M.E. (2016) Pedagogic Barriers in Cameroon Inclusive Classrooms: The Impact of Curriculum, Teachers' Attitudes and Classroom Infrastructures. *Journal of Education and Practice*, **7**, 210-221.

[24] Ministry of Basic Education Statistical Yearbook 2021/2022. https://www.scribd.com/document/673080537/MINEDUB-Statistical-Yearbook-2020-2021

[25] Yongsi, H.B.N. (2008) Pathogenic Microorganisms Associated with Childhood Diarrhea in Low-And-Middle Income Countries: Case Study of Yaoundé—Cameroon. *International Journal of Environmental Research and Public Health*, **5**, 213-229. https://doi.org/10.3390/ijerph5040213

[26] CLSI (2020) Performance Standards for Antimicrobial Susceptibility Testing. 30th Edition, Clinical and Laboratory Standard Institute.

[27] Microbiological Quality Guide for Ready-To-Eat Foods: A Guide to Interpreting Micro-Biological Results.

[28] Zokou, R., Mouafo, H.T., Klang, J.M., Simo, N.B., Mouokeu, R.S. and Womeni, H.M. (2022) Microbiological Quality of Egusi Pudding, a Traditional Cake of Cucurbitaceae Sold in the City of Yaoundé, Cameroon. *Journal of Food Quality*, **2022**, Article ID: 4236921. https://doi.org/10.1155/2022/4236921

[29] Compaore, M.K.A., Kpoda, S.D., Bazie, R.B.S., Ouedraogo, M., Valian, M., Gampene, M., *et al.* (2022) Microbiological Quality Assessment of Five Common Foods Sold at Different Points of Sale in Burkina-Faso. *PLOS ONE*, **17**, e0258435. https://doi.org/10.1371/journal.pone.0258435

[30] Malm, K., Nyarko, K., Yawson, A., Gogo, B., Lawson, A. and Afari, E. (2015) Foodborne

Illness among School Children in Ga East, Accra. Ghana Medical Journal, **49**, 72-76. https://doi.org/10.4314/gmj.v49i2.2

[31] Tanyitiku, M.N., Nicholas, G., Petcheu, I.C.N., Sullivan, J.J. and On, S.L.W. (2022) Public Health Risk of Foodborne Pathogens in Edible African Land Snails, Cameroon. *Emerging Infectious Diseases*, **28**, 1715-1717. https://doi.org/10.3201/eid2808.220722

[32] Tanyitiku, M.N., Teh, E.A., Laison, R.M. and Petcheu, I.C.N. (2023) Foodborne Pathogens in Leafy Vegetables Grown and Consumed Locally in Yaounde, Cameroon: A Public Health Concern. *Journal of Food Research*, **12**, 11-22. https://doi.org/10.5539/jfr.v12n2p11

[33] UKHSA (2024) Guidelines for Assessing the Microbiological Safety of Ready-To-Eat Foods. Health Protection Agency. https://assets.publishing.service.gov.uk/media/5a7efde0e5274a2e8ab497a4/Guidelines_for_assessing_the_microbiological_safety_of_ready-to-eat_foods_on_the_market.pdf

[34] Tschäpe, H., Prager, R., Streckel, W., Fruth, A., Tietze, E. and Böhme, G. (1995) Verotoxinogenic *Citrobacter Freundii* associated with Severe Gastroenteritis and Cases of Haemolytic Uraemic Syndrome in a Nursery School: Green Butter as the Infection Source. *Epidemiology and Infection*, **114**, 441-450. https://doi.org/10.1017/s0950268800052158

[35] Sivalingam, K.M., Sama, D.S. and Vaithilingam, S. (2024) Prevalence and Antibiotic Susceptibility Pattern of Foodborne Bacterial Pathogens Isolated from Spoiled Vegetables at Wolaita Sodo Town, South Ethiopia. *Journal of Food Quality*, **2024**, Article ID: 8823056. https://doi.org/10.1155/jfq/8823056

[36] Kidsley, A.K., Abraham, S., Bell, J.M., O'Dea, M., Laird, T.J., Jordan, D., *et al.* (2018) Antimicrobial Susceptibility of Escherichia Coli and Salmonella Spp. Isolates from Healthy Pigs in Australia: Results of a Pilot National Survey. Frontiers in *Microbiology*, **9**, Article 1207. https://doi.org/10.3389/fmicb.2018.01207

[37] GRAM (2019) The Burden of Antimicrobial Resistance (AMR) in Cameroon. Institute for Health Metrics and Evaluation. https://www.healthdata.org/sites/default/files/2023-09/Cameroon.pdf

[38] Ngogang, M.P., Nkoth, A.f., Ngaleu, W., Mfouapon, H., Ekoume, P., Nibeye, Y., *et al.* (2024) Antimicrobial Susceptibility Testing Data Analysis over 3 Years at the Yaoundé General Hospital, Cameroon. *JAC-Antimicrobial Resistance*, **6**, dlae043. https://doi.org/10.1093/jacamr/dlae043

[39] Mancuso, G., Midiri, A., Gerace, E. and Biondo, C. (2021) Bacterial Antibiotic Resistance: The Most Critical Pathogens. *Pathogens*, **10**, Article 1310. https://doi.org/10.3390/pathogens10101310

[40] Scallan, E., Mahon, B.E., Hoekstra, R.M. and Griffin, P.M. (2013) Estimates of Illnesses, Hospitalizations and Deaths Caused by Major Bacterial Enteric Pathogens in Young Children in the United States. *Pediatric Infectious Disease Journal*, **32**, 217-221. https://doi.org/10.1097/inf.0b013e31827ca763

[41] Tack, D.M., Marder, E.P., Griffin, P.M., Cieslak, P.R., Dunn, J., Hurd, S., *et al.* (2019) Preliminary Incidence and Trends of Infections with Pathogens Transmitted Commonly through Food—Foodborne Diseases Active Surveillance Network, 10 U.S. Sites, 2015-2018. *MMWR. Morbidity and Mortality Weekly Report*, **68**, 369-373. https://doi.org/10.15585/mmwr.mm6816a2

[42] (2024) Young Children and Foodborne Illness. A Fact Sheet from the Pew Charitable Trusts, American Academy of Pediatrics, and the Center for Foodborne Illness.

https://www.pewtrusts.org/foodsafety

[43] Vo, T.H., Le, N.H., Cao, T.T.D., Nuorti, J.P. and Minh, N.N.T. (2014) An Outbreak of Food-Borne Salmonellosis Linked to a Bread Takeaway Shop in Ben Tre City, Vietnam. *International Journal of Infectious Diseases*, **26**, 128-131. https://doi.org/10.1016/j.ijid.2014.05.023

[44] Kimura, A.C., Palumbo, M.S., Meyers, H., Abbott, S., Rodriguez, R. and Werner, S.B. (2005) A Multi-State Outbreak of *salmonella* Serotype Thompson Infection from Commercially Distributed Bread Contaminated by an Ill Food Handler. *Epidemiology and Infection*, **133**, 823-828. https://doi.org/10.1017/s0950268805004127

[45] Lathrop, A.A., Taylor, T. and Schnepf, J. (2014) Survival of Salmonella during Baking of Peanut Butter Cookies. *Journal of Food Protection*, **77**, 635-639. https://doi.org/10.4315/0362-028x.jfp-13-408