



## **Coliform Bacteria Profile of the Surface of Raw Salad Vegetables Sold in Open Markets in Owerri Metropolis, South Eastern Nigeria**

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### **Authors' contributions**

*This work was carried out in collaboration with all authors. Authors ECC and MCM designed the work. Authors ECC, NUN, EM and MCM wrote the protocol and carried out the experiments. Authors GCA, JCN, RIN and JCI analyzed data obtained. Authors JCI, GCA, JCN, EM and MCM wrote the initial manuscript. Authors ECC, NUN, RIN and GCA read and also approved the final manuscript.*

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### **ABSTRACT**

The consumption of fresh vegetables has great health benefits. However, this has been linked to several food borne infections and disease outbreaks in the past because some of these vegetables have been identified as agents in the transmission of human food pathogens. This study examined the coliform bacteria profile of raw salad vegetables sold in open markets in Owerri metropolis, South Eastern Nigeria. The samples of different raw salad vegetables (cabbage, cucumber, carrot and tomatoes) bought from different vendors in open markets were examined for the presence of coliform bacteria. Surface wash water of samples were used for the enumeration of total and fecal coliforms. The results from the study showed that all the samples harboured coliform bacteria with

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the cabbage recording the highest coliform count ( $CA_3 = 2.8 \times 10^7$  cfu/g on MacConkey agar) while the highest *E. coli* count occurred in tomato ( $TO_3 = 2.7 \times 10^6$  cfu/g on EMB agar); carrot ( $CB_3 = 2.6 \times 10^4$  cfu/g on MacConkey agar) and cucumber ( $CU_2 = 3.9 \times 10^2$  cfu/g on EMB agar) recorded the lowest coliform and *E. coli* counts respectively. The percentage prevalence of the isolates on the samples were *Enterobacter* species (83.3%), *Escherichia coli* (66.6%) and *Klebsiella* species (33.3%). The counts were obviously above the coliform acceptable limit (<100cfu/g) for salad vegetables. This suggests that salad vegetables used in this study are of public health concern because, they harbour microorganisms that could be hazardous to human health. Positive detection of coliforms (especially, *E. coli*) is an effective confirmation of fecal contamination, hence good hygiene measures should be observed throughout the processing chain and consumers should also practice appropriate hygiene during the preparation of salad vegetables for consumption. This will eventually help in reducing the microbial contents of the vegetables before consumption.

**Keywords:** Serial dilution; coliform count; inoculated; spread plate technique; prevalence; good hygiene.

## 1. INTRODUCTION

“Vegetable” usually refers to the fresh edible portion of certain herbaceous plants- roots, stems, leaves, flowers, fruits or seeds. They are either eaten fresh or prepared in a number of ways, usually as a savory, rather than sweet dish [1]. Vegetables are rich in carbohydrates, antioxidants, minerals (especially, calcium and iron), vitamins (principally A and C) and fibres and often consumed uncooked. Most fresh vegetables are low in calories and have water content in excess of 70%, with only about 3.5% protein and less than 1% fat [2]. Nutritionists emphasize the importance of raw vegetables in healthy diets, and researchers and governmental publicity campaigns around the world tend to recommend consumption of at least five servings of fruits and vegetables per day.

Apart from the health benefits of consuming vegetables, the consumption of fresh vegetables has also been associated with risk for consumers [3]. Vegetables, especially when consumed raw have been increasingly recognized as important vehicles for the transmission of human pathogens and disease outbreaks [4,5]. Consequently the increase in global consumption of fresh vegetables is greatly threatened by an upsurge of microbial contamination [6].

Different agricultural practices can contaminate vegetables in different stages of production. Raw vegetables can become contaminated with coliforms some of which might be pathogenic while growing in fields, or during harvesting, post-harvesting, handling, processing and distribution [7,8,9]. Microorganisms that adhere to the surface of the vegetables are mainly coliforms that may survive even after washing

and sanitizing steps due to the formation of biofilms on the surface of the vegetable or form protection by the cuticle of the vegetable [10].

Microbiological contamination is common and inevitable in vegetables growing in soil and typical environmental microorganisms found in soil and irrigation water contaminate plants by infiltrating through roots or exposed surfaces (wounded or cut) and get internalized by the plant's coating that creates a natural biofilm that protects them from surface treatments. The microflora can be further modified by other microorganisms that come in contact with the product during each step of the production chain [11,12].

