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Analysis of Microbial and Physio-Chemical Attributes in Fresh, Sun-Dried, and Oven-Dried Tomatoes *(Solanum Iycopersium)*

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ABSTRACT

This study accessed the microbial and physiochemical qualities of fresh, oven-dry, and sun-dry tomatoes to comprehensively understand the impact of drying methods on the quality and safety of this widely consumed fruit. Microbial and physiochemical analysis were done using standard methods. It revealed the variations in microbial population with the results showing the total viable bacterial count ranged from 1.3×10^{6}cfu/g to 2.7×10^{6}cfu/g with fresh tomato (FT) slices having the highest value (2.7×10^{6}cfu/g). Sun-dried tomatoes (SD) (2.3×10^{6}cfu/g), oven-dried at 40°C (1.6×10^{6}cfu/g) and oven-dried at 60°C (1.4×10^{-6}cfu/g) respectively. The least count was obtained from sample oven-dried (OVD) at 80°C (1.3×10^{6}cfu/g). The total viable fungal count the fresh tomato (FT) slices had the highest counts (2.6×10^{4}cfu/g) and the least count was obtained from sample oven-dried at 40°C (6×10^{3}cfu/g), highlighting the dynamic microbial changes during different drying processes. Additionally, physiochemical assessments encompassed proximate composition, pH and ascorbic acid levels. The pH range was between 4.1 (for fresh tomatoes) and 5.2 (for sun-dried tomatoes). Ascorbic acid levels also showed Fresh tomatoes (28.32mg/100g) were the highest but in this case, Oven-dried at 80°C had the least (9.21mg/100g). Notable differences emerged, shedding light on the consequences of drying techniques on key quality indicators. In conclusion, this study provides a comprehensive analysis of the microbial and physiochemical properties of fresh, oven-dry, and sun-dry tomatoes, elucidating the impact of various drying methods on the quality and safety of this widely consumed fruit. More so, the observed variations in physiochemical properties suggest the need for careful consideration of other drying methods such as vacuum drying and freeze-drying to preserve flavor, enhance shelf life, and maintain nutritional quality.

1. INTRODUCTION

The new trends in trade patterns, agriculture, various food processing methods, and dietary habits have created an increased risk associated with bacterial contamination in our modern world [1][2]. Although vegetables are vital sources of nutrients required by the body, consumption of unwholesome/contaminated vegetables could lead to food-borne diseases [3][4]. Research indicates that foodborne infections have been on the rise in recent times due to the revived interest in vegetable consumption as a primary source of vitamins among other nutrients [5][6].

Tomato (*Solanum lycopersicum*) is a juicy and sweet perishable vegetable widely cultivated and consumed throughout the world [7][8]. Its fruit is the red edible berry of the plant [9]. It serves as a major source of antioxidants, and lycopene; is rich in nutrients; and is a valuable part of a healthy diet [10]–[12]. Due to its nutritive values, taste, accessibility, and affordability consumers' purchases have been high and provide high returns for small-scale farmers in developing countries [13]–[15]. However, due to its high-water content of 95%, tomatoes are highly perishable and have a short life span and as a result predispose them to spoilage by microorganisms especially pathogenic bacteria, when specialized handling practices are not adhered to

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[16][17]. Also, its failure can pose a significant threat to the health of consumers. Tomatoes may contain foodborne pathogens [18][19]. Some bacteria commonly associated with tomatoes include *Salmonella, Shigella, E. coli 0157 H7, Listeria, Campylobacter, Cryptosporidium* and some viruses such as hepatitis A [20][21]. Vegetables are a very beneficial part of the diet and play an essential role in maintaining health and preventing disease [22]. However, unhygienic preparation and consumption of vegetables can lead to various infectious diseases.

Identified vegetables among the food groups with greater frequency in recent years as causative agents of enteric diseases [23]. Most of the bacterial pathogens according to have been associated with foodborne illnesses. *Shigella spp., Salmonella spp, enterotoxigenic* and *enterohemorrhagic Escherichia coli, Campylobacter spp, Listeria monocytogenes, Bacillus cereus, Clostridium botulinum*, and other viruses and parasites like *Giardia lamblia, Cryptosporidium* are of public health concern [3]. In the ever-evolving world of food science and technology, the preservation and processing of food products have become increasingly important to ensure their safety, quality, and longevity. One such essential food item is the tomato, which is widely consumed across the globe in various forms. Drying is a common method used to preserve tomatoes, as it helps to extend their shelf life and maintain their nutritional value [24][25]. In this study, we aim to analyze the microbial and physio-chemical attributes for fresh, sun-dried, and oven-dried tomatoes to understand the impact of these drying methods on their overall quality and safety.

