**OCCURRENCE OF STORAGE FUNGI IN DRIED GINGER (*Zingiber* *officinale*) AND THEIR IMPACT ON ITS NUTRITIONAL COMPOSITION**

**ABSTRACT**

Ginger (*Zingiber officinale*) is a crop well known for its spicy and medicinal rhizome Fungi rots can cause spoilage and subsequent reduction in quality of dried ginger during storage. Rot fungi identification and management are crucial for sustainable cultivation of ginger and storage. This study was carried out to identify various fungi causing dry ginger rot and their effects on its proximate and phytochemical composition. Dried ginger samples (n=10) were purchased from two main markets in Umuahia from which fungi were isolated and identified. Proximate and phytochemical content of fungi-inoculated ginger were also determined. Experiment design was CRD in triplicates. ANOVA at α0.05 was performed for data. *Rhizopus* sp. had highest incidence (38%), followed by *Fusarium oxysporum* (19%), *Trichoderma* sp (17%). *Rhizopus* sp. and *F.* oxysporum caused highest rot percentage (50%), while *Aspergillus* *niger* and *A. flavus* caused moderate rot (20-40%). Fungi significantly altered phytochemical and proximate contents of inoculated ginger samples. *Fusarium Solani* and *Rhizopus* sp reduced saponin content, while *Rhizopus* sp, *A. flavus*, *F. Solani* significantly reduced flavonoid and tannin content. Phenol was reduced in *F. oxysporum, A. ochraceous* and *Rhizopus* inoculated samples. Crude fiber and ash were significantly lower in fungi-inoculated samples than control. Fungal contamination significantly alters composition of dried ginger and affect its quality.

Key words: Dried ginger, proximate composition, phytochemical content, fungi rots

**1.0 INTRODUCTION**

Ginger (*Zingiber officinale*) is a flowering plant known for its rhizome, commonly used as a spice and for medicinal purposes. Ginger belongs to the family Zingiberaceae. This family includes other aromatic plants like turmeric. Its flavor is pungent and slightly sweet, contributing to its widespread use in culinary applications. Ginger has been studied for its potential anti-inflammatory and antioxidant effects, as well as its traditional use in alleviating nausea and digestive issues. Ginger is widely used for its distinctive flavor and potential health benefits. Its spicy aroma is mainly due to presence of ketones, especially the gingerols, which appear to be the primary component of ginger studied in much of the health-related scientific research. Indians and Chinese are believed to have produced ginger as a tonic root for over 5000 years to treat many ailments, and this plant is now cultivated throughout the humid tropics, with India being the largest producer. Historically, ginger was traded extensively along the ancient spice routes and became one of the first spices to be internationally traded. This contributed to its widespread distribution and popularity in different cuisines and home remedies. Today, ginger is commercially grown in many countries, with the major producers being India, China, Indonesia, Nepal, Thailand, and Nigeria (Bode and Dong, 2011; Chandra, 2018).

Ginger is used in numerous forms, including fresh, dried, pickled, preserved, crystallized, candied, and powdered or ground. The flavor is somewhat peppery and slightly sweet, with a strong and spicy aroma. Its unique and pungent flavor adds a distinctive taste to dishes, making it a popular ingredient for cooking used in both fresh and dried forms. Ginger has been valued for its medicinal properties in traditional medicine systems. It contains bioactive compounds, including gingerols, shogaols, and zingerone, which exhibit potent antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. In addition to traditional medicine, ginger is used in herbal remedies and natural health as well as in the production of beverages such as ginger tea, ginger beer, and other ginger-infused beverages, confectionery and preservatives (Bode and Dong, 2011).

Despite the numerous benefits and popularity of ginger, it is susceptible to certain diseases and pests that can affect its growth, yield, and quality. Ginger is susceptible to various diseases such as bacterial wilt, rhizome rot, and fungal infections (Anand and Ram, 2020; Hui, and Liu, 2023; Kajal *et al.,* 2021). Disease management is crucial for a successful harvest. Fungal diseases are among the major challenges faced by ginger growers worldwide particularly during processing and storage. These diseases can cause yield losses, affect the market value of the crop, and impact export opportunities. . Improper handling and storage can lead to spoilage and reduce the quality of ginger. Adequate post-harvest practices are essential preserve ginger during storage. Therefore, understanding and managing fungal diseases is crucial for the sustainable cultivation and storage of ginger. The objectives of this study were to: to identify fungi pathogens causing spoilage of dried ginger and to evaluate the effect of fungi pathogens on nutrient composition of ginger.

