

REVIEW ARTICLE

Evaluation of Microbial Quality of Vegetables and Fruits in Nigeria: A Review

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ABSTRACT

Fruits and vegetables play significant roles in human diet. There is a rise in the patients of food borne diseases resulting from street vended fruits and vegetables. This review evaluated the microbial safety profile of fruits and vegetables that were utilized by the Nigeria populace. Secondary data from previously published studies were sourced using Google Scholars and Pubmed data bases. Microbial contamination, fruits and vegetable safety, fruits poisoning were the search words used. Studies that met the context of the review topic were evaluated and summarized. Samples were evaluated for bacterial and fungal loads, as well as parasitic prevalence. Bacteria isolated from most samples included *Staphylococcus aureus*, *Escherichia coli*, *Shigella spp.*, *Salmonella spp.*, *Klebsiella pneumoniae*, *Micrococcus spp.*, *Lactobacillus spp.*, *Enterobacter aerogenes*, *Pseudomonas spp.*, *Proteus spp.*, *Bacillus spp.* and *Streptococcus spp.* Fungi isolated included *Aspergillus spp.*, *Rhizopus*, *Saccharomyces spp.*, *Penicillium spp.*, *Rhizopus spp.*, *Fusarium spp.*, and *Neurospora spp.* Parasite found were *Ascaris lumbricoides*, *Strongyloides stercoralis*, *Trichuris trichiura*, hookworms, *Strongyloides stercoralis*, *Giardia lamblia*, *Schistosoma spp.* and *Entamoeba hartmani*. Improper washing of fruits and vegetables, untreated human faeces and agricultural bio-solid were major predisposing factors. Adequate education on proper hygiene, decontamination approaches towards improving the quality of fruits and vegetables vended in Nigeria were recommended by most authors. This study revealed that adequate works are still needed to implement calls for strict implementation of various highlighted recommendations.

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A7 Introduction

Fruits and vegetables could be described as agricultural products having tissues that are subjected to normal living characteristics such as respiration, excretion, metabolism, etc. (1). They are fleshy portions of plants with edible characteristics, which could be eaten wholly, pre-cut, or sliced. They could be served in retail outlets and in ceremonies (2). Fresh vegetables and fruits are widely available in various cities, towns, and villages in Nigeria (3). Consumption of vegetables and fresh fruits is persuaded world-wide by both government and privately-owned health agencies or groups. For culinary purposes, they are useful in improving the quality of soup and African dishes for healthy living (4).

They are rich in water, fiber, vitamins, sugar, proteins and phytochemicals which are of great benefits to mankind (5). Their high cellulose and fiber contents also help in the regulation of the digestive system (4, 6). Regular intake of fruits and vegetables has been associated with low incidence of chronic diseases such as osteoporosis, cancer, chronic obstructive pulmonary and cardiovascular diseases, etc. (7). International organizations including the Food and Agricultural Organization (FAO), Center for Disease Control and Prevention (CDC), and the World Health Organization (WHO) have encouraged people to eat more fresh fruits and vegetables (8).

Nigeria is endowed with favorable climate and seasons which enables the growth of varieties of fruits and vegetables (9). They are also affordable, accessible and readily available to consumers (5). Besides the health and economic benefits of fruits and vegetables, there is much concern about their contamination by human pathogens, after they have been consumed fresh, or moderately cooked (10). Fruits and vegetables can be easily contaminated with microbiological, chemical, and physical hazards, because they are often grown in open environment (8).

Microorganisms, bacteria, fungi and viruses are ubiquitous and could be found resident on fresh vegetables and fruits as sources of nutrients for their survival (11). Thus, they are considered as proper vehicles to transmit human pathogens. Outbreak of food borne pathogens due to contamination of fruits and vegetables beyond acceptable limits over the past decades cannot be overemphasized (12). In both developed and developing countries, there is increase in the incidence of food poisoning and gastroenteritis due to consumption of raw foods, especially sprouts, over the counter salad vegetables, and cut vegetables and fruits (13-16).