However, the drying process can lead to changes in the physicochemical and microbial properties of tomatoes [26][27]. Sun drying and oven drying are two commonly used methods for this purpose, each of which has its own advantages and disadvantages [28][29]. Sun drying is a traditional, environmentally friendly method that uses solar energy to remove moisture from tomatoes[30]–[32]. This process can take days or even weeks, depending on the weather conditions. Oven drying, on the other hand, is a more controlled and faster method, using an electric oven to achieve the desired moisture content [33]–[35]. Both methods have their own implications for the quality, safety and nutritional value of tomatoes [34]. The study will provide valuable insights into the impact of sun-drying and oven-drying on the quality and safety of tomatoes. This information can be utilized by food scientists, researchers, and industry professionals to optimize drying processes and develop better-preserved tomato products. Moreover, consumers can benefit from this research by making informed decisions regarding the selection of dried tomato products that best suit their needs and preferences. The analysis of microbial and physio-chemical attributes in fresh, sun-dried, and oven-dried tomatoes is a crucial step towards understanding the effects of various drying methods on the quality, safety, and nutritional value of this widely consumed food item [36]–[39]. By conducting this study, we aim to determine the microbial and physicochemical composition of fresh, oven-dry, and sun-dry tomatoes sold within the Port Harcourt metropolis and can contribute to the advancement of food science and technology, ultimately benefiting both the industry and consumers alike. The structure of this paper consists of Section 2 on the method, Section 3 contains the results and discussion, and Section 4 contains the conclusion.

2. MATERIALS AND METHOD

2.1. Study Design

This involved the collection of tomato samples from Choba Market in Port Harcourt Rivers State. The samples were divided into 3 parts (fresh, sundry, and oven-dry). The microbial load (Bacteria and fungi) was evaluated using standard microbiological methods. The samples were each evaluated to ascertain the physicochemical constituents of the vegetables

2.1.1. Study Area

The study was carried out in Rivers State, located on the coastal plain of the Eastern Niger Delta. It is an oil-producing State in the south-south geo-political zone of Nigeria, with its capital in Port Harcourt. The capital city Port Harcourt has one of the largest seaports in the country. Rivers State covers about 11,000 square kilometers, it has boundaries to the North with Anambra, Imo, and Abia States; the South border with the Atlantic Ocean, the West with Bayelsa and Delta States and the East border with Akwa Ibom State. The research was conducted in the Microbiology Laboratory of the Department of Microbiology while samples were collected from two different markets, Choba and Boundary.

2.1.2. Sample Collection

A total of 80 fresh tomatoes were randomly selected from Choba market, and 20 pieces of sun-dry tomatoes were also selected from Boundary market, Alu. The samples were purchased, packaged in sterile zip-lock bags, and delivered to the Microbiology laboratory for immediate analysis.

2.1.3. Sample Processing

The tomatoes were divided into 3 parts and each was labeled A, B, and C. A was to be analyzed as fresh tomatoes, B was the sun-dried tomatoes and C was oven-dried before analysis.

For sample C, the sample was cut into 4 equal halves and was oven-dried at 40ºC, 60ºC & 80ºC till they were each completely dry 6,3 and 1.5 hours respectively.

2.2. Isolation and Characterization of Pathogenic Bacteria and Fungi

2.2.1. Spread Plate Method

The petri dishes were labeled with the name of each of the prepared tomato samples. Serial dilution was conducted by measuring 1 gram of the samples into 10 ml of sterile normal. A 6-10 fold serial dilution was conducted and saline 0.1 µl of the last dilution was pipetted into an already prepared Nutrient agar and Potato dextrose agar plates and spread using a sterile bent glass rod. The plates were inverted and incubated for 24 hours at a temperature of 37◦C for bacteria and at room temperature for 3-7 days incubation period for fungi.

After incubation, each count of microbial load in each grade of tomato was expressed in colony forming unit per ml (CFU ml−1) and the formula used for its calculation was;

CFU ml−1= {(Number of colonies × Dilution factor) ÷Volume of inoculums}

2.2.2. Streak Plate Method

After incubation, each of the colonies were subcultured by streaking onto the various media. They were inverted and put into an incubator of temperature 37◦C for 24 hours for colonies to form.

2.3. Total Heterotrophic Bacteria (THB)

A 10g of sample was weighed into 90ml sterile diluent under aseptic conditions. It was then shaken vigorously to homogenize and serially diluted. Then 0.1ml aliquot of the inoculum was collected using a sterile pipette, inoculated on Nutrient Agar (NA) medium. The inoculum was spread evenly with a sterile hockey stick. Plates were incubated at 37^0C for 24 hours. Thereafter, colonies were counted to obtain colony forming unit (cfu) value per gram of the sample. Distinct colonies with different morphological patterns were picked and streaked or subcultured on freshly prepared nutrient agar medium to obtain a pure culture after 24 hours of incubation at 37^0C. The pure cultures were gram stained for microscopic examination. It was also used to carry out biochemical tests for the characterization/identification of the isolates.

2.4. Total *Staphylococcus spp*. count

Exactly a 0.1ml aliquot of inoculum was aseptically inoculated using the spread plate technique. Inoculated plates of Macconkey agar were incubated at 37ºc for 24hrs. Incubated plates were observed for development of colonies. The colonies were counted to obtain the population of bacteria in colony forming units per gram (cfu/g) of samples [40]. Colonies with characteristics of red/pink pigmentation were isolated/subcultured on a freshly prepared NA plate and subjected to biochemical tests for identification.

