**Prevalence of *Listeria* species and growth potential of *Listeria monocytogenes* in typical Nigerian traditional street foods**

**Abstract**

**Aims**: Listeriosis is a deadly disease associated with foods contaminated by *Listeria* species particularly *L. monocytogenes* (Lm). Listeriosis has been under-reported in Africa especially from consumption of typical street foods. The investigation was therefore directed at determining the presence of *Listeria* species in typical Nigerian street foods and the potential to support growth of Lm.

**Study design:** Laboratory experiments were designed to ascertain *Listeria* presence and growth in randomly selectedstreet foods (akara, moimoin, suya meat, fried fish, and roasted plantain and yam) from 6 towns across Delta State, Nigeria during wet and dry seasons

**Place and duration of study:** Department of Microbiology laboratory, Delta State University Abraka, Nigeria was used for the study conducted in July-September, 2023 and January-March, 2024 covering wet and dry season, respectively.

**Methodology:** *Listeria* selective medium was used for isolation and enumeration of *Listeria* species from 180 samples of the street foods after rejuvenation in Buffered Peptone Water. Identification was by microscopic and biochemical tests. The European Union Reference Laboratory guide was used for growth potential tests.

**Results**: Prevalence of *Listeria* by towns and food type were 6.6-25.9 and 15.7-22.8%, respectively without significant seasonal differences. *Listeria* populations significantly differed in the foods (F=5.32-49.20; *P*=0.000) except in one town. The identified species were: *L. monocytogenes, L. innocua, L. ivanovii, L. grayi,* *L*. *seeligeri* and *L. weishmeri* with prevalence of 53.9, 15.6, 13.3, 8.9, 4.4 and 3.9%, respectively. Roasted yam and plantain (starchy foods) failed to support growth of Lm (δ=0.20-0.34) while the other protein-based foods did (δ=0.58-1.58 log cfu/g). Contaminated foods did not support growth of Lm except in fried fish stored in refrigerators (δ=0.59) and suya (δ= 0.52).

**Conclusion:** *Listeria* species can be found in typical Nigerian traditional street foods some of which can support the growth of *L. monocytogenes* the causative agent of listeriosis.

**Keywords: street foods; *Listeria* species, prevalence; growth potential**

**1.0 Introduction**

*Listeria* species are rod-shaped facultative anaerobic, Gram-positive bacteria that are capable of growth in cold and warm temperatures (Dufailu et al., 2021). There are 20 species of *Listeria* that have been characterised according to the report by Nwaiwu (2020). However, only *L. monocytogenes* and *L. ivanovii* are associated with food-borne disease in human and animals (Kayode et al., 2020). *Listeria monocytogenes* is the causative agent of invasive and non-invasive listeriosis and it is associated with ready-to-eat (RTE) foods such as meat and dairy products, poultry, leafy vegetables, cakes and ice cream (Fagerlund et al., 2020; Şentürk et al., 2022). Indeed an outbreak of listeriosis linked with RTE meat products was reported in South Africa and it involved 1060 cases that resulted in 216 deaths (Thomas et al., 2020). *Listeria* species are scarcely isolated or mentioned in reports on microbial contamination of street foods in Nigeria and sub-Sahara Africa (SSA) countries despite the incidents of listeriosis.

