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Identification of bacteria and parasites in unprocessed vegetables retail in Ijebu metropolis, Ogun state and antibiogram of the bacteria

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Abstract

Vegetables contain essential nutrients that enhance the growth and vital health of humans but can also harbour a wide range of microbial contaminants. This research aims at identifying bacteria and parasites contaminants in vegetables retail in Ijebu metropolis of Ogun State. Ten different unprocessed vegetables were purchased in the fresh state from three markets viz: Ago-Iwoye, Ijebu-Igbo and Oke-Aje on a weekly basis. Bacteria and eggs/cysts of parasites in the vegetables and sprinkling water samples were identified using biochemical techniques and morphology respectively. The bacterial isolates were subjected to antibiotic susceptibility testing. For fruity vegetables, the highest total viable, coliform and *Salmonella Shigella* counts of 8.0×10^6, 5.2×10^6 and 4.2×10^6 CFU/g were recorded in carrot, cucumber and watermelon respectively, for leafy vegetables, fluted pumpkin leaf has the highest viable and coliform counts of 8.0×10^6 and 5.0×10^6 CFU/g respectively while cabbage had the highest *Salmonella Shigella* count of 3.9×10^6 CFU/g. Different species of bacteria were recovered from the vegetables and sprinkling water with *Escherichia coli* (28.2%) having the highest incidence while *Serratia marcescens* had the least (1.2%). For the parasites in the vegetables, *Taenia* eggs had the highest occurrence of 31.7%, with Hookworm eggs (3.2%), *Diphyllobothrium latum* eggs (3.2%) and *Trichuris trichuria* (3.2%) having the least. Most bacterial isolates were resistant to the antibiotics. This study has demonstrated the presence of pathogens in the retailed vegetables; therefore, it is necessary for consumers to practice appropriate food hygiene before consumption of these vegetables to avoid food poisoning.

Key words: Antibiotics, Bacteria, Markets, Parasites, Unprocessed Vegetables

1. Introduction

Generally, vegetables are leafy out-growths of plants or plant shoots used as food [1]. They provide vitamins and minerals required for the maintenance of good health in human especially the old. Globally, they can be consumed raw, cooked or used as desserts [2].

According to Akoachere *et al.* [3] and Sato *et al.* [4] various fresh vegetables and fruits including lettuce, tomato, melon, spinach and sprouts have been reported as pathogen vectors thereby increasing food poisoning as a result of constant consumption of these contaminated vegetables through unhygienic practices. Contamination of vegetables may take place before, during and after harvest [5]. For instance, the extensive use of contaminated water for irrigation during cultivation can introduce contaminants to the vegetables [6]. Documented outbreaks of human infections associated with the consumption of raw vegetables have also been reported [7].

A number of studies in various parts of Nigeria have reported on the bacteria and parasites associated with raw vegetables sold in markets [8 -10]. *E. coli*, *Enterobacter* sp., *Salmonella* sp., *Shigella* sp and *Pseudomonas aeruginosa*, have been associated with vegetables in parts of Abuja [11] and Enugu State [9]. Also, Alade *et al.* [12], Simon-Oke *et al.* [13] and Agbalaka *et al.* [14] reported intestinal parasites amongst vegetables sold in Kwara, Ondo and Plateau States respectively.

Pathogenic infections are among the major public health and socio-economic concerns that affect the well–being of the poor especially amongst the pre-age children and children of school age in developing countries. Adekanle *et al.* [15] and Obinna and Destiny [16] reported the presence of *E. coli*, *Staphylococcus aureus* and *Pseudomonas* species in vegetables sold in Sagamu and Sango-Ota in Ogun State. Furthermore, Fagbenro *et al.* [17] and Nwadike *et al.* [18] in their studies on parasites in vegetables purchased in some parts of Ogun State recovered *Ascaris lumbricoides* and *E. histolytica* as the most dominant parasites respectively. Although, these studies have indicated that pathogens are commonly found in vegetables frequently eaten uncooked, there is still a dearth of data on the level of microbial contamination and parasites associated with vegetables within Ijebu metropolis and so the need for the present study. Hence, we investigated the bacteria and parasites associated with vegetables and the water used in sprinkling the vegetables retail in markets in Ijebu metropolis.

