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Antifungal Properties of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger) on Fungi Isolated from Postgraduate Student Hostels' Bathrooms, University of Benin, Benin City

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Abstract

Allium sativum (Garlic) and *Zingiber officinale* (Ginger) are herbaceous, perennial and monocotyledonous plants, with several medicinal and nutritional values. The formation and physical appearance of black mould spots and patches on walls and floors indicate the presence of fungi. The aim of this investigation was to evaluate the antifungal properties of *Allium sativum* and *Zingiber officinale* on fungi isolated from Bathrooms of the three (3) Postgraduate Student Hostels. Qualitative and quantitative studies were performed to determine the presence and concentration of the phytochemical substances which were extracted using ethanol and water. Swab samples were collected from the Bathroom walls before and after cleaning. The fungal isolates were characterized using the standard microbiological techniques. Antifungal susceptibility of 4 concentrations of each plant extracts was carried out on the isolates, the mycelia extended growth rate of each fungus were measured and the percentage mycelia growth inhibition was calculated. The fungal counts of the bathrooms' walls ranged from 0.20 ± 0.20 to $6.20 \pm 0.38 \times 10^4$ cfu/cm ^{2} before cleaning and from 0.00 ± 0.00 to $1.00 \pm 0.02 \times 10^4$ cfu/cm^2 after cleaning. The fungal isolates identified were: *Aspergillus nidulans, A. fumigatus, A. niger, A. tamarii, A. flavus, Penicillium cyclopium, P. oxalicum, Trichophyton rubrum, Microsporum* sp., *Mucor mucedo, Cladosporum* sp., *Candida albicans and Rhodotorula* sp. The ethanolic extract of *Zingiber officinale* was observed to exhibit the most antifungal potential against *Aspergillus fumigatus.* The aqueous extract showed the most potent antifungal activity of *Zingiber officinale* against *Aspergillus tamarii.* Both medicinal plant extracts showed antifungal activities in varying degrees and could be used as herbal treatments against fungi diseases.

1. Introduction

Damp environments, such as bathrooms, kitchens, toilets are known to promote the growth of fungi. The formation and physical appearance of black mould spots and patches on walls and floors indicate the presence of fungi. The species of fungi, growth medium and the conditions under

which they are cultivated and discharged all influence how quickly they develop in a given habitat. Air velocity, substrate and fungal type, relative humidity and temperature all determine the types and amounts of intact spores and fragments that are aerosolized [1]. The ventilation system in a building is a means through which fungi are dispersed into the indoor environment of a building from the outdoor environment. This can be achieved through a mechanical ventilation system that lacks a sufficient air filter for pollutants, or through a naturally ventilated building with open windows and doors, where the outdoor to indoor pollution ratio is almost at equilibrium. The unclean airways and filters of Bathrooms window can serve as a substratum for the growth of fungi owing to the accumulation of dust. Air handling unit filters analyzed (DNA-based analysis) by Luhung *et al.* [2] revealed fungi of the genera; *Aspergillus, Cladosporium,* and *Lentinus*. Dust are trapped by oil residues in ventilation ducts, which serve as a medium for the proliferation of fungi which may be dispersed through the windows into the indoor environment [1].

Medicinal plants/ herbs (like garlic and ginger) are used in herbal therapies for a variety of human illnesses and they are the primary source of medication in rural areas of underdeveloped countries [3]. Since 3,000 BC, *Allium sativum* (garlic) is a vegetable cultivated abroad that serves as spices in food and herbs in the treating various ailments. Allicin is one of the active compounds in garlic that allows it to carry out its antibacterial, antifungal, and antiviral actions, while other garlic compounds give antioxidant, hypocholesterolemia, and vasodilator properties. It also possesses anti-cancer as well as immune-modulatory properties [4]. Sulphur-derived chemicals such as diallyl sulphide are formed after production of allicin. As a result of this fact, several researchers hypothesized that the antibacterial activity is caused by a mixture of sulphur and sulphur-related chemicals [5].

Zingiber officinale (ginger), a member of the Zingiberaceae family with tuberous or non-tuberous rhizomes, is known for its strong aromatic and medicinal properties and has been used as a medicinal plant for the treatment of some illnesses like constipation, sprains, arthritis among others [6]. Ginger contains minerals (iron, calcium and phosphorous) and vitamins (thiamine, niacin and vitamin C and riboflavin). The type, variety, farming conditions, curing procedures, drying and storage conditions all influence the composition [7].

Procedures involving exclusion of the pharmacon from plant materials either by physical techniques or been solubilized in an appropriate solvent such as alcohol or water is known as extraction. It is the isolation of medicinally active components of plant or animal tissues in the pharmaceutical industry [8]. The existence of bioactive chemicals in plant extracts has been associated to antimicrobial properties, which protects the plant from microbial infections while also displaying antimicrobial capabilities on these microorganisms [7].

Due to their increased antioxidant activity, reducing capabilities and free radical activity, phytochemical substances recovered in polar solvents are more relevant in the pharmaceutical industries [9]. Alkaloids are heterocyclic organic nitrogen molecules with a variety of chemical configurations, they are base-forming water-soluble salts produced from an amino acid. They can be found in several parts of the plant, but certain compounds are restricted to a specific type [10]. Plant phenols are important natural biological compounds because of their broad range of therapeutic potential. They have an aromatic ring in their molecular structure with one or more hydroxyl groups, and they range from simple or complexed molecules. Plant phenolic acids are divided into several classes depending on structural properties, the most prevalent of which being flavonoids, phenolic acids, and non-flavonoids [10]. In terms of human health, they have shown to be effective in the treatment of a variety of chronic disorders, including bacterial infection, cancer, diabetes, and cardiovascular disease. Plant flavonoids are the 2-phenyl-benzo-γ-pyrane

nucleus with two benzene ring-containing plant phenolic compounds with promising antimicrobial activities. Many classes of flavonoids like flavanones and flavonols have been identified to inhibit growth of microorganisms [11].