Recent evaluation revealed that vegetables

are carriers of protozoan cysts and oocysts (16). Consumption of improperly washed fruits and vegetables among children have led to worm infestation, impaired cognitive functions and growth retardation (17). Consumption of raw or partly cooked vegetables such as salad and other fruits is a common practice among the populace, which does not allow complete removal of microbial pathogens following exposure to the digestive system (18, 19). This is corroborated by the recommended statement "please do not eat salad" serving as a warning signals against infections caused by contamination of raw vegetables (20).

In Nigeria and other developing countries, ready-to-eat sliced fruit and vegetables are becoming rampant due to their high patronage (21). Surprisingly, some of these fruits and vegetables are not washed before being consumed. Also, most vendors are not educated or instructed on personal and public hygiene because such products are exposed to contaminated air (air-borne infections), unclean environments and packaging materials (11). This has aroused researchers' interest in investigating the microbial safety profile of over the counter vegetables and fruits. Several studies have been carried out on the microbial safety of vegetables and fruits. Thus, this review assessed the mount of microbial contamination in vegetables and fruits in Nigeria.

Sources of Microbial Contamination of Vegetables and Fruits

Fruits and vegetable possess normal or natural microbial flora, as also found in other living organisms. They could also be contamination from soil, environment, and inoculation via water irrigation. But, this may be altered in the course of harvesting, transportation and processing for consumption (22). According to WHO, level of microbial contamination in production systems can occur because of many variables including water, post-harvest practices, local environment, workers' health and hygiene and fertilizers (23).

Some pathogenic microorganisms could have access to fruits and vegetables via damaged surfaces, and such organisms adapt, survive and reproduce in them and subsequently pose health hazard to consumers (24). Although, microbial contamination of vended fruits and vegetables can change at every stage of the food chain, from cultivation to processing and point of consumption, poor hygienic conditions and environmental pollution during cultivation could also increase the risk of contamination (25).

Application of manure for fertilization from animal sources, and poor hygiene of workers are not exceptions (22). A study by Moses and co-

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workers on the prevalence of *Escherichia coli* O157 in vegetables, fruits and animal fecal wastes applied as manure in farms of few communities in Akwa Ibom State, Nigeria recognized goat and cow dung as potential sources of *E. coli* O157 contamination for farm products, when consumed as manure (26). On this basis, contaminated irrigation or water channel, poor sanitation and improper maintenance of equipment, the use of manure for fertilization from animal sources, and poor hygiene of workers are contributing factors (22).

Various pathogenic microbes can contaminate fresh vegetables and fruits at any point in the chain. *Escherichia coli* O157:H7, *Salmonella spp.*, *Listeria monocytogenes*, *Staphylococcus aureus* and *Campylobacter spp.* are the most important pathogenic organisms that can contaminate the fresh vegetables and fruits (25). The pathogens of main concern are *Escherichia coli* O157:H7 and *Salmonella spp.* (3).

Literature Review of Studies on Microbial Contamination of Vegetables and Fruits in Nigeria

The highlighted outcomes of studies carried out

by researchers regarding the microbial profile of vegetables and fruits in various parts of Nigeria have been summarized in Tables 1-3. A study conducted on safety profile of fresh tomatoes presented in major markets of South-Eastern Nigeria revealed the presence of the following bacteria: *Staphylococcus aureus*, *Bacillus cereus*, and *Lactobacillus spp.* The fungal isolates consist of *Aspergillus oryzae*, *Penicillium spp.*, and *Aspergillus niger*. The authors showed that the isolated microbes were traced in water that was used in washing vegetable and therefore recommended the adoption of good agricultural practices (22).

A number of fruits and vegetables were examined for geohelminth ova and larvae contamination from land irrigated with household effluents and river water including *Corchorus olitorius*, *Lycopersicon esculentum*, *Amaranthus cruentus*, *Lactuca sativa*, *Capsicum annum* and *Solanum macrocarpon* in some selected gardens in Gusau Local Government area of Zamfara State. A total of 132 ova and 26 larvae were examined from four gardens, majority of which were *Ascaris*

Table 1: Summary of studies on microbial quality and safety of fruits and vegetables in Nigeria.