2.5. Total *Coliform* count

Exactly a 0.1ml aliquot of inoculum was aseptically inoculated using the spread plate technique. Inoculated plates of Macconkey agar were incubated at 37ºc for 24hrs. Incubated plates were observed for development of colonies. The colonies were counted to obtain the population of bacteria in colony forming units per gram (cfu/g) of samples [40]. Colonies with characteristics of red/pink pigmentation were isolated/subcultured on a freshly prepared NA plate and subjected to biochemical tests for identification.

2.6. Total *Salmonella Spp.* count

Exactly a 0.1ml aliquot of inoculum was aseptically inoculated using the spread plate technique. Inoculated plates of Salmonella Shigella Agar were incubated at 37ºC for 24hrs. Incubated plates were observed for development of colonies. The colonies with black pigment were counted to obtain colony forming units per gram (cfu/g) of samples [40]. Colonies with characteristic black pigment were isolated/subcultured on a freshly prepared NA plate and subjected to biochemical tests for identification.

2.7. Total *Escherichia Coli* count

Exactly a 0.1ml aliquot of inoculum was aseptically inoculated using the spread plate technique. Inoculated plates Eosin methylene blue agar were incubated at 37ºC for 24hrs. Incubated plates were observed for development of colonies. The colonies with greenish metallic sheen were counted to colony forming units per gram (cfu/g) of samples [40]. Colonies with characteristics of red/pink pigmentation were isolated/subcultured on a freshly prepared NA plate and subjected to biochemical tests for identification.

2.7. Total *Pseudomonas Spp.* count

Exactly a 0.1ml aliquot of inoculum was aseptically inoculated using the spread plate technique. Inoculated plates of Cetrimide agar were incubated at 37ºC for 24hrs. Incubated plates were observed for

development of colonies. The colonies were counted to obtain the population of bacteria in colony forming units per gram (cfu/g) of samples [40]. Colonies were isolated/subcultured on a freshly prepared NA plate and subjected to biochemical tests for identification.

2.8. Total Heterotrophic Fungi (THF)

10g of sample was weighed into 90ml sterile diluent under aseptic conditions. It was then shaken vigorously and serially diluted. A 0.1ml aliquot of inoculum was inoculated on Potato Dextrose Agar (PDA) acidified with 0.1% lactic acid to inhibit the growth of bacteria and allow for only the growth of fungi. Inoculated plates are incubated at ambient temperature for 5-7 days. Colonies were counted to obtain colony forming units per gram (CFU/g) of sample [40]. Cultural characteristics of isolates were observed and subcultured for purification. Microscopic examination was done using lactophenol cotton blue stain with x400 magnification.

2.9. Physicochemical Analysis

2.9.1. pH level

The determination of pH in the tomato samples involved the use of a pH [41]. This analytical tool facilitates a prompt and direct assessment of the acidity or alkalinity of the tomato solution, offering insights into taste and overall quality [42]. The pH scale, ranging from 0 to 14, delineates acidity below 7, neutrality at 7, and alkalinity above 7.

2.9.2. Ascorbic Acid

The ascorbic acid content was determined by titration method using the 2,6-dic*hlorophenolindophenol* Tillman's reagent (Tillman's method). The results are expressed in milligrams of *ascorbic acid* per 100 g of sample.

2.9.3. Proximate Analysis

Proximate Analysis is an analytical method used to determine the basic chemical composition of a material, especially organic materials Proximate analysis (carbohydrate, protein, moisture content, fiber, ash and lipid) was done as described [43].

2.9.4. Statistical Analysis

Analysis of variance (ANOVA) was used to compare means at $p < 0.05$. This analysis was performed to visualize the association between the microbial loads of the different tomato samples using SPSS (Statistical Package for the Social Sciences), also known as IBM SPSS Statistics, is a software package used for the analysis of statistical data.

3. RESULTS AND DISCUSSION

Figure 1 explaining the total heterotrophic bacteria count from different types of tomatoes: FT stands for fresh tomatoes, SD for sun-dried tomatoes, and OVD refers to oven-dried tomatoes at varying temperatures—40°C, 60°C, and 80°C.

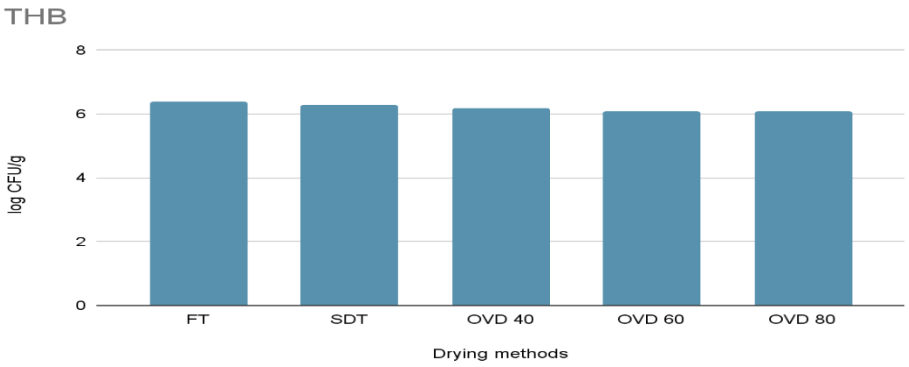

Figure 1. Total heterotrophic bacteria count from the different processing methods

Figure 2 explaining the total fungi count from different processing methods: FT stands for fresh tomatoes, SD for sun-dried tomatoes, and OVD refers to oven-dried tomatoes at varying temperatures—40°C, 60°C, and 80°C.