Essential oils are a blend of many low-mass natural compounds or phytochemicals from plants. They are well-known for their significant antibacterial properties and are frequently utilized in traditional medicine. Lipophilic and volatile plant compounds can be extracted from a variety of plant components, like fruits and flowers and they are restricted to just a few plant families. Terpenes, terpenoids, aliphatic aldehydes, aromatic, and phenols, are the principal sources. Short-chain aliphatic hydrocarbon derivatives are also classified as essential oils and they are a reservoir of antibacterial agents [12, 13].

2.0. Methodology

The study area for sampling were three postgraduate (Akingbola, Hall 7 and intercontinental) hostel bathrooms, University of Benin, Benin City. Analysis was carried out in the University of Benin Microbiology Department Laboratory. Samples were collected from the walls of the hostels' bathrooms using swabs sticks, before and after cleaning of the bathrooms. A solution of 1% glucose peptone diluent was labelled and used to moisten the swab and 5 cm of the bathroom's wall was swabbed systematically in two directions at 90° to one another while slowly rotating the swab around its long axis to give an area of 25 cm^2. The cotton end was then placed into the diluent bottle and snapped off into the 10ml bijou bottle containing 1% glucose peptone (1 g of glucose in 100 ml of peptone water) and transferred to the laboratory and then incubated for 24 hours after which a ten–fold serial dilution was carried out on each sample before inoculation [14, 15].

2.1. Collection of Plant Materials

Zingiber officinale (ginger) rhizomes and *Allium sativum* (garlic) bulbs were purchased from the New Benin market in Benin City, Edo State, Nigeria.

2.2. Preparation and Sterilization of Media and Materials

Potato dextrose agar was prepared according the manufacturer's instruction. The medium and glassware (test tubes and conical flasks) were sterilized for 15 minutes in an autoclave at 121°C. The agar media were supplemented with 25mg/ml chloramphenicol [16].

2.3. Screening of *Allium sativum* and *Zingiber officinale* for their biochemical components

To evaluate the real amount of bioactive components present in their extracts, a quantitative phytochemical screening of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger) was carried out aseptically. The phytochemicals determined were Alkaloids, Saponins, Flavonoids, Phenols, Tannins, Anthraquinones, Terpenoids, Steroids and Cyanogenic glucosides [17].

2.4. Garlic and Ginger Extract

Peeled garlic cloves and peeled ginger rhizomes were washed thoroughly with distilled water, air dried and ground using an industrial blender. A 100g of each were weighed using weighing balance and saturated in 100ml of ethanol in sterile conical flask (for each medicinal plant) for 24 hrs. The mashes were then agitated by shaking with vigor to aid total extraction of active compounds. With the aid of a sterile Whatman's No. 1 filter paper, the crude extracts were filtered into a sterile conical flasks and refrigerated at 4^oC for storage. The repetition of the above extraction technique was done using distilled water as the extractive solvent [18, 19]. A two-fold serial dilution was

done in triplicates to obtain the following concentrations of the extracts: 1000 mg/ml, 500 mg/ml, 250 mg/ml and 125 mg/ml [20].

2.5. Inoculation/Enumeration

A 1 ml of each diluted sample (10^4) was dispensed into empty labelled sterile plates in triplicates. The amended sterile medium were poured aseptically into the petri dishes, allowed to solidify and incubated at 28±2℃ for 4–7 days. The heterotrophic fungal counts were enumerated and converted to cfu/cm² as shown in equation 1 below [21, 22].

$$\text{Count per swab} = \frac{C}{v(n_1+0.1n_2)d} \times n_3 \quad (1)$$

C is the sum of colonies on all plates counted; v is the volume dispensed on each plate
n_1 is the number of plates counted at the first dilution; n_2 is the number of plates counted at the second dilution; n_3 is the original volume of neat suspension

2.6. Isolation of Pure Culture

After incubation, appearance of discrete, well separated colonies in culture plates were examined for suspected fungal species based on their colonial morphology. Each distinct colony of fungi were sub–cultured into separate potato dextrose agar plate by picking minute amount of hyphae or spores onto a non-inoculated solidified agar plate at the center of the agar plate so as to support best colonial growth and spore formation of the fungi. The incubation of the plates was done at 28± 2°C. Fungal growth (pure culture) were usually seen 3 days after incubation [23].

2.7. Direct Microscopy

The sub-cultured fungi were identified based on the mycelia, spore type and other fruiting bodies by viewing a lactophenol cotton blue wet mount of the isolate with a x40 objective lens of a compound microscope. *Candida albicans* were identified by carrying out germ tube test [24, 25, 26].

2.8. Antifungal Disc Susceptibility Test

The fungal isolates were sub-cultured in parallel into Potato dextrose agar and incubated for 24 h at 35°C. Disk diffusion testing of voriconazole, fluconazole and nystatin on the parallel isolates was then performed [27].

