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Microbial Safety, Contamination Risk and Health Implications of Polypropylene-Packaged Sliced Watermelon Fruits Sold in Owerri, Imo State

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ABSTRACT

The microbial safety and contamination risk of polypropylene-packaged sliced watermelon fruits sold in Owerri, Imo State, Nigeria, were assessed using standard microbiological techniques. A total of 50 randomly selected samples were collected from various markets for analysis. The findings revealed that bacterial counts ranged from $0.06 \times 10^2 \pm 0.17$ to $1.54 \times 10^2 \pm 0.16$ CFU/g, while fungal counts varied from $0.01 \times 10^3 \pm 0.05$ to $1.30 \times 10^3 \pm 0.13$ CFU/g. Seven bacterial and five fungal genera were identified, including *Bacillus* species, *Escherichia coli*, *Pseudomonas* species, *Staphylococcus aureus*, *Salmonella* species, *Lactobacillus* species, and *Klebsiella* species for bacteria, while the fungal isolates comprised Mucor species, *Rhizopus* species, *Saccharomyces* species, *Aspergillus* species, and *Candida species*. Contamination of these fruits can arise from multiple sources, including poor hygiene, environmental exposure, and inadequate packaging practices. Given these concerns, there is an urgent need for increased awareness of proper hygiene, as well as the implementation of good manufacturing practices (GMP). Strengthening food safety measures will help mitigate the risks associated with consuming contaminated watermelon fruits, and ensuring better public health outcomes.

Keywords: *Hygiene practices; Food safety; Public health; Hazard.*

1. INTRODUCTION

Watermelon (*Citrullus lanatus*) is a popular warm-season fruit cultivated worldwide, with Nigeria being one of its key producers. It is predominantly grown in the northern region and transported in large quantities to the south, where it is widely consumed. Known for its refreshing and hydrating properties, watermelon is often enjoyed as a dessert fruit or blended into beverages. It belongs to the *Cucurbitaceae* family and features a smooth, hard rind with distinctive dark green stripes or yellow spots. The edible flesh, which can be either red or yellow, is juicy and packed with seeds. According to [1], watermelon contains approximately 93% water, which explains the "water" in its name [2]. The term "melon" is derived from its large, round shape and sweet, pulpy flesh [3]. However, due to its high moisture content [4], watermelon is highly perishable and susceptible to microbial spoilage, particularly by gram-positive bacteria that thrive in low-acid environments [5].

Ensuring the safety of food, including watermelon, requires a collective effort across the food supply chain. Contamination by harmful microbes is one of the leading causes of foodborne illnesses, often resulting from preventable behaviors such as consuming raw or contaminated food, drinking unsafe water, or practicing poor food hygiene [6, 7]. Food contamination can occur at various stages, including harvesting, processing, storage, distribution, transportation, and preparation [8, 9]. Poor food hygiene practices can lead to foodborne diseases, which, in severe cases, may result in death [9].

Food safety is a major concern in both developed and developing countries, affecting individuals, food businesses, and regulatory bodies [10, 11]. This concern underscores the philosophical concept of justice, a principle that resonates with deontological ethics, which emphasizes duty and the inherent rights of individuals not a privilege. While food safety should be a fundamental aspect of any food process, it is sometimes overlooked in pursuit of efficiency and productivity. This pursuit of efficiency, while important for resource allocation, raises ethical questions about the balance between economic productivity and the fundamental human right to safe food [12]. Hazards can enter food through its ingredients or through contamination during processing and handling. The growing incidence of foodborne diseases poses a significant public health challenge, contributing to high morbidity and mortality rates [13]. Outbreaks of foodborne illnesses also lead to substantial economic losses and negatively impact the food industry [14]. Food hygiene plays a critical role in ensuring that food is safe from production to consumption. It is essential that all food processing steps prioritize safety, ensuring that consumers receive products free from harmful contaminants. Proper personal hygiene and safe food handling practices are vital in preventing the transmission of pathogens from food handlers to consumers [15, 16, 17]. This highlights the ethical significance of individual responsibility in maintaining public health, aligning with the philosophical notion of general welfare. Good Hygiene Practices (GHP) involve the application of best-practice principles in food handling and preparation [18]. Since over 200 known diseases are transmitted through food [19], proper food preparation is key to preventing most foodborne illnesses. Food is considered hygienic when it is free from hazardous substances that could pose risks to human or animal health [20]. Given the widespread consumption of hawked watermelon snacks, this study aims to evaluate their microbial profile and assess their safety, ensuring that consumers are not exposed to potential health risks.