No	Location	Study outcome/Organism detected	Conclusion/Remark	Reference
1	South-Eastern Nigeria Markets	Bacteria: <i>Bacillus cereus</i> , <i>Lactobacillus spp.</i> and <i>Staphylococcus aureus</i> . Fungi: <i>Penicillium spp.</i> , <i>Aspergillus niger</i> , and <i>Aspergillus oryzae</i> .	Isolated microbes was traced to in water that was used in washing vegetable. They recommended the adoption of good agricultural practices.	22
2	Gusau Local Government area of Zamfara State	<i>Scaris lumbricoides</i> , <i>Trichuris trichiura</i> , hookworm and <i>Strongyloides stercoralis</i> . <i>Amaranthus cruentus</i> was the most contaminated while <i>Solanum macrocarpon</i> was the least contaminated	Use of untreated human faeces as fertilizer should be prohibited. Adequate education on the need of composting human night soil and animal dung prior to their use as manure was recommended.	27
3	North-Western Nigeria	<i>Staphylococcus aureus</i> , <i>Streptococcus spp.</i> , and <i>Escherichia coli</i> , <i>Klebsiella spp.</i> , <i>Enterobacter spp.</i> and <i>Citrobacter spp.</i>	<i>Staphylococcus aureus</i> was the most abundant with 80% relative occurrence, while <i>Streptococcus spp.</i> was the least abundant with 2% relative prevalence. Use of clean water for washing of fruits and vegetables by retailers and consumers was recommended.	28
4	Abeokuta Ogun State	Fungi isolated include <i>Penicillium spp.</i> , <i>Aspergillus niger</i> , <i>Aspergillus flavus</i> , <i>Rhizopus spp.</i> , <i>Fusarium spp.</i> , <i>Saccharomyces cerevisiae</i> and <i>Neurospora spp.</i> Bacteria isolated were <i>Staphylococcus aureus</i> , <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i> , <i>Enterobacter aerogenes</i> , <i>Proteus vulgaricus</i> , <i>Bacillus spp.</i> , <i>Salmonella typhi</i> , <i>Shigella dysenteriae</i> and <i>Pseudomonas aeruginosa</i>	Fruits from these locations were below acceptable standard due to the presence of food-borne pathogens. They recommended the need for their adequate pre- treatment before consumption	29

Table 2: Summary of studies on microbial quality and safety of fruits and vegetables in Nigeria.

No	Location	Study outcome/Organism detected	Conclusion/Remark	Reference
5	Calabar, Cross River State	Organism prevalence included non-fecal coliform (80%), fecal coliform (60%), molds (70%), yeasts (50%) and heterotrophic bacteria (90%).	The author called for microbial safety analysis of fruit salad meant for human consumption.	24
6	Ijebu area of Ogun State	The microbial load for these fruits ranged as follows: Watermelon ($3.0-9.3 \times 10^5$ cfu/mL) > pawpaw ($2.6-8.0 \times 10^5$ cfu/mL) > pineapple ($1.2-2.3 \times 10^5$ cfu/mL) > coconut ($0.5-5.6 \times 10^5$ cfu/mL).	They recommended the need for health education in other to eliminate bacteria mediated food poisoning.	13
7	Osogbo metropolis, Osun State	<i>Pseudomonas aeruginosa</i> , <i>Staphylococcus aureus</i> , <i>Enterococcus faecalis</i> , <i>Bacillus cereus</i> , <i>Listeria monocytogenes</i> , <i>Citrobacter spp.</i> , and <i>Candida spp.</i> Two parasitic organisms, cysts of <i>Entamoeba coli</i> and ova of <i>Ascaris lumbricoides</i> were also detected.	Resident of Oshogbo metropolis should be educated on the dangers associated with unhygienic practice.	17
8	Sanga-Ota, Ogun State	<i>Staphylococcus aureus</i> (29.2%) > <i>Staphylococcus spp.</i> (12.5%), <i>Klebsiella spp.</i> (12.5%), <i>Salmonella spp.</i> (12.5%) > <i>Actinomycetes</i> (4.2%), <i>Escherichia coli</i> (4.2%) were detected.	Increasing vinegar concentration from 0.5-2.5% reduced microbial loads by 15-82%. Consumers should be educated on the risk associated with the consumption of contaminated fruits and vegetables.	21
9	Dutsin-Ma town Kastina State	A total of 45 samples were found to be positive for <i>Ascaris lumbricoides</i> , <i>Strongyloides stercoralis</i> , <i>Schistosoma spp.</i> , <i>Giardia lamblia</i> and <i>Entamoeba hartmani</i> .	Sterilization of organic manure prior to use for cultivation of vegetables, improvement of the sanitary condition of fruits and vegetables, proper decontamination of fruits and vegetables prior to consumption.	14
10	Karu and Nyanyan in Abuja	Bacteria load was higher on the fruits and vegetables during the dry season than in the raining season	Consumers should exercise caution during dry season and also ensure proper hand washing to avoid the transmission of pathogens.	30
11	Benin metropolis, Edo State	<i>Pseudomonas spp.</i> and <i>Bacillus spp.</i> were detected. Bacterial counts ranged from $2.3 \times 10^3-5.7 \times 10^7$ cfu/mL.	Consumption of rotten fruits samples could be injurious to consumers' health.	19