The human infections associated with consumption of raw fruits and vegetables have increased during the past decade and as most of these produce are eaten with minimal processing or without further processing, their microbial content may represent a risk factor for the consumer's health and therefore a food safety problem. Most of the reported outbreaks of gastrointestinal disease linked to the fresh produce have been associated with coliform bacteria contamination, particularly with members of the *Enterobacteriaceae* family.

Salad vegetables are therefore considered as potential hazard sources since the occurrence of pathogens cannot be excluded and the product is consumed without heating. However, to the best of our knowledge, efforts have been geared mostly towards studying the nutritional constituents of salad vegetables and there seem to be dearth of information on the microbiota that contaminate these vegetables.

Therefore, this study represents one of the few studies in this area that will provide an insight to the microbiological characteristics of salad vegetables thereby providing information on the safety associated with their consumption and also to enhance better understanding of the microorganisms associated with salad vegetables particularly some pathogenic microbes that could cause health hazard and human diseases.

## 2. MATERIALS AND METHODS

### 2.1 Sample Collection

Fresh salad vegetables (cucumber, carrots, tomatoes and cabbage) were bought from five different markets located in Owerri metropolis, Imo State; namely- Ihiagwa, Naze, Irete, Obinze and Relief Markets. The vegetable samples were put in separate sterile polythene zip lock bags and transported to the laboratory at temperature range 4–6°C and analysed within 24 hours of collection.

### 2.2 Preparation of Media

All media used were prepared according to manufacturer's specification and as described by Akusu [13]. The media used included Nutrient agar, Eosin Methylene Blue Agar (EMBA) and MacConkey agar (MA).

### 2.3 Isolation of Coliform Bacteria

Twenty-five grams of each of the salad vegetable sample was immersed in 225 ml of sterile distilled water for 15 min, vigorously agitated and surface wash water used for analyses. Ten (10) folds serial dilution was made (for each sample) after vigorous shaking to suspend the sample. An aliquot portion (0.1 ml) of the  $10^{-7}$  and  $10^{-4}$  dilutions were spread plated onto MacConkey Agar and EMB Agar respectively. The inoculums were evenly distributed with a sterile glass rod and incubated at 37°C for 24 hours. Total colony forming units per gram was expressed as (cfu/g) after incubation [14].

### 2.4 Characterization and Identification of Coliform Bacteria Isolates

The bacterial isolates were characterized using standard cultural (colonial), microscopic and biochemical methods. The identities of the

isolates were cross-matched with reference to standard manuals for the identification of bacteria [15].

## 3. RESULTS

Table 1 shows the total heterotrophic bacterial counts from fresh vegetables on MacConkey agar plates and Eosin Methylene Blue Agar plates. From Table 1, it was observed that the highest Total Coliform Counts occurred in Cabbage (CB<sub>3</sub>) and the highest *E. coli* Counts on Tomato (TO<sub>3</sub>). The vegetable with the Lowest Total Coliform Counts was Carrot (CA<sub>2</sub>) and cucumber had the lowest *E. coli* counts (CU<sub>3</sub>). Table 2 shows the distribution of bacterial isolates on the raw vegetable samples. The microorganisms identified were *Klebsiella* sp, *Escherichia coli* and *Enterobacter* sp. From the table 2, it was observed that *Escherichia coli* and *Enterobacter* sp were present in all the four vegetable samples. Fig. 1 represents the frequency of occurrence of the bacterial isolates. *Enterobacter* species had the highest occurrence among the bacterial isolates from the vegetable samples while *Klebsiella* species had the lowest occurrence.

## 4. DISCUSSION

Salads are fresh vegetables which require minimal washing and processing and cut into desired shapes and sizes with knives or other shredding utensils and usually serve along with other foods including rice [16]. Worldwide, salad vegetables are considered a major source of nutrients for people and particularly as sources of cancer fighting agents for the skin [17,18].

The consumption of vegetables and vegetable products are vital for the total health of every individual, however, microbial contamination of these vegetables has become a serious challenge deserving of greater attention. Food safety problems continue to persist across the globe and remain a great challenge [19].

