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Effect of Fungal Spoilage on Nutritional Composition and Mineral Content of *Canarium schweinfurthii* Fruits Sold in Port Harcourt Metropolis, Rivers State

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ABSTRACT

This study evaluated the nutritional compositions of infected and uninfected fruits of *Canarium schweinfurthii* (African elemi) to determine the effect of fungal infection on proximate and mineral contents. Fresh fruits were collected from Ebonyi State, Nigeria, and analyzed under laboratory conditions using standard Association of Official Analytical Chemist (AOAC) methods. A Completely Randomized Design (CRD) was adopted, and data were subjected to one-way Analysis of variance (ANOVA) with mean separation by Duncan's Multiple Range Test (DMRT) at a 5% probability level. Results showed that fungal infection significantly ($p < 0.05$) altered the proximate composition of the fruits. Infected fruits exhibited reduced crude proteins (1.77–2.13%) and lipid (21.96–28.11%) compared to uninfected controls (7.11% and 45.48%, respectively), while carbohydrate content increased markedly (45.97–48.66% vs. 6.42%). Similarly, essential minerals such as Iron (Fe), Zinc (Zn), Magnesium (Mg) and Sodium (Na) were significantly lower in infected fruits, although copper levels remained relatively stable across treatments. The result revealed that probable fungi identified were *Aspergillius aflatoxiformans, Apotrichum* sp and *Dothideales* sp. The findings suggest that fungal pathogens compromise the nutritional and mineral integrity of *Canarium schweinfurthii* fruits, thereby reducing their dietary and economic value.

Keywords: *Canarium schweinfurthii,* proximate composition, mineral content, fungal infection, nutritional quality.

Introduction

Canarium schweinfurthii Engl., widely known as African elemi, is a multipurpose indigenous tree species distributed across much of West and Central Africa, including Nigeria, Cameroon, Ethiopia, Tanzania, Ghana, Angola, Uganda, and Senegal (Dawang *et al.,* 2016; Abodenyi and Salawudeen, 2020). A member of the Burseraceae family, the species is particularly valued for its fruits, which yield an edible oil rich in unsaturated fatty acids, proteins, and essential minerals (Kiin-Kabari *et al.,* 2020; Muhammad *et al.,* 2023). Beyond their nutritional value, the fruits and seeds play an important role in traditional medicine, where they are employed in managing gastrointestinal disorders, skin infections, and inflammatory conditions (Garba *et al.,* 2024; Monthe *et al.,* 2023). Additionally, the oil and resin are widely used in cosmetics, varnishes, and other industrial applications, underscoring the economic importance of the species (Kamtu *et al.,* 2022; Lawal *et al*., 2024).

In Nigeria, African elemi contributes meaningfully to food security and rural livelihoods. It provides an accessible and affordable source of dietary energy, proteins, fats, and micronutrients for both rural and urban populations, thereby serving as an important supplement to staple diets (Ehwarieme *et al.,* 2022; Omeje *et al.,* 2022).

Despite its value, however, *C. schweinfurthii* fruits are highly perishable, and postharvest deterioration represents a significant barrier to their wider utilization and marketability. Fungal pathogens are among the primary agents of this spoilage, contributing to both qualitative and quantitative losses. Infected fruits often undergo rapid tissue softening, discoloration, and off-flavor development, alongside compositional changes that compromise their nutritional profile (Saleh and Al-Thani, 2019; de Oliveira Filho *et al.,* 2021; Serag *et al*., 2022). Studies show that fungi such as *Aspergillus*, *Dothideales*, and *Apotrichum* sp. invade fruits through the secretion of hydrolytic enzymes, which degrade structural polysaccharides, proteins, and lipids.

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This enzymatic activity reduces crude protein, lipid, fiber, and mineral contents, while carbohydrates typically increase due to the conversion of complex macromolecules into simple sugars that serve as substrates for fungal metabolism (Ma *et al*., 2019; de Vries and Visser, 2001; Al-Hindi *et al*., 2022).

