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Microbiological assessment of street foods at the point of sale in Maputo (Mozambique)

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Abstract

Objectives: The aim of this study was to assess the microbiological quality and safety of street food sold in the main streets and informal markets of Maputo, the capital of Mozambique.
Materials and Methods: From 83 different vendors selling different types of foods, 83 samples of ready-to-eat (RTE) street food were analyzed. Mesophiles, *Escherichia coli* and total coliforms were used as quality and hygiene indicators. *Listeria monocytogenes (L. monocytogenes) Salmonella* and coagulase-positive *staphylococci* were used as food safety indicators.
Results: High proportions of unsatisfactory food samples were found in both traditional hot (76.7%) and cold (75%) foods. *L. monocytogenes* and *Salmonella* were tested negative in this survey. However, when coagulase-positive *staphylococci* was used as a food safety indicator, approximately 25% (23/83) of the food samples analyzed were classified as unsatisfactory/potentially hazardous.
Conclusions: These results, showing that street food sold in Maputo clearly requires adequate sanitary conditions for its preparation and sale, contribute to the development of good manufacturing practices (GMP) for street food in Maputo, Mozambique. This is the first report on the microbiological quality and safety of street food in Mozambique.

Key words: ready-to-eat street food; *Escherichia coli*; coagulase-positive *staphylococci*; good manufacturing practices (GMP); good hygiene practices (GHP).

Introduction

In developing countries, one of the main challenges is to ensure food security, i.e. to provide a sufficient amount of food for the entire population. However, another dilemma in these countries is food safety (Paudyal *et al.*, 2017). More than 200 types of diseases are estimated to be caused or spread by food, occasionally causing long-term health problems in vulnerable groups such as the elderly, pregnant women, children and immunocompromised people (Loukieh *et al.*, 2018; WHO, 2019). Thus, it is important to ensure food safety, as a public health measure toward reducing mortality rate (Paudyal *et al.*, 2017).

It is estimated that 2.5 billion people worldwide consume street food daily (Jaffee *et al.*, 2019). The sale of ready-to-eat (RTE) street food is frequent, particularly in large urban centers (Cortese *et al.*, 2016). Street food contributes significantly to the diet of many people in developed and developing countries (WHO, 2019). In developing countries, street food vending is a livelihood for millions of 'urban poor' families, and makes a considerable contribution to the economy of these countries (Loukieh *et al.*, 2018). In Mozambique, as in many other developing countries, street food vendors are often found in almost every street in major urban centers (Gelormini *et al.*, 2015). The main reasons for street food sales

are associated with the growing demand for low-cost, RTE foods, but also with the poverty that most citizens face. In various parts of Maputo, there is a proliferation of informal markets (unknown to the domestic taxing authority) operating without minimum hygiene and sanitation conditions.

In developed countries, the sale of RTE foods is regulated by hygiene and safety criteria (Abrahale *et al.*, 2018), often not the case in developing countries (Paudyal *et al.*, 2017). Problems including the use of untreated water, poor sanitation and personal hygiene and the use of contaminated utensils by street food vendors act as vectors of foodborne pathogens (Onyeneho and Hedberg, 2013; Schirone *et al.*, 2018). A defective water supply system has often been reported as a major challenge for the sale of RTE street food in developing countries (Onyeneho and Hedberg, 2013; Weststrate *et al.*, 2019). Other factors include poor sanitation and exposure of food to dust, flies and other insects, which may harbor pathogens (Alimi, 2016; Shiningeni *et al.*, 2019). Furthermore, the low level of education and the lack of short-term training initiatives have resulted in most street vendors' ignorance of these factors. This has been reported in several studies relating the poor hygiene of street vendors with the lack of safe food handling (Monney *et al.*, 2014; Abrahale *et al.*, 2018). Consequently, street foods have been associated with outbreaks of foodborne diseases in several countries (Aluko *et al.*, 2014).

With this framework, this study aimed to assess the microbiological quality and safety of street foods at the point of sale, in the city of Maputo. We performed a survey on 83 different RTE foods, from 83 different street vendors within 132 km^2, to encompass a wide diversity of food and sale types. International guidelines for the microbiological quality of RTE foods sampled at the point of sale were used to interpret the data. To our knowledge, this is the first report on the microbiological quality and safety of street food, not only in Maputo, but also in Mozambique.