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2. Materials and Methods

2.1 Sample collection

A total of 30 whole fruity and leafy fresh vegetable samples comprising ten different species were randomly collected under normal purchase conditions from the sellers in the different markets in Ago-Iwoye, Ijebu-Igbo and Ijebu-Ode early in the morning. The fruity vegetables collected with their codes are: Carrot (CR) - *Daucus carota*, Cucumber (CC) - *Cucumis sativus*, Okra (OR) - *Abelmoschus esculentus*, Water melon (WM) - *Citrullus lanatus*, while the leafy ones are: Cabbage (CB) - *Brassica oleracea*, Jute leaf (EW) - *Corchorus olitorius*, Fluted pumpkin leaf (UG) - *Telfairia occidentalis*, Water leaf (GB) - *Talinum triangulare*, Lagos spinach (SK) - *Celosia argentea*, African Spinach (TT) *Amaranthus hybridus*. They were collected into separate sterile, labeled polythene bags and transported immediately to the Microbiology laboratory, for bacteriological analysis while the parasitological analysis was carried out in Zoology and Environmental Biology laboratory. The sample of water used in sprinkling the vegetables were also collected for analysis.

2.2 Isolation of Bacteria from Vegetable and Sprinkling water samples

Ten (10) grams of each vegetable sample was washed with sterile distilled water, weighed aseptically, shredded and dissolved in 90 mL sterile peptone water in a conical flask and swirled gently to mix. One (1) mL of each sample and sprinkling water were serially diluted in sterile peptone water up to 10^{-5} dilution. 0.1 mL each of the 10^{-5} dilution was spread over Nutrient agar, MacConkey and *Salmonella-Shigella* agar (SSA) plates respectively. The plates were incubated at 37ºC for 24 hours while MacConkey plates were incubated at 35ºC for 24-48hrs. Discrete colonies were sub-cultured on nutrient agar and incubated at 35ºC for 24 hours to obtain a pure colony [19]. The pure bacterial isolates were stocked on Nutrient Agar in MacCarthney bottles at 4ºC in the refrigerator.

2.3 Microbial load

The microbial load on Nutrient, MacConkey and *Salmonella Shigella* agar plates after incubation were recorded as aerobic, coliform and *Salmonella Shigella* (SS) counts respectively, and were expressed as colony forming unit per gram of sample.

2.4 Characterization and Identification of bacterial isolates

The bacterial colonies were differentiated first on the basis of their colonial morphology followed by Gram staining and biochemical tests as described by [19 - 20].

2.5 Isolation and Identification of Parasites in vegetables

Isolation of parasitic eggs, cysts, larvae and oocysts from each vegetable sample was carried out as described by Khawaja *et al.* [21]. The eggs/cysts were identified based on morphological details as described by Soulsby *et al*. [22]. The process was repeated thrice for each sample.

2.6 Antibiotic Susceptibility Test

Bacteria isolates were subjected to *in vitro* susceptibility test using the Kirby-Bauer method [23] with broad-spectrum antibiotics: ceftazidime (30 µg), amoxycillin/clavulanic acid (20 µg/10 µg) and ceftriaxone (30 µg). The susceptible, intermediate and resistant categories were assigned on the basis of the critical points recommended by the Clinical and Laboratory Standards Institutes[24].

3. Results and Discussion

3.1 Results

The microbial loads in the studied vegetables are presented in table 3.1. For fruity vegetables total aerobic, coliform and *Salmonella Shigella* counts ranged from 2.4 - 8.0 x 10^6 CFU/g, 1.8 - 5.2 x 10^6 CFU/g and 0.9 - 4.2 x 10^6 CFU/g respectively, while counts in leafy vegetable ranged from 0.7 - 8.0 x 10^6 CFU/g, 0.3 - 5.0 x 10^6 CFU/g and 0.2 - 3. 9 x 10^6 CFU/g respectively. Tables 3.2 shows the microbial load in water used in sprinkling vegetables.

Most of the isolates were Gram negative rods, while two were Gram positive cocci and one Gram positive rod. For the biochemical tests, fourteen (14) bacterial species were recovered and identified from the vegetables: *Escherichia coli*, *Enterobacter cloacae, Klebsiella pneumoniae, Bacillus cereus, Shigella* spp., *Staphylococcus aureus, Salmonella typhi, Citrobacter freundii*, *Enterobacter aerogenes, Pseudomonas aeruginosa*, *Aeromonas hydrophila*, *Proteus mirabilis*, *Micrococcus luteus* and *Serratia marcescens* (Table 3.3). The spread of the bacterial isolates in both fruity and leafy vegetables is presented in Table 3.4 with the highest and lowest prevalence of 28.2 % and 1.2 % reported in *E. coli* and *S. marcescens* respectively.

