Study on the Correlation between Some Physical and Microbial Quality Characteristics of Peeled Sweet Orange (*Citrus sinensis*)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript

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ABSTRACT

Background /Aim: The consumption of ready-to-eat fruits such as oranges has increased in recent times. This study assessed the correlation between some physical and microbial quality characteristics of peeled sweet orange (*Citrus sinensis*) sold in Yenagoa, the capital of Bayelsa State, Nigeria.
Methodology: A total of thirty peeled oranges were purchased, three from each location. Standard microbiological methods were applied for the analysis.
Results: Results showed that the *in situ* characteristics and microbiological load of peeled oranges sold in Yenagoa, Nigeria were in the ranges of 1.86 to 3.15 Log CFU/g (total fungi), 1.56 to 2.86 Log CFU/g (total heterotrophic bacteria), 3.14 to – 4.19 (pH), 1.84 to 3.03 ppt (salinity), 3.27 to 5.00 mS/cm (conductivity) and 2.56 to 4.10 ppt (total dissolved solid). There was statistical deviation

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(p<0.05) for the *in situ* characteristics only. There was a positive significant association between the total dissolved solids and conductivity, and total heterotrophic bacteria and total fungi. Salinity negatively correlates with total heterotrophic bacteria and total fungi. The microbial isolates found in the samples include *Staphylococcus aureus*, *Escherichia coli*, *Enterobacter*, *Bacillus*, *Proteus*, and *Micrococcus species*, *as well as Aspergillus*, *Penicillium*, *Mucor*, *Fusarium*, *Saccharomyces cerevisiae*, and *Trichoderma* species.

Conclusion: However, with improved handling and hygiene levels among orange vendors, the microbial load could be reduced. Furthermore, the study showed that similar factors affected the total dissolved solids, conductivity, total heterotrophic bacteria, and total fungi. While the negative correlations that exists between salinity and total heterotrophic bacteria and total fungi revealed that diverse factors affect their concentrations in the orange.

1. INTRODUCTION

The growth, development, and maintenance of the body's important systems depend on essential elements found in food for human survival [1,2]. There are several criteria used to classify food, but one of the most common one is based on how simple it is to eat [1]. The other food groups require processing before consumption, while foods that are ready to eat do not. In a number of public places, such as markets, streets, roads, and hospitals, ready-to-eat foods are sold for purchase. Consumption of ready-to-eat foods has increased due to its portability and capacity to handle only a few simple domestic duties [1]. According to Izah et al. [3], ready-to-eat food consumption is on the rise due to its accessibility, affordability, and convenience.

The ready-to-eat foods are further grouped into two categories: uncooked foods such as fruits like Pawpaw (*Carica papaya*), Watermelon (*Citrullus lanatus*), Pineapple (*Ananas comosus*), Orange (Citrus species), Apple (*Malus domestica*), and Cucumber (*Cucumis sativus*), and cooked foods such as nutritive food drinks like fruit juices and refined alcoholic and non-alcoholic beverages [3]. Most of these fruits are sold whole or sliced when fresh [1]. The increased consumption of these fruits could be due to their nutritional value. In recent times, so many fruits have been blended into fruit drinks or fruit juices and packaged in more secure ways. In addition, some fruits are also used as additives in the preparation of nutritive drinks. For instance, Nwachukwu et al. [4] reported that sugar cane, pineapple, and orange can be used to sweeten the sharp, sour taste of raw zobo (Hibiscus) drink extract. Agwa et al. [5] reported industrially made uses of orange to include Fanta Orange Drink, SoyGood, Chi Happy Hour, Chivita Premium, Bobo Orange, Caprisonne, FanDango Citrus, Yojus Orange Drink, Piko, and Jove Orange Drink. Typically, about 90% of Nigeria's total fruits are processed into fruit juices [6]. Also, Lateef et al. [7] stated that oranges account for about 90% of the total fruit production in southern Nigeria.

Freshly sliced fruits are consumed in several parts of Nigeria, including urban and rural areas. Some fruits that are usually sold in sliced forms include pineapple, papaya, and watermelon, while others such as apple, cucumber and carrots are sold as whole fruits. Fruits such as oranges meant for ready consumption in street outlets and public places are usually sold with their rinds or peels removed using knives.

