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Nutritional Composition of Fresh and Spoilt Tomato (*Solanumlycopersicum* L.) Fruits and Associated Spoilage Fungi in Delta State, Nigeria

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ABSTRACT
Tomatoes, rich in minerals, amino acids, sugar and dietary fibre contribute to balanced diet consumed fresh or cooked in sauces and soup dishes. Recently, due to improper postharvest handling, tomatoes have become increasingly contaminated with spoilage microorganisms while consumers prefer damaged fruits due to rising costs. This study aimed to identify the spoilage fungi and compare the proximate composition of fresh and spoilt tomatoes obtained from five markets in Delta State, Nigeria, with the objective of informing consumer choices and health implications. A total of 200tomato fruits were randomly purchased from Abraka main, Abraka small, Eku, Obiaruku and Warri markets, Delta State. From each market, 20 fresh and 20 spoilt tomatoes were purchased from 5 sellers. Samples were packaged into sterile containers and transported to the laboratory for analysis. The proximate composition and data analysis were conducted using standardized methods of the Association of Analytical Chemists (AOAC) and analysis of variance (ANOVA). The results revealed the proximate composition varied significantly between fresh and spoilt tomatoes at $P<0.05$. Fresh tomato had higher levels of carbohydrate, protein, fat, moisture, ash and fibre compared to spoilt tomato fruits. Five (5) genera and six (6) species of fungi were isolated from the damaged tomatoes and characterised culturally including *Aspergillus ochraceus, Aspergillus niger Fusarium oxysporum, Rhizopus stolonifer* and *Saccharomyces cerevisiae, Sclerotinia sclerotiorum,* with the most predominant fungus being *Saccharomyces cerevisiae* (36%). The study emphasizes proper postharvest treatments of tomatoes to prevent nutritional loss and minimize risks associated with spoilage fungi for optimal health benefits.

Keywords:
Spoilage fungi,
Proximate composition,
Solanumlycopersicum,
Saccharomyces-cerevisiae.

INTRODUCTION

Fruits and vegetables add vibrancy, taste, and essential nutrients to our meals. While they are most appealing and nutritious when consumed fresh, many people lack the ability to maintain gardens that can provide a constant supply throughout the year. For generations, many staples including beans maize, rice, and tomato which were once considered subsistent crops are now globally cultivated and imported serving the needs of the world's population (Yakubu *et al.*, 2024). The cultivated tomato (*Solanumlycopersicum* L.) is a member of the *Solanum* genus within the Solanaceae family, which also includes other notable crops like tobacco, chili pepper, potato, and eggplant (Valdes & Gray, 1998). Tomato is the most widely consumed vegetable globally, serving as a fundamental ingredient in various raw, cooked, and processed foods. Belonging to the Solanaceae family, which includes several other significant crops, tomato is cultivated worldwide for local consumption or export. According to FAOSTAT (2017), the world's tomato production reached 171 million tonnes in 2014, with China and India being the leading producers. In the United States, tomato production is a significant contributor to the national agricultural industry, ranking fourth globally (USDA-AMS, 2017). Tomatoes are dicotyledonous plants, consisting of various anatomical structures that contribute to their growth and development. The commercially significant tomato fruit exhibits diverse characteristics in terms of color, size, and shape (Vaughan & Geissler, 1997). Composed primarily of water, the fruit also contains vitamins, minerals, and some carbohydrates, with low

amounts of proteins and fats. Additionally, it is rich in carotenoids like lycopene and beta-carotene, which contribute to its red and orange hues. Modern tomato cultivars have been bred to produce fruits with up to 3% sugar content. Furthermore, the fruit contains the alkaloid tomatine, which possesses fungicidal properties and decreases in concentration as the fruit matures. The variability in tomatine concentration can be utilised in crop breeding for cultivated tomatoes (OECD, 2008). Although many studies have highlighted the proximate composition of fresh and spoilt tomato fruits in Nigeria, many consumers still prefer to use spoilt tomato fruits in their dishes. The degradation of tomato fruits due to spoilage not only diminishes their market value but also compromises their nutritional quality. Various factors, including pre and postharvest diseases, contamination by moulds, improper handling, and other adverse conditions, can adversely affect the nutritional value and overall quality of freshly harvested tomato fruits (Tandel & Ansari, 2022).