The nutritional implications of fungal spoilage are particularly concerning in regions where fruits such as African elemi represent an important dietary resource. Reduced nutrient density not only undermines consumer health but also diminishes the fruit's commercial and industrial potential. In addition, the possible production of mycotoxins by contaminating fungi poses further risks to food safety (Mailafia *et al.,* 2017; Saleh and Al-Thani, 2019). While several studies have reported on the proximate and mineral composition of *C. schweinfurthii,* relatively few have compared the nutritional integrity of infected and uninfected fruits under controlled laboratory conditions.

Given the ecological, nutritional, and socio-economic significance of African elemi, a clearer understanding of how fungal infections alter its composition is critical. This study therefore examines the proximate and mineral contents of infected and uninfected *C. schweinfurthii* fruits. By elucidating the biochemical consequences of fungal colonization, the findings aim to guide strategies for improved postharvest management, storage, and utilization, thereby safeguarding both the nutritional quality and economic value of this important indigenous fruit.

Materials and Methods

Study Area

The study was conducted at the Laboratory of Forestry and Environment (Forest Pathology/Mycology Unit), Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, in collaboration with the Department of Food Science and Technology Laboratory of the same institution.

The laboratories are strategically located within the Rivers State University main campus in Port Harcourt, Rivers State, Nigeria. Geographically, the study site lies at Latitude 4.50°N and Longitude 7.00°E, with an average elevation of about 18 meters above sea level.

The area experiences a tropical humid climate, typical of the Niger Delta ecological zone. The climatic condition is characterized by a mean annual temperature of approximately 27 °C and an annual rainfall ranging from 2,000 mm to 2,467 mm (Chukunda, 2014). Rainfall is bimodal, with a long rainy season extending from March to July and a shorter rainy season occurring from September to November, while December to February marks the relatively dry months. High relative humidity, often exceeding 80%, is common throughout the year.

The soil type of the surrounding environment is predominantly sandy-loam and alluvial deposits, which is typical of the Niger Delta region. This soil composition, coupled with abundant rainfall and consistently warm temperatures, creates a favorable environment for the growth and proliferation of fungi and other microorganisms, making it suitable for studies in forest pathology, mycology, and food science applications.

Collection of *Canarium schweinfurthii* Fruits

Fresh fruits of *Canarium schweinfurthii* (commonly known as African elemi) were bought from Mile 3 market, Port Harcourt. The fruits were carefully managed to avoid physical damage that could predispose the fruits to contamination prior to laboratory analysis.

Immediately after collection, the fruits were carefully packed in sterile polythene bags and transported under hygienic conditions to the Laboratory of Forestry and Environment (Forest Pathology/Mycology Unit), Rivers State University, Port Harcourt. Upon arrival at the Laboratory, the fruits were subjected to initial treatment, which included sorting, washing with sterile distilled water, and surface sterilization where necessary, in order to reduce the influence of extraneous microorganisms.

To assess the susceptibility of the fruits to fungal colonization during storage, a portion of the collected fruits were stored under ambient Laboratory conditions for a period of seven days. This was done to mimic natural postharvest storage and handling practices. The stored fruits were then carefully monitored to observe any changes in texture, color, or visible fungal growth. Samples were taken at the end of the storage period to isolate and identify the fungal pathogens responsible for spoilage.

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This approach allowed for a comparative evaluation between freshly treated fruits and those exposed to short-term storage conditions, thereby providing insights into both field- and storage-associated microbial infections of *Canarium schweinfurthii* fruits (Chukunda *et al.,* 2015a, b).

Isolation of Fungi from Infected African Elemi Fruits

The standard blotter method of the International Seed Testing Association (I.S.T.A, 1976) was used for the isolation of the fungi. The African Elemi fruit samples was pre-treated with 1% Sodium hypochlorite solution for five minutes of the fruits to remove contaminants on the surface before plating five seeds per Petri-dish. They were incubated in an incubator at 25 ± 2^0C for seven days. One hundred seed was treated for the post-harvest fruits. Pure culture was prepared from the fungal growth on the fruits. Identification of the fungi was carried out using stereo-binocular microscope (6-50) based on their habit character and spore characteristics. Where necessary, spores of fungal mycelia was made on slides and viewed under compound microscope (X_{40}) to confirm the organisms. The identification was done, following the fungal description by Barnett and Hunter (1992) and Klich (2002).