Street food refers to a wide variety of foods and beverages that are usually prepared or sold by vendors in streets, pushcarts or any public place for direct human consumption immediately or later. These foods are generally inexpensive and are attractive to low- and middle-income classes especially in the developing world (Alimi, 2016; Sabuj *et al*., 2018). Despite the advantages and economic benefits of street foods to both the vendors and consumers, reports have shown that they are vulnerable to microbial contamination and are consequently associated with food-borne diseases (Ossai, 2012; Oluwafemi et al., 2013; Hassan *et al*., 2016; Birgen *et al*., 2020; Rosales et al., 2023). Generally, the bacteria frequently isolated from street foods especially in Nigeria and SSA countries include *Escherichia coli, Bacillus sp., Staphylococcus aureus, Eenterococcus faecalis, Citrobacter sp., Proteus sp. Klebsiella sp., S. epidermis Salmonella sp* *Enterobacter, Shigella, Pseudomonas, Micrococcus* and *Vibrio sp.* (Madueke et al., 2014; Temesgenet al., 2016; Moloi et al., 2021; Garba., 2023: Islam et al., 2024). Although Sarr et al (2023) reported that *Listeria* spp were detected in RTE foods such as meat, dairy products, poultry, smoked and dried fish, leafy vegetables, cakes and ice cream in several African countries (Nigeria, Ghana, Ethiopia, South Africa, Egypt, Morocco and Botswana), these RTEs are not typical *stricto sensu* street foods in SSA settings. For example the presence of *Listeria* in foods such as rice, beans, yam (roasted or fried), bean pudding (moimoin/akara), plantain (fried or roasted) and roasted beef (suya) that are popular and widely consumed typical Nigerian street foods are rarely reported..

Listeriosis is a deadly food-borne disease hence investigations should be extended to street foods especially in SSA where the data on listeriosis is limited (Dufailu, 2021). According to FAO/WHO (2022), the data on incidence and burden of listeriosis is available for limited number of high income countries, but absent in Africa except South Africa. It is expected that the incidence of listeriosis will be higher in SSA due to poor sanitation and unhygienic practices in food processing and sales (Geteneh et al., 2022). The potenrial presence of *Listeria* in street foods has not received adequate attention from researchers in Nigeria and SSA countries. Thus the objective of this study is to determine the presence and extent of occurrence of *Listeria* spp in some traditional street foods in urban areas of the Delta State region of Nigeria; and ascertain the potential of the foods to support the growth of *L. monocytogenes.* The study outcome may update the information on the presence food-borne *Listeria* spp in Africa and alert public health agencies to the possibility of listeriosis arising from consumption of typical traditional street foods.

**2.0 Materials and Methods**

*2.1* *Selection of street food samples*

A list of 10 commonly eaten foods sold along the streets was compiled (roasted yam, roasted plantain, suya, fried fish, moimoin, akara, white rice and stew, jollof rice, beans porridge and meat-pie) out of which 6 most frequently consumed foods were selected. The selection was based on a face-to-face interview with 100 adult respondents after obtaining their informed consent using the following scale/options: 1, I don’t; 2, sometimes; 3, most of the time; 4 all the time. Roasted plantain and yam, suya meat, moinmoi (bean pudding), akara (bean cake), and fried fish were subsequently selected for the study (Appendix A).

*2.2 Description of selected street foods*

Yam (*Dioscorea* species) is a predominantly root tuber starchy food widely cultivated in Africa, Caribbean, South America, Asia and Oceania (Obidiegwu et al., 2020). It can be consumed as boiled, fried or roasted yam in an open-flame. Plantain *(Musa parasidisiaca*) is mainly a carbohydrate food like yam. (Uneanya et al., 2017). Open-flame roasted plantain like yam is also a popular street food in Nigeria; and reports have shown that both foods are frequently contaminated by pathogenic and food spoilage microorganisms (Uneanya et al., 2017; Omorodion & Chiwon, 2022) hence their shelf lives are limited to 24-36 h.

Unlike yam and plantain, moimoin, akara, suya meat and fried fish are regarded as protein-based foods because of their high protein contents. Moimoin and akara are prepared from a paste made from de-hulled wet-milled beans (cowpea, *Vigna unguiculata*) and mixed with pepper, onions and salt. For moimoin, vegetable oil is added before steaming to a gel which solidifies after coolingwhile in the case of akara, the paste is fried directly with vegetable oil. These preparation processes are often carried out on street sides where the moimoin and akara are exposed to microbial contaminations hence they are perishable with shelf-lives limited to 16 hours at room temperature and 3 days in the refrigerator (Frank-Peterside et al., 2001; Agbara et al., 2018).