lumbricoides, followed by *Trichuris trichiura*, hookworm and *Strongyloides stercoralis* (27). Vegetables were found to harbor more parasitic infection than fruits. *Amaranthus cruentus* was the most contaminated, while *Solanum macrocarpon* was the least contaminated. As a means to prevent contamination from the point of cultivation to consumption, the authors recommended the prohibition of the use of fertilizers sourced from untreated human feces, adequate education on the need of composting human night soil and animal dung prior to their use as manure, as well as treated irrigation water (27).

Ehimemen et al. isolated Gram positive and Gram negative bacteria consisted of *Enterobacter spp.*, *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus spp.*, *Citrobacter spp.*, and *Klebsiella spp.* and from vegetables and fruits sold in North

Western Nigeria. Among the isolated organisms, *Staphylococcus aureus* was the most prevalent one with 80% occurrence, while *Streptococcus spp.* was the least prevalent with 2% occurrence. Applying clean water and good handling for washing of vegetables and fruits by retailers and consumers was suggested by authors (28).

In another study, 200 samples of ready to eat pineapple, pawpaw, and watermelon fruits packaged in polyethylene were provided from various street vendors in Abeokuta Ogun State and were analyzed for microbial contamination. The mean aerobic plate counts ranged from 6.34 log₁₀ cfu/g to 8.99 log₁₀ cfu/g, the total fungal counts ranged from 6.18 log₁₀ cfu/g to 8.40 log₁₀ cfu/g, while total coliform counts ranged from 6.18 log₁₀ cfu/g to 8.43 log₁₀ cfu/g. Fungi isolated included *Saccharomyces cerevisiae*, *Penicillium spp.*, *Aspergillus flavus*, *Aspergillus*

Table 3: Summary of studies on microbial quality and safety of fruits and vegetables in Nigeria.