Percentage disease incidence was identified and calculated using the formula of Chukunda (2014).

$$D_I = \frac{D_o}{D} \times \frac{100}{1} \quad \text{…….. Equation (i)}$$

Where:

D_I = Disease incidence, D_o = Number of diseased fruits, D = Total number of fruits pulp and seed plated.

Proximate Determination of Infected and Uninfected Fruits of African elemi

The infected and uninfected fruit of *Canarium schweinfurthii* fruits obtained from Mile 3 Market, Port Harcourt, Rivers state were kept in a dried clean container, opened, deseeded and weighed. The fleshy fruit pulps was cut opened and air dried in a dry cabinet at 60^0C for 5 days. The dried fruit pulp/ seeds were grounded into powder and analysed for moisture, ash, protein, crude fibre, crude fat and carbohydrate content according to AOAC (1990, 2000 and 2005).

Estimation of Moisture Content

Fresh fruit sample materials were be taken in a flat bottom dish and kept overnight in a hot air oven at 100-110°C and weighed. The loss in weight was regarded as a measure of moisture content.

Estimation of Ash

According to (AOAC, 2005), an empty crucible was accurately weighed, and then 10ml of sample was weighed in it using sensitive balance. The sample in crucible was placed in muffle furnace at 550°C for more than 3 hours until white to grey ash was obtained, then crucible was removed from furnace to a desiccator to cool, then weighed.

Estimation of Crude Lipid (Ether extract)

Five grammes of dry sample was weighed on a piece of glazed paper and transferred into an extraction thimble. The thimble was introduced into soxhlet extractor over a pad of cotton wool, so that top of the thimble is well above the top of the siphon. A clean dry flask was taken, weighed and was fitted with the extractor. Ether was poured along the side of the extractor until it begins to siphon off. Then another half-a siphonful of ether was added. The equipment thus assembled with the flask wad placed on a water bath at 60-80°C and the extractor was connected with the condenser. Cool water circulation was started in the condenser and allowed the extraction for 8 hr. Then the thimble with the material was removed from the extractor. The apparatus was assembled again and heated on a water bath to recover all the ether from the receiver flask. The receiver flask was disconnected and dried it in a hot air oven at 100°C for 1hr, cooled and weighed.

Determination of Crude Fibre

About 2gm of moisture and fat free sample was weighed and transferred to the spout less one litre beaker. Thereafter, 200 ml 1.25% H_2SO_4 was added. The beaker was placed on hot plate and allowed to reflux for 30 mins, timed from onset of boiling. The content was shaken after every 5 min. The beaker was removed from the hot plate and filtered through a muslin cloth using suction. The residue was washed with hot water till it was free from acid. The material was transferred to the same beaker and added 200ml of 1.25% NaOH solution and refluxed for 30 mins.

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Again, filtered and the residue was washed with hot water till it was free from alkali. The total residue was transferred to a crucible and placed in hot air oven, allowed to dry to a constant weight at 80-110 °C and weighed.

The residue was ignited in muffle furnace at 550-600°C for 2-3hrs, cooled and weighed again. The loss of weight due to ignition was the weight of crude fiber.

Determination of Crude Protein

Crude protein content was determined using Kjeldahl method and calculated by multiplying the amount of nitrogen by 6.25 .10ml of sample was weighed in Kjeldahl flask, half a tablet of catalyst mixture (10 parts K_2SO4 to one part of $CuSO_4$ and 25ml of concentrated H_2SO_4 were added.