The extracts were tested in four concentrations of 1000 mg/ml, 500 mg/ml, 250 mg/ml and 125 mg/ml. A total of 198 sterile dry plates were labelled for sensitivity testing, with 18 plates each corresponding to the 11 test fungi. Forty four plates were labelled and used for each for aqueous extract of garlic, aqueous extract of ginger, ethanolic extracts of garlic and ethanolic extract of ginger. Positive (ethanol only) controls and negative (without extract nor ethanol) controls were labelled on 22 sterile plates for each test fungi. From each concentration of the aqueous extract of garlic, 1ml was dispensed with the aid of a sterile micropipette into the petri dishes labelled aqueous extract of garlic. This procedure was repeated by dispensing 1ml of each concentration of the aqueous extract of ginger, ethanolic extract of garlic, ethanolic extract of ginger and ethanol solution to each of it's labelled plates. A 20ml of the cooled sterilized molten Potato Dextrose Agar (PDA) was dispensed separately into all plates. Proper mixing of the extract and the PDA was

ensured by gently swirling the plates. From each test fungus isolated in pure culture, 5mm mycelia disc was transferred to the center of the agar plates. The plates were then incubated at room temperature (28±2ºC) for 7 days. The diagonal, horizontal and vertical diameter of each test fungi (mycelium extended growth rate) were measured with the aid of a ruler and mean values determined. The percentage mycelia growth inhibitions of the test fungi were then calculated [5, 18, 28, 29].

2.9. Calculation of Percentage Mycelial Growth Inhibition of Fungi

Percentage mycelial growth inhibition (% MGI) = $\frac{(dc-dt)}{dc-5} \times 100$ (2)

dc is the mycelial growth diameter in control sets while dt is the mycelial growth diameter in treatment sets

2.10. Data Analysis

Results were presented as mean ± standard error (SE) of triplicate data. Significance difference between different groups was tested with double tailed t-test and two ways analysis of variance at 5% level of probability using SPSS version 20. The graphs were plotted using Microsoft Excel [30].

3.0. Results and Discussion

Table 1 shows the total fungal count isolated from the hostels before washing with detergents and disinfectants at three consecutive time. Akingbola Hostel had the highest fungal load while Hall 7 Hostel had the least fungal load. There was a significant reduction in the fungal loads after cleaning of the walls. Health effects such as infections, allergic reactions and toxic responses are associated with fungal exposures. As a result of the wetness (moist) and chilly temperature in the basement of the building, there are instances of indoor mould in buildings with basements [31, 32]. The dirty ducts and filters serve as a substrate for fungal growth due to the accumulation of dust, and the bathrooms' windows might act as a reservoir for indoor fungi [1]. The mean heterotrophic fungal counts of the bathrooms' walls ranged from 0.00 ± 0.00 to 1.00 ± 0.02 x 10 4 cfu/cm ^{2} after cleaning and from 0.40 ± 0.04 to 7.00 ± 0.30 x 104 cfu/cm ^{2} before cleaning.

3.1. Cultural morphology of fungi isolated from postgraduate hostels' bathrooms

In Table 2, the identities and characteristics of the fungal isolates on the basis of their cultural morphologies are shown. While Table 3 shows the microscopic identification and confirmation of fungi isolates. Thirteen (13) fungal isolates which include were *Aspergilus nidulans, A.niger, A. tamarii, A. fumigatus, A. flavus, Penicillium cyclopium, P. oxalicum, Trichophyton rubrum, Microsporum* sp., *Mucor mucedo, Cladosporum* sp., *Candida albicans and Rhodotorula* sp. It was discovered that the ground floor's bathroom in Akingbola Hostel was more contaminated than the upstairs' bathroom, and this could be as a result of the abuse of the bathroom by passers-by who tend to urinate there. In Intercontinental Hostel, the upstairs' bathroom which is only used by female students is more contaminated than the ground floor's bathroom which is used by the male students, and this could be as a result of sex-linked factors such as the introduction of *Candida albicans* which is a normal flora in the female vagina and the introduction of *Microsporum* sp. by the washing of dirty and infected hairs. This is in line with the findings of Bradford and Ravel [33], who found that *Candida albicans* attaches to vaginal epithelial cells at a higher rate than other species and the report of White *et al.* [34], which states that skin fungi are associated with

dandruff, eczema, ringworm, athletes foot, jock itch and nail infections and these diseases are attributed to the genera of *Trichophyton, Microsporum* and *Epidermophyton.* Ponsoni and Raddi [35], reported that a large area allows better ventilation thus reducing the fungal load as seen in Hall 7 Hostel. The Hall 7 Hostel has the largest area while Akingbola has the least area. Thorough cleaning destroys the cell wall of fungi and interferes with their growth and metabolism. *Mucor mucedo* was the most predominantly isolated fungi after washing, and this could be as a result of dispersal of spores from the outdoor environment through the ventilating system (window and doors) or the bathrooms not thoroughly cleaned. There was a significant reduction of the fungal loads after cleaning.

3.2. Frequency of occurrence of fungal isolates

The most frequently isolated fungi from Akingbola hostel was of the species *Candida albicans* (26.19%) (Figure 1). *Penicillium oxalicum* was the most frequently isolated fungi (24.32%) from Hall 7 hostel (Figure 2), while Intercontinental hostel had *Penicillium cyclopium* (16.96%) as its most frequently isolated fungi (Figure 3). *Mucor mucedo* was mostly isolated from all hostels after washing of the bathrooms. Frequency of fungal isolates showed that *Candida albicans* (26.19%) was the most occurring fungi from Akingbola Hostel, and this work is similar to the work of Jabber *et al.* [36], which states that *Candida albicans* had the highest occurrence percentage in a female bathroom. *Penicillium oxalicum* (24.32%) occurred most from Hall 7 Hostel, while *Penicillium cyclopium* (16.96%) were isolated most from Intercontinental Hostel. *Mucor mucedo* was the mostly isolated fungi after cleaning of the bathrooms. It was also discovered that during the sports festival hosted in the University of Benin, Benin City, Edo State, in April, 2021, fungal species such as *Trichophyton rubrum*, *Microsporum* sp. and *Cladosporium* sp. were isolated from the walls of the bathrooms in Hall 7 Hostel. The occurrence of *Microsporum* sp. in Intercontinental Hostel which wasn't included to host the sports men and women could be as a result of fungal infections on skin and infected hairs of the female occupants.