Suya is roasted meat from cows, sheep or goat that is devoid of bones. Suya meat is usually placed on stakes and treated with vegetable oil, spices and onions and roasted on open flames. Reports have shown that it is highly perishable on account of microbial contamination arising from exposure on the street (Adesoji et al., 2019; Osunde et al., 2024). Fish like meat is also highly perishable, but when fried the shelf life could be extended to 1-2 weeks (Daramola et al.,2023; Ahmad et al., 2024)..

*2.3 Collection of samples*

Samples of the selected street foods were collected from 6 towns (Asaba, Kwale, Abraka, Ughelli, Warri, and Ozoro) spread across Delta State area of Nigeria. Each of the 6 foods were purchased at one per street in 5 randomly selected streets per town thereby bringing the total number of samples to 180. They were transported immediately in ice-packs to the laboratory for analysis. The study was conducted during the wet (July-September) and dry (January – March) seasons.

*2.4 Isolation, enumeration and identification of* *Listeria* spp*.*

The direct plating method recommended in Biological Analytical Manual (BAM) (Hitchins et al., 2022) was used. A homogenate of 25g of each of the selected street foods in 225ml of buffered peptone water (BPW) was prepared and set aside for 4h to enable rejuvenation or resuscitation of *Listeria* cells. BPW was used based on the report of Sheridan et al., (1994). Thereafter 1ml was used to inoculate triplicate plates of *Listeria* selective agar (Lifesave Biotech, San Diego USA) and incubated at room temperature (30±2oC) for up to 72 h. The emerging colonies were counted and their identities were determined by morphological and biochemical tests. The tests were conducted according to the procedure of BAM (Hitchins et al., 2022) and they include Gram stain, catalase reaction, motility (tumbling/umbrella), carbohydrate fermentation (Rhamnose, Xylose, and Manitol), β-haemolysis and Christie-Atkins-Munch-Peterson (CAMP) test, for haemolysis enhancement with S*taphylococcus aureus*. A *S. aureus* isolate from contaminated food was used after testing for weak β-haemolysis

*2.5 Determination of growth potential of L. monocytogenes* (Lm) *in street foods*

Lm is known to be associated with listeriosis and the preliminary results showed that it was the dominant species hence it was used for growth potential tests. The Lm strains isolated from each type of food were used for growth potential tests in the same food instead of reference strains because of direct relevance in the tropical environment. A total of 6 isolates (strains), one from each of the 6 towns, were used. Food samples were purchased from vendors in the morning upon their arrival on the street to begin sales. Suya and fried fish were purchased immediately after roasting and frying, respectively. All the food samples were placed in sterile ice-packed containers and transported to the laboratory for the tests. The foods were initially tested for the presence of bacteria using Nutrient agar. The presence of bacteria served as indication of microbial contamination; and contaminated samples were separated from those without contamination. For the test on growth potential, contaminated and non-contaminated street food samples were inoculated with 102 Lm cells/g. The inoculum was developed using the procedure of Spanu et al (2014) with a minor modification in respect of incubation temperature (30 oC was used instead of 37). Lmcolonies from the selective medium were streaked onto Trypticase Soy Agar (TSA) and incubated at 30 oC for 24 h. Thereafter 6 tubes each containing 10 ml of Trypticase Soy broth (TSB) were inoculated with loopfuls of Lm from the TSA plates and incubated at 30 oC overnight. The 6 tubes stood for the 6 selected foods; and each tube was inoculated with 6 strains of *Lm* that were isolated from the same type of street food from the 6 towns. The mixed strains in each tube were subsequently diluted with normal saline to obtain an inoculum size of 102 *Lm* cells/ml, ascertained by plate counts on TSA..

The challenge test guideline of EURL (2021) was adopted for the growth potential tests which were carried out in batches of 3. The batches were taken from a town in each of the 3 senatorial districts in the state. S total of 5 sets of triplicate samples from each batch were inoculated with the mixed strains (102 *Lm* cells per g) and incubated at room temperature (30±2oC) for 48 h. samples were withdrawn at 12 h intervals (0, 12, 24, 36 and 48 h) and analysed for Lm growth. A 48 h incubation limit was adopted for moimoin, akara, suya, and roasted plantain and yam because they usually become unsuitable for consumption after 24h. On the other hand, fried fish is not usually as perishable hence the test period was extended to 7 days during which Lm growth was determined at daily intervals.. This procedure was repeated for fried fish at refrigerator temperature (4 oC) because some consumers often store fried fish in refrigerators. The analyses for *Lm* growth counts was by by direct plating of 1ml of the food homogenate on *Listeria* selective agar.