Generally, most ready-to-eat fruits sold are prone to microbial contamination, which occurs at several stages of processing, including handling, storage, and distribution [8,9]. This is probably due to the poor sanitary conditions in which these fruits are handled and displayed for sale [10]. The poor hygienic conditions could expose consumers to the risk of foodborne diseases. Some microbes such as *Escherichia coli, Staphylococcus aureus, Enterobacter, Streptococcus, Bacillus, Micrococcus, Proteus, Pseudomonas, Corynebacterium, Klebsiella, Salmonella* (bacteria), *Saccharomyces cerevisiae, Aspergillus, Penicillium, Mucor, Fusarium,* and *Rhizobacter* species (fungi) have been widely reported in ready-to-eat foods [1, 11-20]. Babalola et al. [21] also stated that *Salmonella breandercup, Salmonella enteritidis, Streptococcus pyogenes, Clostridium welchii, Clostridium botulinum, Vibrio parahaemolyticus,* and *Bacillus cereus* are common food poisoning bacteria. Some bacteria, most notably those from the Enterobacteriaceae family, are extremely

toxic and can cause illness, especially in those with compromised immune systems.

In oranges, especially *Citrus sinensis*, the peels inhibit the infestation and growth of some microbes although there is a natural opening in the rinds near the navel and stem-end vascular tissue where infiltration of solution is possible [8]. Orange is typically stored after harvest prior to sale. Polydera et al. [22] stated that during storage, orange juice undergoes a number of deteriorative reactions, resulting in quality degradation. The spoilage or decay could be due to their sugar content. Several microbes are usually known to ferment sugary substrates. Some of the microbes that infiltrate the orange through the rind could cause spoilage, leading to a reduction in their shelf life. The vital factors affecting the spoilage of juices include pH, oxidation reduction potential, water activity, nutrients, antimicrobial effects, and competing microflora [23]. Of all these factors, pH and water activity are the two most prominent parameters affecting juice spoilage [23]. Therefore, the association between pH and some other *in situ* characteristics such as conductivity, salinity, total dissolved solids and microbial density (total fungi and total heterotrophic bacteria counts) is important.

In research, correlational analysis is a statistical method used to identify the relationship between two variables and assess the strength of their linear relationship. Thus, it is used to measure the magnitude of change in one variable as a result of the change in the other. Therefore, it will be important to apply this tool to show whether a change in pH and other *in situ* characteristics will statistically affect the microbial population.

Therefore, this study was designed to [1] assess the concentration of the *in situ* characteristics of orange juice, [2] enumerate the density and identify the microorganisms found in oranges with rinds removed sold in public places in Yenagoa metropolis, Nigeria, and [3] show the association between the *in situ* characteristics of orange juice and the microbial density of the orange. The findings of the study will help orange consumers and the general public.

2. MATERIALS AND METHODS

2.1 Field Sampling

Freshly peeled orange samples were purchased from ten areas: Igbogene, Akenfa, Agudama-

Epie, Edepie, Okutukutu, Opolo, Kpansia, Amarata, Onopa, and Swali in the Yenagoa metropolis, Nigeria. The oranges were purchased from thirty fruit vendors, three from each sampling area. The oranges were packaged in sterile Ziploc bags and stored in an ice pack. Analysis was done approximately 3 hours after sample collection.

2.2 Sample Preparation

About 20 grams of the orange was blended (BLG-450, Binatone, Nigeria) in 180 ml of sterile water. The blender was washed and rinsed with sterile water prior to re-use.

2.3 Enumeration of Microbial Counts

Three media (Nutrient Agar, Sabouraud Dextrose Agar, and Salmonella-Shigella Agar) were used to enumerate the microbial population. The media was prepared according to the manufacturer's instructions. The pour-plate method previously described by Pepper and Gerba [24] and Benson [25] was used in the study. About 1 ml of the serially diluted peeled orange sample was plated in the media. The agar plates meant to enumerate total heterotrophic bacteria, Salmonella Shigella counts, and total fungi using Nutrient Agar, Salmonella-Shigella Agar, and Sabouraud Dextrose Agar were incubated inverted at room temperature for 24-48 hours and 3-5 days, respectively. The colonies that grew on the agar plates were counted and expressed as colony forming units (CFU)/g of the peeled orange sample and the colonies were isolated into pure culture.