3.3. Antifungal Disc Susceptibility Test

Table 4 shows that Voriconazole had the highest zone of inhibition of the fungal isolates, and an intermediate resistance was obtained with Fluconazole against the fungal isolates except for *Candida albicans* and *Rhodotorula* sp. The fungal isolates were resistant to Nystatin. The highest inhibition by Voriconazole was against *Rhodotorula* sp. (25.33 mm) while the least inhibition by Nystatin was against *Penicillium cyclopium, P. oxalicum, Aspergillus nidulans, A. niger* and *Trichophyton rubrum* (5.00 mm). All fungal isolates were susceptible to voriconazole (1µg), showed intermediate resistance to Fluconazole (10 µg), except *Candida albicans* and *Rhodotorula* sp. which were susceptible to Fluconazole. The isolates were all resistant to Nystatin (100 µg). This research supports the findings of Khan *et al.* [37], who found voriconazole to have the highest antibacterial activity.

3.4. Comparative Analysis of the Phytochemical Content of both Aqueous and Ethanolic Extracts of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger)

Table 5 demonstrates that the water and ethanol extracts of *Allium sativum* and *Zingiber officinale* include tannin, anthraquinones, alkaloids, steroids, saponin, terpenes, cyanogenic glycosides, flavonoids and phenols. *Zingiber officinale* contains higher concentrations of phenols and terpenes when compared to *Allium sativum.* The knowledge of the phytonutrients compounds of medicinal plants such as garlic and ginger is long in advance and their antifungal characteristics have been

investigated and reported abroad [18]**.** Allicin, the main component of *Allium sativum* is being attributed to its antimicrobial actions [4]. *Zingiber officinale* contains caprylic acid, vitamins, minerals and used widely to treat infections. According to Talib and Mahasneh [38], medicinal plants consist of numerous phytochemicals such as flavonoids, alkaloids, tannins and terpenoids, which exhibit antimicrobial and antioxidant properties. The phytochemical constituents detected in both plants were alkaloids, phenols, saponins, tannins, flavonoids, terpenoids, cyanogenic glycosides, arthraquinones and **s**teroids. *Zingiber officinale* extracts had higher concentrations of phenols and terpenes when compared to *Allium sativum* extracts. While *Allium sativum* had a higher concentration of alkaloids, flavonoids, tannin, anthraquinones and saponins than *Zingiber officinale.*

3.5. Mean growth diameter of aqueous and ethanolic garlic and ginger extracts on test fungi after an incubation period of seven days

Table 6 shows the mean growth diameter of aqueous and ethanolic *Allium sativum* (Garlic) extracts on test fungi after an incubation period of 7days. The mycelial growth diameter of control were: *Aspergillus nidulans* (85 mm), *A. tamarii* (52 mm), *A. fumigatus* (75 mm), *A. flavus* (85 mm), *A. niger* (85 mm), *Penicillium cyclopium* (85 mm), *P. oxalicum* (85 mm), *Microsporum s*p. (75 mm), *Mucor mucedo* (85 mm), *Trichophyton rubrum* (70 mm), *Cladosporium* sp. (75 mm).

The greatest inhibition of mycelial growth by aqueous Allium sativum extract was on *Penicillium oxalicum* (10.00 mm) while its least inhibition was on *Penicillium cyclopium* and *Aspergillus nidulans* (63.30 mm). The greatest inhibition of mycelial growth by ethanolic *Allium sativum* extract was on *Cladosporium* sp. (12.00 mm) while its least inhibition was on *Aspergillus niger* (47.30 mm).

The mean growth diameter of aqueous and ethanolic *Zingiber officinale* (Ginger) extracts on test fungi after an incubation period of 7 days is presented on Table 7.

The greatest inhibition by aqueous *Zingiber officinale* extract was on *Aspergillus tamarii* (7.00 mm) while its least inhibition was on Aspergillus niger (25.00 mm). The greatest inhibition by ethanolic *Zingiber officinale* extract was on *Aspergillus fumigatus* (9.00 mm) while its least inhibition was on *Mucor mucedo* (37.00 mm). The 1000 mg/ml concentration of *Allium sativum* and *Zingiber officinale* extracts produced the most potent antifungal effect and the least inhibition potential was with 125 mg/ml.

3.6. Percentage mycelial growth inhibition of Allium sativum and Zingiber officinale on test fungi

The aqueous extraction (Table 8) showed that *Zingiber officinale* greatest inhibition on *Mucor mucedo* (96.25%) was greater than the *Allium sativum* greatest inhibition on *Penicillium oxalicum* (93.75%). The *Zingiber officinale* extracts showed greater inhibition potency than *Allium sativum* extracts.