2. MATERIALS AND METHODS

2.1 Study area

The study area is Owerri, Imo State, Nigeria, and an "Igbo" dominated city with "Igbo" language as the major mother tongue. Owerri city is a hospitality hub (*Igba Oringo* in *Igbo*). The geographical coordinates are latitude 5.4836 °N and longitude 7.0332 °E. The area is of tropical climatic conditions with rain forest features. The soil type is silt-clay and the weather is typical of rain forest, with average annual temperature ranging between 25-35 °C as lowest and highest values, respectively.

2.2 Collection of samples

A total of fifty (50) samples of polypropylene-packaged sliced watermelon fruits (pp-packaged sliced watermelon fruits) were bought at random from five different markets (*Ahia* in *Igbo*) in Owerri metropolis in the Southeastern Nigeria. Random samples of the purchased watermelon samples were aseptically handled and transported in ice bags to Microbiology Laboratory for analysis. The study's methodology was designed to minimize environmental impact, reflecting an ethic of care that prioritizes responsible stewardship of natural resources [21]. The standardization of these procedures, while crucial for scientific rigor and reproducibility, also reflects an underlying philosophical commitment to objectivity and the belief that empirical methods can yield reliable knowledge about the natural world [22].

2.3 Sample preparation

The watermelon samples prior to culturing were macerated using blender (QASA Blender & Grinder, Model No. QBL-20L330), and macerated samples were ready for microbiological analysis. Thereafter, the blender was washed with sterile water prior to re-use.

2.4 Microbiological analysis of samples

Ten-fold serial dilutions of the macerated watermelon samples were done using sterile peptone water. One gramme (1 g) each of the samples was aseptically transferred into a sterile test tube containing nine milliliters (9 mLs) of sterile peptone water, stirred with sterile glass rod and shaken vigorously to ensure adequate disengagement of microorganisms to obtain 10^{-1} dilution. Serial dilutions of the homogenates were continued and made step-wisely till the fifth (5th) tube, to obtain dilutions of 10^{-2} to 10^{-5}. Spread plate techniques of [23] were used to enumerate bacteria and fungi in the samples and each dilution was plated in replicates using plate count agar for mean bacterial count and fortified Sabouraud dextrose agar (SDA) for mean fungal count. The plates were incubated at 35±2 °C for 72 hours for mean bacterial counts and 25±2 °C for 120 hours for mean fungal counts. Pure bacterial isolates were identified using cultural, morphological and biochemical characterization. Identification of the bacteria to genera level was based on the schemes of [24]. The purified fungal isolates were identified on the basis of macroscopic and microscopic characteristics by slide culture technique and lactophenol staining. The scheme of [25] was used for the identification.

2.5 Statistical analyses

All obtained data in this study were analyzed using analysis of variance (ANOVA). Descriptive statistics in form of mean, standard deviation, and Duncan post hoc were also used to assess the data, and analyses were done using SPSS version 20 (Statistical Product and Service Solutions).