2.4 Identification of Microbial Diversity

The total heterotrophic bacteria isolates were identified based on biochemical tests (gram reaction, citrate, catalase, oxidase, Indole, coagulase, motility, Voges-Proskauer, methyl red, urease) using the guide of Cheesbrough [26] and Benson [25]. Thereafter, the resultant characteristics were compared with those of known taxa using the scheme of Cheesbrough [26] and Bergey's Manual of Determinative Bacteriology by Holt et al. [27]. In addition, the isolates that grew on the Nutrient Agar plates were streaked on Blood Agar, Mannitol Salt Agar, Levine's eosin Methylene Blue and incubated for 24 hours. The

interpretations were done following the guide provided by Benson [25] and Cheesbrough [26].

Microscopic and macroscopic methods were employed for the identification of the fungi. The yeasts were identified following traditional microbiological methods based on their cultural, morphological, and physiological/biochemical characteristics (using carbon fermentation and assimilation tests, and growth based on temperature using glucose-peptone-yeast extract broth) as described by Kurtzman and Fell [28], APHA [29], and Benson [25], and used by Iwuagwu and Ugwuanyi [30], Okoduwa et al. [31], and Izah et al. [32-35].

For the moulds, the physical observation of the fungal isolates was compared with the guide provided by Benson [25], while the microscopic morphology was determined using Lactophenol cotton blue stain as described by Pepper and Gerba [24] and Benson [25] as applied by Izah and Ohimain [36]. The resultant microscopic characteristics for both mould and yeast were compared with the schemes of Pepper and Gerba [24], Ellis et al. [37], and Benson [25].

2.5 Determination of the *in situ* Characteristics of the Water

The manufacturers' guide determined all the *in situ* parameters using a multipurpose meter (OAKTON PCTSTestr 5 Multiparameter Pocket Tester) that analyses pH, total dissolved solid, conductivity, salinity, and temperature.

2.6 Statistical Analysis

SPSS software version 20 was used to carry out the statistical analysis. The microbial density data was transformed to a logarithmic scale. The data was presented as mean ±standard. A one-way analysis of variance at P = 0.05 was carried out for all parameters (in situ characteristics and microbial counts), and Waller Duncan test statistics were used to discern the source of the observed variations. Furthermore, a box plot was carried out, showing the minimum, maximum, median, lower interquartile, upper interquartile, and interquartile range for each of the parameters. The Pearson's correlation was used to show the degree of association between the parameters at p = 0.05 and p = 0.01.

3. RESULTS AND DISCUSSION

Table 1 shows the *in situ* characteristics and microbiological load of peeled oranges sold in Yenagoa, Nigeria. Total fungal counts ranged from 1.86 (at Kpansia) to 3.15 Log CFU/g (at Okutukutu). There were no significant differences at p=0.05. The box plot showed that samples from Agudama-Epie, Akenfa, Okutukutu, and Onopa have very high deviations however, the samples from Kpansia have a lower deviation from the median mean (Fig. 1).

Total heterotrophic bacteria count ranged from 1.56 (at Kpansia) to 2.86 Log CFU/g (at Onopa). There were significant variations (p=0.122). However, multiple comparisons showed that the deviation observed is a result of the values recorded in Kpansia, Swali, and Onopa. The box plot showed that the values in the samples from Amarata and Okutukutu have higher and lower deviations from the median mean (Fig. 1).

pH ranged from 3.14 (at Opolo) to 4.19 (at Agudama-Epie), being statistically different at p<0.05. The mean separation showed that the deviation observed is a result of the values recorded in Onopa, Okutukutu, and Agudama-Epie, as well as Opolo and Kpansia. The box plot showed that the values in the samples from Kpasia and Opolo have higher and lower deviations from the median mean (Fig. 2).

Salinity ranged from 1.84 (at Opolo) to 3.03 (at Kpansia), being statistically different at p<0.05. Multiple comparisons showed that the statistical deviation observed is a result of the values recorded in Kpansia and Swali and Opolo and Amarata. The box plot showed that the values in the samples from Opolo and Okutukutu have higher and lower deviations from the median mean (Fig. 2).