The ethanolic extraction (Table 9) showed that *Zingiber officinale* greatest inhibition on *Aspergillus fumigatus* (94.29%) was higher than *Allium sativum* greatest inhibition on *Cladosporium* sp (90.00%). Results from ethanolic extraction method showed that the ethanolic extracts of garlic and ginger significantly inhibited growth of the isolated fungi ($P<0.05$) over an incubation period of seven days in line with the works by Tagoe *et al.* [18]**.** The considerable inhibitory efficacy of ginger can be attributed to the presence of about 400 different chemical components, including shogaols, zingerone, gingerols, sesquiterpenoids and monoterpenoid [39, 40]. There was a greater inhibition potency of the four concentrations of ginger against the mycelia

growth rate of *Penicillium cyclopium, Aspergillus nidulans, Aspergillus tamarii, Microsporum* sp., *Aspergillus fumigatus, Trichophyton rubrum, Penicillium oxalicum* and *Aspergillus niger* than of garlic. From the results above, when compared to the PDA control, the ethanolic extract of ginger had a stronger inhibitory potential on the test fungus ($P<0.05$). This research supports the findings of Grzanna *et al*. [40], who found that ginger had stronger antioxidant activity than garlic, however antibacterial action varies depending on the microorganisms.

Results from the inorganic water based extraction, showed that the four concentrations of ginger exerted a greater inhibition on the mycelia growth rate of *Penicillium cyclopium, Aspergillus nidulans, Aspergillus tamarii, Microsporum* sp., *Mucor mucedo, Aspergillus fumigatus, Aspergillus flavus, Trichophyton rubrum* and *Aspergillus niger* than of garlic. The most potent inhibition (7.00 ± 0.05 mm) was exhibited by 1000 mg/ml of *Zingiber officinale* aqueous extract against *Aspergillus tamarii* while the least inhibition of mycelium growth (63.30 ± 1.09 mm) and (63.30 ± 1.89) was recorded with 125 mg/ml aqueous extract of *Allium sativum* against *Aspergillus nidulans* and *Penicillium cyclopium* respectively. In the results above to the PDA control, it can be stated that the aqueous extract of ginger had a better inhibitory potential on the test fungus ($P<0.05$) than garlic. This is also in line with the findings of Kumar *et al.* [41], which claimed that ginger has stronger antioxidant activity than garlic.

The water base extracts produced significantly better inhibitory results than the ethanol base extracts in more fungal isolates such as *Penicillium oxalicum, Mucor mucedo, Microsporum* sp., *Aspergillus niger, A. flavus, A. tamari* and *Trichophyton rubrum* with the four concentrations of aqueous ginger extracts, which is in line with the work of Nile and Park [42] whose work showed that an aqueous extract had higher antioxidant properties than ethanol extract did, and against the mycelia growth rate of *Penicillium oxalicum, Aspergillus niger* and *A. fumigates* with the four concentrations of aqueous garlic extracts, this is consistent with the findings of Daniel *et al.* [5], who found that aqueous solutions of garlic extract were more active than ethanol dilutions of the extracts. The greatest mycelium growth inhibition was achieved with 1000 mg/ml aqueous extract of *Allium sativum* (93.75%) against *Penicillium oxalicum* and with 1000 mg/ml aqueous extract of *Zingiber officinale* (96.25%) against *Mucor mucedo*. This is in agreement with the work carried out by Daniel *et al*.; Nile and Park [5; 42] and in contract to the works of Sharif and Bennett; Kutawa *et al.* [43; 44].

The medicinal plant extracts inhibited the growth rate of the test fungus in a substantial way, and their application in fungal disease control in humans and animals, as well as lowering food spoilage, is advised. However, these extracts which can be used as an option to antibiotics and artificial preservatives could be easily obtained by the aqueous extraction method.

Table 1: Fungal counts before and after cleaning of the bathrooms

Hostel Location	**Bathrooms**	**Month 1** 10^4 **(cfu/cm²)**		**Month 2** 10^4 **(cfu/cm²)**		**Month 3** 10^4 **(cfu/cm²)**	
		Before cleaning	**After cleaning**	**Before cleaning**	**After cleaning**	**Before cleaning**	**After cleaning**
Akingbola	Ground floor	5.80±0.38	0.60±0.06	5.40±0.38	0.20±0.02	6.20±0.38	0.40±0.04
	Up-stair	2.60±0.20	0.40±0.00	2.20±0.20	0.20±0.02	3.00±0.20	0.20±0.02
Hall 7	Ground floor	2.80±0.00	0.80±0.00	2.80±0.40	0.40±0.00	2.60±0.20	0.40±0.00
	Up-stair	4.60±1.00	0.40±0.04	4.40±0.80	0.20±0.02	5.00±1.00	0.20±0.02
Intercontinental	Ground floor	2.60±0.14	1.00±0.02	3.00±0.14	Nil	2.20±0.14	Nil
	Up-stair	4.80±0.80	0.40±0.00	5.80±0.60	0.40±0.00	4.00±0.80	0.20±0.02
P – value (before – after cleaning)		0.003		0.002		0.002	

$p>0.05$= no significance
$p<0.05$ = significant

Table 2: Cultural and morphology of the fungi isolates

Texture	Surface Colour	Reverse Colour	Zonation	Sporulation	Colonial Topography	Phenotypic identity
Wooly	Dark brown	Yellow	Less radially furrowed	Light	Flat	*Aspergillus niger*
Granular	Yellow-green	Tan	Less radially furrowed	Slighty heavy	Flat	*Aspergillus flavus*
Velvety	Blue green	Tan	Less radially furrowed	light	Flat	*Aspergillus fumigatus*
Powdery	Olive	Dark brown	Less radially furrowed	Slightly heavy	Flat	*Aspergillus tamarii*
Wooly	Dark buff	Olive	Radially furrowed	Slightly heavy	Flat	*Aspergillus nidulans*
Velvety	Blackish grey	Yellow	Radially furrowed	Slightly heavy	Raised	*Penicillium cyclopium*
Velvety	Blue-green	Yellow	Radially furrowed	Heavy	Flat	*Penicillium oxalicum*
Cottony	Creamy	Red	Radially furrowed	Slightly heavy	Flat	*Trichophyton rubrum*
Cottony	Pink	Orange	Less radially furrowed	Slightly heavy	Raised	*Microsporum* sp.
Powdery	Grey	Black	Radially furrowed	Slightly heavy	Flat	*Cladosporium* sp.
Cottony	White	Red	Radially furrowed	Light	Raised	*Mucor mucedo*
Mucoid	Creamy	Yellowish brown	Conical	Light	Flat	*Candida albicans*
Mucoid	Pink	Pink	Conical	Light	Flat	*Rhodotorula* sp.