Methodology

Study area

Maputo city, the capital and the most crowded Mozambican city, has an estimated area of 347.69 km^2 and a population density of 3670.6/km^2 (CENSO, 2017). Maputo has very diverse cultural groups gathering nationals and foreign immigrants from both rural and urban areas (Barros *et al.*, 2014). The administrative division of Maputo City is comprised of seven municipal districts. This study focused on five out of the seven municipal districts, namely KaMpfumu, Nlhamankulu, KaMaxaquene, KaMavota and KaMubukwana, where the main street food sales activities are concentrated (Gelormini *et al.*, 2015).

Characterization of street food vendors' activities

The characterization of RTE street foods and street food vendors was based on observational analysis of the various types of foods sold in the main informal markets characterized by a high concentration of potential customers (close to bus stops, schools, hospitals and health centers), where the main street food sales activities are concentrated (Gelormini *et al.*, 2015). An informal conversation was held with the vendors in order to obtain information about their age, time spent selling street food, source of food ingredients, food preparation methods and main daily difficulties. Precaution was taken not to disturb the normal course of sales, as suggested by Trafialek *et al.* (2017).

Street food vendors were divided into two groups: (1) those preparing food at their homes and transporting them to previously-selected strategic points of sale (Figure 1A) and (2) those who prepare or cook food in fixed locations in the streets. In the latter case, these locations may be informal markets (Figure 1B) or the streets (Figure 1C) without any physical structure, such as restaurants or canteens, to support food preparation.

Figure 1. Street food and associated environments in Maputo. A) rachel, B) cooking badjia in the street, C) sanana, cooking badjia in the street, D) vending food in cars, E) cooking food in the informal market, F) consumption at the point of sale.

The first group of vendors are usually denoted 'street hawkers', as they do not have a fixed selling point. They sell all types of food included in this study, including fruits, sandwiches, salads, full meals (hot food) and other typical Mozambican foods. Typically, the vendor of hot meals is present at lunch time, transporting food items in 20 L buckets equipped with a lid. Meals are served on reusable plastic dishes, which, after being used by one customer, are washed in water in a basin with standing water and served to the next customer. Eventually, at the customer's request, food may be served in a take-away container with an additional cost. Because these foods are sold at a lower cost than those that are prepared on place, their consumers are mainly low-income people, who live on the streets or work sporadic jobs.

The second group of vendors is typically composed of women preparing foods, either in informal markets or at the entrance of informal markets, and near places of high concentration of people, such as schools, health centers and bus stops. The best-selling products of this segment, throughout the day, include assorted sandwiches, typical Mozambican cold foods such as badjia, sanana, and, at lunch time, full meals (mainly hot foods). Ingredients used for food preparation are from the local market, and meals are usually served on plastic or porcelain plates. After use, the plates are washed in a basin with standing water for re-use by the next customer. In all cases, the standing water was carried in buckets and there were no toilets available.

Food sampling

The street foods analyzed (Table 1) included, (1) sandwiches like palone and rachel (Figure 1D); (2) traditional Mozambican cold foods, such as molina or lifete, badjia (Figure 1E) and sanana (Figure 1F); and (3) traditional Mozambican hot foods such as xima and chatine or rice and matapa. Eighty-three food samples were purchased from 83 vendors (68 women, 10 children and 5 men), in the period of September to October 2019. From these vendors, 32 were 'street hawkers' and 51 prepared food at the point of sale. The information provided by the vendors regarding street foods and their ingredients is presented in Table 1. The samples were purchased, immediately packed in sterile sample bags, placed in a refrigerated (4–8 °C) thermal box and transported to the National Laboratory of Food Hygiene and Water (Mozambican Ministry of Health). The samples were kept between 4–8 °C, until microbiological analysis was performed, <24 h after sampling.

Microbiological analyses

Food samples were analyzed for each of the following microbial indicators: mesophiles, total coliforms, *Escherichia coli (E. coli)*, coagulase-positive *staphylococci*, *Listeria monocytogenes (L. monocytogenes)* and *Salmonella*. The reference strains were used as positive controls for biochemical tests of identification, namely: *Staphylococcus aureus* (CECT86T) for coagulase tests; and *L. monocytogenes* (CECT4032 = NCTC11994) and *Listeria innocua* (CECT910T = NCTC11288) onto ALOA chromogenic medium (Gellose Listeria selon Ottaviani et Agosti).

For the enumeration of mesophiles, *E. coli,* total coliforms and coagulase-positive *staphylococci*, 10 g of sample was aseptically weighed into a sterile BagFilter (Interscience, France) and 90 mL of Ringer Solution (RS) was added. Samples were homogenized using a paddle blender, 85 rpm for 30 s. Afterwards, decimal dilutions were made with RS diluent according to ISO Standard (ISO, 2017b).