The parasites identified from the vegetables were: *Taenia* eggs (31.7%), *Entamoeba histolytica* (20.5%), *Schisto*soma eggs spp. (14.3%), *Hymenolepis* egg spp. (9.5%), *Paragonimus* egg (4.8%), Unfertilized *Ascaris* eggs (4.8%), *Fasciola* eggs (4.8%), Hookworm eggs (3.2%), *Diphyllobothrium latum* eggs (3.2%) and *Trichuris trichuria* (3.2%) (Figure 3.1).

The antibiotics susceptibility profile (antibiogram) is presented in table 3.5. All the isolates were resistant to ceftriaxone, 13 to amoxycillin-clavulanic acid and 11 to ceftazidime. Only *S. aureus* was susceptible to ceftazidime and amoxicillin- clavulanic acid.

Table 3.1: Microbial loads (CFU/g) in fruity and leafy vegetables sold in markets in Ijebu Metropolis

Location	Sample Code	Fruity vegetables TVC	TCC	TSSC	Location	Sample	Leafy vegetables TVC	TCC	TSSC
			x 10^6					**x** 10^6	
Ago – Iwoye	WM	5.5	3.5	1.4	Ago – Iwoye	CB	3.2	0.7	1.8
	CR	4.3	3.2	2.0		UG	8.0	2.0	3.5
	CC	5.6	4.3	3.9		SK	1.2	0.7	1.0
	OR	2.4	2.0	1.7		TT	0.8	0.4	0.6
						GB	1.8	1.8	2.4
Ijebu – Ode	WM	6.3	4.9	3.7		EW	1.2	1.5	1.7
	CR	3.5	1.8	1.7					
	CC	6.7	5.2	2.9	Ijebu Ode	CB	4.2	3.7	3.9
	OR	3.1	2.3	3.0		UG	3.2	5.0	2.5
						SK	1.0	0.4	0.4
Ijebu - Igbo	WM	7.3	3.2	4.2		TT	0.7	0.3	0.2
	CR	8.0	2.5	3.1		GB	2.5	3.0	0.6
	CC	5.3	3.9	2.8		EW	0.8	0.3	0.4
	OR	6.0	3.7	0.9					
					Ijebu – Igbo	CB	3.9	1.8	2.0
						UG	7.0	1.4	3.0
						SK	1.1	0.4	0.5
						TT	0.7	0.3	0.5
						GB	5.3	0.5	2.0
						EW	1.5	0.5	0.4

Key: WM – Water melon, CR – Carrot, CC – Cucumber, OR – Okra, CB – Cabbage, EW – Jute Leaf, UG – Fluted Pumpkin Leaf, GB – Water Leaf, SK – Lagos Spinach, TT – African Spinach, NG – No growth TVC – Total viable count, TCC – Total coliform count, TSSC – Total *Salmonella-Shigella* count

Table 3.2: Microbial load of bacteria from water sample used to sprinkle the vegetables (CFU/ml)

Sample code	Total Viable count	Total coliform count	Total *Salmonella Shigella* count
AWT	TNTC	TNTC	7.6×10^6
IWT	TNTC	6.4×10^6	3.2×10^6
OWT	TNTC	5.0×10^6	2.0×10^6

Key: AWT: Water sample from Ago-Iwoye; IWT: Water sample from Ijebu Igbo; OWT: Water sample from Ijebu Ode

Table 3.3: Biochemical Characterisation of bacteria isolates from vegetables and sprinkling water samples

No of isolates	Gram stain/ Shape	Catalase	Citrate	Oxidase	Indole	Urease	KIA H_2S	Gas	Lactose	Glucose	Sucrose	Probable organism
48	- R	+	-	-	+	-	-	+	+	+	-	*Escherichia coli*
16	- R	+	+	-	-	+	-	+	+	+	+	*Klebsiella pneumoniae*
12	+ C	+	+	-	-	+	-	-	+	+	+	*Staphylococcus aureus*
4	+ C	+	+	+	-	+	-	-	-	-	-	*Micrococcus luteus*
16	- R	+	-	-	-	-	-	-	-	-	-	*Shigella* spp.
16	+ R	+	+	-	-	-	-	-	-	+	+	*Bacillus cereus*
10	- R	+	-	-	-	-	+	+	-	+	-	*Salmonella typhi`*
8	- R	+	+	-	-	-	+	+	+	+	+	*Citrobacter freundii*
2	- R	+	+	-	-	+	-	+	-	+	+	*Serratia marcescens*
8	- R	+	+	-	-	-	-	+	+	+	+	*Enterobacter aerogenes*
16	- R	+	+	-	-	-	-	+	+	+	+	*Enterobacter cloacae*
3	- R	+	+	-	-	+	+	+	-	+	-	*Proteus mirabilis*
5	- R	+	+	+	+	-	+	+	-	+	+	*Aeromonas hydrophila*
6	- R	+	+	+	-	-	-	-	-	-	-	*Pseudomonas aeruginosa*