The conductivity ranged from 3.27 (at Agudama-Epie) to 5.00 mS/cm (at Swali). There were statistical variations at p<0.05. Multiple comparisons showed that the deviation observed is a result of the values recorded in Kpansia, Igbogene, Agudama-Epie, and Swali. The box plot showed that the values in the samples from Opolo and Edepie have higher and lower deviations from the median mean (Fig. 2).

Total dissolved solids ranged from 2.56 (at Agudama-Epie) to 4.10 ppt (at Swali). There were statistical variations at p<0.05. Multiple comparisons showed that the deviation observed

is a result of the values recorded in Onopa, Opolo, Agudama-Epie, and Swali. The box plot showed that the values in the samples from Opolo and Edepie have higher and lower deviations, respectively from the median mean (Fig. 2).
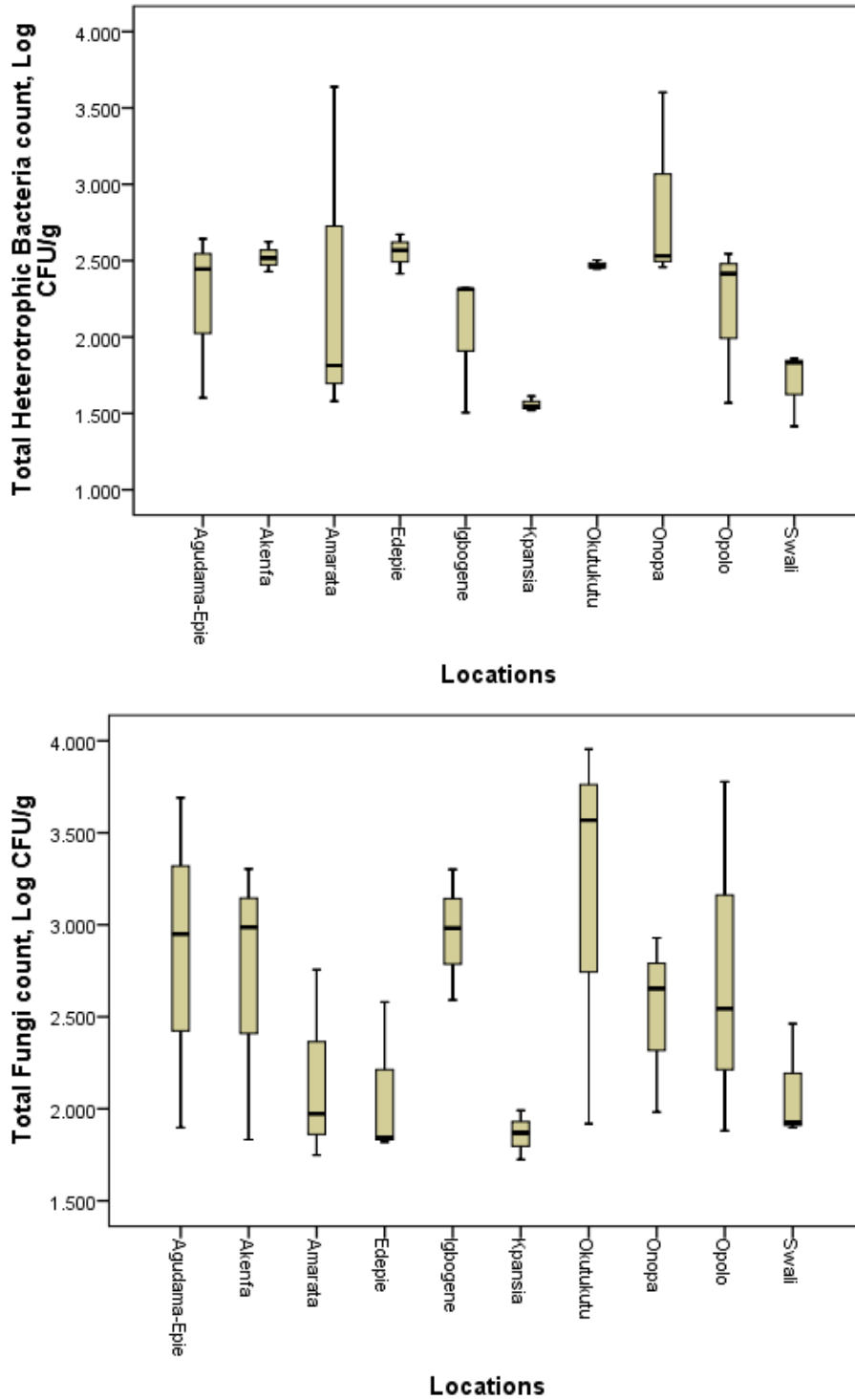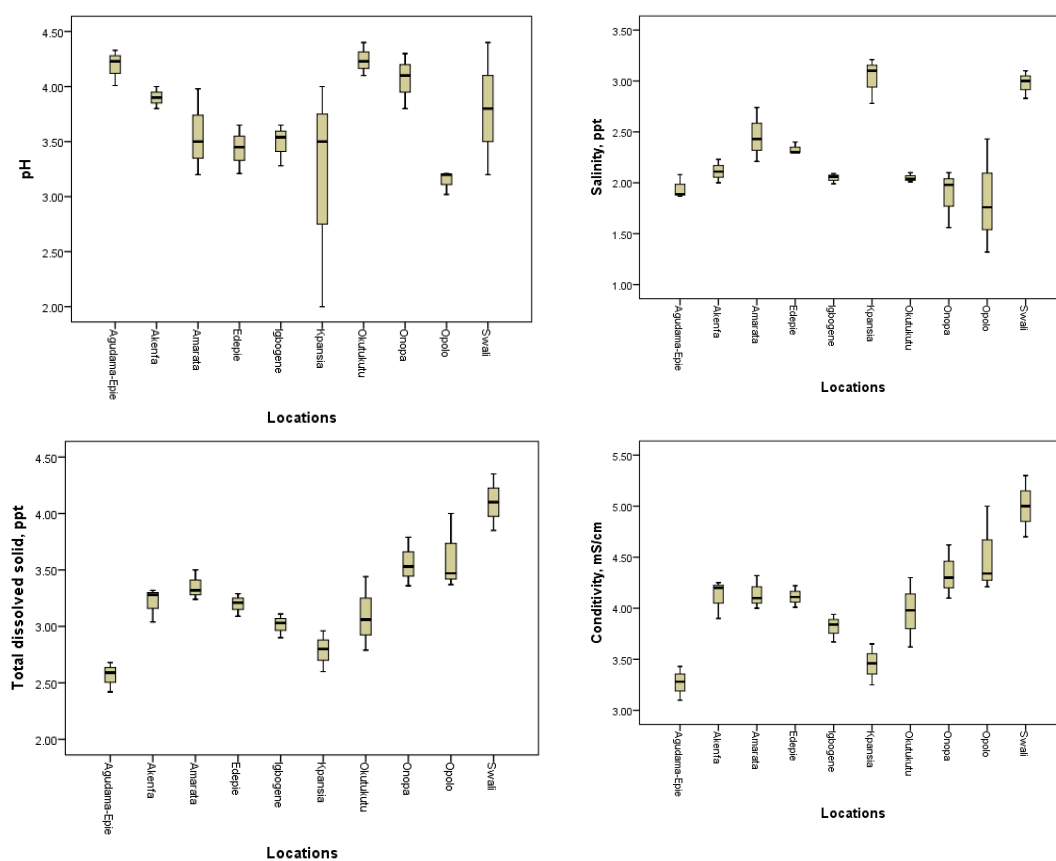