*2.6 Data analysis*

. Prevalence was based on the number of food samples where *Listeria* was detected. ANOVA was performed after log transformation to indicate *Listeria* species population differences in the 6 street foods while *t* test was used to compare the 2 seasonal populations. The growth potential was computed in accordance with the guideline of EURL (2021) where the difference between Lm counts at time zero and the highest count at the end of incubation becomes the growth potential designated as δ.. Growth is considered supported if δ is >0.5 log cfu/g and the highest in a batch is the reference growth potential.

**3.0 Results**

The results presentedin Figure 1 show that prevalence of *Listeria* in street foods varied by town and did not exceed 26% and there was no statistical significant seasonal difference in each of the towns. Compared to towns, prevalence of *Listeria* spp by type of food tended to be lower and the variations were also markedly lesser except with toasted yam (Figure 1). There was also no statistical significant seasonal differences (Figure 1). The results in Table 1 show that there were highly significant differences in the population of *Listeria* species isolated from the 6 street foods in all but one town. Generally, the protein-based foods (akara, moimoin, suya meat and fried fish had higher populations of *Listeria* species than in the starchy plantain and yam as can be seen in Table 1

Figure 1 Prevalence and seasonal variations of *Listeria* spp isolated from street foods by by source locations (town) and food type.

Table 1 Comparison of the population of *Listeria* species in street foods

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Location (town) | Log cfu.g±SD | | | | | | F(*P*) |
|  | Roasted plantain | Roasted yam | Akara | Moimoin | Suya | Fried fish |
| Abraka  Ozoro  Kwale  Ughelli  Warri  Asaba | 0.62±0.56  0.75±0.70  0.72±0.41  0.81±0.75  0.00±0.00  0.17±0.37 | 0.64±0.58  0.22±0.30  1.09±0.06  0.81±0.75  1.40±0.14  0.00±0.00 | 1.21±0.17  1.14±0.63  1.40±0.42  1.25±0.11  0.51±0.06  0.00±0.00 | 1.35±0.16  0.75±0.70  0.71±0.40  0.81±0.75  0.00±0.00  0.17±0.37 | 1.60±0.11  1.60±0.13  1.50±0.09  1.47±0.11  1.20±0.11  1.38±0.77 | 1.50±0.03  1.51±0.22  1.43±0.06  1.40±0.08  0.54±0.50  1.28±0.18 | 7.60(0.00)  5.32(.000)  11.2(.000)  1.72(.16)  49.2(.000)  13.8(.000 |

The identified species of *Listeria* were 6 and *L. monocytogenes* was the most frequently isolated while*L. weishimeri* was the least (Table 2). The results of the potential of the street foods to support the growth of Lm are presented in Tables 3-6.. Non-contaminated roasted plantain and yam did not support the growth of Lm whereas akara, moimoin and suya did (Table 3). Suya with δ=0.61 cfu/g, was most supportive of the growth of Lm among the 3 street foods that supported growth of Lm (Table 3).

Non-contaminated fried fish markedly supported the growth of Lm at both room and refrigerator temperatures without marked difference in δ values (Table 4). In contrast, Lm growth was not supported by all the contaminated street foods except in suya (Table 5) and fried fish under refrigerator storage (Table 6).

