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REVIEW

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# Systematic review on the microbiological quality of fresh vegetables and ready-to-eat salad in Nigeria

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## Abstract

**Background:** The consumption of fresh vegetables and salads has become popular, and because of a greater understanding of health benefits, these are most often eaten raw or with minimal processing.

**Main body of the abstract:** The microbiological safety of these vegetables is necessary and the possible source of contamination includes microbial contamination of raw produce, workers hygiene and the condition of the environment and equipment used to process the salad and fresh vegetable for distribution. This article reviewed the previously published literature on the microbiological quality of fresh vegetable and salad. There was 100% isolation of bacteria in all of the studies review which include *Escherichia coli*, *Aspergillus* spp., *Staphyloccocus aureus*, *Salmonella*, *Klebsiella* spp., *Actinomycetes*, *Bacillus subtilis*, *Pseudomonas aeroginosa*, *Staphyloccocus epidermidis*, *Bacillus* spp., *Shigella* spp., *Lactobacillus* and *Streptoccocus* spp.

**Short conclusion:** The review study recommended that fresh vegetables and salad should be properly washed with clean water before preparing.

**Keywords:** Fresh vegetable and salad, Microbiological quality, Contamination

## Background

World Health Organization (WHO) estimated more than 500 children died daily from the consumption of contaminated food and water (WHO 2015). It was reported that illnesses due to contaminated foods are an important cause of reduced economic productivity (Okonko et al. 2008). The incidence rate of foodborne diseases is also rising in, both developed and developing nations due to problems compounded by poverty, inadequate sanitary conditions and poor general hygiene (Udo et al. 2009).

Foodborne illnesses are associated with significant morbidity and mortality rates worldwide (Scallan et al. 2011). Globally, an estimated 2 million people died from diarrheal diseases in 2011 and approximately 70% of these are foodborne. It is estimated 30% of the population in Nigeria are affected by foodborne disease annually (WHO 2011).

Also in Africa, it was estimated that 92 million people fall ill from consuming contaminated foods, resulting in 137,000 deaths each year (Narayan et al. 2017). Foodborne illnesses are major threat to health of people in Nigeria. In 1997, Local Government Health Systems

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profile for Nigeria reported leading causes of deaths in different geo-political zones to foodborne associated illnesses, which accounted for 25% of mortality followed by malaria (21%) and accidents (19%), while the Federal Ministry of Health in 2007, 90,000 cases of food poisoning was reported (FAO/WHO 2008).

Although the full extent of the burden and cost of unsafe food is unknown, the impact on global health and development are considered to be immense. The incidences of foodborne pathogens have been studied in Nigeria with more than 90% of annual cases of food poisoning reported to be caused by *Escherichia coli, Salmonella* spp., *Shigella* spp., *Proteus* spp., *Bacillus cereus,* (Enabulele et al. 2010; Eni et al. 2010; Onyeneho and Hedberg 2013; Adekanle et al. 2015; Ajayi et al. 2017; Negbenebor et al. 2019).

Fresh vegetables served as essential components of healthy diet whose, consumption rates increased in recent years (Sararaj et al. 2014). However, fresh vegetables are also associated with some risks to consumers (Soltan et al. 2015). Greater awareness and desire for healthier life style have led to increase consumption of fresh vegetable and fruits. Vegetables are recognized as an important source of micronutrients, carbohydrates, antioxidants, minerals, vitamins and fibers (Sararaj et al. 2014). Major human pathogens are recognized to be transmitted via uncooked vegetables (Gu et al. 2011).

The production process, use of poor quality in irrigation of farm plots, use of animal manure to fertilize soil and poor labourer hygiene have contributed to spreading of contaminants (Golly et al. 2016).

A number of studies have reported the isolation of pathogenic organisms from fresh vegetables from different points of the world as, enteric pathogens from wide variety of produce including *Listeria monocytogenes*, *Salmonella* spp, and *Escherichia coli* (*E. coli*), *Staphylococcus aureus* (*S. aureus*), *Clostridium perfringes*, *Campylobacter jejuni and Campylobacter coli were* reported in different regions of the world (Bukar et al. 2010; Eni et al. 2010; Denis et al. 2016; Golly et al. 2016).

The aim of this study is to review published articles on the microbiological quality of fresh vegetables and salad.

## Method

### Literature search

Articles published between January 2000 and September 2019 were retrieved from Medline via Pubmed, Biomed, Ajol and google scholar database using the following search terms; "fresh vegetables, microbial quality, salad and vegetables". The review was performed using the preferred reporting items for systematic review and Meta-analysis (PRISMA) statement.