The enumeration of mesophiles was performed according to ISO 4833:2003 (ISO, 2003), incorporating 1 mL of the respective decimal dilution in Plate Count Agar medium (Biokar Diagnostics, Beauvais, France) and incubating for 3 d at 30 ± 1 °C.

The enumeration of *E. coli*, total coliforms and coagulase-positive *staphylococci* was performed by spreading 0.1 mL of the respective decimal dilution according to ISO (2001) and ISO (1999a). Typical colonies of *E. coli* and total coliforms were counted after 24 h at 37 ± 1 °C onto Compass ECC Agar medium (Biokar Diagnostics, Beauvais, France) (ISO, 2001). *Staphylococcus* spp. colonies were counted after 48 h at 37 °C onto Baird Parker Agar medium (Biokar Diagnostics, Beauvais, France) (ISO, 1999a). Subsequently, coagulase testing was performed according to ISO (1999b) in tubes containing 0.3 mL rabbit plasma (Biokar Diagnostics, Beauvais, France) and 0.1 mL culture.

Table 1. Characterization of the street foods analyzed

Street foods		Ingredients	Nature of food
Traditional hot foods	Rice and cooked meat	Rice, meat and tomato and onion	Cooked: full meal
	Rice and peanut curry	Rice, fish, peanut powder	Cooked: full meal
	Rice and beans	Rice, beans and beef tripe	Cooked: full meal
	Xima* and chatine	Xima, dried fish and tomato	Cooked: full meal with added aromatic herbs
	Rice and matapa	Rice, ground cassava leaves and coconut milk	Cooked: full meal
Sandwiches	Egg	Bread, egg, ketchup	Raw
	Palone**	Palone, bread, ketchup	Raw
	Mixed	Bread, egg, ketchup and palone/rachel	Mixture of ingredients
	Rachel***	Bread, rachel, ketchup	Raw
RTE fruit	Pear and apple	Fruit	Raw
	Strawberries	Fruit	Raw
	Sliced watermelon	Fruit	Raw
RTE salads	Home-packed	Lettuce, tomato, onion, olive oil, vinegar	Raw
	Not packed	Lettuce, tomato, onion, olive oil, vinegar	Raw
Traditional cold foods	Molina/lifete	Tapioca, roasted and ground peanuts, sugar	Raw: sweet
	Badjia	Bean paste, salt, aromatic herbs	Cooked: fried
	Sanana	Corn flour, sugar or salt, shredded coconut	Cooked: roasted

RTE, ready-to-eat.

*Xima is a thick paste resulting from cooking corn or cassava flour.

**Palone is a type of mortadella.

***Rachel is a type of sausage.

Detection and enumeration of *L. monocytogenes* and *Listeria* spp. were performed according to ISO (2017c). From each product, 25 g was taken into a sterile BagFilter (Interscience, France) with 225 mL of Fraser Broth (Primary Enrichment Medium) and Half-Fraser Selective Supplement (Biokar Diagnostics, Beauvais, France). Samples were homogenized using a paddle blender, at 85 rpm for 30 s. For enumeration, aliquots of 0.1 mL were spread onto PALCAM medium (Biokar Diagnostics, Beauvais, France) and incubated at 37 ± 1 °C for 48 h. For detection, the BagFilter bag was immediately incubated at 37 ± 1 °C for 24 h. After incubation, 0.1 mL portions from each sample were added to 10 mL each of Fraser medium (Biokar Diagnostics, Beauvais, France) for secondary enrichment, and incubated at 37 ± 1 °C for 24 h. At the end of this incubation period, from each secondary enrichment, ALOA plates (Chromogenic Listeria-selective aga, Biokar Diagnostics, Beauvais, France) were loop inoculated and incubated at 37 ± 1 °C for 24 h for the detection of characteristic colonies (blue colonies with an opaque halo for *L. monocytogenes*, and/or blue colonies with no halo for other listeria).