The ash content of the flask was digested under boiling at maximum heat for 2-3 hours and then the flask was distilled using NaOH 40%, the ammonia was received in 100ml conical flask containing 10ml of 0.1NHCl and crude protein percentage was calculated as follows (AOAC, 2005).

Determination of Carbohydrate Content

The total carbohydrate content of infected and uninfected *Canarium schweinfurthii* fruits was determined by difference method, as recommended by the AOAC (2005).

After conducting proximate analysis to determine moisture, ash, crude protein, crude lipid, and crude fiber contents, the carbohydrate content was calculated using the following formula:

$$Carbohydrate\ (\%) = 100 - (\%Moisture + \%Ash + \%Protien + \%Fat + \%\ Fiber) \quad \text{Equation 2}$$

All proximate components were determined using standard AOAC procedures. The resulting carbohydrate values were expressed on a percentage dry weight basis (% DW).

Mineral Determination of Infected and Uninfected Fruits of Africa elemi

The mineral composition of infected and uninfected *Canarium schweinfurthii* fruits was determined following standard wet-ashing and atomic absorption spectrophotometry (AAS) procedures as described by AOAC (2005).

Approximately 2.0g of oven-dried fruit sample (infected and uninfected) was weighed and transferred into a crucible. The samples were incinerated in a muffle furnace at 550°C for 4–6 hours until white ash was obtained. The ash was then digested using a mixture of nitric acid (HNO_4) and perchloric acid (HClO) in a ratio of 3:1 and heated gently until a clear solution was formed. The digest was cooled, filtered into a 50 mL volumetric flask, and made up to volume with deionized water. The concentrations of essential minerals, iron (Fe), zinc (Zn), copper (Cu), magnesium (Mg), and sodium (Na) were determined using Atomic Absorption Spectrophotometry (AAS) at their respective wavelengths. Calibration curves were prepared using standard solutions of known concentrations for each element.

Experimental Design and Statistical Analysis

The experiment was conducted using a Completely Randomized Design (CRD) to evaluate the different treatments. Data obtained were analyzed using one-way Analysis of Variance (ANOVA) with the SPSS software package (version 25). Where significant differences were observed among treatment means, they were further separated and compared using the Duncan's Multiple Range Test (DMRT) at a 5% level of probability.

Results

The cultural characteristics of fungi pathogen associated with infected fruits of *Canarium schweinfurthii* are presented in Plates 1 to 3. The result revealed that probable fungi identified were *Aspergillius aflatoxiformans, Apotrichum* sp. and *Dothideales* sp.

The data presented in Table 1 indicates the proximate composition of infected and uninfected African Elemi fruits. The proximate analysis includes Moisture Content, Ash content, Crude lipid, Crude fiber, Crude protein, and Carbohydrate content.

The fungal isolates (*Dothideales* sp, *Aspergillius aflatoxiformans* and *Apotrichum* sp) are compared against the uninfected control, with the results presented as percentages. The results indicate significant differences ($p<0.05$) in proximate composition cross treatments.

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Plate 1: ***Aspergillius aflatoxiformans***

Plate 2: ***Dothideales*** **sp**

Plate 3: ***Apotrichum*** **sp**

Table 1: Proximate Determination of Infected and Uninfected Fruits of African Elemi

Fungal Isolates	Moisture Content (%)	Ash (%)	Crude Lipid (%)	Crude Fiber (%)	Crude Protein (%)	Carbohydrate (%)
Dothideales sp	$24.74^{a}\pm 1.43$	$1.13^{b}\pm 0.08$	$21.96^{d}\pm 0.95$	$2.42^{c}\pm 0.13$	$1.77^{b}\pm 0.17$	$47.98^{ab}\pm 1.02$
Aspergillius aflatoxiformans	$17.96^{b}\pm 1.00$	$1.89^{b}\pm 0.21$	$28.11^{b}\pm 1.37$	$3.94^{b}\pm 0.24$	$2.13^{b}\pm 0.25$	$45.97^{b}\pm 1.01$
Apotrichum sp	$19.22^{b}\pm 0.84$	$1.48^{b}\pm 0.44$	$25.71^{c}\pm 0.76$	$2.85^{cb}\pm 0.14$	$2.08^{b}\pm 0.49$	$48.66^{a}\pm 0.96$
Control (Uninfected)	$23.32^{a}\pm 2.88$	$9.14^{a}\pm 1.22$	$45.48^{a}\pm 0.50$	$13.13^{a}\pm 1.20$	$7.11^{a}\pm 1.17$	$6.42^{c}\pm 1.59$