**MATERIALS AND METHOD**

# Experimental Location

The experiment was carried out in the laboratory of the Department of Plant Health Management, College of Crop and Soil Sciences and fishery laboratory Michael Okpara University of Agriculture, Umudike and the laboratory ofDepartment of Toxicology of Michael Okpara University of Agriculture, Umudike.

# 3.2 Samples Collection

Dried ginger samples used in this study were purchased from two main markets in Umuahia: Orie-Ugba and Ubani where there is bulk sales of dried ginger. Five ginger samples were purchased from different traders in each of the markets. The diseased ginger was first purchased and used for isolation and identification of pathogens while fresh healthy ginger was purchased and used for pathogenicity test.Samples were collected into sterile polythene bags and taken to the laboratory for fungi isolation and identification. Each sample from a trader was collected in a separate sterile and labelled polythene bags and taken to the laboratory for studies.

# 3.3 Preparation of Culture Medium

Thirty-nine grams (39 g) of Potato Dextrose Agar (PDA) per litre of distilled water was mixed thoroughly and carefully dispensed into four sterile 250 ml conical flasks and autoclaved at 121°C/151b pressure for 15 minutes and was allowed to cool allowed to cool down to 40°C before dispensing into the Petri dishes. The prepared PDA was dispensed (15 ml) into sterile Petri-dishes and allowed to solidify after adding 2 drops of lactic acid to the sterile PDA to prevent bacterial contamination (Obani and Ikotun, 2014).

# 3.4 Isolation and Identification of the Fungal Pathogens

Some dried ginger pieces were selected and surface sterilized with 1% sodium hypochlorite and three changes pf sterile distilled water to remove surface contaminants. They were then cut into smaller pieces of 3mm using surgical blade, 5 pieces picked with forceps and plated in Petri dishes containing a solidified PDA. The plating was done in a closed and sterilized inoculation chamber. After plating, the Petri dishes were incubated for 7 days at room temperature. Then they were examined under microscope (40x) to identify the fungi growth from the ginger rhizome for the period of incubation. Fungi identification was done by using microscope to examine the colony characteristics of the fungal pathogens identified based on their colony. Observations were recorded on colony colour, structure, shape, size, pigment and structure of mycelium, its branching, presence of Conidiophores, Sclerotia and shape were compared with literatures. The morphology and characteristics of the pathogens was compared with structures in relevant literatures (Alexopoulos *et al*., 2002; Barnett and Hunter, 1999).Distinct organisms were counted, sub cultured and identified and used for pathogenicity test.

**Determination of percentage incidence of the fungal isolates**

This was done to determine the percentage occurrence of the different fungi isolates. The total number of each isolate in all samples were obtained against the total number of the isolates in all the samples screened. Frequency of occurrence was determined as follows:

$$Percentage incidence (\%)=\frac{No of observation in which a fungus appeared}{Total nunber of fungal isolates } X \frac{100}{1}$$

 (Obani *et al*., 2021).

 **3.5 Pure Culture of Isolated Fungi**

This was done by getting the identified organism isolated from diseased ginger to grow all alone in the medium without any contamination. An inoculation needle was sterilized and used to pick the fungi from the pieces of ginger tissues that were earlier plated and transferred into the Petri dishes containing PDA medium. They were incubated for about 7 days at room temperature. Any plate that was found contaminated by any other organism was discarded and the fungus sub cultured until axenic cultures were obtained.