3. RESULTS

The microbial loads of the polypropylene-packaged sliced watermelon fruits are presented in Tables 1and 2. The bacterial counts are shown in Table1, while that of fungal counts are shown in Table 2. The frequency of occurrence of bacterial and fungal isolates obtained from the p-p sliced watermelon samples is shown in Table 3. The mean bacterial counts ranged from $0.06 \times 10^2 \pm 0.17$ to $1.54 \times 10^2 \pm 0.16$ CFU/g, while mean fungal counts ranged from $0.01 \times 10^3 \pm 0.05$ to $1.30 \times 10^3 \pm 0.13$ CFU/g. A close holistic assessment showed that samples bought from Ekeonunwa market had chunk of higher bacterial counts, while the least of same counts were with samples from New market. The highest bacterial count was recorded in sample W_5 of Relief market, while the least bacterial count was seen in sample W_3 of New market. Also the highest in fungal count was with sample W_7 of Ekeonunwa market, while the least in fungal count was with sample W_4 of same Ekeonunwa market. In Table 3, frequency of occurrence recorded high values for fungal isolates with Mucor leading (14%) while least values were with bacterial isolates with *Klebsiella* and *Salmonella* species at the floor (4%). All values obtained when compared along rows, followed by the same alphabets are not significantly different ($p>0.05$) but those followed by different alphabets are significantly different ($p<0.05$). The statistical analysis employed here, with its reliance on probability and significance testing, illustrates the inherent uncertainty in empirical research and the acceptance that conclusions are always provisional, subject to revision with further evidence. This approach contrasts with purely deterministic views of causality [26].

Table 1: Mean bacterial count

Watermelon samples (CFU/g) x 10^2	**Sample Locations**				
	Cluster Market	**Alaba Market**	**Ekeonunwa Market**	**Relief Market**	**New Market**
W_1	0.48 ± 0.41^{c}	1.18 ± 0.06^{a}	0.71 ± 0.35^{b}	0.27 ± 0.02^{cd}	0.12 ± 0.66^{d}
W_2	0.19 ± 0.17^{cd}	1.10 ± 0.03^{ab}	1.10 ± 0.33^{ab}	0.26 ± 0.23^{c}	1.30 ± 0.16^{a}
W_3	0.83 ± 0.11^{c}	0.24 ± 0.15^{d}	1.42 ± 0.66^{a}	1.21 ± 0.34^{ab}	0.06 ± 0.17^{e}
W_4	1.12 ± 0.38^{bc}	0.34 ± 0.26^{d}	1.43 ± 0.43^{a}	0.15 ± 0.45^{e}	1.33 ± 0.42^{ab}
W_5	0.20 ± 0.16^{b}	0.17 ± 0.15^{b}	0.18 ± 0.04^{b}	1.54 ± 0.16^{a}	0.16 ± 0.73^{b}
W_6	1.11 ± 0.14^{bc}	0.91 ± 0.03^{d}	1.20 ± 0.04^{a}	1.15 ± 0.22^{ab}	0.17 ± 0.15^{e}
W_7	0.19 ± 1.03^{c}	0.17 ± 0.23^{c}	0.50 ± 0.89^{a}	0.27 ± 0.55^{bc}	0.44 ± 0.21^{ab}
W_8	0.72 ± 0.04^{b}	0.30 ± 0.57^{c}	0.94 ± 0.73^{a}	0.84 ± 0.43^{ab}	0.36 ± 0.17^{c}
W_9	0.66 ± 0.15^{b}	0.27 ± 0.72^{d}	1.10 ± 0.16^{a}	0.14 ± 0.33^{de}	0.51 ± 0.32^{bc}
W_{10}	0.45 ± 0.55^{c}	0.72 ± 0.16^{b}	0.78 ± 0.03^{b}	1.10 ± 0.79^{a}	0.25 ± 0.48^{d}

Within rows, values followed by the same alphabets are not significantly different ($p>0.05$) but those followed by different alphabets are significantly different ($p<0.05$). Recommended Standard Counts: Aerobic bacteria count (abc) = $\leq 10^5$/g, Fungal count (fc) = $\leq 10^4$/g [27, 28]. Key: W = watermelon sample