Note: Mean values bearing different superscripts in the same column differs significantly ($p<0.05$) ± Standard deviation

The moisture content in the infected fruits (24.74% for *Dothideales* sp, 17.96% for *Aspergillius aflatoxiformans*, and 19.22% for *Apotrichum* sp) was lower than in the uninfected control (23.32%). Among the fungal treatments, *Dothideales* sp showed the highest moisture content. The ash content in the control (9.14%) was significantly higher than in the infected fruits. Among the infected fruits, *Aspergillius aflatoxiformans* showed the highest ash content (1.89%).

Crude lipid content was significantly lower in infected fruits than in the control, with *Aspergillius aflatoxiformans* having the lowest lipid content (28.11%), while the control had the highest (45.48%). Crude fiber content was much lower in infected fruits (2.42% for *Dothideales* sp, 3.94% for *Aspergillius aflatoxiformans* and 2.85% for *Apotrichum* sp) compared to the control (13.13%).

Crude protein content was significantly lower in the infected fruits (1.77% for *Dothideales* sp, 2.13% for *Aspergillius aflatoxiformans*, 2.08% for *Apotrichum* sp) compared to the control (7.11%).

Carbohydrate content was significantly higher in the infected fruits (47.98% for *Dothideales* sp, 45.97% for *Aspergillius aflatoxiformans*, and 48.66% for *Apotrichum* sp) compared to the control (6.42%).

Table 2 presents the mineral content of Iron (Fe), Zinc (Zn), Copper (Cu), Magnesium (Mg), and Sodium (Na) in African Elemi fruits, comparing infected fruits with uninfected controls. *Dothideales* sp*, Aspergillius aflatoxiformans,* and *Apotrichum* sp fungal isolates were tested against the control (uninfected fruits). The results indicate significant differences ($p<0.05$) in mineral concentrations across treatments, with the control showing higher mineral levels in almost every parameter compared to the infected fruits. The control had significantly higher iron content (18.85 mg/l) compared to all infected treatments. Among the fungal isolates, *Dothideales* sp had the lowest iron concentration (2.14 mg/l). The control again showed the highest zinc concentration (6.53 mg/l), while *Dothideales* sp had the lowest zinc levels (1.36 mg/l). Other fungal isolates (*Aspergillius aflatoxiformans* and *Apotrichum* sp) also showed lower zinc concentrations compared to the control.

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Table 2: Mineral Content of Infected and Uninfected Fruits of Africa elemi

Fungal Isolate	Iron (Fe) (mg/l)	Zinc (Zn) (mg/l)	Cupper (Cu) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)
Dothideales sp	2.14^{b}±0.56	1.36^{b}±0.31	3.01^{a}±0.02	4.87^{b}±0.63	0.58^{b}±0.37
Aspergillius aflatoxiformans	3.68^{b}±1.63	1.87^{b}±1.30	4.54^{a}±1.39	5.73^{b}±1.72	0.21^{b}±0.24
Apotrichum sp	4.86^{b}±1.30	2.70^{b}±1.66	4.15^{a}±1.21	5.02^{b}±0.11	1.00^{b}±0.62
Control/ Uninfected	18.85^{a}±3.42	6.53^{a}±1.85	4.21^{a}±1.33	9.32^{a}±2.51	10.43^{a}±1.69

Note: Mean values bearing different superscripts in the same column differs significantly ($p<0.05$) ± Standard deviation

Copper content did not show significant differences between the fungal isolates and the control, with *Dothideales* sp (3.01 mg/l) having the highest copper concentration among the infected fruits, closely followed by *Aspergillius aflatoxiformans* (4.54 mg/l) and *Apotrichum* sp (4.15 mg/l), with the control having 4.21 mg/l. Copper concentrations were relatively stable, although the control still had slightly higher values.