Tomato production in Delta State, Nigeria, and other regions faces numerous challenges, including susceptibility to diseases, pests, and environmental factors that impact yield. Inadequate storage and transportation infrastructure further exacerbates these issues (Akaeze & Aduramigba, 2017; Dayok *et al.*, 2024). Despite these obstacles, tomato sales remain a vital economic activity, contributing significantly to local livelihoods and Nigeria's agricultural sector. One major concern is the prevalence of tomato diseases, particularly fungal moulds that cause substantial crop losses and compromise production quality and quantity (Surechain, 2021). Microbial spoilage of fresh tomatoes results in significant waste and economic losses (Akinniran *et al.*, 2020). Fungal colonization during pre- and post-harvest stages affects the quality and nutritional value of fresh tomato fruits (Akinniran *et al*., 2020). Fungi are primary plant pathogens that affect various staple foods and fruits during storage (Okpewho *et al*., 2024). Due to their perishable nature, tomatoes often decay before reaching distant consumers. To address this issue, many producers opt for converting fresh tomatoes into more durable forms, such as tomato pastes (Akinniran *et al*., 2020; Dayok *et al.*, 2024). Although many studies have highlighted the proximate composition of fresh and spoilt tomato fruits in Nigeria, many consumers still prefer to use spoilt tomato fruits in their dishes. This is driven by economic constraints and limited access to fresh, healthy tomatoes posing public health threats to nutrition as spoilage compromises the nutritional quality and safety of this staple vegetable; highlighting the need for a comprehensive understanding of the proximate composition of fresh and spoiled tomatoes. These concerns informed the current study, which aims to evaluate the nutritional differences between fresh and spoiled tomatoes and identify common spoilage fungi.

MATERIALS AND METHODS

Study area

The experiment was carried out in 2024 at the pharmacy laboratory of the Faculty of Pharmacy, Delta State University, Abraka Campus, Site 3. Abraka is located in Ethiope-East Local Government area of Delta State within the tropical rainforest zone at latitude 5° 24.1` N and longitude 6° 55.8` E of the equator.

Samples collection

A total of 200 fresh and damaged tomato fruits were used for this experiment. At each location, 20 fresh and 20 spoilt tomato samples were randomly collected in sterile polyethylene bags from five selected markets in Delta State. The markets include Abraka main and small markets (Ekrejeta), Eku, Obiaruku and Warri markets. Samples were sent to the laboratory for further processing.

Methods for determination of nutrients

For crude protein determination, Nitrogen, Moisture content, crude fat, crude fibre and total ash were determined by the method described by the Association of Official Analytical Chemist (AOAC, 2005). Carbohydrate was calculated by subtracting the sum of the values of the other nutrients from 100.

Determination of the moisture content

The moisture content was determined using the gravimetric method. A 2.5g sample was placed in a pre-weighed, dry crucible and oven-dried at 105 ^{o}C for 2 hours. The crucible and sample were then cooled in a desiccator and reweighed. This process of drying, cooling, and weighing was repeated until a constant weight was achieved, indicating that all moisture had been removed (Alawode, 2024). The moisture content was calculated using the following formula:

Moisture content (%) = (Initial weight - Final weight) / Initial weight) x 100

where:

Initial weight = Weight of sample and crucible before drying

Final weight = Weight of sample and crucible after drying to constant weight.

Determination of ash content

The ash content was determined using the furnace incineration gravimetric method. A 2.4 g sample was placed in a pre-weighed porcelain crucible and incinerated in a muffle furnace at 550^{o}C for 2-3 hours, until the sample was completely burned to a gray ash. The crucible was carefully removed from the furnace, taking care not to disturb the ash, and cooled in a desiccator (Alawode, 2024). The weight of the ash was determined by reweighing the crucible, and the ash content was calculated as:

Ash content (%) = (Weight of ash / Initial weight of sample) x 100
where:
Weight of ash = Weight of crucible and ash after incineration
Initial weight of sample = Weight of sample before incineration.

Determination of crude fiber
A 2.5 g defatted sample was refluxed in 200 ml of 1.25 % H_2SO_4 solution for 30 minutes, then washed with hot water using a muslin cloth to trap particles. The sample was transferred back to the flask, and 20 ml of 1.25 % NaOH solution was added. After boiling for another 30 minutes, the sample was washed again with hot water and transferred to a pre-weighed porcelain crucible. The sample was dried in an oven at 105°C for 2 hours, cooled in a desiccator, and reweighed. The crude fiber content was calculated gravimetrically as:
Crude fiber (%) = (Weight of dried sample - Weight of ash) / Initial weight of sample) x 100
where:
Weight of dried sample = Weight of sample after drying in oven
Weight of ash = Weight of sample after ignition (burning) to ash
Initial weight of sample = Weight of sample before analysis.