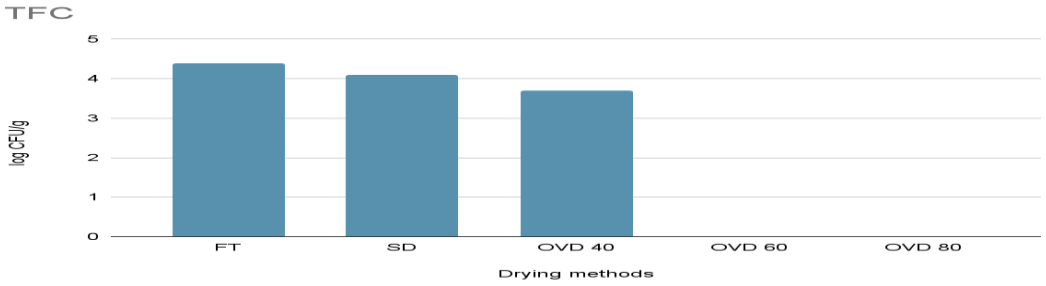

Figure 2. Total fungi count from the different processing methods

Figure 3 explaining the total coliform count from different processing methods: FT stands for fresh tomatoes, SD for sun-dried tomatoes, and OVD refers to oven-dried tomatoes at varying temperatures—40°C, 60°C, and 80°C.

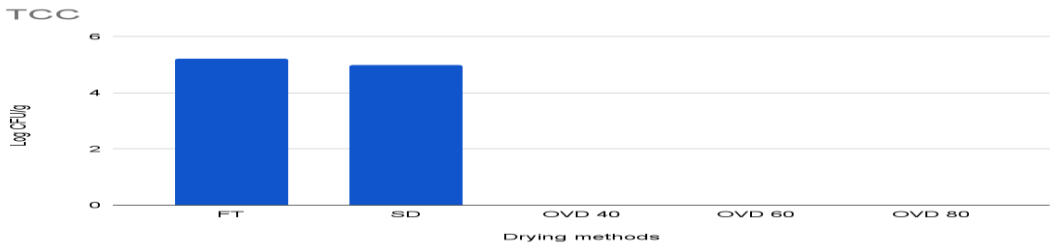

Figure 3. Total coliform count for the different drying methods

Figure 4 explaining the total staph count from different processing methods: FT stands for fresh tomatoes, SD for sun-dried tomatoes, and OVD refers to oven-dried tomatoes at varying temperatures—40°C, 60°C, and 80°C.

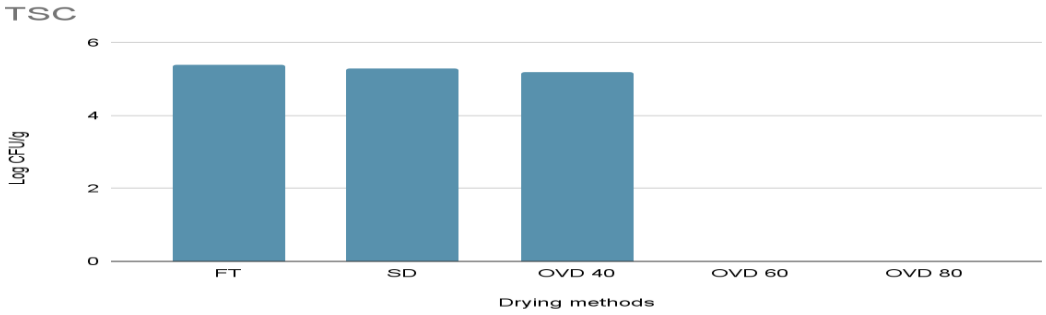

Figure 4. Total Staph. Count obtained from the different processing methods

Figure 5 explaining the mean microbial count from different processing methods: THB stands for total heterotrophic Bacteria, THP for total heterotrophic Fungi, TCC for total Coliform count, TSC for total Staphylococcus count, TEC for total E. Coli count, TPC for total Pseudomonas count, TSaC for total Salmonella count Percentage occurrence of Bacterial isolates from all the samples

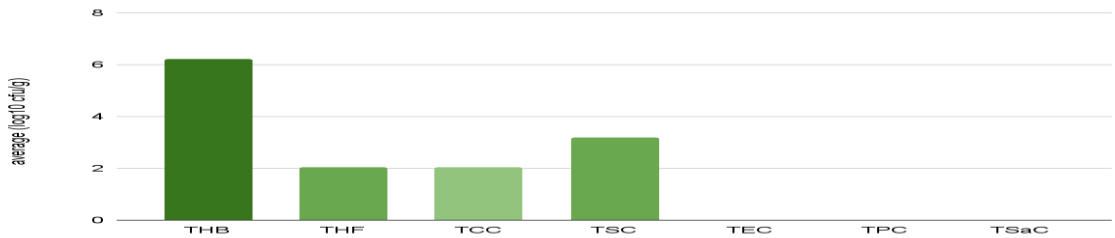

Figure 5. Mean microbial count from the different processing methods

Table 1 explaining the percentage occurrence of bacteria while table 2 explaining the percentage occurrence of fungal isolated from different processing methods, such as fresh tomatoes, sun-dried tomatoes and oven-dried tomatoes.