The control exhibited the highest magnesium content (9.32 mg/l), significantly higher than all the infected fruits. Among the fungal isolates, *Aspergillius aflatoxiformans* had the highest magnesium content (5.73 mg/l), followed by *Apotrichum* sp (5.02 mg/l) and *Dothideales* sp (4.87 mg/l). Sodium content was significantly higher in the control (10.43 mg/l) compared to the fungal treatments. Among the fungal isolates, *Aspergillius aflatoxiformans* had the lowest sodium content (0.21 mg/l), followed by *Dothideales* sp (0.58 mg/l) and *Apotrichum* sp (1.00 mg/l).

Discussion

This study has revealed theeffect of fungal infection on the nutrient composition and mineral content of Infected and Uninfected Fruits of *Canarium schweinfurthii* (African elemi). The moisture content of African elemi fruits infected with fungal isolates (*Dothideales* sp *Aspergillius aflatoxiformans* and *Apotrichum* sp) was lower than that of the uninfected control, which suggests that fungal infection may influence water retention in the fruit. Fungal infections in fruits can significantly impact their water regulation mechanisms, leading to lower moisture content. This phenomenon can be attributed to two primary factors: increased transpiration or evaporation and enzymatic degradation of water-retaining structures. *Dothideales* sp had the highest moisture content among the infected fruits, while the *Aspergillius aflatoxiformans* showed the lowest.

Studies carried out by Prusky and Sionov, (2021) and Bano *et al*., (2023), reported that fungal pathogens often induce metabolic activities that can elevate the transpiration rates in infected fruits. As fungi grow and proliferate, they can alter the physiological state of the fruit, leading to increased water loss through evaporation. This is particularly evident as the fruit ripens and becomes more susceptible to fungal colonization, which can enhance the permeability of the fruit's skin, allowing for greater water loss. This aligns with the data where fungal infection tends to lower moisture content.

In addition to affecting transpiration, fungal infections can also lead to the enzymatic breakdown of polysaccharides and other structural components within the fruit. Pathogenic fungi produce a variety of hydrolases, such as pectin methylesterases and cellulases, which degrade the cell walls and other water-retaining structures in the fruit (Alkan and Fortes, 2015; Bano *et al*., 2023). This degradation not only compromises the fruit's integrity but also contributes to a decrease in its overall moisture content. The release of reactive oxygen species (ROS) and other metabolites during fungal growth further exacerbates oxidative stress in fruit tissues, leading to additional cellular damage (Wang *et al.,* 2019; Guo *et al.,* 2023). Ash content reflects the total mineral composition of the fruit. The low ash content in infected fruits suggests that fungal infection might affect the uptake and utilization of minerals by the plant. Fungi may either sequester certain minerals or disrupt the plant's transport systems for nutrients, leading to lower mineral concentrations in the fruit. This is in agreement with the work carried out by Doehlemann *et al.*, (2017) and Tripathi *et al.,* (2022). They found out in their different studies that fungal pathogens can alter the mineral composition in infected plants, often depleting essential minerals like calcium and magnesium, which can lower ash content.

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However, *Aspergillius aflatoxiformans* having the highest ash content among infected fruits could indicate that this fungal isolate either did not affect the mineral uptake pathways as much or it might be utilizing the fruits in a way that leaves more mineral residues.

Lipids are crucial components of plant membranes and play vital roles in energy storage, signaling, and structural functions (Yu *et al.*, 2021; Moreau and Bayer, 2023; Creative Proteomics, 2025). As such, understanding lipid metabolism and composition is essential for optimizing plant lipid content for nutritional and industrial purposes. The reduced lipid content in the infected fruits could be due to fungal consumption of lipids during the infection process (Griffiths *et al*., 2023).