Determination of crude fat
The fat content of the samples was determined using the continuous solvent extraction method with a Soxhlet apparatus. A 2.5 g sample was wrapped in filter paper and placed in a Soxhlet reflux flask containing 200 ml of petroleum ether. The flask was connected to a condenser and heated using an electro-thermal heater, causing the solvent to vaporize and condense into the reflux. The wrapped sample was fully immersed in the solvent, allowing for continuous extraction of oil. This process was repeated for approximately 4 hours, after which the defatted sample was removed and reserved for crude fiber analysis. The solvent was recovered, and the extracting flask with the oil content was dried in an oven at 60 °C for 3 minutes to remove any residual solvent (Alawode, 2024). After cooling in a desiccator, the flask was reweighed, and the weight of fat extracted was determined by difference and expressed as a percentage of the sample weight.
Fat content (%) = (Weight of extracting flask with oil - Weight of empty extracting flask) / Sample weight) x 100.

Determination of crude protein
The protein content was determined using the Kjeldahl method. A 0.5 g tomato sample was mixed with 10 ml of concentrated sulfuric acid and a selenium catalyst in a Kjeldahl digestion flask. The mixture was heated under a fume hood until a clear solution was obtained. A blank control was prepared by digesting the acid and reagents without the sample. The digests were then transferred to a 100 ml volumetric flask and made up to the mark with distilled water. A 100 ml portion of each digest was mixed with an equal volume of 45 % NaOH solution in a Kjeldahl distillation unit. The mixture was distilled, and the distillate was collected into 10 ml of 4 % boric acid solution containing a few drops of indicator (Alawode, 2024). The distillate was titrated against 0.02M H_2SO_4 solution until a deep red endpoint was reached. The nitrogen content was calculated as follows:
Nitrogen content (%) = (Volume of H_2SO_4 used x Molarity of H_2SO_4 x 14) / Weight of sample) x 100
Protein content (%) = Nitrogen content x 6.25
where:
Volume of H_2SO_4 used = Volume of acid used for titration
Molarity of H_2SO_4 = Concentration of acid
Weight of sample = Initial weight of tomato sample.

Determination of carbohydrate
The carbohydrate content was calculated by subtracting the total crude protein, crude fiber, ash, and lipid from the total dry matter.
Carbohydrates (%) = 100 - (% Moisture + % Ash + Crude fat + % Crude fibre + % protein).

Isolation and characterization of Fungal Isolates
Spoiled tomato samples underwent surface sterilization by washing under running tap water, followed by a 3-minute immersion in 1 % sodium hypochlorite solution, and rinsing with sterile distilled water. The affected areas were then excised using a sterile scalpel and plated on Potato Dextrose Agar supplemented with streptomycin sulphate solution (Udoh *et al*., 2015). Fungal growth was evident within 5-7 days of inoculation, yielding distinct colonies that were subsequently sub-cultured. Fungal isolates were identified based on their macroscopic and microscopic features, which were cross-referenced with previously reported characteristics by Chikwem *et al*. (2020) to confirm their identity.

Statistical data analysis
The statistical analysis software was used for analysis of variance (ANOVA) while the Duncan's Multiple Range Tests (DMRT) was used to separate the meansat significance level $P < 0.05$.

RESULTS AND DISCUSSION

Results
The proximate analysis of fresh tomato samples revealed that those obtained from Eku had the highest moisture content, with a value of 62.46. In contrast, samples from Warri contained higher levels of protein, while those from Abraka small market had the highest

carbohydrate content. Accordingly, for the spoilt tomato fruits, the Abraka main market sample shad the highest moisture content. Incontrast, tomato samples from Obiaruku market contained the highest level soft protein, whereas those from Eku market had the highest carbohydrate content. The detailed proximate composition of the fresh and spoilt tomato samples is presented in Table 1.

Table 1: Nutritional composition of fresh tomato

Sample location	Status	Moisture	Ash	Crude fibre	Crude fat	Protein	Carbohydrate
Abraka main market	Fresh	60.36a	0.17ab	26.65b	5.20a	2.86h	11.96ghi
	Spoilt	60.43a	0.20bc	21.7bc	1.90abc	1.82ef	4.77bcd
Abraka small market	Fresh	60.65a	0.16ab	26.55bc	2.50de	2.87g	15.02d
	Spoilt	60.29b	0.13ab	20.20a	2.70bcd	1.66i	7.29j
Eku market	Fresh	62.46a	0.08cd	26.35cd	4.30a	2.91gh	9.81bc
	Spoilt	60.19ab	0.26ab	23.40bc	0.40e	1.68g	7.48ef
Obiaruku market	Fresh	60.51a	0.13bc	24.51de	5.20ab	2.93ghi	11.34de
	Spoilt	60.18ab	0.32abc	22.53de	0.41bcd	2.51hi	5.51fg
Warri market	Fresh	60.42c	0.07cd	25.21f	4.56e	3.18ijk	12.48h
	Spoilt	59.35ab	0.28bc	23.48a	1.37f	1.51gh	4.37l

Key: Means within a column with the same superscript are not significantly different at $P < 0.05$.