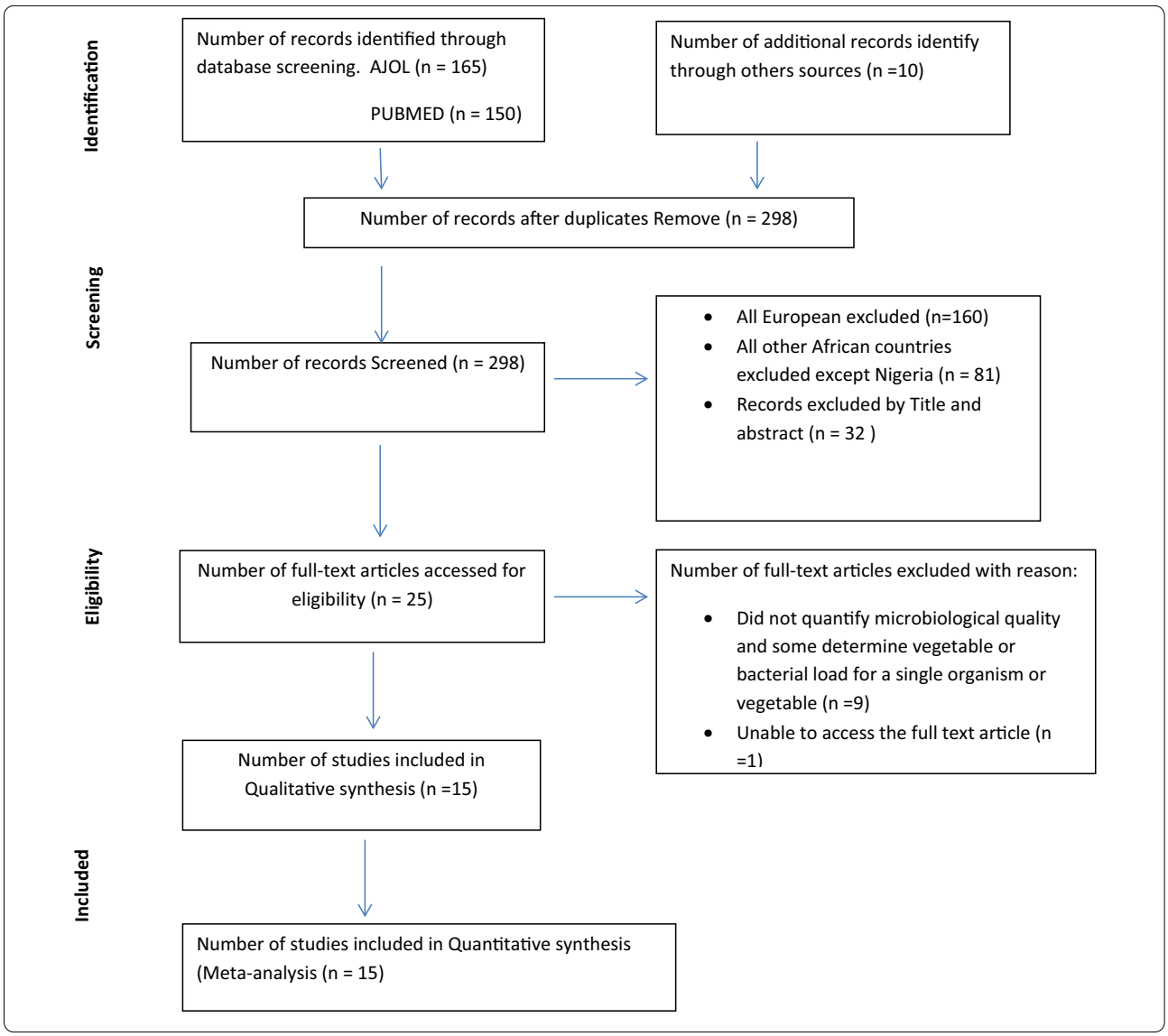
### Articles selection and data extraction

The titles and abstracts of all potential papers were assessed to ensure all studies had been identified and duplicates removed. Relevant data were extracted using a database that listed the variables; author, year of study, location of study, methods of identification, commonest microorganism isolated, vegetables fresh produce components, quantitative indicators of fresh vegetables contamination, and microbial count were summarized.