The detection of *Salmonella* was performed according to ISO (2017a). From each product, 25 g was taken into a sterile BagFilter bag (Interscience, France) with 225 ml of buffered peptone water (Biokar Diagnostics, Beauvais, France). Samples were homogenized in a paddle blender, 85 rpm for 30 s, and incubated at 37 ± 1 °C for 24 h. After, 0.1 ml aliquots were added to 10 ml of Muller-Kauffmann Tetrathionate Novobiocin Broth (MKTTn) enrichment medium (Biokar Diagnostics, Beauvais, France) and portions of 1 ml were respectively added to 10 ml of Rappaport enrichment medium-Vassiliadis soya (RVS) (Biokar Diagnostics, Beauvais, France). Tubes were incubated at 37 ± 1 °C and 42 °C for 24–48 h, respectively. After 24–48 h, aliquots of 0.1 ml were removed from each enrichment medium and loop inoculated onto XLD Agar and VBM Agar Plates. Incubation proceeded at 37 ± 1 °C for 24 h for detection of characteristic colonies.

Data interpretation

For each type of street food, and microbiological enumeration, average values and respective standard deviations from duplicate plates were calculated. The guidelines for the microbiological quality of RTE foods sampled at the point of sale of National Institute of Health, by Dr. Ricardo Jorge, Portuguese Ministry of Health (INSA, 2019), and the guidelines for assessing the microbiological safety of RTE foods, proposed by Public Health Laboratory Service, United Kingdom (PHLS, 2009), were used for the interpretation of the microbiological quality and safety of street foods. For the interpretation of the coliforms level, the guidelines used were from Santos *et al.* (2005). Table 2 summarizes the criteria used according to the food category analyzed and the guidelines mentioned above.

Results

Characteristics of street vendors

One hundred and forty-six street food vendors were interviewed. The majority (79.5%) were female (Table 3). Forty-five-point two percent of sellers have primary education, and there was a greater percentage (82.8%) of singles and widows (mostly women). The total of sellers, 61.6% belong to the group of 'street hawkers' (Table 3).

Quality and hygiene indicators of street foods

Mesophiles

Table 4 shows the number and percentage of unsatisfactory food samples, and the average values of mesophiles. All 83 food samples presented mesophile values higher than 2.8 log CFU/g. The food categories with the higher percentages of unsatisfactory samples regarding mesophiles were: traditional hot foods, where 76.7% of the samples were classified as unsatisfactory (>4 log CFU/g); and traditional cold foods, where 75% of the samples were classified as unsatisfactory (>5 log CFU/g). In RTE fruits, only 12.5% of the samples were classified as unsatisfactory (>6 log CFU/g).

E. coli and total coliforms

The number and percentage of unsatisfactory food samples, and the average values of *E. coli* and total coliforms, are shown in Table 4. In traditional hot foods, 63% of the samples were classified as unsatisfactory with regard to *E. coli* (>2.8 log CFU/g). When the total coliforms were considered as a hygiene indicator, this percentage rose to 76.7% (>2 log CFU/g). In sandwiches, 62.5% of the samples presented >2.5 log CFU of *E. coli*/g, and were classified

Table 2. Guidelines for the microbiological quality of RTE foods analyzed in this work

Food category*	Criterion	Microbiological quality (CFU/g)				Reference
		Satisfactory	Acceptable	Unsatisfactory	Unacceptable/potentially hazardous	
1	Mesophiles	$\leq 10^2$	$>10^2, \leq 10^4$	$>10^4$	Not applicable	PHLS, 2009
2		$\leq 10^3$	$>10^3, \leq 10^5$	$>10^5$	Not applicable	INSA, 2019
3		$\leq 10^4$	$>10^4, \leq 10^6$	$>10^6$	Not applicable	
1	Coliforms	≤10	$>10, \leq 10^2$	$>10^2$	Not applicable	Santos *et al.*,
2		≤10	$>10, \leq 10^3$	$>10^3$	Not applicable	2005
3		$\leq 10^2$	$>10^2, \leq 10^4$	$>10^4$	Not applicable	
1, 2	*E. coli*	<10	Not applicable	≥10	Not applicable	PHLS, 2009
3		≤10	$>10^1, <10^2$	$\geq 10^2$	Not applicable	INSA, 2019
1–3	Coagulase-positive *staphylococci*	$<10^2$	Not applicable	$\geq 10^2, \leq 10^4$	$>10^4$	
1–3	*Salmonella*	Not detected in 25 g	Not applicable	Not applicable	Detected in 25 g	
1–3	*L. monocytogenes*	<100 cfu/g	Not applicable	Not applicable	≥100 cfu/g	

E. coli, *Escherichia coli*; *L. monocytogenes*, *Listeria monocytogenes*.

*Category 1: fully cooked foods, not handled after heat treatment (traditional hot foods and traditional cold foods, except molina or lifete). **Category 2**: foods composed of fully cooked/pasteurized foods added with raw components or raw meat or fish (xima and chatine, sandwiches and molina or lifete). **Category 3**: includes raw fruits and vegetables such as salads and sliced fruits.