Table 1. Percentage occurrence of bacteria from Fresh, Sun-Dried, and Oven-Dried tomatoes

Organisms	frequency	Percentage (%)
Bacillus Spp	5	31.25
Enterobacter Spp	3	18.75
Staphyloccus Spp	7	43.75
Klebsiella Spp	1	6.25
Total	16	100%

Table 2. Percentage occurrence of fungal isolates from Fresh, Sun-Dried, and Oven-Dried tomatoes

Organisms	frequency	Percentage (%)
Saccharomyces Spp	3	60
Aspergillus Spp	1	20
Penicillium Spp	1	20
Total	5	100

3.1. Physicochemical Parameters

Table 3 explaining the physicochemical analysis performed on different processing methods: FT stands for fresh tomatoes, SD for sun-dried tomatoes, and OVD refers to oven-dried tomatoes at varying temperatures—40°C, 60°C, and 80°C.

Table 3. Physicochemical analysis performed on the samples

Sample	pH	Ascorbic acid	Moisture content (%)	Ash (%)	Fat & oil (%)	Protein (%)	Crude fibre (%)	Carbohydrate (%)
FT	4.10	28.32	74.00	5.30	15.10	1.70	1.21	0.39
SD	5.20	10.10	11.21	10.23	38.11	19.80	9.23	11.42
OVD 40	4.60	21.22	47.00	8.02	23.90	10.84	4.90	5.34
OVD 60	4.60	15.01	35.00	9.01	26.70	12.19	8.00	9.10
OVD 80	4.50	9.21	21.54	9.74	31.80	18.32	8.85	9.76

3.2. Discussion

3.2.1. Microbial Quality of Fresh, Sun-Dried, and Oven-Dried tomatoes.

This study investigated the impact of different drying methods (oven drying at 40, 60, and 80°C, and sun drying) on the physicochemical and microbial properties of tomatoes. The results revealed significant changes in microbial communities, pH, ascorbic acid content, and proximate composition compared to fresh tomatoes. Microbiological quality is a common criterion used to determine the acceptability and shelf life of dehydrated plant-based products. Some microorganisms are destroyed in the process of drying, though the process is not lethal enough for all microbes. Fresh and dried tomato slices had both bacteria and fungi when isolated.

As presented in Figure 1 the total heterotrophic bacteria count was between 1.3×10^6cfu/g and 2.7×10^6cfu/g with fresh tomato (FT) slices having the highest value (2.7×10^6cfu/g) and oven-dried tomatoes at

80°C (OVD 80) with the least value (1.3×10^6cfu/g). Samples Sun dried (SD) (2.3×10^6cfu/g), OVD 40(1.6×10^6cfu/g) and OVD 60 (1.4×10^6cfu/g) respectively which are all above the internationally acceptable range of 10^3CFU/g of aerobic mesophilic count (FAO 2016). . The heterotrophic counts obtained from the different tomato samples, indicates a statistically significant difference between the mean total heterotrophic bacteria of fresh, sun dried and oven dried tomatoes being compared ($p < 0.05$).

Drying processes generally reduce microbial counts compared to fresh products due to decreased water activity. For oven-dried tomatoes at different temperatures: Oven-dried at 40 ° C: 1.6×10^6cfu/g, Oven-dried at 60 ° C:1.4×106cfu/g, and Oven-dried at 80 ° C 1.3×10^6. For oven-dried tomatoes, similar to sun-dried tomatoes, oven drying typically reduces microbial counts further due to higher temperatures. The counts obtained at different temperatures (40, 60, and 80 ° C) are all lower than the counts for fresh and sun-dried tomatoes, indicating a reduction in microbial load with increasing drying temperature. These counts also fall within an acceptable range for dried food products.