Table 3: Microscopic identification and confirmation of fungi isolates

Isolated spores	Conidia	Conidiophore	Fungi isolates
Conidiospores	Dark-brown, globose and rough-walled	Hyaline and smooth walled	*Aspergillus niger*
Conidiospores	Globose, pale-green and echinulated	Hyaline and coarsely roughened	*Aspergillus flavus*
Conidiospores	Globose, green and finely roughened	Hyaline and smooth walled	*Aspergillus fumigatus*
Conidiospores	Yellow brown	Double-walled spore	*Aspergillus tamarii*
Conidiospores	Globulose and rough-walled	Brown and smooth. Septate hyphae	*Aspergillus nidulans*
Conidiospores	Round, rough walls. Septate hyphae. Spores in chains	Hyaline, branched conidiophore supporting phialides in clusters	*Penicillium cyclopium*
Conidiospores	In chains. Septate hyphae. Smooth walled	Hyaline and finger-like	*Penicillium oxalicum*
Conidiospores. Tear shaped microconidia	Septate hyphae. Microconidia in group or single	Hyaline, smooth walled	*Trichophyton rubrum*
Conidiospores	Spores in chains. Dark hilum, smooth, echinulate	Erect	*Cladosporium* sp.
Sporangiospores	Hyaline and non-septate hypae. Sporangiospores in clusters in sporangia	Rough, grey to black, slightly elongated	*Mucor mucedo*
Ascospores. Cylindrical shaped	Globose ascoma, smooth walled. Septate	Hyaline and thin walled. Spores in clusters	*Microsporum* sp.
Chlamydiospores	Pseudohyphae		*Rhodotorula* sp.