Table 2: Mean fungal count

Watermelon samples (CFU/g) x 10^3	Sample Locations				
	Cluster Market	**Alaba Market**	**Ekeonunwa Market**	**Relief Market**	**New Market**
W_1	0.15 ± 0.15^{c}	0.13 ± 0.05^{cd}	2.20 ± 0.13^{a}	0.11 ± 0.07^{d}	0.48 ± 0.41^{b}
W_2	0.06 ± 0.21^{ab}	0.04 ± 0.05^{bc}	0.11 ± 0.05^{a}	0.07 ± 0.05^{ab}	0.03 ± 0.18^{bc}
W_3	1.00 ± 0.03^{a}	0.70 ± 0.31^{bc}	0.07 ± 0.12^{e}	0.80 ± 0.26^{ab}	0.11 ± 0.15^{d}
W_4	0.04 ± 0.08^{d}	0.11 ± 0.07^{ab}	0.01 ± 0.05^{e}	0.12 ± 0.06^{a}	0.08 ± 0.22^{c}
W_5	1.10 ± 0.24^{ab}	1.00 ± 0.11^{bc}	1.22 ± 0.07^{a}	0.70 ± 0.13^{d}	0.11 ± 0.04^{e}
W_6	0.16 ± 0.62^{d}	0.24 ± 0.55^{bc}	0.11 ± 0.06^{de}	0.26 ± 0.45^{ab}	0.33 ± 0.33^{a}
W_7	0.10 ± 0.55^{bc}	0.15 ± 0.33^{b}	1.30 ± 0.13^{a}	0.12 ± 0.58^{bc}	0.17 ± 0.74^{b}
W_8	0.25 ± 0.16^{c}	0.50 ± 0.59^{b}	0.26 ± 0.15^{c}	0.71 ± 0.51^{a}	0.25 ± 0.25^{c}
W_9	0.13 ± 0.13^{d}	0.36 ± 0.21^{b}	1.01 ± 0.34^{a}	0.29 ± 0.15^{bc}	0.24 ± 0.41^{c}
W_{10}	1.12 ± 0.07^{ab}	0.80 ± 0.12^{c}	1.12 ± 0.17^{ab}	1.20 ± 0.14^{a}	0.59 ± 0.16^{d}

Within rows, values followed by the same alphabets are not significantly different ($p>0.05$) but those followed by different alphabets are significantly different ($p<0.05$). Recommended Standard Counts: Aerobic bacteria count (abc) = $\leq 10^5$/g, Fungal count (fc) = $\leq 10^4$/g [27, 28]. Key: W = watermelon sample

Table 3: Frequency of occurrence of bacterial and fungal isolates obtained from watermelon samples

Isolates	Numbes of isolates	Frequency of occurrence (*%*)
Bacillus species	04	08
Mucor species.	07	14
Escherichia coli	03	06
Rhizopus species	06	12
Pseudomonas species	03	06
Saccharomyces species	05	10
Staphylococcus aureus	03	06
Aspergillus species	05	10
Salmonella species	02	04
Candida species	04	08
Lactobacillus species	06	12
Klebsiella species	02	04
TOTAL	50	100

4. DISCUSSION

The microbial counts obtained in the investigated samples were on the high thresholds although they were within microbiological acceptable limits recommended by regulatory bodies for hawked/vended fruit products. According to [29, 9], most of the retailed products either sold at a stationary stand or hawked in and around the market were un-hygienically prepared and exposed. The p-p sliced watermelon fruits sold in Owerri metropolis is not left out in the ugly trend of poor and unhygienic processing conditions prior to packaging. However, after processing some of the sliced samples are left open under the attack of some harmful environmental elements such as houseflies, bees and dust deposits for a while before been wrapped with polypropylene bags. It should be noted that most of the packaging materials are already contaminated after production, and on transit before the intended use. The consumed fruits are not subjected to any further treatment before eating. These are various sources of contamination that attested to the high microbial counts recorded in the study.

The high bacterial and fungal counts recorded in the study are indicative of contamination, even as they are within acceptable thresholds. The profile of microorganisms obtained in the p-p sliced watermelon fruits sold around Owerri metropolis can be traced to some factors such as poor hygiene practices involving use of dirty water during washing, use of dirty and contaminated utensils (knives, trays, and wrapping bags), unwashed hands etc and environmental factors involving exposure of processed samples to spoilage and pathogenic aerosols in an improper manner during polypropylene-packaging. The film bags used in the wrapping has actually helped in preventing further contamination and in extending the shelf life of fresh fruit by maintaining a balance in the correct mix of oxygen, carbon dioxide, and water vapor inside the bag. It is for this reason that the film bags need to be free from contamination on arrival. It could be recalled that the film bags are clear and transparent, thereby allowing for easy inspection of the contents while being displayed. The films bags are available in a wide range of thicknesses and grades, which were engineered to control the environmental gases inside the bag. The reliance on technological solutions like polypropylene packaging to extend shelf life, while addressing practical problems of food preservation, also raises broader philosophical questions about the human relationship with nature and the extent to which technology can or should intervene in natural processes. Furthermore, the economic motivations behind this practice, as highlighted by the need for affordability in developing countries, intersect with ethical considerations of equitable access to safe food and the potential for prioritizing economic benefits over health risks [30]. A total of seven (7) bacterial and five (5) fungal genera were isolated and identified to include: *Bacillus* species, *Escherichia coli*, *Pseudomonas* species, *Staphylococcus aureus*, *Salmonella* species, *Lactobacillus* species, *Klebsiella* species, and *Mucor* species, *Rhizopus* species, *Saccharomyces* species, *Aspergillus* species, *Candida* species, respectively. This result was in agreement to the findings of [31, 32, 33].