R = Rod; C = Cocci; + = Positive; - = Negative KIA= Kligler's Iron Agar

Table 3.4: Percentage occurrence of bacteria isolates in fruity and leafy vegetable samples

Type of vegetable	Sample code	Total no of Isolates	*E. coli*	*K. pneumoniae*	*E. cloacae*	*B. cereus*	*Shigella* spp.	*S. aureus*	*S. typhi*	*E. aerogenes*	*M. luteus*	*C. freundii*	*S. marcescens*	*P. mirabilis*	*A. hydrophila*	*P. aeruginosa*
Fruity vegetables	WM	17	6 (3.5)	1 (0.6)	3 (1.8)	1 (0.6)	1 (0.6)	1 (0.6)	2 (1.2)	1 (0.6)	-	-	1 (0.6)	-	-	-
	CR	16	4 (2.4)	3 (1.8)	2 (1.2)	2 (1.2)	1 (0.6)	-	-	-	1 (0.6)	1 (0.6)	-	1 (0.6)	1 (0.6)	-
	CC	17	6 (3.5)	2 (1.2)	-	2 (1.2)	-	2 (1.2)	2 (1.2)	-	1 (0.6)	1 (0.6)	-	1 (0.6)	-	-
	OR	14	3 (1.8)	2 (1.2)	2 (1.2)	-	3 (1.8)	1 (0.6)	-	1 (0.6)	1 (0.6)	-	1 (0.6)	-	-	-
Leafy vegetables	CB	15	2 (1.2)	2 (1.2)	1 (0.6)	2 (1.2)	2 (1.2)	2 (1.2)	-	2 (1.2)	1 (0.6)	1 (0.6)	-	-	-	-
	EW	15	4 (2.4)	1 (0.6)	1 (0.6)	1 (0.6)	-	1 (0.6)	2 (1.2)	1 (0.6)	-	-	-	-	2 (1.2)	2 (1.2)
	UG	17	6 (3.5)	-	3 (1.8)	1 (0.6)	3 (1.8)	-	-	-	-	3 (1.8)	-	-	-	1 (0.6)
	GB	16	7 (4.1)	-	-	1 (0.6)	-	2 (1.2)	3 (1.8)	-	-	2 (1.2)	-	-	-	1 (0.6)
	SK	16	2 (1.2)	2 (1.2)	3 (1.8)	2 (1.2)	3 (1.8)	1 (0.6)	-	2 (1.2)	-	-	-	-	1 (0.6)	-
	TT	10	1 (0.6)	-	1 (0.6)	3 (1.8)	2 (1.2)	1 (0.6)	-	-	-	-	-	1 (0.6)	1 (0.6)	-
Sprinkling water		17	7 (4.1)	3 (1.8)	-	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)	1 (0.6)	-	-	-	-	-	2 (1.2)
	Total	170	48	16	16	16	16	12	10	8	4	8	2	3	5	6
			28.2%	9.6%	9.6%	9.6%	9.6%	7.2%	6.0%	4.8%	2.4%	4.8%	1.2%	1.8%	3.0%	3.6%

KEY: WM – Water melon, CR – Carrot, CC – Cucumber, OR – Okra, CB – Cabbage, EW – Jute Leaf, UG – Fluted Pumpkin Leaf, GB – Water Leaf, SK – Lagos Spinach, TT – African Spinach. Figures in parentheses are in percentage.