Fungi are known to break down stored lipids for energy or to create fungal structures. Additionally, lipids are important in plant defense mechanisms, and their depletion may be a result of a compromised immune response due to fungal invasion (Beccaccioli *et al*., 2019). *Aspergillius aflatoxiformans* dramatic reduction in lipids could be due to a more aggressive or metabolically active fungus that requires more lipids for its growth (Keymer *et al*., 2017; Beccaccioli *et al*., 2019; Kuźniak and Gajewska, 2024). Some studies, such as Rella *et al*. (2016), Pan *et al*. (2018) and, Gołębiowski *et al*. (2020), have suggested that fungal infection might alter lipid composition by increasing certain types of fatty acids. This could be due to the fact that some fungal species might induce the biosynthesis of lipids in the host fruit as part of their infection strategy, leading to increased lipid content in infected tissues.

The increase in carbohydrate content in the infected fruits might be due to a shift in metabolism caused by the fungal infection. Fungal pathogens often manipulate host plant metabolism to create an environment favorable for their growth and survival resulting in the breakdown of complex compounds (such as lipids and proteins) into simpler sugars, which might accumulate in the fruit (Divon and Fluhr, 2007; Fernandez *et al*., 2014; Zeilinger *et al* 2016).

Additionally, this could be a response by the plant to the stress of infection, where it produces more carbohydrates as an energy reserve (Yang *et al*., 2021; Bashir *et al*., 2021; Jeandet *et al*., 2022; Kopecká *et al*., 2023).

Given that the *Apotrichum* sp had the most carbohydrate content; it may be using other nutrients less actively and leaving more sugars behind (Pearson, 2023; Morales and Brown, 2024). Generally, Chukunda and Offor (2015 a, b); Pepple et al (2016); Chukunda et al (2015); Ukioma et al (2012) in their earlier findings reported that the involvement of fungal pathogens in fruits had caused significant reduction in nutrient and mineral content of African pears and African bread fruits sold in Port Harcourt metropolis.

Iron is a vital mineral or micronutrient that plays a key role in several enzyme-driven processes in plants, including photosynthesis and respiration (Morrissey and Guerinot, 2009; Kobayashi and Nishizawa, 2012; Marschner, 2012). When we observe a drop in iron levels in infected fruits, it could mean that fungi are either competing with the plant for this nutrient or even hindering the plant's ability to absorb it. In fact, some fungi release siderophores compounds that tightly bind iron thereby reducing the amount available to the host plant (Haas, 2003; Schrettl *et al*., 2007; Morrissey and Guerinot, 2009). Notably, *Dothideales* sp was found to cause the most pronounced iron depletion, which might indicate that it aggressively consumes iron or severely impairs the plant's iron uptake. Renshaw *et al.* (2002); Haas *et al.* (2008); and Pandey, (2023) in their studies explain that fungi can dramatically drain a plant's iron reserves by secreting these siderophores, effectively sequestering the iron away from the plant. However, Smith and Read (2008) observed that some fungal pathogens may actually increase the bioavailability of iron in the host by altering root architecture or symbiotic interactions with beneficial microbes, which could explain higher iron content in some cases of infection.

Zinc is a critical micronutrient that supports various plant functions, notably in enzyme catalysis and protein synthesis (Sadeghzadeh, 2013; Cabot *et al*., 2019; Saleem *et al*., 2022). The observed decrease in zinc levels in infected fruits may suggest that fungal pathogens are either competing for zinc or interfering with the plant's ability to absorb it. This concept is supported by Marschner (2012), who noted that many fungal species compete with plants for essential minerals such as zinc, leading to reduced nutrient levels in infected tissues. Copper is indispensable for plant health, serving as a crucial catalyst in oxidative reactions while also playing a central role in the electron transport chain essential for photosynthesis.