# 3.6 Pathogenicity Study of the Isolated Fungi

The pathogenicity test of the isolates was carried out according to Amadioha and Uchendu (2003) and Amadioha (2004). The purpose of this study was to know if the fungi isolated from the dried ginger can cause rot in the healthy ginger when they were inoculated. Clean ginger rhizomes were selected and surface sterilized with 1% sodium hypochlorite and put in Petri dishes lined with moist sterilized cotton wool. A sterilized inoculation needle was used to pick out inoculum from the 7day old fungi cultures and used to inoculate the ginger. The control was inoculated with ordinary agar without any fungi, these served as control. All the inoculated ginger were incubated for 15 days at room temperature and observed for rot development. . After colonization by fungi, re-isolation was made from kernels which showed symptoms of rot on a fresh plate containing PDA and incubated again for 5 days at 28°C to confirm pathogenicity. The culture was compared with the original isolate. The isolates that caused rot were identified as pathogenic organisms causing the rot of stored dried ginger. The experiment was laid out in completely randomized design with three (3) replicates. Disease severity to determine the extent of rot development in each ginger was determined using a 0 -5 scale as follows:

0=No infection, 1-20 % infected = slight infection, 21-40 % infected = moderate infection, 41-60 % infected = severe infection, 61-80 % infected = highly infected, 81-100 % infected = complete rot**.**

**3.7** **Proximate analysis:**

Moisture content was determined by drying fresh sample to constant weight in a hot air circulating oven at 100oC. Proximate compositions which included percentage moisture, fat, crude protein, fibre and ash were determined according to the standard methods of the AOAC (1984, 2005, 2010).

The total percentage carbohydrate content was determined by the difference method (Onyeike *et al,* 1995), which involved adding the total values of crude protein, crude fat, crude fibre, moisture and ash constituents of the sample and subtracting it from 100. The value obtained is the percentage carbohydrate constituent of the sample.

# 3.8 Statistical Analysis

Data on disease incidence and proximate composition collected were analyzed using Statistical Package for Social Sciences (SPSS) version 2023 analysis of Variance (ANOVA) and means were separated using least significant difference (LSD) at 5 % probability level.

# RESULTS

**Incidence of fungi species isolated from dried ginger samples.**

The incidence of different fungi species isolated from market dried ginger samples is shown in figure 1. *Aspergillus* species (*A. flavus, A. niger*, *A. tamari, A. ochraceus, A. terreus, Strain SBG*), *Fusarium* species (*F. solani* and *F. oxysporium*), *Trichoderma* spand *Rhizopus* were isolated and identified from dried ginger samples (Plates 1 and 2). *Rhizopus*sp had the highest percentage incidence (38 %) followed by *F. oxysporium* (19 %), then *Trichoderma* sp (17 %), *A. niger* (7 %), *A. flavus* (5 %)*, A. ochraceus* (4 %), *F. solani* (4 %), *Strain SBG* (3 %), *A. tetreus* (2 %), while *Penicillium* sp recorded the least incidence (1 %) (Figure 1).

## Pathogenicity of different fungi on ginger

Table 1 shows the rot percentage of various fungi isolated and identified from different ginger samples. *Rhizopus* sp and *F. oxysporium* caused 50% rot on inoculated healthy ginger samples, followed by A. niger (40 %), A. ochraceous (30 %), *A. flavus* (20 %), *F. solani* (20 %), *Strain SBG* (20 %), *A. Tamari* (20 %), while *Trichoderma* sp *A. terreus*, *Penicillium* sp caused 10 % rot with a rating of 1. The control caused no rot and had 0 rating.



Figure 1: Percentage incidence of fungal species isolated from dried ginger samples

\* For each bar the vertical line represents the standard error of means**.**

**Table 1: Pathogenicity of different fungi on ginger**

|  |  |  |
| --- | --- | --- |
| **fungi**  | **Rot (%)**  | **Rating**  |
| ***Rhizopus* sp**  | 50  | 3  |
| ***Aspergillus flavus***  | 20  | 1  |
| ***Aspergillus niger***  | 40  | 2  |
| ***Fusarium solani***  | 20  | 1  |
| ***Fusarium oxysporium***  | 50  | 3  |
| ***Trichoderma sp***  | 10  | 1  |
| ***Aspergillus ochraceous***  | 30  | 2  |
| ***Aspergillus terreus***  | 10  | 1  |
| ***Penicillium sp***  | 10  | 1  |
| ***Strain SBG***  | 20  | 1  |
| ***Aspergillus tamari***  | 20  | 1  |
| **Control**  | 0  | 0  |

 \*Rating Scale: 0 = No infection**,** 1-20 % = slight infection, 21-40 % = moderate infection, 41-60 % = highly infected, 61-80 % = severely infected, 81 = 100 % complete rot/infection.