### Data synthesis

Using the PRISMA statement, data were extracted and reported as outlined by authors without any alteration following the search, a total of 325 articles were identified, duplicates were removed and 309 records excluded because the microbial quantity was not determined as well as incompatible title and abstract. One article was excluded due to inability to access the journal and irrelevant outcome compared to the objectives. Altogether, fifteen articles were included in the final data synthesis.

## Main text




In seven previous studies, percentage of vegetable tested produced high bacterial load (Aboh et al. 2011; Eni et al. 2010; Adeshina et al. 2012; Owolabi 2013; Adekanle et al. 2015; Oji 2016; Negbenebor et al. 2019). Five studies indicated high bacterial load of contaminated vegetables without percentage of the microorganism (Uzeh et al. 2009; Abdullahi and Abdulkareem 2010; Oluwafemi et al. 2013; Nwankwo et al. 2015; Oji 2016). Only four studies analyzed in this review were able to isolate fungi (Uzeh et al. 2009; Oluwafemi et al. 2013; Adekanle et al. 2015; Nwankwo et al. 2015).

There was 100% isolation of bacteria in all of the studies analyzed which include *Escherichia coli*, *Staphylococcus aureus*, *Salmonella*, *Klebsiella* spp., *Bacillus subtilis*, *Actinomycetes*, *Pseudomonas aeroginosa*, *Staphyloccocus epidermidis*, *Bacillus* spp., *Shigella* spp., Lactobacillus and *Streptoccocus* spp. Base on isolates obtained at individual fresh vegetables, cabbage (88.3%), cucumber (46.66%) and carrot (66.66%) from studies nine (Table 1).

## Discussion

Microorganisms found in salad and fresh vegetables explain the sanitary and hygienic quality of cultivation water, harvesting, transportation, storage and processing of products. All bacteria isolates reported in this review study have been previously isolated from salad vegetables and fresh vegetables in other studies basically in Nigeria. Various researches had different result methods documented; some quantify the bacterial load count in salad vegetables and fresh vegetables, while others

**Table 1** Microbiological quality of fresh vegetables and salad

| Author (s) | Location of study | Method of identification | Commonest microorganism isolated/identified | Fresh vegetables/salad component | Quantitative indicators | Viable count |
|---|---|---|---|---|---|---|
| Abdullahi and Abdulkareem (2010) | Zaria, Nigeria | Cultural morphological biochemical characteristic | *Baccillus* spp., *Stapyloccocus aureus* | Lettuce, cabbage, cucumber | The percentage of occurrence amongst the isolates was not recorded | Cucumber $1.3 \times 10^5$ lettuce $2.5 \times 10^8$ cabbage $2.1 \times 10^8$ cfu/g |
| Adeshina et al. (2012) | Zaria, Nigeria | Cultural morphological biochemical characteristic | *E. coli, Staphyloccocus, Pseudomonas. aureginosa* | Vegetables salad | *E. coli* 33.3%, *S. aureus* 25%, *Ps. aureginosa* 16%, *Salmonella* 25% | $6.0 \times 10^4$–$2.0 \times 10^6$ cfu/g |
| Adekanle et al. (2015) | Sagamu, Nigeria | Cultural morphological biochemical characteristic | *Pseudomonas* spp., *S. aureus, Bacillus* spp., *Kleb.* spp., *Aspergillus* spp. | Fresh vegetables | *Pseudomonas* spp., 14.4%, *S. aureus* 38.3%, *Bacillus* spp. 25%, *Kleb.* Spp. 6.0%, A *spergillus* spp. 13.3% | Higher microbial contamination |
| Afolabi et al. (2011) | Abeokuta, Nigeria, | Cultural morphological biochemical characteristic | *S. aureus, Salmonella* spp., *E. coli* | Fresh vegetables | *S. aureus* 45.4%, *Salmonella* spp. 32.2%, *E. coli* 45.6% | 2.80 log10 cfu/g–15.60 log10 cfu/g |
| Eni et al. (2010) | Ota, Nigeria | Cultural morphological biochemical characteristic | *S. aureus, Kleb* spp., *Salmonella* spp., *E. coli, Bacillus* spp., *Actinomycetes, Ps.* Spp | Fresh vegetables | *S. aureus* 29.2%, *S.* spp. 12.5%, *Kleb.* Spp. 12.5%, *Salmonella* spp., 12.5%, *E. coli* 4.2%, *Actinomycetes* 4.2%, *Bacillus* spp 8.3%, *Micrococcus* spp. 8.3%, *P*seudomonas spp. 8.3% | Cabbage $1.8 \times 10^7$ lettuce $1.7 \times 10^7$ cucumber $1.3 \times 10^7$ carrot $2.9 \times 10^7$ cfu/g |
| Owolabi (2013) | Ota, Nigeria | Cultural morphological biochemical characteristic | *Gram + ve Bcacilli* | Cabbage, carrot, cuccumber, lettuce | *Bacillus brevis* 30%, *Nocardia* spp. 18%, Bacillus spp. 12%, *Bacillus subtilis* 12%, *Bacillus megaterium* 6%, *Bacillus circular* 6%, *Bacillus spaericus* 6%, *Bacillus pumilus* 6% | $1.8 \times 10^6$–$4.1 \times 10^6$ cfu/g |
| Osamwonyi et al. (2013) | Edo, Nigeria | Cultural morphological biochemical characteristic | *Ps. aeroginosa, Staph. epidermidis, E. coli, Proteus mirabilis, Kleb. pneuomoniae, Enterobacter aerogenes* | Salad vegetables | *Ps. aeroginosa* 44%, *Staph. epidermidis* 17%, *E. coli* 31%, *Enterobacter. aerogenes 56%* | $1.5 \times 10^4$–$2.8 \times 10^4$ cfu/g |
| Wogu and Iwezeuna (2013) | Benni city, Nigeria | Morphological biochemical characteristics | *Salmonella* spp., *E. coli, S. aureus* | Ready-to-eat vegetable salads | *Salmonella* spp. 40%, *E. coli* 60%, *S. aureus* 25% | $3.1 \times 10^3$–$1.5\ 10^6$ cfu/g |
| Nwankwo et al. (2015) | Umuahia, Nigeria | ,, | *S. aureus*, *E. coli*, *Ps. aeruginosa*, *Bacillus* spp., *Enterobacter* spp and *Proteus* spp, *Aspergillus* spp., *Cladosporium* spp., *Penicillium* spp. and *Rhizopus* spp. | Salad vegetables | The percentage of occurrence amongst the isolates was not recorded | Cabbage $9.50 \times 10^5$ carrot $8.50 \times 10^5$ cucumber $3.40 \times 10^5$ cfu/ml |