Fig. 1. Box plot of microbial density of peeled oranges sold in Yenagoa metropolis, Nigeria

Table 1. *In situ* characteristics and Microbiological load of peeled oranges sold in Yenagoa metropolis, Nigeria

Locations	pH	Salinity, ppt	Total dissolved solid, ppt	Conductivity, mS/cm	Total Heterotrophic Bacteria, Log CFU/g	Total coliform, Log CFU/g	Samonella-Shigella, Log CFU/g
Akenfa	3.90±0.10ab	2.11±0.12abc	3.21±0.15cd	4.12±0.19cde	2.52±0.10ab	2.71±0.77a	ND
Igbogene	3.49±0.19ab	2.05±0.05abc	3.01±0.11bc	3.82±0.14bc	2.05±0.47ab	2.96±0.36a	ND
Agudama-Epie	4.19±0.16b	1.95±0.12ab	2.56±0.13a	3.27±0.17a	2.23±0.55ab	2.85±0.90a	ND
Edepie	3.44±0.22ab	2.33±0.06bc	3.20±0.10bcd	4.11±0.11cde	2.55±0.13ab	2.08±0.43a	ND
Okutukutu	4.24±0.15b	2.05±0.05abc	3.10±0.33bc	3.97±0.34cd	2.47±0.03ab	3.15±1.08a	ND
Opolo	3.14±0.11a	1.84±0.56a	3.61±0.34d	4.52±0.42ef	2.18±0.53ab	2.73±0.96a	ND
Kpansia	3.17±1.04a	3.03±0.22d	2.79±0.18ab	3.45±0.20ab	1.56±0.05a	1.86±0.13a	ND
Amarata	3.56±0.39ab	2.46±0.27c	3.35±0.13cd	4.14±0.16cde	2.34±1.13ab	2.16±0.53a	ND
Onopa	4.07±0.25b	1.88±0.28ab	3.56±0.22d	4.34±0.26de	2.86±0.64b	2.52±0.49a	ND
Swali	3.80±0.60ab	2.98±0.14d	4.10±0.25e	5.00±0.30f	1.70±0.25a	2.09±0.32a	ND

The same alphabet along the column indicates not significantly different at P>0.05 according to the Waller-Duncan test statistics; Each value is expressed as mean ± standard deviation (n =3); ND= Not Detected.

Fig. 2. Box plot of the basic *in situ* characteristics of peeled oranges sold in Yenagoa metropolis, Nigeria

Salmonella-Shigella counts were not found in any of the samples. Furthermore, lack of statistical variation in the density of total heterotrophic bacteria and total fungi counts could be attributed to similar peeling and marketing strategies employed by fruit vendors in the study area. Most of the vendors peel the oranges with knives and slice it open upon request by customers. The peeled oranges are often displayed in trays which lack covering. Sometimes, the peeled oranges are displayed in the sun, which makes them dry. The findings of this study are comparable to previous reports on some fruit juices. Odu and Adeniji [6] reported the microbial counts of packaged orange juice sold in Port Harcourt, Nigeria, in the range of $0.35–7.1 \times 10^3$ cfu/mL (total heterotrophic bacteria) and $1.5–2.5 \times 10^2$ CFU/mL (total fungi). Agwa et al. [5] reported the microbial population from orange juices processed industrially (Fanta Orange Drink, SoyGood, Chi Happy Hour, Chivita Premium, Bobo Orange, Caprisonne, FanDango Citrus, Yojus Orange Drink, Piko, Jove Orange Drink) and locally sold in Port Harcourt Metropolis, Nigeria and it ranged from $1.0–4.0 \times 10^3$ CFU/ml and $1.1–5.0 \times 10^5$ CFU/ml, respectively (total heterotrophic bacteria) and $1.0 – 6.0 \times 10^2$ CFU/ml and $1.0 – 7.0 \times 10^2$ CFU/ml, respectively (total fungi). The population of microbes found in this study is slightly lower than the result from orange juices previously reported. Lateef et al. [7] reported the microbial load of orange juices produced locally in Ogbomoso, Nigeria, in the range of $3.5 \times 10^4 – 2.15 \times 10^5$ CFU/ml (bacteria) and $7.5 \times 10^4 – 1.25 \times 10^5$ CFU/ml (yeasts). Generally, the microbial population reported from orange fruit juice is within the range of 10^2-10^5 CFU/mL, as reported by Lateef et al. [7].

Generally, the low population of microbes, especially the bacteria found in the freshly peeled orange, may be due to the pH, which is acidic (Table 1). Low pH (i.e., acidic) could inhibit the growth of pathogenic bacteria [23-39] and encourage the growth of lactic acid bacteria and acid-tolerant molds and yeasts. Furthermore, the pH recorded in this study is within the range 3.0-4.5 which has also been reported in different fruit juices [23-39].

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Conductivity is one of the parameters used to show early changes in a medium. Conductivity and total dissolved solids are *in situ* quality parameters that are commonly used to describe salinity levels [40]. The two parameters are often correlated. Total dissolved solids provide information about all dissolved inorganic and organic substances in a medium, which can be ionized, colloidal, etc. The statistical deviation observed across the different locations suggests variation in the *in situ* characteristics of the orange. These differences could be due to the ripeness of the orange and the level of deterioration in biochemical compositions. These parameters are highly unstable and can be influenced by quite a number of conditions, including temperature. Similar trends have been reported in the fermentation media of maize for ogi production [41] and cassava for the production of fufu [42].