 **Plate 1: Different fungi growing on dried ginger rhizomes plated on PDA**



 **Plate 2: Pure cultures of some of the fungi isolated from dried ginger samples; (a) *Aspergillus flavus (*b). *Fusarium solani (*c). *Fusarium oxysporium (*d). *Aspergillus niger (*e). *Rhizopus* sp**

**Effect of different fungi on photochemical (mg/100 g) content of dried ginger samples.**

The effect of different fungi on the saponin, flavonoid, phenol and tannin composition of inoculated healthy ginger samples is shown in Table 2. Saponin content was significantly (p=0.05) lower in samples inoculated with *Fusarium Solani* (0.37mg/100g) than the control (0.54 mg/100g). *Rhizopu*s sp also recorded lower saponin composition than the control. However, other fungi inoculated samples had higher saponin (0.58-0.81mg/100g) than the control samples. *Rhizopus* sp (3.07mg/100g), *A. flavus* (2.27mg/100g), and *F. Solani* (2.57mg/100g), significantly reduced flavonoid content compared to their respective controls; a similar trend was recorded for tannin *Rhizopus* sp (0.97mg/100g), *A. flavus* (0.59mg/100g), and *F. Solani* (0.76mg/100g). Phenol was lower in *F. oxysporium* (1.08 mg/100g), *A. ochraceous* (1.36 mg/100g)and *Rhizopus* (1.49 mg/100g)inoculated ginger samples than the control. (Table 2).

Table 2: Effect of different fungi on **phytochemical** (**mg/100g)** content of **dried ginger samples**

|  |  |
| --- | --- |
|   | Phytochemical content mg/100g |
| Fungi species | Saponin | Flavonoid | Phenol | Tanin |
| *Aspergillus flavus* | 0.81 | 2.27 | 2.77 | 0.59 |
| *Aspergillus niger* | 0.58 | 3.74 | 2.03 | 0.81 |
| *Aspergillus ochraceous* | 0.73 | 2.39 | 1.36 | 1.18 |
| *Fusarium oxysporium* | 0.68 | 3.33 | 1.08 | 1.20 |
| *Fusarium Solani* | 0.37 | 2.57 | 1.89 | 0.76 |
| *Rhizopu*s sp | 0.50 | 3.07 | 1.49 | 0.97 |
| Control | 0.54 | 3.54 | 1.84 | 1.08 |
| LSD (p≤0.05 | 0.06 | 0.97 | 0.08 | 0.04 |

**Effect of different fungi on proximate composition of dried ginger samples.**

Table 3 presents the effect of different fungi on the proximate content of inoculated ginger samples. Moisture content was higher infungi-noculated ginger samples (8.74-11.37 %) than the control (8.68mg/100g). *A. niger* had the highest moisture content of 11.37 %, followed by *A. flavus* (10.73 %), while control (8.68 %) had the least moisture content percentage. Crude protein was lowest in samples inoculated with *A. flavus although* not significantly different from the control (5.34%),while *F. solani* (5.92 %) recorded the highest crude protein content. Ginger inoculated with *A. ochraceous* (5.55%)and *F. Solani* (4.38 %)had lower fat content than the control(4.58 %). Crude fibre content was highest in un-inoculated ginger sample (10.13 %) followed by *F. oxysporium* inoculated sample (9.32 %), while *A. ochraceous* had the lowest (8.1 %). Crude fiber (8.55-9.32 %) and ash (4.35-4.95 %) were significantly lower in fungi-inoculated samples than their controls 10.13 % for crude fibre and 6.87 % for ash; except *A. ochraceous* inoculated ginger samples where ash (6.93 %) was slightly higher than the control (6.87 %) (Table 3)