Table 2 Prevalence of identified *Listeria* species isolated from street foods

|  |  |  |
| --- | --- | --- |
| Species | Prevalence (*N*=180\*) | |
| *n* | % |
| *L. monocytogenes*  *L. innocua*  *L. ivanovii*  *L. grayi*  *L. seeligeri*  *L. weishimeri* | 97  28  24  16  08  07 | 53.9  15.6  13.3  8.9  4.4  3.9 |

\*, No of food samples

Table 3 Growth potential of Lmin non-contaminated street foods at room temperature (30±2 oC)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Food | Batch | Mean *Lm* counts (log cfu/g) in sampling units at: | | | | | Growth potential (δ) | |
| 0 | 12 | 24 | 36 | 48h | Single | Group  0.59\*  0.58\*  0.61\*  0.34  0.20 |
| Akara  Moimoin  Suya  Roasted plantain  Roasted yam | 1  2  3  1  2  3  1  2  3  1  2  3  1  2  3 | 2.02±0.04  2.04±0.05  2.00±0.00  2.02±0.05  2.04±0.02  2.00±0.00  2.02±0.05  2.04±0.05  2.03±0.02  2.01±0.02  2.03±0.04  2.03±0.03  2.01±0.05  2.02±0.04  2.03±0.02 | 2.04  2.05  2.06  2.02  2.08  2.07  2.05  2.10  2.08  2.03  2.10  2.24  2.04  2.05  2.06 | 2.08  2.14  2.10  2.07  2.10  2.18  2.09  2.19  2.21  2.07  2.23  2.28  2.07  2.09  2.10 | 2.34  2.25  2.27  2.30  2.24  2.26  2.32  2.30  2.40  2.13  2.29  2.35  2.14  2.14  2.17 | 2.60  2.58  2.59  2.58  2.42  2.51  2.63  2.61  2.57  2.09  2.33  2.37  2.07  2.16  2.23 | 0.58  0.54  0.59  0.58  0.38  0.51  0.61  0.57  0.54  0.12  0.30  0.34  0.13  0.14  0.20 |
| \* Growth is supported at: >0.5 log cfu/g) | | | | | | | | |

Table 4 Growth potential of Lmin non-contaminated fried fish at room and refrigerator temperature

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Batches | |  | Mean Lmcounts (log cfu/g) in sampling units at daily intervals | | | | | | | Growth potential (δ) | |
|  | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Single | Group |
| A  B | 1  2  3  1  2  3 | 2.01±0.02  2.02±0.03  2.00±0.00  2.02±0.04  2.01±0.03  2.02±0.03 | 2.05  2.10  2.09  2.06  2.05  2.04 | 2.07  2.18  2.16  2.15  2.14  2.10 | 2.23  2.26  2.27  2.25  2.28  2.24 | 2.52  2.48  2.31  2.64  2.57  2.46 | 3..10  3.30  3.32  2.36  2.90  3.00 | 3.35  3.35  3.34  3.40  3.25  3.42 | 3.30  3.37  3.34  3.52  3.47  3.50 | 1.34  1.35  1.34  1.50  1.46  1.48 | 1.35\*  1.48\* |

Storage at: A, room temperature (30±2 oC); B, refrigerator (4 oC); \* Growth is supported at: >0.5 log cfu/g)

Table 5 Growth potential of Lmin contaminated street foods at room temperature (30±2 oC)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Food | Batch | Mean Lmcounts (log cfu/g) in sampling units at: | | | | | Growth potential ((δ) | |
| 0 | 12 | 24 | 36 | 48 h | Single | Group |
| Akara  Moimoin  Suya  Roasted plantain  Roasted yam | 1  2  3  1  2  3  1  2  3  1  2  3  1  2  3 | 2.01±0.02  2.02±0.01  2.01±0.01  2.03±0.02  2.02±0.01  2.02±0.02  2.04±0.02  2.04±0.03  2.03±0.02  2.01±0.01  2.01±0.01  2.03±0.02  2.03±0.03  2.01±0.01  2.00±0.00 | 2.05  2.06  2.04  2.04  2.05  2.05  2.10  2.09  2.10  2.04  2.05  2.05  2.05  2.02  2.03 | 2.09  2.09  2.07  2.08  2.06  2.07  2.25  2.19  2.20  2.06  2.08  2.07  2.06  2.05  2.04 | 2.10  2.09  2.10  2.12  2.09  2.07  2.38  2.36  2.39  2.09  2.10  2.08  2.10  2.05  2.04 | 2.10  2.11  2.10  2.14  2.09  2.07  2.56  2.53  2.54  2.10  2 .12  2.12  2 .10  2.09  2.07 | 0.09  0.09  0.09  0.11  0.07  0.05  0.52  0.49  0.51  0.09  0.10  0.09  0.07  0.08.  0.07 | 0.09  0.11  0.52\*  0.10  0.08 |