Table 3.5: Antibiogram of bacteria isolated from vegetables

Probable Organism	Zone of inhibition (mm) Ceftazidime (30µg)	Amoxycillin/Clavulanic acid (20/10µg)	Ceftriaxone (30µg)
Aeromonas hydrophila	0 (R)	0(R)	0 (R)
Bacillus cereus	0 (R)	15(R)	0 (R)
Citrobacter freundii	11 (R)	12(R)	7 (R)
Enterobacter aerogenes	15 (R)	11(R)	0 (R)
Enterobacter cloacae	14 (R)	12(R)	0 (R)
Escherichia coli	20 (I)	15(R)	15 (R)
Klebsiella pneumoniae	20 (I)	10(R)	0 (R)
Micrococcus luteus	0 (R)	0(R)	0 (R)
Proteus mirabilis	18 (I)	11(R)	15 (R)
Pseudomonas aeruginosa	20 (R)	0(R)	0 (R)
Salmonella typhi	18 (I)	15(I)	7 (R)
Serratia marcescens	25 (S)	0 (R)	0 (R)
Shigella spp	24 (S)	17 (I)	13 (R)
Staphylococcus aureus	25 (S)	18 (S)	10 (R)

Key: I = Intermediate; S = Sensitive; R = Resistant

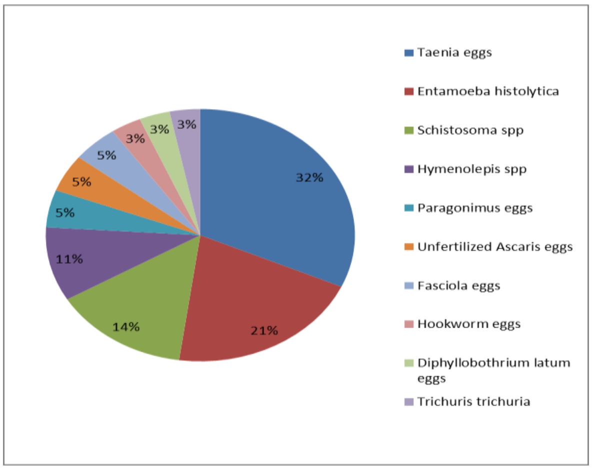

Figure 3.1: Parasites occurrence as observed in leafy and fruity vegetables in the study area

3.2 Discussion

The findings of this research have shown that vegetables retailed in Ijebu Metropolis harbour pathogenic bacteria and parasites. The result of the microbial load is in line with the findings of Akoachere *et al.* [3], who observed bacterial contamination in vegetables in the range of 2.5 × 10^6 to 15 × 10^6 CFU/g, but total coliform from 4 to >2400 CFU/g and faecal coliforms < 3 to 1100 CFU/g which was lower than what was reported in this work. Kaur and Bhowate [25] also reported microbial loads of 7.2 × 10^5 – 30.4 × 10^5 CFU/g in vegetables from local markets. The high microbial contamination observed in the fruity vegetables in this study may be a reflection of storage conditions and how long this produce were kept after harvesting and before they were sold out. Bacteria on storage materials contaminate the vegetables particularly where produce are pre-washed with the same wash water by the vendor or processor. More importantly, bacteria on the produce may multiply over time depending on the storage conditions especially those that are psychotropic [26 - 27].

The study showed that water melon had the highest level of bacterial contamination across the markets followed by cucumber and cabbage having the least aerobic count. This is supported by the findings of Orji *et al.* [28] who stated that the total aerobic plate count of water melon was higher than that of carrot. Alemu *et al.* [29] reported that cabbage was the most frequently contaminated vegetable. Rai and Kaur [30] also reported cucumber has having the highest count of 5 × 10^8 CFU/g. Fluted pumpkin was found to have the highest aerobic count among the leafy vegetables, followed by water leaf with Lagos spinach and African spinach having the least count. This is supported by the findings of Obieze *et al.* [31] who reported the highest counts in fluted pumpkin in Calabar Metropolis.

Fourteen (14) species of bacteria were recovered from the vegetables after standard biochemical tests: twelve species were common to both fruity and leafy vegetables while two other species were recovered from only fruity vegetable. Poorna [32] reported the presence of *Salmonella* spp., *Serratia* spp., *Enterobacter* spp., *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* in vegetables and fruits. Rai and Kaur [31] also recovered *E. aerogenes*, *Serratia entomophilia*, *B. cereus*, *L. monocytogenes*, *P. vulgaris*, *E. faecalis* and *Micrococcus* from fresh vegetables. Oluboyo *et al.* [33] also recovered similar bacteria from vegetables sold in major markets in Ado-Ekiti. *Escherichia coli* had the highest average occurrence of 26.6%, followed by *Enterobacter cloacae* with 10.4% while the least occurrence was *Serratia marcensens* with 1.3%. This is in line with the findings of Orji *et al.* [28], Kemajou *et al.* [34] and Alemu *et al.* [29] who reported *Escherichia coli* as the most frequent contaminants of vegetables.