**Table 1** (continued)

| Author (s) | Location of study | Method of identification | Commonest microorganism isolated/identified | Fresh vegetables/salad component | Quantitative indicators | Viable count |
|---|---|---|---|---|---|---|
| Uzeh et al. (2009) | Lagos, Nigeria | Cultural morphological biochemical characteristic | *Mucor* spp., *Aspergillus. fumigatus*, *Trichoderma* spp., *Neurospora crassa*, *Rhizopus* spp., *Aspergillus niger*, *Proteus vulgaris*, *Proteus mirabilis*, *S. aureus, Ps. aeruginosa* and *Citrobacter fruendii* | Salad ingredients (carrot, cucumber, cabbage) | The percentage of occurrence amongst the isolates was not recorded | Cucumber $1.3 \times 10^2$<br>carrot $3.0 \times 10^2$<br>cabbage $2.1 \times 10^2$<br>lettuce $2.0 \times 10^2$ cfu/g |
| Oluwafemi et al. (2013) | Abeokuta, Nigeria | Cultural morphological biochemical characteristic | *Micrococcus* spp., *Ps.* spp; *Bacillus* spp., *S. aureus, E. coli, Rhizopus* spp.; *Aspergillus* spp.; *Penicillium* spp. and *Mucor* spp. | Ready-to-eat vegetables (lettuce, cabbage, cucumber, carrot) | The percentage of occurrence amongst the isolates was not recorded | Lettuce $3.0 \times 10^3$<br>cabbage $3.0 \times 10^3$<br>cucumber $2.0 \times 10^3$<br>carrot $3.0 \times 10^3$ cfu/g |
| Oji (2016) | Anambra, Nigeria | Cultural morphological biochemical characteristic | *Staphyloccocus, Bacillus, Salmonella, Esherichia coli, Pseudomonas* and *Staphylococcus aureus* | Salad vegetable | The percentage of occurrence amongst the isolates was not recorded | $1.83 \times 10^7$–$3.26 \times 10^7$ cfu/g |
| Negbenebor et al. (2019) | Kaduna, Nigeria | Cultural morphological biochemical characteristic | *Staphyloccocus aureus, Streptoccocus* spp., *Enterobacter* spp., *Escherichia coli, Citrobacter* spp. *and Klebsiella* spp., *Staphylococcus aureus* | Salad vegetable | Klebsiella spp. 33.33%, *Bacillus* spp 23.80%, *E. coli* 14.28%, *Staphylococcus aureus* 14.28%, *Ps. aureginosa* 14.28% | Higher microbial load |
| Aboh et al. (2011) | Abuja, Nigeria | Cultural morphological biochemical characteristic | *Esherichia coli, Pseudomonas aureginosa, Proteus* spp., *Klebsiella* spp., *Salmonella, Shigella, Enterobacter and S. aureus* | Salad vegetable | *S. aureus* (46.7%), *Klebsiella* spp. (26.7%), *Enterobacter* spp. (20.0%), *Proteus* spp. (13.3%), *and P. aeruginosa* (13.3%), *E. coli* (6.7%), *Shigella* spp. (6.7%) *and Salmonella* spp. (6.7%) | $1.6 \times 10^6$ to $2.9 \times 10^8$ cfu/g |
| Ajayi, et al. (2017) | Iwo, Nigeria | Cultural morphological biochemical characteristic | *Staphyloccocus, Pseudomonas, Bacillus and E. coli. Proteus* spp., *Streptococcus, Enterobacter aerogenes, Micrococcus* spp., *Lactobacillus* | Ready-to-eat vegetable | *Staphyloccocus* 100%, *Bacillus* 65% *pseudomonas* 65%, *Enterobacter* 65%, *Proteus* spp. 65%, *E. coli* 35%, *Lactobacillus* 35%, *Streptoccocus* spp. 35% | $3.8 \times 10^5$–$1.2 \times 10^7$ cfu/g |