The fungal isolates comprised six genera, including *Aspergillus*, *Rhizopus*, *Fusarium*, *Sclerotinia*, and *Saccharomyces*, with the latter being the predominant genus. The morphological features of these isolated fungi are summarized in Table 2.

Table 2: Morphological Features of the observed Fungal Isolates

Fungi isolate	Color	Texture	Edge shape	Diameter	Feature revealed under microscope
Aspergillusniger	Brownish black	Powdery	Irregular	44 mm	Conidiosphore with Large Black Sporing Heads, Black round Conidia covering surface of vesticles.
Aspergillusochraceus	Pinkish to purple	Soft	Irregular	26 mm	Phialides with smooth or finely roughened surfaces are organized in a biseriate arrangement on the conidial heads.
Fusariumoxysporium	White	Cottony	White	38 mm	Fusiform Pointed at Edge With 4 Septa
Rhizopusstolonifer	Greyish brown	Cottony	Spherical	43 mm	Composed of branched, non-septate white hyphae
Saccharomyces cerevisiae	Cream	Smooth	Irregular	27 mm	Round to ovoid
Sclerotiniasclerotiorum	White	Smooth	Irregular	26 mm	Branched, septate and transparent hyphae

The frequency of occurrence of the fungal isolates revealed that Saccharomyces cerevisiae was the most prevalent, accounting for 36% of the isolates. *Sclerotiniasclerotiorum* followed with a frequency of 8%, while *Aspergillusochraceus*, *Rhizopus stolonifer*, *Fusariumoxysporum*, and *Aspergillusniger* had lower frequencies, ranging from 8% to 20%.

Table 3: Frequency of occurrence (%) of fungi isolates from spoilt tomato

Fungal isolate	No. of isolate	% Occurrence
Aspergillusochraceus	4	16
Aspergillusniger	5	20
Fusarium oxysporium	2	8
Rhizopus stolonifera	3	12
Saccharomycescerevisae	9	36
Sclerotiniasclerotiorum	2	8
Total	25	100

Discussion

In Nigeria, commercially sold damaged tomatoes are considered important alternatives to fresh tomatoes based on the physical appearance and nutrients they are perceived to contain. Generally, from the samples analyzed, there were differences in the nutrient content of fresh and spoilt tomatoes from the market. The differences in their content may be attributed to the period between spoilage and analysis. The spoilt tomatoes still retained nutrients even though they may look spoilt (Wang *et al*., 2024). Another reason may be that slight deterioration by microbes has only taken place. However, fresh tomatoes had more contents than the spoilt samples. In general, spoilage had major effects on the carbohydrate, protein, or fat content of the tomato samples. From table 1, comparing the moisture contents of fresh and spoilt tomatoes, there is an indication that fresh tomato had higher moisture ranging between 60.36 to 62.46 than their spoilt counterparts with values between 59.35 and 60.18. Water in addition to hydrating the body serves also as a thermo-regulator and also functions in the fluid balance (Popkin *et al*., 2010). Several factors are attributed to this difference including breakage on the wall of the spoilt tomatoes leading to the loss of water from within the fruit, microbial proliferation and metabolism and biochemical condition. Other factors could be the species, evaporation due to exposure and geographical location. The result of the moisture content conforms with the report of Chime and Aiwansoba, (2023). High moisture content is synonymous with low ash contents (Abdullahi *et al*., 2016). The study revealed low ash contents in fresh and spoilt tomatoes samples from all sites studied. The low ash content of this study is attributed to the high moisture of fresh and spoilt tomatoes contributing to the low dry matter which contains the crude fibre. Dietaryfibre is an indigestible component of food that enhances peristaltic movement in the bowels. It also aids the prevention of colon cancer as well as difficulty in stooling. The study showed that fresh tomato contained higher fibre than spoilt tomato. These are some of the advantages of eating fresh foods. Physical injuries and microbial degradation of parts of the spoilt samples may have caused the reduction in dietary fiber from the tomato samples. The market samples from showed significant differences in the crude fat composition of tomato. Fresh tomato samples had higher fat contents compared to the spoilt samples. The breaks and biodeterioration from physical injury, softening and microbial proliferation might have caused the reduced fat contents. The geographical area and soil condition within which they were propagated may have caused such differences. When microbes proliferate in food materials, they utilize the available nutrients in the food for their own benefits. Therefore, the fats may have been broken down for use by microbes. Tomatoes are an essential source of protein, which plays a vital role in cell growth and repair. A deficiency in protein can lead to various health issues. An analysis of the percentage composition of crude protein revealed that fresh tomatoes from Warri had the highest protein content, significantly differing from spoiled tomatoes. This is expected, as fresh tomatoes naturally possess higher nutritional value, including protein, compared to spoiled ones. Although, the protein contents is low, significant differences exist between the fresh and spoilt tomato samples compared to those from the study conducted by Shina and Tambai (2018) who reported higher protein contents (4.05±0.10) between their tomatoes samples. Physical damage or spoilage and the stage of harvest or maturation can lead to decreased protein content, explaining the significant difference in protein levels between fresh and spoiled tomatoes. Carbohydrates play a crucial role in energizing cells, serving as a primary source of immediate energy. In this study, the carbohydrate content of tomatoes from different markets were significantly different at $P < 0.05$, revealing that Abraka small market tomatoes had the highest overall carbohydrate content, followed by Warri and Abraka main market tomatoes, respectively. Notably, even the highest carbohydrate content found in spoiled tomatoes was significantly lower compared to fresh tomato samples. This discrepancy may be attributed to seed quality and high water content in fresh tomatoes. The findings of this study showed a lower carbohydrate content in fresh tomatoes compared to the values reported by (Shina and Tambai, 2018). However, the carbohydrate composition in this study was consistent with the results reported by (Chime and Aiwansoba, 2023).