Table 2 shows the Pearson's Correlation of some *in situ* and microbial characteristics in peeled oranges sold in the Yenagoa metropolis, Nigeria. Salinity showed a strong negative and significant ($p<0.05$) association with total heterotrophic bacteria and total fungi. Total dissolved solids showed a very strong positive statistical correlation ($p<0.01$) with conductivity, an indication that they are influenced by similar conditions. Generally, total dissolved solids provide information about the inorganic salts and small amounts of organic matter in a medium, while conductivity shows the ability of the orange juice to conduct electrical current. Total heterotrophic bacteria count strongly correlates ($p<0.05$) with total fungi, an indication that they are influenced by similar conditions. The correlation between total fungi and total heterotrophic bacteria is evident. The negative shows that they are from different sources. This

is because high salinity is supposed to prolong the lag time and reduce the microbial communities, but due to the fact that many of the microbes are opportunistic pathogens and may have entered the fruit due to handling, therefore, the density is a function of the hygienic condition of the vendors as well as the status of the peeled oranges prior to purchase. Generally, studies have shown that parameters that correlate are from similar sources [43-52]. Therefore, diverse parameters influence the salinity, total heterotrophic bacteria, and total fungi.

Table 3 presents the microbial isolates of freshly peeled oranges sold in Yenagoa, Nigeria. The bacterial diversity includes *Staphylococcus aureus, Escherichia coli, Enterobacter, Bacillus, Proteus* and *Micrococcus* species, while the fungal isolates are *Aspergillus, Penicillium, Mucor, Fuarium Saccharomyces,* and *Trichoderma* species. The similarity in the microbial diversity in this study could be associated to similar handling procedures practiced by the fruit vendors and same life style and climatic conditions. The microbial isolates are similar to a previous study on orange juice. Lateef et al. [7] isolated *Saccharomyces cerevisiae, Bacillus cereus, B. subtilis, Escherichia coli, Staphylococcus aureus, Streptococcus pyogenes, Micrococcus,* and *Rhodotorula* species from locally processed pasteurized orange fruit juices sold in Ogbomoso, Southwest Nigeria. Agwa et al. [5] reported *Bacillus, Micrococcus, Staphylococcus, Enterococcus* species, *Escherichia coli* (bacteria), *Aspergillus, Penicillium, Trichoderma* species, and *Saccharomyces cerevisiae* from industrially and locally processed orange juices sold in Port Harcourt, Nigeria. Bello et al. [39] reported *S. aureus, Klebsiella, Salmonella* species, *Aspergillus niger, and*

Table 2. Pearson's Correlation of some physical and microbial characteristics in peeled oranges sold in Yenagoa metropolis, Nigeria

Parameters	pH	Salinity	Total dissolved solid	Conductivity	Total heterotrophic bacteria	Total fungi
pH	1					
Salinity	-.238	1				
Total dissolved solid	-.030	.119	1			
Conductivity	-.019	.074	.991[**]	1		
Total heterotrophic bacteria	.302	-.363[*]	.055	.089	1	
Total fungi	.183	-.444[*]	-.082	-.050	.379[*]	1

*. Strong statistical association at the 0.05 level; **. Very Strong statistical association at the 0.01 level