The presence of certain identified bacteria genera in the polypropylene-packaged sliced watermelon samples such as *Bacillus* species has always been an index of food hygiene by [34] and further corroborated by [29]. *Escherichia coli, Salmonella* species, and *Klebsiella* species are intestinal tracts organisms and belong to the family of *Enterobacteriaceae*, and presence depicts evidence of feacal contamination. Also, the duo presence of *Klebsiella* species and *Escherichia coli* might be due to water used for washing the watermelon fruit before the slicing. According to [35, 36], the presence of *Staphylococcus aureus* in samples clearly depicts contamination from human, since *Staphylococcus aureus* is a normal flora of the human body. Consumption of *Staphylococcus aureus* infected food and fruits can lead to foodborne illness. The presence of *Pseudomonas* species could be linked to contamination from soil, particulate matter or water, hence are classified as environmental contaminants. *Lactobacillus* species was the only bacteria that shares high frequency of occurrence with fungal isolates. According to [34], fungi survive in low pH conditions, while most bacteria do not. This is the reason for the high fungal counts and frequency of occurrence recorded in this study, when compared with the bacteria counterpart. Watermelons like any other fruits have acidic pH which discourages growth of bacteria and encourages that of fungi. This is why spoilage of fruits like watermelon are caused by mainly by fungi except for genera of *Lactobaccillus* that are rooted in fermentation with production of organic acids, hence can survive low pH conditions of fruits.

Consuming contaminated watermelon fruits can lead to various illnesses, including food poisoning (*Staphylococcus aureus*), gastroenteritis (*E. coli*, *Salmonella*, *Klebsiella*), typhoid fever (*Salmonella*), and respiratory or urinary infections (*Klebsiella*). Fungal contaminants (*Candida*, *Aspergillus*) may cause infections, while *Aspergillus* can also produce harmful mycotoxins linked to liver damage. Poor hygiene, exposure to contaminants, and unsafe packaging contribute to these risks, emphasizing the need for better food safety practices.

5. CONCLUSION

In response to the economic challenges faced by consumers in developing countries, the practice of slicing fruits and packaging them in polypropylene bags for better visibility and affordability has become increasingly common. This study reveals that polypropylene-packaged sliced watermelon fruits are susceptible to contamination from multiple sources, including poor hygiene practices and exposure to unsanitary environmental conditions before being sealed in bags. Additionally, the packaging materials themselves may contribute to the contamination. Ultimately, ensuring the safety of street-vended food like polypropylene-packaged watermelon is not merely a technical or regulatory challenge. It is fundamentally an ethical imperative that acknowledges the inherent dignity and right to health of every individual, regardless

of their economic circumstances. This calls for a holistic approach that integrates scientific knowledge with social responsibility and a commitment to justice in public health [37]. Given these concerns, there is an urgent need for awareness campaigns (*igbasa ozi* in *Igbo*) promoting proper hygiene and the implementation of good manufacturing practices (GMP). This necessity underscores the social responsibility of food producers and vendors to ensure the well-being of consumers, a concept central to stakeholder theory [38]. Strengthening food safety measures is essential to reducing the risks associated with consuming contaminated fruits and ensuring public health.

6. ACKNOWLEDGEMENTS

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7. CONFLICT OF INTEREST

The authors report no conflicts of interest.

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