Singh *et al.* [35] reported that after the farmers, vegetables vendors are the important handlers sprinkling vegetables with water from the same bucket again and again for days without any disinfection of the bucket. From our findings, the vendors rarely wash their buckets with any form of detergent, they only rinse it with the same well water, and then use it to sprinkle water on the vegetables.

Beuchat [36] stated that contamination of soil with animal wastes and increased application of improperly composted manures to soil may contribute to the contamination of vegetables. This may be responsible for the high occurrence of *E. coli*; an indicator of faecal contamination in the vegetables. *Salmonella typhii* is the aetiologic agent of typhoid fever and several outbreaks have been associated with the consumption of contaminated fruity vegetable grown in contaminated soil or fertilized with sewage [37].

Vegetable contamination by *B. cereus* may be partly attributed to contact with soil or air during field planting [38-39] and exposure to air during transportation and sale. Upon contamination, *B. cereus* may form a biofilm on the surface of the vegetables, thereby persisting for long [40]. The presence of *S. aureus* may be explained by the fact that individuals who process or vend these vegetables carry this organism on/in several parts of their bodies [41] as part of the normal microbial flora of their mucus membranes and skin [42].

The observed presence of various types of parasites associated with the fruity and leafy vegetables in the study area calls for concern as humans are at high risk at the ingestion of raw or uncooked vegetables contaminated with viable eggs. The difference in the parasite's incidence was also reported by Abubakar *et al.* [43]. The dominance of *Taenia* sp. in this study agreed with Rojas *et al.* [44] and Abubakar *et al.* [43]. *Taenia* sp. prevalence in this current study was higher than studies reported by [43, 45-46] in the Northern parts of Nigeria. The differences could be attributed to variations in the environmental, climatic and sanitation conditions in the different study areas which could include the droppings of infected stray animals on farmlands, type of water used in watering the vegetables and the source of the water used in washing the vegetables before selling at the various markets. Cysticercosis, which affects both animals and humans caused by the larval stage of *Taenia* spp. is common in Nigeria [47].

The presence of *Schistosoma* spp in this study was like the findings of Auta *et al*. [45] in Kastina State, Nigeria. Contamination of soil and water sources with faeces from infected humans and poor sewage disposal such as the use of soil as manure could lead to the contamination of vegetables with parasite eggs and cysts [48]. The occurrence of hookworm could also be attributed to infected faecal of humans used as manure. This poses a threat to consumers' health. The occurrence of *A. lumbricoides* in some water bodies has been reported by the Solomon *et al.* [49] which is also a predisposing factor to the contamination of vegetables when such water is used for irrigation.

The detection of the only protozoan, *Entamoeba histolytica* in this study conforms with the findings of Obebe *et al.* [50] in Ibadan, Oyo State Nigeria. The occurrence of this particular protozoan cyst could be attributed to the contamination of fresh vegetables before harvest, either by irrigation and wastewater contaminated with human faeces or directly from human faeces [51].

More than 50% of bacteria recovered from the sprinkling water samples were observed to be coliforms. Generally, coliforms are indicator of water quality. Their presence in the samples of water used in sprinkling the vegetables in the present study, is indicative of contamination and non-potability. The water samples could also be a source of contamination of the vegetables.

All the bacteria isolates were resistant to ceftriaxone followed by amoxycillin-clavulanic acid and then ceftadizime. *S. aureus* was sensitive to both ceftazidime and amoxycillin-clavulanic acid. Fanta *et al.* [52] reported in his study that most *Enterobacteriaceae* isolates were resistant to ceftriaxone and ceftadizime. Similarly, *in vitro* antimicrobial study in Senegal revealed that most of the isolated *Enterobacteriaceae* strains were resistant to third-generation cephalosporins [53]. In Nigeria, Adesetan *et al.* [54]) also reported 100% resistance by *Bacillus cereus* isolated from vegetables such as carrot, cabbage, runner bean, cabbage and sweet pepper to amoxycillin-clavulanic acid.

4. Conclusions

This study has revealed the potential risk of contracting foodborne infections especially through the ingestion of vegetables retail in local markets in Ijebu Metropolis. The vegetables were all contaminated by a wide variety of potentially pathogenic bacteria. Vegetables can become contaminated with pathogenic organisms during harvesting, transportation, marketing; and this contamination can arise from environmental, animal or human sources. Good agricultural and handling practises remain the prerequisite corner stones for food safety management.

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