As shown in Figure 4 the total *staphylococcus spp*. The count for fresh tomatoes was 2.4×10^5 cfu/g. *Staphylococcus* is a bacterium commonly associated with foodborne illnesses. The acceptable limit for *Staphylococcus* in food products is typically less than 10^3cfu/g. *Staphylococcus* count for sun-dried tomatoes was 2.0×10^5cfu/g. Sun-drying usually reduces microbial counts compared to fresh produce. The count obtained for sun-dried tomatoes is lower than that of fresh tomatoes, which is expected during the drying process. For oven-dried Tomatoes, results obtained showed: Oven Dry at 40 ° C: 1.6×10^5cfu/g; Oven Dry at 60 ° C: Nil; Oven Dry at 80 ° C: Nil. The counts obtained for oven-dried tomatoes show a reduction in *Staphylococcus* count, especially at higher drying temperatures. The presence of *Staphylococcus* species agrees with the report of cross-contamination from tomato handlers during processing since it is normal flora of the skin, raw tomatoes are usually carried on the body by vendors in Nigeria due to a lack of education, the large water content in tomato fruit makes it highly susceptible to spoilage by microorganisms. The absence of *Staphylococcus* growth at 60 and 80 ° C indicates effective microbial control at these temperatures. The *Staphylococcus* counts obtained for fresh, sun-dried, and oven-dried tomatoes are above the commonly accepted limit of 10^3cfu/g for *Staphylococcus* in food products. Oven-drying, especially at higher temperatures (60 and 80 ° C), effectively reduces Staphylococcus counts to undetectable levels, indicating microbial control within acceptable limits.

As illustrated in Figure 3 the *coliform* counts were 1.7×10^5cfu/g and 1.0×10^5 respectively for fresh Tomatoes and Sun-dried Tomatoes which are considerably higher than the standards of 10^2 CFU/g, suggesting poor microbiological quality. No *coliforms* were detected at any temperature from the oven-dried tomatoes which is generally a good sign, potentially exceeding safety standards.

E. coli is a common indicator of fecal contamination and is not typically tolerated in ready-to-eat foods. The absence of detectable *E. coli* in the samples meets microbiological standards for food safety. *Pseudomonas spp.* are common spoilage bacteria found in a variety of environments, including food. While not all strains are harmful, their presence in high numbers can indicate poor hygiene or improper storage. The absence of detectable *Pseudomonas* counts aligns with microbiological standards for food quality. *Salmonella* is a significant cause of foodborne illness, and its presence in food products is strictly regulated. The absence of detectable *Salmonella* counts in the samples meets microbiological standards for food safety.

As seen in Figure 2 the total fungal count varied among samples, ranging from 6×10^3 cfu/g to 1.2×10^4 cfu/g, with Sun-dried tomatoes (SD) slices exhibiting the highest count at 1.2×10^4 cfu/g, while the lowest count was observed in sample OVD 40 at 6×10^3 cfu/g .The fungi counts obtained from the different tomato samples, indicates a statistically significant difference between the mean total fungi count of the fresh, sun-dried and oven-dried tomatoes samples being compared ($p < 0.05$). Fresh fruits and vegetables typically maintain low fungal counts according to FAO/WHO standards, with counts below 10^3 cfu/g generally considered acceptable for fresh produce. The fungal count for sun-dried tomatoes was 2.6×10^4cfu/g, indicating a reduction compared to fresh produce due to sun-drying. This count falls within the acceptable range of 10^4 cfu/g. oven-dried tomatoes at different temperatures showed varying counts: Oven Dry at 40 ° C yielded 6×10^3 cfu/g, while oven dry at 60 ° C and 80 ° C resulted in 0cfu/g, indicating effective microbial control at higher temperatures. Although slightly higher than findings, the results exhibit a similar pattern, with sun-dried tomatoes showing the highest count. Fresh tomatoes typically have a high moisture content, providing an environment conducive to microbial growth if proper storage conditions are not maintained. However, during the drying process, whether through sun-drying or oven-drying, moisture content decreases significantly, which inhibits microbial growth and extends the shelf life of the tomatoes.

As seen in Table 1 the distribution of the isolated bacteria indicated *Staphylococcus spp.* as the dominant species at 43.75%, followed by *Bacillus spp.* at 31.25%, *Enterobacter spp.* at 18.75%, and *Klebsiella spp.* at 6.25%. This is in contrast that *Klebsiella spp.* (15%) was dominant in fresh tomatoes. In this study, prevalence for *Enterobacter sp.* (18.72%) was found to be slightly lower than the 21.4% reported in Uyo Nigeria. Their presence in tomatoes may be due to handling practices by the vendors. The incidence of *Klebsiella sp.* and

Enterobacter sp. is an indication of human contact, since improper handling of tomatoes during market days may have introduced these organisms into the tomatoes.

In contrast in Table 2, fungal isolates showed Saccharomyces as the dominant species at 60%, while *Aspergillus spp.* and *Penicillium spp.* were both present at 20% each as seen in Figure 2. For fresh tomatoes, the presence of *Bacillus spp.*, *Enterobacter spp.*, and *Staphylococcus spp*. suggests potential contamination from soil or handling, whereas the low occurrence of *Klebsiella spp.* indicates good hygienic practices during handling. In the case of sun-dried tomatoes, the emergence of *Aspergillus spp.* and *Penicillium spp.* suggests fungal growth associated with the drying process, while the persistence of *Staphylococcus spp.* and *Enterobacter spp.* indicates their tolerance to sun drying. The presence of *Saccharomyces spp.* suggests potential fermentation during drying. In oven-dried tomatoes, *Staphylococci* dominated across all the samples except drying temperatures of 60 and 80 °C indicating their heat resistance, while *Bacillus spp.* were present but decreased in number with increasing drying temperature. *Saccharomyces spp*. were observed at 40°C, possibly indicating initial fermentation before heat inactivation, and notably, *Enterobacter spp*. were absent in oven-dried samples, suggesting their sensitivity to heat.