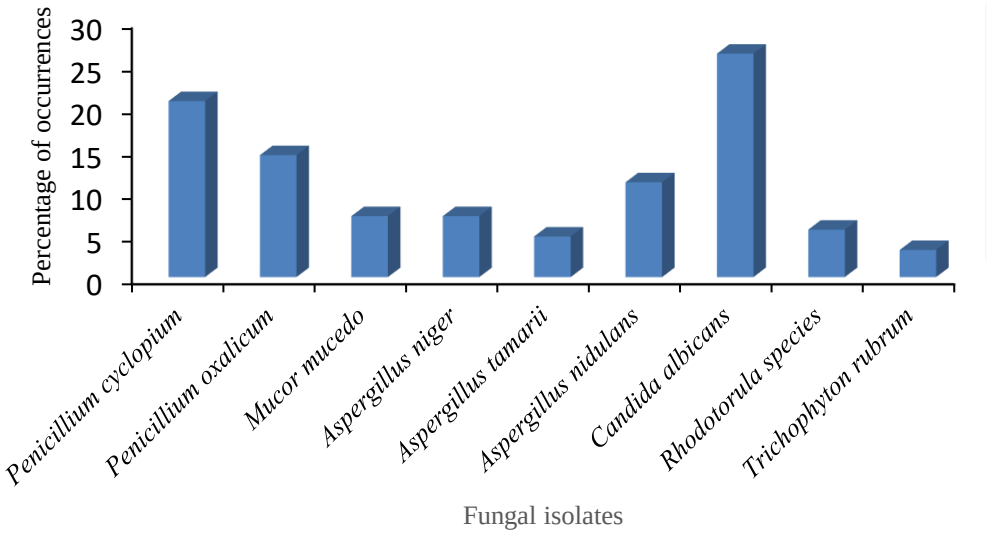

Figure 1: Frequency of occurrence of fungal isolates in Akingbola Hostel

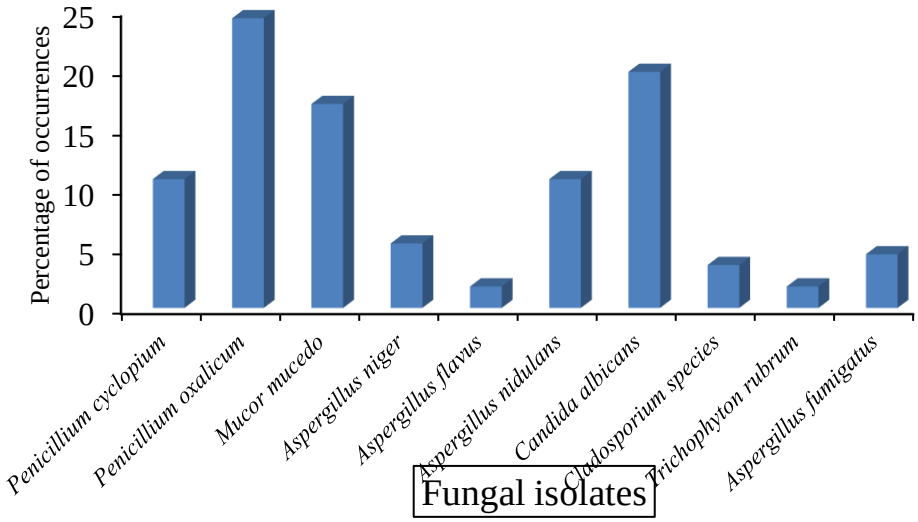

Figure 2: Frequency of occurrence of fungal isolates in Hall 7 Hostel

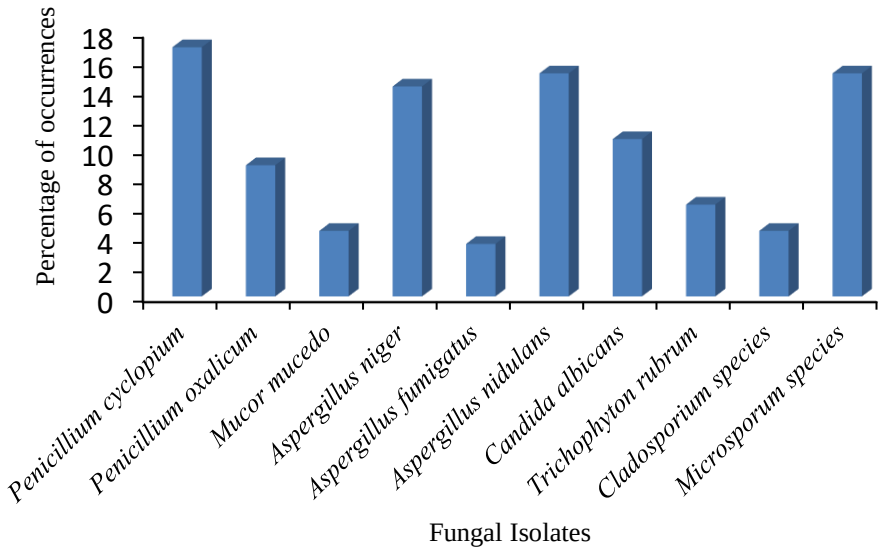

Figure 3: Frequency of occurrence of fungal isolates in Intercontinental Hostel

Table 4: Antifungal disc susceptibility test

Fungal isolates	Voriconazole (1 µg)	Fluconazole (10 µg)	Nystatin (100 µg))
Mucor mucedo	17.67 ± 0.33 (S)	15.67 ± 0.67 (I)	5.33 ± 0.33 (R)
Penicillium cyclopium	17.00 ± 0.00 (S)	15.00 ± 0.58 (I)	5.00 ± 0.00 (R)
Penicillium oxalicum	20.33 ± 0.33 (S)	16.33 ± 0.33 (I)	5.00 ± 0.58 (R)
Microsporum sp.	19.00 ± 0.00 (S)	18.67 ± 0.33 (I)	5.67 ± 0.33 (R)
Aspergillus nidulans	18.33 ± 0.33 (S)	17.67 ± 0.67 (I)	5.00 ± 0.58 (R)
Aspergillus flavus	20.00 ± 0.58 (S)	16.00 ± 0.00 (I)	5.33 ± 0.33 (R)
Aspergillus tamarii	20.00 ± 0.58 (S)	16.00 ± 0.58 (I)	5.67 ± 0.67 (R)
Aspergillus niger	18.67 ± 0.67 (S)	17.00 ± 0.58 (I)	5.00 ± 0.58 (R)
Trichophyton rubrum	19.67 ± 0.67 (S)	18.67 ± 0.33 (I)	5.00 ± 0.58 (R)
Aspergillus fumigatus	20.00 ± 0.58 (S)	16.33 ± 0.33 (I)	5.33 ± 0.33 (R)
Cladosporium sp.	19.33 ± 0.33 (S)	18.67 ± 0.33 (I)	5.67 ± 0.67 (R)
Candida albicans	23.00 ± 0.00 (S)	20.67 ± 0.33 (S)	8.00 ± 0.00 (R)
Rhodotorula sp.	25.33 ± 0.33 (S)	21.67 ± 0.67 (S)	9. 67 ± 0.67 (R)

Values are mean ± S.E. of 3 replicates

KEY

DISC	**SUSCEPTIBLE**	**INTERMEDIATE**	**RESISTANCE**
Voriconazole (1 µg)	≥17	14 – 16	≤13
Fluconazole (10 µg)	≥19	15 – 18	≤14
Nystatin (100 µg)	≥15	10 – 14	≤10

Table 5: Comparative Analysis of the Phytochemical Content of both Aqueous and Ethanolic Extracts of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger)

Phytochemical Constituents	**Aqueous Extracts**		**Ethanolic Extracts**	
	Allium sativum	***Zingiber officinale***	***Allium sativum***	***Zingiber officinale***
Alkaloids	4.23 ± 0.12	0.72 ± 0.01	5.30 ± 0.05	0.36 ± 0.01
Saponin	2.78 ± 0.03	2.51 ± 0.06	3.60 ± 0.03	1.17 ± 0.03
Cyanogenic glycosides	2.11 ± 0.01	5.75 ± 0.12	6.39 ± 0.07	1.51 ± 0.05
Phenols	4.85 ± 0.00	51.53 ± 1.18	5.58 ± 0.06	86.98 ± 1.04
Flavonoids	58.12 ± 0.08	3.86 ± 0.06	70.23 ± 0.15	5.21 ± 0.08
Steroids	0.53 ± 0.04	0.42 ± 0.02	0.64 ± 0.03	0.48 ± 0.02
Terpenes	0.50 ± 0.00	10.37 ± 0.14	0.71 ± 0.03	13.15 ± 0.11
Anthraquinones	1.34 ± 0.02	0.11 ± 0.00	1.43 ± 0.01	0.29 ± 0.03
Tannins	3.10 ± 0.03	1.39 ± 0.08	3.56 ± 0.02	1.22 ± 0.01