No	Location	Study outcome/Organism detected	Conclusion/remark	Reference
12	Calabar, Cross river State	Isolated organism and their prevalence included <i>Staphylococcus aureus</i> (35, 41.18%), <i>Escherichia coli</i> (21, 24.71%), <i>Bacillus spp.</i> (15, 17.65%), <i>Klebsiella aerogenes</i> (11, 12.94%), and <i>Salmonella enterica</i> var Typhimurium (3, 3.53%)	There is need for adequate disinfection, storage of fruits and vegetables during preparation and distribution.	31
13	Abakaliki, Ebonyi State	<i>Staphylococcus aureus</i> , <i>Salmonella spp.</i> , <i>Escherichia coli</i> , <i>Shigella spp.</i> and <i>Pseudomonas spp.</i> , as well as <i>Mucor spp.</i> were isolated.	Sufficient training on sanitary practices should be given to fruit vendors by the concerned regulatory agencies.	11
14	Elele markets, River State	Among the 300 vegetable samples, <i>Talilum triangulare</i> recorded the highest frequency of infected samples (16.0%).	Vendors and consumers should be educated to imbibe good sanitary practices. Quinolone antibiotic could be the drugs of choice in the treatment of bacteria related fruit-borne infections.	15
15	Different markets located in South-eastern Nigeria	Bacteria load ranged from 1.3×10^4 – 1.8×10^6 cfu/g, while fungi load ranged from 3.0×10^4 – 5.2×10^4 cfu/g. Highest bacterial and fungal load was recorded in carrots. <i>Staphylococcus</i> was the most frequently isolated bacteria genera, varying between 60 and 100% in all cases.	Proper washing of fruits and vegetables with vinegar was recommended by the authors.	5
16	Bauchi, Bauchi State	26 out of 182 fruit samples (14.3%), and 82 out of 594 vegetable samples (13.8%) were contaminated with various parasitic ova and cysts.	Education on personal hygiene was recommended to local people.	16
17	Makurdi, Benue State.	Apple had the highest microbial load followed by carrot and banana and least in orange.	Fresh fruits and vegetables should be properly washed and disinfected prior to consumption.	1
18	University of Benin, Edo State	<i>Staphylococcus aureus</i> , Coagulase negative. <i>Staphylococci</i> (CoNS), <i>Escherichia coli</i> and <i>Salmonella enteritidis</i> were organisms identified.	Appropriate decontamination was recommended to ensure bacteriologically safe fruit fit for human consumption.	10

niger, *Fusarium spp.*, *Rhizopus spp.*, and *Neurospora spp.*, while bacteria isolated were *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Escherichia coli*, *Proteus vulgaricus*, *Enterobacter aerogenes*, *Salmonella typhii*, *Bacillus spp.* and *Shigella dysenteriae*. Afolabi and co-workers concluded that fruits from these locations were below acceptable standard due to the presence of food-borne pathogens and thus recommended the need for adequate pre-treatment before consumption (29). Brook conducted a research on street vended fruit salad in Calabar, Cross River State. Different fruits combinations were used for the preparation of the fruit salad. The experimental results on 20 samples used revealed high microbial load up to 90%. Yeasts (50%), molds (70%), fecal coliform (60%), non-fecal coliform (80%), and Heterotrophic bacteria (90%). Fecal and total coliform counts were in the range of 3.2×10^5 to 5.8×10^5 cfu/g, and from 3.7×10^5 to 6.8×10^5 cfu/g respectively; while total fungal

and staphylococcal counts ranged from 3.4 to 6.5 cfu/g in both cases, exceeding the recommended microbiological standards. The authors searched for microbial analysis of fruit salad for human consumption (24).

Adesetan et al. (2013) in the street vended fruits of Ijebu area in Ogun state evaluated the antimicrobial sensitivity of bacterial isolates. A total of 75 samples of sliced fruits including coconut (15), watermelons (15), pineapples (20) and pawpaw (25) were screened. The microbial load for these fruits ranged as follows: Coconut (0.5 – 5.6×10^5 cfu/mL), Pineapple (1.2 – 2.3×10^5 cfu/mL), pawpaw (2.6 – 8.0×10^5 cfu/mL), and watermelon (3.0 – 9.3×10^5 cfu/mL). The bacteria isolated included *Enterococcus faecalis*, *Staphylococcus aureus*, *Bacillus subtilis*, *Micrococcus spp.*, *Streptococcus spp.*, *Lactobacillus spp.*, *Bacillus cereus*, *Escherichia coli*, *Serratia plymuthica*, *Serratia ficaria*, *Klebsiella pneumoniae*, and *Proteus mirabilis*. Majority of isolates were

sensitive to antibiotics. They recommended the need for a health education in order to eliminate bacteria mediated food poisoning (13).