\* Growth is supported at: >0.5 log cfu/g)

Table 6 Growth potential of Lmin contaminated fried fish at room and refrigerator temperatures

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Batches | |  | Mean *Lm* counts (log cfu/g) in sampling units at daily intervals | | | | | | | Growth potential (δ) | |
|  | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Single | Group |
| A  B | 1  2  3  1  2  3 | 2.01±0.01  2.02±0.01  2.02±0.01  2.03±0.02  2.00±0.00  2.02±0.02 | 2.01  2.03  2.05  2.10  2.08  2.08 | 2.07  2.05  2.09  2.18  2.17  2.19 | 2.10  2.15  2.13  2.27  2.26  2.24 | 2.12  2.18  2.16  2.30  2.28  2.29 | 2.14  2.20  2.21  2.35  2.37  2.34 | 2.14  2.18  2.21  2.55  2.26  2.40 | 2.25  2.10  2.19  2.60  2.59  2.57 | 0.24  0.18  0.19  0.57  0.59  0.55 | 0.24  0.59\* |

Storage at: A, room temperature (30±2 oC); B, refrigerator (4 oC); \* Growth is supported at: >0.5 log cfu/g)

**4.0 Discussion**

The results showed that the prevalence of *Listeria* spp in the tested street foods was low (<25.0%). However, it can be considered substantial when viewed against the background of the limited data and the general low prevalence associated with *Listeria* spp in Nigeria and other African countries (Nwaiwu, 2015; Dufailu et al., 2021). This inference is supported by the outcome of studies in Nigeria and other sub-Sahara African countries, where a diversity of microorganisms in street foods were reported without the presence *Listeria* (Oluwafemi et al, 2013; Madueke et al., 2014; Temesgenet al., 2016; Moloi et al., 2021; Garba, 2023). Although it can be argued that there are reports of the presence of *Listeria* spp in RTE foods, (e.g El-Shenawy et a., 2011**;** Ajayeoba et al., 2016; Dufailu et al., 2021;: Sarr et al., 2023; Isa et al., 2023), the RTEs covered were generally not typical street foods like those tested in this study..

The *Listeria* species encountered in the street foods were 6 with *L monocytogenes* being the most prevalent and also the subject of several investigations because of its association with listeriosis (Chuku et al., 2020; Kayode et al., 2020). In addition, WHO (2015) listed it as one of the most deadly organisms in the world. *Listeria ivanoviii* is another species that is associated with listeriosis (Chuku et al., 2020; Kayode et al., 2020) which was also encountered in this study although it was with a markedly lower frequency than *L. monocytogenes*. However, the fact that both organisms were encountered in the street foods indicated the vulnerability of street foods consumers to listeriosis. This underscores the need for paying greater attention to street foods.

The variation and differences observed in the population of *Listeria* in the street foods tended to reflect nutritional composition of the foods. The starchy foods (plantain and yam) had lesser numbers of *Listeria* spp than akara, moimoin, suya meat and fried fish. The difference can be attributed to the protein contents, which is markedly higher in beans, meat and fish thus making them nutritionally more suitable for microbial growth. The protein contents of beans stands at 23-32% (Abebe & Alemayehu, 2022) while it is 3.3% in roasted plantain (Adepoju et al., 2012) and 0.09-18.7% in yam depending on the species (Obidiegwu et al., 2020). Meat and fish are already well known to be nutritionally balanced with high protein content. Thus the greater population of *Listeria* in protein-based street foods was not unexpected. The outcome of the challenge tests with Lm is consistent with this differential population of *Listeria* spp in the street foods.