Table 3. Characterization of street food vendors

Characteristics	*n*	Percentage (%)
Gender		
Male	30	20.5
Female	116	79.5
Age		
8–16	38	26
18–45	83	56.8
>45	25	17.1
Education		
Iliterate	20	13.7
Primary	66	45.2
Secondary	60	41.1
Marital status		
Married	25	17.1
Single	97	66.4
Widow	24	16.4
Type of street vendor		
Those who prepare or cook food in fixed locations in the streets	56	38.4
'Street hawkers'	90	61.6
Duration of food vending (yrs)		
<2	27	18.5
2–5	40	27.4
>5	79	54.1
Where do you buy food		
Informal market	95	65.1
Municipal market/supermarket	51	34.9
Training on food safety		
Yes	24	16.4
No	122	83.6
Total	**146**	

as unsatisfactory. When the indicator was coliform level, this percentage increased to 75% (>3 log CFU/g). In RTE salads, 80% of the samples presented >2.4 log CFU of *E. coli*/g and more than 3.4 log CFU of coliforms/g and were classified by both indicators as unsatisfactory. Regarding traditional cold foods, 43.8% and 68.8% of the samples were classified as unsatisfactory, when *E. coli* (>2.48 log CFU/g) or total coliforms (>2.48 log CFU/g), respectively, were considered as hygiene indicators.

Food safety indicators in street foods

Salmonella and *Listeria*

The 83 food samples were analyzed for the presence of *Salmonella*, while *L. monocytogenes* was only analyzed for in sandwiches and RTE fruits (32 samples). None of the samples were positive for either pathogen (Table 5). However, non-pathogenic *Listeria* spp (non-*L. monocytogenes*) was detected in six sandwiches (one palone, two mixed, and three rachel) with 2.47 and 2.54 log CFU/g in two of the three rachel sandwiches.

Coagulase-positive *staphylococci*

The number and percentage of unsatisfactory/potentially hazardous food samples, and the average values of coagulase-positive *staphylococci*, are in Table 5. For traditional hot foods, 33% of the samples were classified as unsatisfactory/potentially hazardous (>4 log CFU/g). One of the traditional hot foods (xima and chatine) presented all five unsatisfactory/potentially hazardous samples in this category, with a mean value of 5.2 log CFU/g (Table 5). 25% of the sandwich samples were unsatisfactory/potentially hazardous; in RTE salads, this percentage was 40%. The highest percentage of unsatisfactory/potentially hazardous food samples (43.7%) was observed in traditional cold foods. Although unsatisfactory, none of the RTE fruit samples were classified as potentially hazardous (<4 log CFU/g).

Discussion

Characteristics of street food vendors

The survey performed in this work, for 146 food street vendors in five of the seven municipal districts of Maputo, Mozambique, showed that a higher percentage of street food sellers were women. This may be related to cultural habits; in Mozambique in particular, and in Africa in general, men do not participate in food preparation. In addition, the illiteracy rate is higher among women, meaning fewer opportunities for formal jobs. In southern Mozambique, men tend to emigrate frequently to work or do business in South Africa, leaving their wives and children behind. As a means of support, women who take care of their children use street sales as an alternative income. These results corroborate with studies carried out in South Africa, such as those presented by Sibanyoni *et al.* (2017), in Mpumalanga, and by Katiyo *et al.* (2019) in Pretoria, where 83% and 71% of women, respectively, were street food vendors. The percentage variation is due to local development and business opportunities. Children are also often employed in street food selling. These children generally work as helpers to the adults, who may or may not be their parents. This practice is common in many poor countries.