Adeleke et al. examined the microbial and parasitic contaminants of 100 samples of fruits (51 carrots and 49 apples) that were procured from four markets, Alekuwodo, Igbonna, Oke-fia, and Orisumbare in Osogbo metropolis, Osun State. The study showed contamination of samples with pathogens such as *Citrobacter species*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Bacillus cereus*, and *Candida species*; and two parasitic organisms, ova of *Ascaris lumbricoides* and cysts of *Entamoeba coli* were isolated from the fruits. They recommended that residents of Osogbo metropolis should be educated on the dangers associated with unhygienic practices (17).

Eni et al. investigated the microbial quality of 15 samples of fruits and vegetables procured from three different areas, a cafeteria, road side vendor, and a local market in Sanga-Ota, Ogun State. The prevalence of bacteria found in the samples include *Escherichia coli* (4.2%), *Actinomyces* (4.2%), *Salmonella spp.* (12.5%), *Klebsiella spp.* (12.5%), *Staphylococcus spp.* (12.5%), and *Staphylococcus aureus* (29.2%). Increasing vinegar concentration from 0.5-2.5% declined microbial contamination by 15-82%. Authors suggested that consumers should be educated on the risk associated with consumption of contaminated vegetables and fruits (21).

Auta et al. evaluated totally 108 samples of fruits and vegetables purchased from three various stores in Dutsin-Ma town Katsina State for parasitic contamination. Totally, 45 samples were noted to be positive for *Entamoeba hartmani*, *Ascaris lumbricoides*, *Schistosoma spp.*, *Giardia lamblia*, and *Strongyloides stercoralis*. *Ascaris lumbricoides* had the highest occurrence, while *Entamoeba hartmani* was the least. Spinach as vegetable showed the highest level of parasitic contamination, while watermelon and cucumber as fruits were the least contaminated ones. Recommendations given by authors include adequate sterilization of organic manure prior to use for cultivation of vegetables, improvement of the sanitary condition of fruits and vegetables facilities, social media publicity of the health risk associated with the consumption of improperly washed vegetables and fruits and the need for proper decontamination of vegetables and fruits before consumption and provision of clean water by the market management authorities and the government for proper washing of vegetables and fruits (14).

A study on the influence of post-harvest handling

on the bacterial load of some fruits and vegetables (guava, Carrot, cucumber, oranges, banana, garden egg, cabbage, spinach, plantain, and Oha leaves) sold in two markets, Karu and Nyanyan in Abuja was conducted during dry and rainy seasons. Vegetables and fruits were kept for 3 different days (Days 1, 4 and 7). From the study, banana showed the highest bacterial contamination of 8.2 cfu/g in dry season, while oha and cabbage vegetable demonstrated 7.1 and 7.1 cfu/g, respectively in the rainy season; and cucumber and guava had the lowest bacterial contamination of 6.5 and 5.5 cfu/g, respectively in the both seasons. The researchers found that bacterial contamination was higher for the vegetables and fruits during the dry seasons than in the raining ones. They recommended that caution is needed to be carried out by consumers during dry seasons and also to ensure proper hand washing to inhibit transmission of pathogens (30).

Imafidor et al. assessed the microbial content of lettuce sold in Benin metropolis, Edo State. Whole and soft rot samples of the vegetables part were bought, processed and analyzed. Nutrient agar plated for lettuce samples showed bacterial contamination ranging from 2.0×10^3 to 4.7×10^7 cfu/mL. Bacteria isolated were *Bacillus spp.*, and *Pseudomonas spp.*, where *Pseudomonas spp.* was the most prevalent. For MacConkey agar, *Klebsiella spp.*, *Enterobacter spp.*, and *Escherichia coli* were isolated, with bacterial counts ranging from 2.3×10^3 to 5.7×10^7 cfu/mL. The authors concluded that the consumption of rotten fruits samples could be injurious to consumers' health (19).

Bacterial content of ready-to-eat salad samples sourced from three locations (wedding reception parties, fast food centers and birthday reception parties), 50 samples, each was evaluated in Calabar, Cross river State. Samples from wedding receptions were the most contaminated followed by birthday party and those from fast food centers. Isolated organism included *Salmonella enterica* var Typhimurium (3, 3.53%), *Klebsiella aerogenes* (11, 12.94%), *Bacillus spp.* (15, 17.65%), *Escherichia coli* (21, 24.71%) and *Staphylococcus aureus* (35, 41.18%). Bacteria contamination posed by samples inspired the authors to recommend adequate disinfection, storage of fruits and vegetables during preparation and distribution (31).