The non-contaminated roasted yam and plantain (starchy foods) failed to support the growth of Lm whereas the non-contaminated protein-based foods did. Lm has frequently been detected or isolated from foods with significant protein content (e.g. dairy products, meat, poultry and fish) as shown by several reports (e.g. Adeshina et al., 2017; Koskar et al., 2019; Thomas et al., 2020; Şentürk et al., 2022; Isa et al., 2023). This trend suggests that traditional foods rich in protein as typified by akara and moimoin can support the growth of *Listeria* species irrespective of the traditional processing methods. Foods that support the growth of Lm can result in listeriosis hence four of the street foods in this study can be associated with listeriosis. It was observed that fried fish supported the growth of Lmin the refrigerator with a marginal lesser difference in growth potential when compared to growth at room temperature. This substantiates the observation that Lm can grow over a wide range of temperature irrespective of the environment of the source, which in this case is tropical.

The highest growth potential was in fried fish followed by suya meat. The marked difference in growth potential can be attributed to the presence of spices in suya meat because spices are known to retard the growth of microorganisms (Gottadi et al., 2016). In any case, varying growth potentials have been observed with different types of food which has been attributed to the composition of the food, the additives and the environment (Ziegler et al., (2018; Eicher et al., 2020). The results here showed that the contaminated street foods failed to support the growth of Lm except in contaminated fried fish stored in the refrigerator and suya meat.. Competing microflora on food can retard or prevent the growth Lm (Dalgaard et al., 1998; Lappi et a., 2004). This can partly explain the absence of *Listeria* species in the results of several studies on the microbial contamination of street foods. The plausible explanation for the growth of Lm in contaminated fried fish in cold storage is that while it can grow at low temperatures, growth of other competing organisms may be retarded. In the case of suya, the spices used for the preparation may have retarded the growth of some of the competing organisms.

The six street foods used for this investigation are often prepared on street sides and sold on the spot or hawked by vendors or pushcarts. They are therefore typical popular street foods that are constantly exposed to the environment hence they are vulnerable to contamination by bioaerosols bacteria. Thus the paucity of information concerning the occurrence of *Listeria* spp in street foods necessitates greater attention to isolation protocol because of the likely omission of *Listeria* due its slow growing habit and the possibility of being eclipsed by other competing microorganisms.

**5.0 Conclusion**

The outcome of this study demonstrated that microorganisms that contaminate typical Nigerian street foods include *Listeria* species with *L. monocytogenes*, *L. innocua* and *L. ivanovii* being substantially prevalent. The prevalence was not significantly affected by seasonal changes. The population of *Listeria* species were more in protein-based foods (akara, moimoin, suya and fried fish) than in the starchy street foods (roasted plantain and yam). In addition, unlike the protein foods, these starchy foods failed to support the growth of *L. monocytogenes*. The absence of *Listeria* species in several reports on microbial contamination of street foods can be attributed to isolation methods and the presence of competing flora in the street foods. Thus typical traditional Nigerian street foods include foods that can support the growth of *Listeria* species and potentially culminate in listeriosis. It is against this background that public health authorities in Nigeria and sub-Sahara Africa need to pay close attention to street foods as potential sources of *Listeria* species..

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**Appendix A Selection of street foods**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Street food | No of respondents in consumption options (*N*=100) | | | | \*Score |
|  | 1, I dont | 2, Sometimes | 3,Most of the time | 4, All the time |  |
| Akara | 8 | 35 | 37 | 20 | 269 |
| Moimoin | 6 | 36 | 37 | 21 | 273 |
| Suya | 17 | 49 | 29 | 5 | 222 |
| Fried fish | 5 | 33 | 40 | 22 | 279 |
| Roasted Plantain | 11 | 36 | 52 | 1 | 243 |
| Roasted yam | 10 | 32 | 56 | 2 | 246 |
| White rice and stew | 25 | 48 | 20 | 7 | 209 |
| Jollof rice | 24 | 56 | 12 | 8 | 204 |
| Beans porridge | 32 | 61 | 5 | 2 | 177 |
| Meat-pie | 85 | 15 | 0 | 0 | 115 |

\*option point multiplied by the number of respondents in each option