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This dual function underscores its importance in maintaining energy production and overall plant vitality (Yruela, 2005; Xu *et al*., 2004). The consistent copper levels observed across treatments indicate that fungal pathogens may not be as effective in competing for copper compared to other nutrients, or alternatively, that the plant's mechanisms for maintaining copper balance are particularly robust. This finding underscores the resilience of the plant's copper homeostasis in the face of biotic stress. García-Santamarina and Thiele (2015) and Robinson *et al.* (2021) have shown that, in some instances, fungal pathogens may enhance the bioavailability of copper in plants.

However, in most cases, fungal infections appear to have little to no significant impact on copper levels within the plant. While these findings suggest that fungal interactions with copper may be context-dependent, they challenge the assumption that pathogens always compete for or sequester this essential micronutrient.

Magnesium plays a pivotal role in plant life, serving as the core element of the chlorophyll molecule (Ahmed *et al.,* 2023; Salman *et al.,* 2023). This central position is essential because it enables chlorophyll to effectively capture sunlight, driving the photosynthetic process that converts light energy into the chemical energy required for plant growth and survival. The observed decrease in magnesium levels in infected fruits may signal an interruption in photosynthetic processes, potentially due to fungal pathogens extracting magnesium for their own metabolic needs.

Interestingly, *Aspergillius aflatoxiformans* exhibited the highest magnesium content among the infected fruits, suggesting that this particular fungus might utilize a distinct metabolic strategy or engage in a unique interaction with the fruit that promotes magnesium retention. Tripathi *et al*. (2022) and Papadakis *et al.* (2023) reported that fungal infections often lead to a decline in magnesium levels, primarily because magnesium is crucial for maintaining chlorophyll, which degrades during infection. Interestingly, their findings also indicate that, in some instances, the impact on magnesium is less severe than the depletion observed for other minerals.

Sodium is generally found in plants at relatively low concentrations, yet its role is far from insignificant. It plays a vital part in maintaining osmotic balance within plant cells and contributes to the stabilization of cellular structures, supporting overall plant health and resilience, especially under stress conditions (Bloodnick, 2014; Santiago-Rosario *et al.,* 2021; University of California Agriculture and Natural Resources, 2021). The observed decrease in sodium levels in the infected fruits suggests that fungal pathogens may disrupt the plant's ability to regulate sodium properly.

This interference could extend to changes in root system dynamics, potentially impeding the plant's capacity to absorb and transport sodium effectively. Frąc *et al*., (2018); Nie *et al*., (2024) and Chaudhary *et al*. (2025) found that certain fungal species have the ability to impact the ion balance within plants, which can result in either the depletion or accumulation of sodium in plant tissues. The specific outcome largely depends on the characteristics of the fungal infection and its interaction with the plant's physiological processes.

Conclusion

The study demonstrated that fungal infection has a profound impact on the nutritional quality of *Canarium schweinfurthii* fruits. Infected fruits showed marked reductions in crude protein, lipids, fiber, and essential minerals such as iron, zinc, magnesium, and sodium, while carbohydrate levels increased significantly. These changes indicate that fungal pathogens utilize or degrade vital nutrients, thereby diminishing the dietary and economic value of the fruit. Copper appeared less affected, suggesting selective nutrient depletion by different fungal species. Overall, fungal infection compromises the nutritional and mineral integrity of African elemi fruits, underscoring the need for improved postharvest management practices to maintain their quality and safety for human consumption.

Recommendations

1. Additional studies should investigate the mycotoxin profiles of infected fruits to evaluate potential food safety risks and health implications.
2. Application of safe antifungal treatments or biocontrol agents should be explored to reduce infection rates and extend shelf life.

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3. Routine quality assessment of African elemi fruits is recommended to ensure they meet dietary standards, especially for vulnerable populations relying on them as a food source.
4. Extension services should sensitize local farmers and consumers on the nutritional losses associated with fungal infection and promote best practices in harvesting, handling, and storage.
5. Farmers and traders should adopt improved storage methods such as refrigeration, drying, and packaging in sterile conditions to minimize fungal colonization.

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