Orji and co-workers evaluated the total bacterial and fungal counts of 17 over the counter vended fruits in Abakpa Main market, Abakaliki, Ebonyi State. The study revealed the isolation of 5 bacterial species (*Pseudomonas spp.*, *Shigella spp.*, *Escherichia coli*, *Salmonella spp.*, and *Staphylococcus aureus*), as well as 1 fungal species (*Mucor sp.*). A range of 3.5×10^5 -

1.03×10⁶ CFU/mL, total aerobic plate count was recorded. Poor hygiene and contaminated air were the major factors responsible for contamination. They suggested that sufficient training on sanitary practices should be given to fruit vendors by the concerned regulatory agencies (11).

Kemajou et al. evaluated 300 vegetable leaves sold in Elele markets, River State for microbial content. Vegetables studied included *Telfairi occidentalis*, *Genetum gnecanum*, *Talilum triangulare*, *Celosta argentea* and *Vernonia amygdalina*, 60 samples each. From the study, *Talilum triangulare* recorded the highest frequency of infected samples (16.0%), followed by pumpkin leaves (15.0%); whereas, bitter leaves showed the lowest (13.3%). Species of bacteria isolated included *Salmonella spp.* (2.1%), *Micrococcus spp.* (3.7%), *Alcaligenes faecalis* (4.6%), *Shigella spp.* (5.5%), *Pseudomonas aeruginosa* (8.2%), *Enterobacter aerogenes* (18.3%), *Staphylococcus aureus* (22.9%) and *Escherichia coli* (29.3%). The authors recommended that vendors and consumers should be educated to imbibe good sanitary practices, as the result is an indication of poor handling at point-of-sale. They also reported that quinolone antibiotic could be considered as the drug of choice in treatment of fruit-borne bacterial infections (15).

Effect of chemical therapy for bacterial contamination of vegetables and fruits procured from street vendors in different markets located in South-Eastern Nigeria was investigated. Fungi isolated included *Saccharomyces*, *Rhizopus*, and *Aspergillus*, while bacteria were *Klebsiella*, *Salmonella*, *Escherichia*, *Pseudomonas*, *Bacillus*, *Streptococcus* and *Staphylococcus*. Bacterial load was in the range from 1.3×10^4 to 1.8×10^6 cfu/g, while fungi load was in the range from 3.0×10^4 to 5.2×10^4 cfu/g. The highest fungal and bacterial contamination was recorded in carrots. *Staphylococcus* was the most prevalent isolated bacteria, varying between 60 and 100% in all samples. Proper washing of vegetables and fruits by vinegar was recommended by the authors (5).

Istifanus et al. investigated the presence of parasitic agents in 6 different types of vegetables (594 samples) and 776 cases consisted of 4 different types of fresh fruits (182 samples) sold in open markets in Bauchi, Bauchi State. From the study, 82 out of 594 vegetable samples (13.8%) and 26 out of 182 fruit samples (14.3%) were contaminated with various parasitic cysts and ova. *Ascaris lumbricoides* was the most prevalent parasitic contamination in both vegetables and fruits. They recommended that education on personal hygiene should be given to local people (16).

The bacterial contamination of some freshly

supplied vegetables and fruits (oranges, banana, apples, and carrots) in three locations in Makurdi was investigated. The samples were evaluated for bacterial and fungal loads. From the study, apple had the highest microbial load followed by carrot and banana and least in orange. The interaction effects between the microbes and the fruit/vegetables were significant and increased with length of storage. The authors recommended that fresh fruits and vegetables should be properly washed and disinfected prior to consumption (1).