Quality and hygiene indicators of street foods

The results of the present study regarding mesophilic bacteria in hot street foods are in agreement with those reported in the neighboring country of South Africa (Nyenje *et al.*, 2012; Mafune *et al.*, 2016). This is due to hygiene and sanitation conditions at the point of sale, as reported by Loukieh *et al.* (2018) in Beirut. Similarly, Nyenje *et al.* (2012) reported the occurrence of mesophiles at levels >6 log CFU/g in hot street foods sold in South Africa. A low occurrence of coliforms and *E. coli* is expected in hot foods since these foods are cooked and the heat treatment is able to eliminate the non-sporulated bacterial population. However, the unsatisfactory levels of these hygiene indicator microorganisms found in this food category indicate contamination post-preparation, likely associated with specific culinary practices. White rice, present in four of the five types of hot food analyzed, is cooked in water and subsequently washed in cold water to loosen the rice. Thus, the contamination may have originated from cold water. In a parallel study carried out in Maputo, high amounts of mesophiles, *E. coli* and coliforms were found in the waters provided by the same street food vendors (unpublished data). In developing countries, food preparation is based on local habits and customs, and this is often the cause of food contamination, verified in several studies (Abakari *et al.*, 2018; Loukieh *et al.*, 2018; Arshad and Zahoor, 2019).

In sandwiches, high levels of *E. coli* and total coliforms were found. This phenomenon may be associated with the way in which sandwiches are transported and sold. Cross-contamination may be associated with vectors such as flies and other insects (Monney *et al.*, 2014; Kothe *et al.*, 2016). RTE sandwiches are exposed outdoors and handled by vendors without minimum hygiene conditions. Incorrect storage of RTE foods is common among street vendors in several countries. Kothe *et al.* (2016), in Southern Brazil, reported that 75% of the sandwiches were contaminated with total coliforms

Table 4. Unsatisfactory street foods, collected in Maputo, based on food category and quality (mesophiles) and hygiene (*E. coli* and coliforms) indicators

Type and (number) of food samples		Unsatisfactory food samples (average values ± standard deviation of log CFU/g) (%) total percentage		
		Mesophiles	*E. coli*	Coliforms
Traditional hot foods				
Rice and cooked meat		13/13 (5.03 ± 0.54)	7/13 (3.89 ± 0.73)	8/13 (4.13 ± 0.34)
Rice and peanut curry		3/5 (5.08 ± 1.23)	4/5 (3.28 ± 0.66)	4/5 (3.33 ± 0.46)
Rice and beans		1/2 (4.54 ± 1.0)	2/2 (3.36 ± 0.08)	1/2 (4.94 ± 0.43)
Xima and chatine		3/5 (5.19 ± 0.3)	1/5 (3.51 ± 0.0)	5/5 (5.30 ± 0.24)
Rice and matapa		3/5 (4.12 ± 0.47)	3/5 (3.32 ± 0.57)	5/5 (3.57 ± 0.39)
Total (30)		**23/30 (76.7%)** (4.86 ± 0.81)	**19/30 (63%)** (3.36 ± 0.67)	**23/30 (76.7%)** (4.11 ± 0.71)
Sandwiches				
Palone		0/3 (4.85 ± 1.01)	2/3 (2.85 ± 1.36)	2/3 (3.4 ± 0.16)
Mixed		0/6 (5.28 ± 0.48)	4/6 (2.69 ± 0.25)	6/6 (3.37 ± 0.2)
Rachel		0/3 (5.75 ± 0.75)	2/3 (2.91 ± 0.2)	2/3 (3.34 ± 0.88)
Egg		0/4 (5.46 ± 0.65)	2/4 (2.51 ± 14)	2/4 (3.18 ± 0.17)
Total (16)		**0/16** (5.16 ± 0.74)	**10/16 (62.5%)** (2.71 ± 0.84)	**12/16 (75%)** (3.35 ± 0.39)
RTE Fruit				
Pear and apple		0/8 (3.54 ± 0.75)	TN	TN
Strawberries		0/4 (5.58 ± 0.47)	3/4 3.24 ± 0.53)	4/4 (4.34 ± 0.43)
Sliced watermelon		2/4 (4.41 ± 0.04)	TN	3/4 (2.35 ± 0.02)
Total (16)		**2/16 (12.5%)** (4.33 ± 1.14)	**3/16 (18.8%)** (1.24 ± 0.53)	**7/16 (47.8%)** (3.36 ± 0.92)
RTE salads				
Home packed		0/2 (4.61 ± 0.08)	2/2 (2.5 ± 0.06)	2/2 (3.45 ± 0.07)
Not packed		0/3 (5.48 ± 0.27)	2/3 (2.83 ± 0.02)	2/3 (4.03 ± 0.07)
Total (5)		**0/5** (4.94 ± 0.41)	**4/5 (80%)** (2.69 ± 0.17)	**4/5 (80%)** (3.74 ± 0.3)
Traditional cold food				
Molina/lifete		2/5 (5.34 ± 0.4)	3/5 (2.48 ± 0.46)	4/5 (3.29 ± 0.06)
Badjia		7/7 (5.48 ± 0.6)	4/7 (3.19 ± 1.3)	7/7 (3.89 ± 0.3)
Sanana		3/4 (4.87 ± 0.6)	TN	TN
Total (16)		**12/16 (75%)** (5.37 ± 0.73)	**7/16 (43.8%)** (3.19 ± 0.41)	**11/16 (68.8%)** (3.53 ± 0.35)
Total	**83**			