The results from this study highlight the fact that the fresh vegetables sampled were all contaminated with coliforms and thus could possibly act as a transmission vehicle of many diseases. This conforms to the work of Sujeet and Vipin [20], who had also reported that coliforms were detected in all the raw salad vegetables sampled in their study. Vegetables

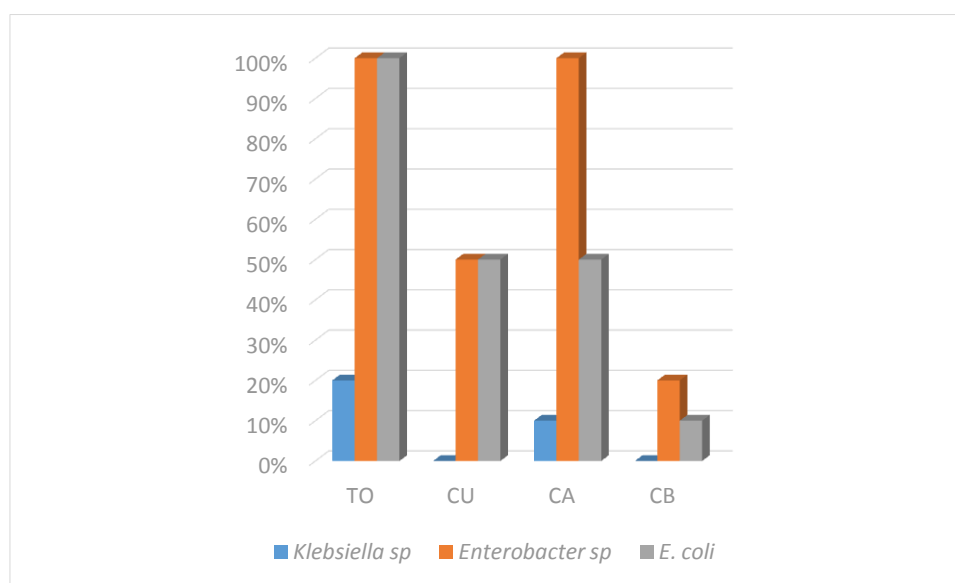
**Table 1 Total counts of bacteria isolated from raw vegetables**

Sample codes	Location/Market	Total counts on MCA (cfu/g)	Total counts on EMBA (cfu/g)
Tomato (TO1)	Ihiagwa	4.0 x 10 <sup>6</sup>	2.9 x 10 <sup>3</sup>
Tomato (TO2)	Irete	5.7 x 10 <sup>6</sup>	1.7 x 10 <sup>3</sup>
Tomato (TO3)	Relief	6.9 x 10 <sup>6</sup>	1.7 x 10 <sup>3</sup>
Tomato(TO4)	Obinze	1.4 x 10 <sup>7</sup>	1.3 x 10 <sup>3</sup>
Tomato(TO5)	Naze	5.0 x 10 <sup>5</sup>	1.9 x 10 <sup>4</sup>
Carrot (CA1)	Ihiagwa	2.0 x 10 <sup>5</sup>	9.4 x 10 <sup>5</sup>
Carrot (CA2)	Irete	2.8 x 10 <sup>7</sup>	2.0 x 10 <sup>6</sup>
Carrot (CA3)	Relief	4.7 x 10 <sup>6</sup>	2.5 x 10 <sup>4</sup>
Carrot (CA4)	Obinze	1.9 x 10 <sup>6</sup>	2.5 x 10 <sup>5</sup>
Carrot (CA5)	Naze	2.8 x 10 <sup>6</sup>	2.1 x 10 <sup>5</sup>
Cucumber (CU1)	Ihiagwa	1.1 x 10 <sup>6</sup>	1.2 x 10 <sup>3</sup>
Cucumber (CU2)	Irete	1.6 x 10 <sup>7</sup>	3.9 x 10 <sup>2</sup>
Cucumber (CU3)	Relief	4.2 x 10 <sup>5</sup>	4.0 x 10 <sup>3</sup>
Cucumber (CU4)	Obinze	5.2 x 10 <sup>5</sup>	5.7 x 10 <sup>3</sup>
Cucumber (CU5)	Naze	4.5 x 10 <sup>6</sup>	6.9 x 10 <sup>4</sup>
Cabbage (CB1)	Ihiagwa	1.4 x 10 <sup>6</sup>	1.0 x 10 <sup>4</sup>
Cabbage (CB2)	Irete	5.3 x 10 <sup>5</sup>	5.0 x 10 <sup>3</sup>
Cabbage (CB3)	Relief	2.6 x 10 <sup>4</sup>	2.0 x 10 <sup>3</sup>
Cabbage (CB4)	Obinze	1.8 x 10 <sup>5</sup>	2.8 x 10 <sup>5</sup>
Cabbage (CB5)	Naze	1.4 x 10 <sup>6</sup>	1.1 x 10 <sup>3</sup>