quantify the microorganism isolated in percentage. Five studies of Uzeh et al. (2009), Abdullahi and Abdulkareem (2010), Eni et al. (2010), Oluwafemi et al. (2013) and Nwankwo et al. (2015) determined the bacterial load in each of these salads and fresh vegetables, i.e. lettuce, cabbage, cucumber and carrot. They only isolated the organism but did not determine the percentage. But Eni et al. (2010), Afolabi et al. (2011), Aboh et al. (2011), Adeshina et al. (2012), Osamwonyi et al. (2013), Wogu and Iwezeuna (2013), Owolabi (2013), Adekanle et al. (2015) and Negbenebor et al. (2019) determined the range of bacterial load and the percentage occurrence of the isolated microorganism which serves as an advantage over other studies.

The isolation of these organisms in the various studies is very disturbing as these samples were reported to be obtained from big fast food centre; most samples were supposedly ready to eat and others from the market. The high incidence of bacterial contamination of the ready to eat salad and fresh vegetables may be due to unhygienic practices. Restaurant staff may not observe basic sanitation requirement for processing products that required no pre-heating before consumption. Another reason may be the non-availability of water in good quantity and quality for washing of fresh vegetables and mass production of salad in big fast food centres. Based on Uzeh et al. (2009) and Oluwafemi et al. (2013), carrot was the more contaminated vegetable, followed by lettuce and cabbage was also high in three various studies (Abdullahi and Abdulkareem 2010; Eni et al. 2010; Nwankwo et al. 2015).

## Conclusions

From the results obtained from the reviewed studies of the microbiological quality of fresh vegetables and ready-to-eat salad, it can be inferred that fresh vegetables and ready-to-eat salad may be contaminated with pathogenic or non-pathogenic microorganisms. Therefore, fresh vegetables and salad should be properly washed with clean water before preparing, maintenance of personnel and kitchen hygiene, during preparation of salad, fresh vegetables other food substance for meal.

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**Authors' contributions**
This review article intends to discuss on the potential risk of contamination of vegetables. IP—wrote the second and final draft, SY—wrote the first draft, GO—review manuscript, AB—review manuscript and BO—conceive the Idea and review the manuscript. All the authors' general statement was good. All authors have read and approved the manuscript.

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**Availability of data and materials**
Not applicable in this section.

## Declarations

**Ethics approval and consent to participate**
Ethical clearance was obtained from Ahmadu Bello University Zaria, Kaduna State. (ABUCUHSR/2019/002). Name of ethical committee in Ahmadu Bello University Zaria, Nigeria. 1. Prof. I.H. Nock- Chairman of ABUCUHSR. 2. Dr. M.K. Lawan- Member of Committee. 3. Prof. G.O. Adeshina- Chairman of supervisor team and committee member.

**Consent for publication**
Not applicable in this section.

**Competing interests**
The authors have no competing interest.

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## Publisher's Note