For mesophiles and *E. coli*, the interpretation of the microbiological results was based on PHLS (2009) and INSA (2019). For coliforms, the interpretation of the microbiological results was based on Santos *et al.* (2005). *E. coli*, *Escherichia coli*; RTE, ready-to-eat; TN, tested negative.

and 30% with fecal coliforms. These contaminations were related to poor storage conditions and a lack of good manufacturing practices (GMP) and good hygiene practices (GHP). Other factors that may contribute to the contamination of these sandwiches are the origin of ingredients and a lack of training of the street vendors in food safety procedures. 65.1% of vendors purchased ingredients in informal markets that often lack minimum hygiene conditions, where only 16.4% of vendors had food safety training (Table 3). The contamination of fresh fruits, such as strawberries and watermelons, with *E. coli* and other coliforms may be due to farm environment,

Table 5. Unsatisfactory/potentially hazardous street foods collected in Maputo based on food category and pathogenic indicators

Type and (number) of food samples	Unsatisfactory/potentially hazardous food samples (average values ± sd of log CFU/g) (%) total percentage		
	Salmonella	*Listeria monocytogenes*	*Coagulase-positive staphylococci*
Traditional hot foods			
Rice and cooked meat	TN	Not analyzed	5/13 (2.88 ± 1.12)
Rice and peanut curry	TN	Not analyzed	0/5 (2.72 ± 0.49)
Rice and beans	TN	Not analyzed	0/2 (2.99 ± 0.52)
Xima and chatine	TN	Not analyzed	5/5 (5.20 ± 0.17)
Rice and matapa	TN	Not analyzed	0/5 (3.37 ± 0.05)
Total (30)	–	–	**10/30 (33.3%)** (3.39 ± 1.1)
Sandwiches			
Palone	TN	TN	0/3 3.46 ± 0.31
Mixed	TN	TN	3/6 4.22 ± 1.0
Rachel	TN	TN	0/3 3.34 ± 0.58
Egg	TN	TN	1/4 3.86 ± 0.56
Total (16)	–	–	**4/16 (25%)** (3.53 ± 0.85)
RTE Fruit			
Pear and apple	TN	TN	TN
Strawberries	TN	TN	0/4 (3.41 ± 0.74)
Sliced watermelon	TN	TN	0/4 (2.33 ± 0.28)
Total (16)	–	–	**0/16** (2.65 ± 0.58)
RTE Salads			
Home packed	TN	Not analyzed	0/2 (2.5 ± 0.11)
Not packed	TN	Not analyzed	2/3 (4.42 ± 1.17)
Total (5)	–	–	**2/5** (2.6 ± 1.18)
Traditional cold food			
Molina or lifete	TN	Not analyzed	4/5 (5.21 ± 0.7)
Badjia	TN	Not analyzed	2/7 (3.91 ± 0.98)
Sanana	TN	Not analyzed	1/4 (3.89 ± 0.53)
Total (16)	–	–	**7/16 (43.8%)** (4.14 ± 0.84)
Total 83			

The interpretation of the microbiological results was based on PHLS (2009) and INSA (2019). RTE, ready-to-eat; TN, tested negative in 25 g.

handling and post-harvest processing. Therefore, it is essential that these fresh fruits are properly cleaned, disinfected and packaged before being consumed. The results presented here showed high levels of coliforms in RTE fruits sold on the streets without protection against insect vectors and dust.

High levels of bacteria were frequently observed in RTE salads. In Kenya, 46% of salad samples were classified as unsatisfactory for *E. coli* (>2 log CFU/g) (Mbae *et al.*, 2018). Mugampoza *et al.* (2013) found concerning levels of coliforms (>11 log CFU/g) and of *E. coli* (>7 log CFU/g) in street salads sold in Uganda. The lack of sanitizing procedures, such as washing with good quality water, were associated with high levels of microorganisms in salads (Mbae *et al.*, 2018).