Seven fungal species, namely *Saccharomyces cerevisiae, Rhizopusstolonifer, Aspergillusochraceus, Aspergillusniger, Fusariumoxysporium,* and *Sclerotiniasclerotiorum*, were isolated from tomato samples collected from five different locations. These fungi were identified as the primary causes of post-harvest spoilage of tomatoes, occurring at varying frequencies across the different sources. Previous studies have also reported the isolation of *Aspergillusniger, Rhizopus stolonifer*, and *Saccharomycescerevisiae* from spoiled tomatoes, attributing the spoilage to poor handling practices, storage conditions, and marketing practices (Mbajiuka & Enya, 2014; Sinno *et al*., 2020). The prevalence of these fungal species suggests that tomatoes are highly susceptible to fungal pathogens, which can contaminate the fruit through various means. Notably, *Saccharomyces* and *Aspergillus* spp. are renowned spoilage molds that can adapt to different environmental conditions, including soil and dry environments. The presence of *Aspergillus*, a mycotoxigenic fungus, poses a risk of toxin

consumption. The frequency of occurrence of the isolated fungi showed that *Saccharomyces cerevisiae* was the most predominant, occurring at 36% across all locations. This could be attributed to contamination during transportation, retailing, or the susceptibility of the tomato variety to spoilage by *Saccharomyces* sp. In contrast, *Aspergillusniger*, *Rhizopusstolonifer*, *Fusariumoxysporium*, *Sclerotinia sclerotiorum*, and *Aspergillusochraceus* occurred at lower frequencies suggesting that some tomato cultivars may possess genetic traits that confer resistance to these fungal pathogens (Dayok *et al*., 2024).

CONCLUSION

The susceptibility of tomatoes to fungal-induced spoilage is significantly influenced by factors such as tomato variety, sorting, storage conditions, packaging materials, transportation methods, and the nature of damage. From the study, the nutrients composition of fresh tomatoes were significantly different from spoilt tomatoes while the associated spoilage fungi include *Saccharomycescerevisiae*, *Rhizopus stolonifer*, *Aspergillusochraceus*, *Aspergillusniger*, *Fusariumoxysporium*, and *Sclerotinia sclerotiorum*. To minimize post-harvest spoilage, it is essential to protect raw tomatoes from contaminants, thereby limiting the proliferation of spoilage microorganisms. The findings of this study can inform the development of effective food preservation systems in the region, tailored to the specific microorganisms encountered. By implementing such systems, the nutritive value of tomatoes can be preserved, promoting healthier consumption and supporting public health.

Authors Contribution

Okpewho, O. P, together conceived and wrote the contents; Agbogidi, O. M. and Solomon, E. J.edited drafts and together completed; and Ogunoye, O. A. and Ebunola, T. E., proofread and reviewed the manuscript.

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