Table 3: Effect of different fungi on proximate composition of dried ginger samples

|  |  |
| --- | --- |
| Fungi species | Proximate content % |
| Fungi | Moisture | Crude protein | Fat | Crude fibre | Ash |
| *Aspergillus flavus* | 10.74 | 5.12 | 4.67 | 9.13 | 4.95 |
| *Aspergillus niger* | 11.37 | 5.38 | 4.95 | 8.75 | 4.72 |
| *Aspergillus ochraceous* | 9.68 | 5.57 | 4.55 | 8.14 | 6.93 |
| *Fusarium oxysporium* | 8.74 | 5.74 | 4.79 | 8.55 | 4.35 |
| *Fusarium Solani* | 9.49 | 5.92 | 4.38 | 9.32 | 4.86 |
| *Rhizopu*s sp | 8.95 | 5.86 | 4.69 | 8.49 | 4.47 |
| Control | 8.68 | 5.34 | 4.58 | 10.13 | 6.87 |
| LSD (p≤0.05 | 0.96 | 0.06 | 0.07 | 0.05 | 1.22 |

 DISCUSSION

The result of this study indicates that *Rhizopus* sp was the most prevalent fungus in dried ginger samples, accounting for 38% of the total fungi incidence. This high incidence could be attributed to the environmental conditions during storage, as *Rhizopus* species are known for their rapid growth and ability to thrive in various substrates, particularly organic materials. This result does not conform to the study by Meenu and Kaushal (2017) who reported that the destructive and versatile pathogen of *Aspergillus* species and *Penicillium* are common pathogens and most abundant fungi species on the farm and in storage causing rot of ginger rhizomes. The presence of of upto 11 fungi genera highlights the diversity of fungal contamination in dried ginger, which can affect its quality and safety. The lower incidences of species like *Aspergillus niger* (7%) and *A. flavus* (5%) suggest that while they are present, their growth may be inhibited by factors such as unfavorable storage conditions and ant nutritional content of ginger. *Penicillium* sp, with the least incidence may indicate either a less favorable environment for its growth or competition from other, more dominant fungi (Dohroo, 2005). Report by Senapati and Ghose (2005) conforms with the result of this study that fungal pathogens infect ginger and thereby limit its production and use.

Rot percentages caused by different fungal species on ginger samples sheds light on the varying pathogenicity of these fungi. *Rhizopus* sp. and *Fusarium oxysporum* were recorded to be the most aggressive pathogens, both causing a significant 50%, this agrees with the report of Rahman *et al*., (2009) that ginger diseases are often related to *F. oxysporum* andotherfungi species . These fungi are known for their ability to cause substantial damage to plant tissues. *Rhizopus* species are particularly notorious for causing soft rot, and their ability to infect ginger highlights the importance of managing storage conditions to avoid such fungal rot outbreaks. Similarly, *Fusarium oxysporum* is a well-established soil-borne pathogen that can lead to root and wilt diseases in various crops, including ginger; whose damage may extend to post harvest stage if not properly handled before storage. The high rot percentage associated with these fungi indicates they pose a serious threat to ginger health, quality and usage, especially under conditions favorable for fungal growth. In contrast, *Aspergillus niger* caused 40% rot with a severity rating of 2, suggesting a moderate level of pathogenicity. *A. nige*r is a common fungus found in decaying organic matter and can produce mycotoxins that affect both plant quality and food safety. While not as damaging as *Rhizopus* or *Fusarium oxysporum*, its ability to induce substantial rot points to its role in post-harvest spoilage. Mycotoxin contamination, which is a concern with *A. niger,* could also compromise the marketability of ginger if it’s not properly managed. The result of this finding is in agreement with the report of He *et al*. (2024) the the fungi recoreded in this study are the prevalent fungi causing postharvest decay of crops. *Fusarium solani* also caused 20% rot, earning a rating of 1. While this fungus is less pathogenic than *Fusarium oxysporum*, it is still capable of causing root rot in many crops, including ginger (Srinivas *et al.,* 2023). The presence of *F. solani* at this level indicates that *Fusarium* species, in general, are a concern for ginger production.