Key: MCA-MacConkey. EMBA-Eosin Methylene Blue Agar

**Table 2. Distribution of bacterial isolates on raw vegetable samples**

Samples	Bacterial isolates
TOMATOES	<i>Escherichia coli</i> , <i>Enterobacter</i> sp, <i>Klebsiella</i> sp
CUCUMBER	<i>Escherichia coli</i> , <i>Enterobacter</i> sp
CARROT	<i>Escherichia coli</i> , <i>Enterobacter</i> sp, <i>Klebsiella</i> sp
CABBAGE	<i>Escherichia coli</i> , <i>Enterobacter</i> sp



**Fig. 1. Frequency of occurrence of bacterial isolates on samples**

such as salad vegetables, after cultivations from the farm pass through series of handling processes and preparations before they are taken to the market or to consumers. This is a clear sign that coliform bacteria could be associated with raw vegetables sold in open markets and it should be of serious health concern [21]. The presence of coliform bacteria on these samples may also be attributed to the different unhygienic practices by food vendors such as poor handling practices during storage and at point of selling, as well as the sources of cultivation from where these vegetables were obtained. [13] had earlier reported that the raw materials for salad making often come into contact with soil and thus improper washing with water may result in high human health risk.

The organisms isolated from this study included *Klebsiella* species (33.3%), *Escherichia coli*(66.6%)and *Enterobacter* species (83.3%).This is in agreement with the work of Boateng [22], who reported 64% contamination of products of vegetable origin (pepper/ tomatoes sauce) with *E. coli* in Kumasi. In a related study, Bonah [23] reported the presence of *E. coli* in 66.6% of sampled ready- to-eat tomatoes sauce in the Tamale Metropolis. *E coli* load of ready-to-eat vegetables  $>10^2$ cfu/g is categorized as unwholesome for human consumption. Abakari et al., [24] had further reported that 'out of 30 salad vegetable *E. coli* were detected in 29 (96.7%) of them'. The presence of *E. coli* in food samples is an indication of faecal contamination and improper hygienic practices by food vendors [25]. Some strains of *E. coli* when present in food could cause gastroenteritis and diarrhoea in humans upon consumption. The presence of some opportunistic bacterial pathogens like *Klebsiella* and *Enterobacter* spp, in vegetables that are eaten raw either as epiphytic flora or as a result of contamination from soil, animal or human points out that fresh vegetables may represent a risk factor for infection in immune-compromised population, and therefore consumption of raw vegetables should be considered as a potential food safety concern in this population.

The highest fecal coliform counts were observed mostly in carrot samples similar to the report of Weldezgina and Muleta [3]. Carrots being a root crop could have received contamination from the soil, irrigation water, animal wastes used as fertilizer, water used for washing and from handlers. Its pits and crevices retain dirt containing organisms which may not be easily

removed by slight washing. Studies in Cameroon [26,27,3] had shown that these vegetables are usually irrigated with water polluted with faeces. The presence of all three types of bacteria in the vegetable samples is probably a reflection of the nature of the environmental conditions of the markets in this study [20]. During sample collection, it was clearly observed that the surroundings and places for vegetable salads display in the markets were not clean and tidy, and the handlers were not wearing hand gloves while the vegetables are being handled. Apart from these, the vegetable salads sold at markets sometimes have a long holding time, which could contribute to the accumulation of pathogenic bacteria [28]. This is, however, in variance with the work of [19], who recorded a low coliform count in cabbage; hence the least contaminated. *Escherichia coli* and *Enterobacter* species were constantly isolated (most prevalent) in all the four vegetable samples. Populations of *E. coli* are often measured for monitoring the sanitary condition of food and as an indicator of contamination of fecal origin [29].

Numerous disease outbreaks linked to contaminated fruit and vegetables have been summarized in recent reviews [30]. These outbreaks emphasize the effect that contaminated produce can have on human health. The risk of disease transmission is increased when fruit and vegetables are consumed raw.

During cultivation in fields or orchards or during harvesting, post-harvest handling, refining and distribution, vegetables become contaminated with pathogenic microorganisms [31]. At the market, microbial population levels can compromise the product quality by reducing its shelf-life, as well as pose a risk to consumer health [32].

## 5. CONCLUSION

The incidence of food borne illness is increasing each day in Nigeria. From the results obtained, all the salad vegetables were contaminated with coliform bacteria, which could be a threat to public health. However, the presence of pathogenic bacteria such as *E. coli* should not be underestimated, particularly when the vegetables are meant for raw consumption. In view of the above findings, more hygiene practices need to be adopted by vegetable vendors and consumers to minimize the risks of transmission of pathogens. The result can serve as an index

for identifying microorganisms associated with particular vegetables. In addition, the government should promote surveillance on the activities of vegetable vendors to minimize the risk of disease outbreak associated with consumption of contaminated salad vegetables.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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