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Saccharomyces cerevisiae as microbial contaminants found in orange juices sold in Sagamu, Ogun state, Nigeria. The occurrence of these fungi and *Lactobacillus* species in the oranges could be attributed to the acidic conditions, which enhance their growth. Some species of Lactobacillus are beneficial to human health; hence, they can be classified as probiotics. Again, *Micrococcus,* and *Bacillus* species cause major spoilage in citrus products [6]. Basically, lactic acid bacteria such as lactobacillus are responsible for the sour taste of orange that is undergoing spoilage. Hence, the population of lactobacillus species in this study could depend on how ripe the oranges were prior to sampling. The presence of bacteria such as *Staphylococcus aureus*, *Escherichia coli,* and *Streptococcus* species could be associated with contamination from the handling processes, such as the water used in washing oranges prior to peeling. Sometimes, fruit vendors sell more than one type of fruit and use the same water for washing, which could lead to cross-contamination. This is because microbes such as *Staphylococcus aureus* hardly thrive under acidic conditions, but yet they are isolated from the peeled oranges, hence their presence could be from cross contamination. *Escherichia coli* was found in all the orange samples. Aneja et al. [23] stated that *E. coli* can survive the acidic conditions of fruit juices due to the acid stress response. The species of bacteria found in the peeled oranges could cause foodborne diseases. For instance, Lateef et al. [7] stated that *Bacillus subtilis* and *Escherichia coli* could produce heat stable enterotoxins, which are responsible for diarrhea and food poisoning. Fungi such as *Penicillium* and *Aspergillus* species produce toxins in food products. Dubey and Maheshwari [53] stated that *Aspergillus* species produce aflatoxins and ochratoxin B, and *Penicillium* species produce citrinin and cyclopiazonic acid. Generally, these fungi rarely cause disease except for individuals with immunocompromised conditions. The potential diseases caused by these fungi that produce toxins includes Aspergillosis (*Aspergillus* species) and hyalohyphamycosis (*Penicillium* species). The infections from these fungi are classified as opportunistic systemic mycoses. Hence, the occurrence of these pathogens in oranges, especially the bacteria, is a source of public health concern.

Table 3. Microbial isolates from peeled oranges sold in Yenagoa Metropolis, Nigeria

Locations	Microbial isolates	
	Bacteria	**Fungi**
Akenfa	*Staphylococcus aureus*, *Escherichia coli, Bacillus,* and *Micrococcus* species	*Saccharomyces Aspergillus* and *Trichoderma* species
Igbogene	*Staphylococcus aureus*, and *Bacillus* species	*Saccharomyces, Aspergillus* and *Penicillium* species
Agudama-Epie	*Staphylococcus aureus* and *Escherichia coli*	*Aspergillus* and *Saccharomyces* species
Edepie	*Staphylococcus aureus*, *Enterobacter* and *Bacillus* species	*Aspergillus, Fuarium* and *Penicillium* species
Okutukutu	*Staphylococcus aureus*, *Escherichia coli*	*Aspergillus* and *Saccharomyces* species
Opolo	*Staphylococcus aureus*, *Bacillus* and *Micrococcus* species	*Aspergillus, Penicillium* and *Saccharomyces* species
Kpansia	*Staphylococcus aureus*, *Escherichia coli, Bacillus* species	*Aspergillus, Saccharomyces* and *Mucor* species
Amarata	*Staphylococcus aureus*, *Escherichia coli, Proteus* species	*Saccharomyces* and *Trichoderma* species
Onopa	*Staphylococcus aureus*, *Escherichia coli, Bacillus,* and *Micrococcus* species	*Aspergillus, Penicillium* and *Saccharomyces* species
Swali	*Staphylococcus aureus*, and *Bacillus* species	*Aspergillus,*and *Penicillium* species

The microbes listed in each location were identified in at least of the triplicate samples of the orange

4. CONCLUSION

Fruits are sources of vitamins and minerals. This study evaluated the correlation between some physical and microbial densities of peeled sweet oranges sold in Yenagoa, Bayelsa State, Nigeria. Conductivity, total fungi, and total heterotrophic bacteria displayed a positive, statistically significant association. Salinity, total heterotrophic bacteria and total fungi populations are inversely correlated. This demonstrates how a number of variables affect the density and *in situ* characteristics of the orange. The microbial load was in the range of 10^1–10^3 CFU/g depending on the type of microbe, i.e., total heterotrophic bacteria and total fungi. The occurrence of most bacterial isolates indicates contamination from the environment, probably due to poor handling and hygienic conditions. The study showed that diverse factors are enhancing the microbial densities and salinity of sweet orange juice. Also, similar factors are affecting the total dissolved solid and conductivity. Furthermore, with improved hygienic conditions and good packaging, the number of microbial isolates could be reduced. The use of clean water for the washing of oranges prior to peeling and the use of show glasses for displaying oranges during sale or distribution could minimize contamination. Also, frequent hand washing by orange vendors could reduce microbial contamination.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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