The findings of this study have several important health implications regarding the microbial and physicochemical properties of tomatoes subjected to different drying methods.

Staphylococcus spp., Bacillus spp., Klebsiella spp., Saccharomyces, Aspergillus spp., and *Penicillium spp.* are a diverse group of microorganisms that can have varying public health significance. *Staphylococcus spp*. include several species, with *Staphylococcus aureus* being particularly notable for its ability to cause foodborne illnesses, skin infections, and potentially life-threatening conditions such as toxic shock syndrome. *Bacillus spp*., including *Bacillus cereus*, are known foodborne pathogens capable of causing gastrointestinal illnesses through the production of toxins in contaminated food. *Klebsiella spp*. can cause a range of infections, including pneumonia, urinary tract infections, and bloodstream infections, especially in healthcare settings where they are known for their antibiotic resistance. *Saccharomyces*, commonly used in food fermentation processes, is generally considered safe but can cause opportunistic infections in immunocompromised individuals. *Aspergillus spp*. and *Penicillium spp*. are ubiquitous molds that can produce mycotoxins in food and cause allergic reactions or respiratory infections, particularly in individuals with pre-existing respiratory conditions. While some species within these genera are harmless or even beneficial, others can pose significant risks to public health, emphasizing the importance of proper food handling, hygiene practices, and environmental monitoring to prevent infections and minimize exposure to potentially harmful microorganisms.

Firstly, from a microbial perspective, the study demonstrates that while drying processes generally reduce microbial counts compared to fresh produce, there are variations in the effectiveness of different drying methods in controlling microbial growth. Oven drying, especially at higher temperatures (60°C and 80°C), was effective in reducing microbial counts, including those of *Staphylococcus aureus* and *coliforms*, to acceptable levels. However, sun drying and lower-temperature oven drying (40°C) resulted in microbial counts that exceeded recommended limits for certain microorganisms, indicating potential microbiological risks associated with these methods.

These microbial findings are significant for food safety, as high microbial counts, particularly of pathogenic bacteria such as *Staphylococcus aureus* and *coliforms*, can pose health risks if consumed. Therefore, careful consideration of drying methods and processing conditions is crucial to ensure microbiological safety and minimize the risk of foodborne illnesses associated with dried tomato products.

3.2.2. Physicochemical Quality of Fresh, Sun-Dried, and Oven-Dried tomatoes.

As seen in Table 3 the pH range was between 4.10 and 5.2 with fresh tomatoes being more acidic and oven-dried being the least acidic. Others were 4.6, 4.6, 4.1 for oven-dried at 40°C 60°C and 80°C respectively. Both sun drying and oven drying at 40°C caused slight increases in pH. However, higher drying temperatures (60°C and 80°C) led to a more significant increase in pH. This might be due to moisture loss and the concentration of organic acids. pH levels may vary slightly between fresh and dried tomatoes, with dried tomatoes possibly exhibiting a slightly higher pH due to concentration effects during drying.

The *ascorbic acid* range was between 9.21mg/100g and 28.32mg/100g with fresh tomatoes having the high *ascorbic acid* content and sun-dried having the least as seen in Table 3 ,Others were 21.22mg/100g, 15.01mg/100g, and 10.11mg/100g for oven-dried at 40°C 60°C and 80°C respectively. *Ascorbic acid* is susceptible to degradation when exposed to heat, light, and oxygen, but fresh tomatoes contain high levels of this vitamin when harvested. The content of vitamin C in fresh tomatoes can vary depending on factors such as variety, ripeness at harvest, and growing conditions, but it generally ranges from 15 to 30 mg per 100 grams of fresh weight. The drying process can also cause some degradation of ascorbic acid, particularly if exposed to high temperatures or prolonged drying times.

Sun-dried tomatoes may retain more of their original vitamin C content compared to oven-dried tomatoes, as they are dried at lower temperatures and may undergo less heat-induced degradation. Despite some loss during drying, dried tomatoes can still be a good source of vitamin C, with concentrations ranging from

approximately 5 to 15 mg per 100 grams of dried weight, depending on drying method and processing conditions.

According to ICMSF, ascorbic acid content of tomatoes is about 16.9mg/100g, and for the ascorbic acid content of the fresh tomato used for the research was 28.32mg/100g, while that of the dried tomato samples ranged from 21.22mg/100g to 9.21mg/100g (10.11, 21.2, 15.01, & 9.21 for sun-dried, for oven-dried at 40°C 60°C and 80°C respectively. The two drying methods (sun and oven) reduced the ascorbic acid content of the tomatoes, which was in line with the report a decrease in ascorbic acid content at different drying conditions.