Other species of *Aspergillus,* such as *Aspergillus ochraceus* and *Aspergillus flavus,* also contributed to rot of dried ginger, though at lower levels. *A. ochraceus* is notable for producing ochratoxin, a potent mycotoxin that can contaminate crops, and *A. flavus* is very famous for its production of aflatoxins (Obani and Ikotun, 2014), which are hazardous to human health. Though these fungi caused less rot compared to the more aggressive species, their presence in the ginger samples suggests that their role in contamination and post-harvest spoilage should not be overlooked. Their potential to produce harmful toxins further underscores the importance of controlling fungal infections during storage and handling. Strains like *Strain SBG,* *Aspergillus tamarii,* and *Penicillium* sp. caused a relatively low rot (20%). These fungi tend to be less aggressive but can still contribute to post-harvest rot under certain conditions. For example, *Penicillium* species are known to cause spoilage of stored crops, and although their impact is minor in this study, their role in ginger deterioration shouldn't be disregarded. Interestingly, *Trichoderma* sp. and *Aspergillus tereus* caused only 10% rot. *Trichoderma* is typically a beneficial fungus, often used in agricultural practices as a biocontrol agent against other plant pathogens. However, some *Trichoderma* species can act as opportunistic pathogens under certain circumstances, which could explain its minimal role in ginger rot. *A. tereus,* while less common, is another fungal species that could potentially contribute to rot under specific environmental conditions, though its impact was minimal in this study. The control group, which was free from fungal inoculation, showed no rot, confirming that the observed damage was indeed caused by the inoculated fungi. This serves as a baseline and reinforces the pathogenic nature of the fungi involved in the study (Islam *et al.,* 2019).

From the result of this study, there was a significant variations in the phytochemical composition of inoculated ginger samples. The highest saponin content was observed in samples inoculated with *Aspergillus flavus* (0.81 mg/100g), suggesting that this fungus may influence the biosynthesis of saponins, which have known health benefits. Conversely, *F. oxysporium* also showed a high saponin level (0.68 mg/100g), indicating its potential role in phytochemical production. The flavonoid content was highest in samples inoculated with *A. niger* (3.74 mg/100g), highlighting its possible contribution to antioxidant activity, which is important for both nutritional quality and health benefits. In contrast, *A. flavus* had the least flavonoid content, which could indicate a suppressive effect on flavonoid biosynthesis. Tannin content was highest in *F. oxysporium-*inoculated samples (1.20 mg/100g), which may contribute to the antimicrobial properties of ginger, while *A. niger* recorded the lowest (0.59 mg/100g), suggesting differential effects of these fungi on the biosynthesis of these compounds.

Robert *et al.*, (2017) found out in their study that fungal pathogens can alter the nutrient composition of certain plants, in this study, the highest moisture content was recorded in *A. nige*r inoculated samples (11.37 mg/100g), which may indicate that this fungus facilitates higher moisture retention, potentially leading to spoilage. Conversely, the control sample had the lowest moisture content (8.68 mg/100g), emphasizing the importance of proper storage conditions to minimize fungal growth. Crude protein content was highest in *F. solani*-inoculated samples (5.92 mg/100g), suggesting that this fungus may enhance protein accumulation in ginger, which can be beneficial for nutritional quality. *Rhizopus* sp also showed a high crude protein level (5.86 mg/100g), aligning with its dominant presence among the isolated fungi. In contrast, *A. flavus* had the lowest crude protein content (5.12 mg/100g), which might indicate its negative impact on the protein synthesis pathways in ginger. Fat content was highest in *A. niger*-inoculated samples (4.95 mg/100g), indicating that this fungus might promote lipid accumulation, which could affect the flavor profile and overall quality of dried ginger. Crude fiber content was highest in the uninoculated control sample (10.13 mg/100g), emphasizing that fungal growth can reduce the fiber content, which is essential for digestive health (Ramakraishanan,1942). The ash content and mineral content, was highest in *A. ochraceous-*inoculated samples (6.93 mg/100g). This could suggest a higher retention of minerals in the presence of this fungus compared to *F. oxysporium*, which recorded the lowest ash content (4.35 mg/100g).

**CONCLUSION**

The results of this study demonstrate that different fungi have significant impacts on both the phytochemical and proximate compositions of dried ginger samples. The predominance of certain fungi like *Rhizopus* sp and *F. oxysporium* highlights the need for effective post-harvest management strategies to mitigate fungal contamination, thereby preserving the quality and nutritional value of ginger. The variations in saponin, flavonoid, and tannin levels indicate that fungal contamination can alter the nutrient composition of ginger. There is need to implement effective storage practices to minimize moisture levels and inhibit fungal growth, monitor dried ginger for fungal contamination using rapid detection and explore management options that can inhibit the growth of pathogenic fungi while preserving beneficial phytochemicals in ginger.

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