Microbial contamination is frequent in traditional cold foods, due to the way in which foods are prepared, handled, preserved and packaged. Cross-contamination may also be associated with insect vectors (Monney *et al.*, 2014; Kothe *et al.*, 2016). High values of coliforms and *E. coli* have been found in traditional cold foods sold in Nigeria (Aluko *et al.*, 2014). Overall, the unsatisfactory levels of food hygiene and of food quality indicator microorganisms found in this study are consistent with those found in other developing countries.

The water used to wash and cook food is a major contributor to food contamination. The survey in this work was carried out during the drought period (September to October); whereas, if the survey was conducted during the rainy season (in Mozambique, December to April), the expected levels of contamination would have been higher, due to the occurrence of floods in several regions of Mozambique, including Maputo. Bancessi *et al.* (2020) reported that in Guinea-Bissau, a country also characterized by cyclical flooding, a lower level of enteric bacteria was found in the water in the dry season compared to the rainy season.

Pathogenic indicators in street foods

Despite the high prevalence of unsatisfactory food samples, according to food quality and hygiene indicators (mesophiles, *E. coli* and coliforms), (Table 4) *Salmonella* and *L. monocytogenes* were not detected in the food samples analyzed (Table 5). Although in cooked foods the occurrence of *Salmonella* is not common, it may be frequently observed in street foods due to post-contamination. Nevertheless, other authors have also reported the absence of *Salmonella* in street foods sold in other African countries, including Nigeria, Uganda and South Africa (Nyenje *et al.*, 2012; Mugampoza *et al.*, 2013; Aluko *et al.*, 2014).Considering the presence of non-pathogenic *Listeria* spp (non-*L. monocytogenes*) in six sandwiches, the presence of *L. monocytogenes* was expected, given the origin of the sandwich ingredients and the occurrence of listeriosis outbreaks in neighboring countries, such as South Africa (Boatemaa *et al.*, 2019; Katiyo *et al.*, 2019). Notwithstanding, it is known that interactions between *L. monocytogenes* and background microbiota vary between zero effect, positive effects and antagonistic effects (Oliveira *et al.*, 2012). The non-pathogenic *L. innocua* may provide specific growth inhibition of certain *L. monocytogenes* strains, while other *L. monocytogenes* withstood this competitive effect (Heir *et al.*, 2018).

When coagulase-positive *staphylococci* were used as a food safety indicator, approximately 25% (23/83) of the food samples analyzed were classified as unsatisfactory/potentially hazardous. Other authors also reported high percentages of street food contaminated with coagulase-positive *staphylococci* at hazardous levels. Taulo *et al.* (2008) reported 64% of traditional food samples in Malawi were potentially hazardous for *S. aureus*, with values of 4.26 log CFU/g detected in traditional food served in rural households. Oranusi and Braide (2012) also reported a high prevalence of *S. aureus* in traditional food in Nigeria. The contamination by coagulase-positive *staphylococci* most likely indicates poor food

manipulation practices and transmission by insect vectors, since the food is left unprotect and exposed to dust and insects.

Given the absence of *Salmonella* and *L. monocytogenes*, coagulase-positive *staphylococci* appears to be a more adequate safety indicator under the local conditions of street vending.

Conclusions

This study was based on a diverse sampling, including different types of RTE street foods and vending conditions within a large urban area of approximately 132 km^2, corresponding to five out of the seven municipal districts of the city of Maputo, where the main street food sales activities are concentrated. The results showed that most of the RTE foods sold in Maputo city are of very low microbiological quality, and some even may constitute a potential risk to consumer health. The high levels of *E. coli*, coliforms and coagulase-positive *staphylococci* found in street food suggest fecal contamination and improper handling. The absence of safe piped water does not allow for proper cleaning and disinfection of hands and utensils, including dishes and cutlery that are continuously re-used by the consumers. To our knowledge, this is the first study on the quality and safety of street food sold in the city of Maputo. In addition, no other reports are known for any other region of Mozambique. The results from this study will hopefully contribute to the development of GMP and GHP for street food in Maputo, Mozambique, in accordance more proactive approaches in identifying and reducing food safety risks advised by the World Bank (Jaffee *et al.*, 2019) and the United Nations (UN, 2015).

Author Contributions

Acácio Salamandane: Carried out the experiments, interpreted the results and wrote the manuscript. Ana Carla Silva: Carried out part of the experiments. Luísa Brito: Planned the experiments, interpreted the results and wrote the manuscript. Manuel Malfeito Ferreira: Planned the experiments and wrote the manuscript.

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Conflict of Interest

The authors declare no conflicts of interest.

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