Drying significantly reduced moisture content which was between 74% for fresh tomatoes (highest) and 11.21% for sun-dried tomatoes (lowest). Others were 47.00%, 35.00%, & 21.52% for oven-dries at 40°C 60°C and 80°C respectively. as seen in Table 3. The results show that higher drying temperatures led to progressively lower moisture content. In both sun dried and oven-dried tomatoes, the moisture content is significantly lower compared to fresh tomatoes due to the drying process, which removes water from the fruit. This study is in agreement with the reports who reported that the dehydration of the tomatoes plays an important role on the microorganisms [28]. The removal of water is a method of controlling microbial growth, since they require water to develop their metabolic activities.

Ash content ranged from 5.3% to 10.23% for fresh and sun-dried tomatoes respectively as seen in Table 3. Oven-drying resulted in moderate ash content increases, possibly due to concentration of minerals as moisture evaporates. Higher drying temperatures led to even more pronounced ash increases.

Drying methods had minimal impact on fat and oil content, suggesting relative heat stability of these components. With results ranging from 15.1% to 38.11% for fresh and sun-dried tomatoes. oven-dried at 40°C 60°C and 80°C had 23.90%, 26.70% & 31.81% respectively. When tomatoes are dried, whether by sunlight or in an oven, the water content decreases significantly, leading to a concentration of other nutrients, including lipids. Therefore, the lipid content, when measured as a percentage of dry weight, may appear higher in dried tomatoes compared to fresh ones.

Protein content increased with all drying methods, likely due to moisture loss and concentration of protein. The highest protein content (19.8%) was observed from sun-dried samples and the lowest for fresh tomato samples (1.7%) as seen in Table 3. During drying, the moisture content of the tomato decreases significantly, leading to a reduction in weight. However, the protein content remains relatively constant on a weight basis. As a result, the protein becomes more concentrated in the dried tomatoes compared to fresh ones.

In the case of oven-dried tomatoes, the drying process typically involves exposure to heat, which further reduces the moisture content. This concentration effect is particularly noticeable in the protein content because proteins are not volatile and do not degrade significantly under moderate heat conditions used in drying. Therefore, while the absolute amount of protein in the tomatoes remains relatively constant, the proportion of protein to the total dry weight increases, resulting in a higher protein content in oven-dried tomatoes compared to fresh and sundried tomatoes.

As seen in Table 3 Sun drying tomatoes increase in carbohydrate content ranging from 0.39% for fresh tomatoes to 11.42% for sun-dried, possibly due to concentration of sugar this is due to the loss of water content during drying, sugars become more concentrated. Oven drying at 40°C and 60°C resulted in further increases, while the highest temperature (80°C) caused slight caramelization and subsequent decrease in carbohydrate content.

As seen in Table 3 crude fiber content increased from 1.21% for fresh tomatoes to 9.23% for sun-dried with all drying methods, likely due to the relative stability of fiber compared to other components. The highest increase was observed from the sun-dried sample. Sun-dried and oven-dried tomatoes generally have a higher concentration of fiber compared to fresh tomatoes due to the removal of water. The exact fiber content can vary depending on the specific drying method and any additional processing (such as removing seeds or skin).

While drying processes led to reductions in moisture content and ascorbic acid content, they also resulted in increases in protein, carbohydrate, and crude fiber content. These changes in nutrient composition could have implications for the dietary quality and nutritional value of dried tomato products, particularly regarding protein and fiber intake. The results correspond with the recommendations of Association of Official Analytical Chemists International (AOAC). Overall, the findings underscore the importance of selecting appropriate drying methods and optimizing processing conditions to ensure both microbiological safety and nutritional quality in tomatoes . Additionally, adherence to established microbiological standards and guidelines is essential to safeguard consumer health and well-being. Further research could explore innovative drying techniques and processing strategies to enhance the microbiological safety and nutritional value of tomato, ultimately contributing to improved public health outcomes

4. CONCLUSION

From this study, it could be concluded that oven dried tomato slices gave better results in terms of all the parameters studied compared to sun dried samples. Tomato slices dried in the oven can be preserved longer

than sun dried samples due to lower moisture content and microbial load. Ascorbic acid concentration was highly diminished among all the samples dried. We could also say that sun drying and oven drying can be adopted by these low-income tomato farmers to preserve their numerous tomato output and equally increase their income generation. Further studies are needed to determine the optimum storage conditions, suitable packaging materials and yield of dried tomato slices. Also, subsequent studies should include sensory evaluation to determine consumers' preference.

Additionally, the identification of specific microorganisms in fresh, sundried, and oven-dried tomatoes offers valuable information for quality control. Considering the persistence of certain microbes, such as *Staphylococcus spp.*, in sun-dried and oven-dried samples, it becomes imperative to explore effective methods for their elimination or control during processing. The different bacterial species identified in this study suggest that bacteria contamination on tomatoes can be a potential risk to consumers. Such contamination can lead to food poisoning and food-borne illnesses.

The impact of drying methods on pH, ascorbic acid content, and proximate composition emphasizes the need for careful consideration in tomato processing. Future research could delve into developing optimized drying conditions to minimize nutrient loss while ensuring microbial safety

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