A total of 200 samples of five fruits were prepared from four regions within Ugbowo campus of University of Benin, Edo State and were examined for bacterial contamination. From the study, bacterial growth was found in majority (62.5%) of the fruit samples when compared to the other samples (37.5%) without bacterial growth. *Salmonella enteritidis*, *Escherichia coli*, *Staphylococcus aureus*, and Coagulase negative *Staphylococci* (CoNS) were the identified organisms. The authors recommended appropriate decontamination by washing of fruits, hands and packaging materials to ensure bacteriologically safe fruit fit for human consumption (10).

Means to Minimizing Contamination of Vegetables and Fruits

Various approaches of curtailing microbial contamination of vegetables and fruits were recommended by authors. They include adoption of good sanitary condition, while handling, soaking vegetables and fruits in appropriate amount of vinegar for at least 10 minutes, so as to minimize the level of microbial contamination (5). Mahapatra et al. recommended that appropriate and feasible disinfection system should be developed by the government (6). Kibitok and Nduko recommended that the government should establish safety control measure as well as analysis of the hazards and the critical control point control principles (18).

In some of the studies evaluated, *Staphylococcus aureus*, a flora of the human skin and nasal cavity could have occurred through inappropriate use of unwashed hands by buyers or end users during the time of selecting the choice of fruits to buy (10). It was also reported that most vendors of fruits and vegetables are neither educated on proper hygiene practice (11). This calls for adequate public sensitization by the constituted authorities. Oluwatoyin et al. (32) recommended the use of high concentration of salt or chlorinated water in washing sliced fruits packaged in polyethylene to ensure that pathogens are removed before consumption. Although, modified atmospheric packaging (MAP)

may reduce spoilage by aerobic microorganisms, it can also enhance the virulence of microbes, e.g. *Escherichia coli* O157:H7 (33).

Iyoha and Agoreyo in their study recommended that the government should make law persuading hawkers or venders of ready to eat fruits to use cool temperature controlled system or cabinet or cupboard (10). In addition, Orji et al. recommended that government health officials should carry continual inspections to production, harvesting, processing and marketing sites of fruits and vegetable to ensure that the source of water that they use in washing their fruits and vegetables, packaging materials and personal hygiene of venders is appropriate (11).

Polluted water used in washing processing and packaging materials after slicing or cutting, which were also listed as major source of contamination should be avoided (34). Chemical disinfection can also produce minimal reduction in the initial bacterial contamination, but irradiation may produce a more efficient result (35). Organic fertilizer, manure and municipal sludge should be well decontaminated before application for plantation purposes. Also, pathogens arising from humans or animals reservoirs as well as the environment due to unhygienic production practice are not left out of place (18). This calls for proper personal hygiene. Sensitization movement to consumer and venders on the dangers associated with unhygienic practice should be put in place by various food regulatory agencies (18).

In attempt to maximize profit, most venders combine contaminated fruits and vegetables with good ones during storage leading to the spread of bacteria from contaminated fruits to the good ones (36). Being that there might not be visible signs of spoilage at the initial stage of bacteria infestation, consumers are unlikely to detect the damage and thus go ahead to purchase and consume these contaminated fruits. Thus, sensitizing venders on the need of disposing or segregating contaminated fruits from good ones would go a long way in reducing consumption of contaminated fruits by the populace (36).

Conclusion

The present evaluation revealed that majority of fruits and vegetables vended or displayed in strategic locations in Nigeria were contaminated by microorganism beyond permissible limit. Presence of pathogenic organism, *Staphylococcus aureus*, *Escherichia coli*, *salmonella spp.*, in most vegetables and fruits reflects poor sanitary condition adopted during cultivation, harvesting, transportation, storage and utilization or preparation process ranging from peeling, slicing, trimming,

packaging, handling and marketing. For example, *salmonella spp.* are associated with humans gastrointestinal disorders, fever, abdominal cramp, vomiting and diarrhea due to food poisoning, while enteropathogenic *Escherichia coli* are also implicated in diarrhea originating from poor sanitary conditions and virulent factors. This is of a public health concern, which calls for caution to be exercised by consumers and venders. Proper implementation of the above recommendations would go a long way in curtailing microbial risk associated with fruits and vegetable consumption in Nigeria.

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Conflict of Interest

None declared.

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