Values are mean ± S.E. of 3 replicates

Table 6: Mean growth diameter of aqueous and ethanolic *Allium sativum* (Garlic) extracts on test fungi after an incubation period of 7days

Test fungi	Aqueous extracts (mm)				Ethanolic extracts (mm)			
	1000 mg/ml	500 mg/ml	250 ml/ml	125 mg/ml	1000 mg/ml	500 mg/ml	250 mg/ml	125 ml/ml
Mucor mucedo	12.00 ± 0.00	30.00 ± 0.00	40.00 ± 0.00	45.00 ± 0.00	15.00 ± 0.00	20.00 ± 0.00	25.00 ± 0.00	25.00 ± 0.00
Penicillium cyclopium	32.00 ± 0.25	50.00 ± 0.76	60.00 ± 1.25	63.30 ± 1.89	18.00 ± 0.11	21.30 ± 0.06	26.30 ± 0.20	30.00 ± 0.00
Penicillium oxalicum	10. 00 ± 0.00	10.00 ± 0.06	11.00 ± 0.00	11.00 ± 0.06	18.00 ± 0.60	26.00 ± 0.20	30.00 ± 0.00	30.00 ± 0.10
Microsporum sp.	30.60 ± 0.06	35.00 ± 0.05	37.60 ± 0.23	39.00 ± 0.30	20.00 ± 0.03	29.30 ± 0.06	38.30 ± 0.03	46.00 ± 0.10
Aspergillus nidulans	40.00 ± 0.00	50.00 ± 0.76	60.00 ± 1.25	63.30 ± 1.09	20.00 ± 0.03	25.00 ± 0.03	36.00 ± 0.03	45.00 ± 0.03
Aspergillus flavus	17.00 ± 0.00	17.00 ± 0.00	17.00 ± 0.08	17.00 ± 0.11	15.00 ± 0.00	15.00 ± 0.12	16.00 ± 0.06	18.00 ± 0.00
Aspergillus tamari	19.60 ± 0.06	24.30 ± 0.06	27.00 ± 0.13	31.00 ± 0.20	19.00 ± 0.00	24.00 ± 0.05	27.00 ± 0.10	36.00 ± 0.33
Aspergillus niger	30.00 ± 0.05	31.00 ± 0.10	35.00 ± 0.11	35.30 ± 0.18	30.00 ± 0.05	38.00 ± 0.10	43.00 ± 0.11	47. 30 ± 0.08
Trichophyton rubrum	21.00 ± 0.05	23.00 ± 0.13	26.00 ± 0.11	29.00 ± 0.00	20.00 ± 0.05	20.00 ± 0.08	20.00 ± 0.30	20.00 ± 0.33
Aspergillus fumigatus	20.00 ± 0.00	20.00 ± 0.03	21.00 ± 0.15	22.00 ± 0.10	21.00 ± 0.00	21.00 ± 0.08	23.00 ± 0.11	23.00 ± 0.23
Cladosporium sp.	15.00 ± 0.05	15.00 ± 0.10	17.00 ± 0.11	18.00 ± 0.20	12.00 ± 0.00	12.00 ± 0.06	13.00 ± 0.12	13.00 ± 0.18

Table 7: Mean growth diameter of aqueous and ethanolic *Zingiber officinale* (Ginger) extracts on test fungi after an incubation period of 7 days

Test fungi	Aqueous extracts (mm)				Ethanolic extracts (mm)			
	1000 mg/ml	500 mg/ml	250 mg/ml	125 mg/ml	1000 mg/ml	500 mg/ml	250 mg/ml	125 mg/ml
Mucor mucedo	8.00 ± 0.00	10.00 ± 0.00	15.00 ± 0.00	18.00 ± 0.00	32.00 ± 0.00	35.00 ± 0.00	35.00 ± 0.00	37.00 ± 0.00
Penicillium cyclopium	15.30 ± 0.08	16.30 ± 0.08	16.30 ± 0.08	17.00 ± 0.10	12.60 ± 0.14	13.30 ± 0.16	14.60 ± 0.13	15.00 ± 0.10
Penicillium oxalicum	10.00 ± 0.00	10.00 ± 0.06	11.00 ± 0.00	11.00 ± 0.06	12.00 ± 0.08	13.00 ± 0.10	14.00 ± 0.00	14.00 ± 0.14
Microsporum sp.	10.00 ± 0.00	11.00 ± 0.05	15.00 ± 0.00	19.30 ± 0.06	20.00 ± 0.25	25.30 ± 0.12	28.00 ± 0.15	29.00 ± 0.20
Aspergillus nidulans	9.06 ± 0.08	10.30 ± 0.39	10.60 ± 0.18	12.30 ± 0.14	14.00 ± 0.15	14.00 ± 0.30	17.00 ± 0.15	17.00 ± 0.20
Aspergillus flavus	16.00 ± 0.00	16.00 ± 0.10	17.00 ± 0.00	17.00 ± 0.30	21.00 ± 0.08	23.00 ± 0.10	25.00 ± 0.00	25.00 ± 0.06
Aspergillus tamari	7.00 ± 0.05	9.30 ± 0.03	9.30 ± 0.03	10.30 ± 0.03	19.00 ± 0.05	23.30 ± 0.17	27.00 ± 0.15	21.00 ± 0.00
Aspergillus niger	12.00 ± 0.00	17.00 ± 0.06	23.00 ± 0.15	25.00 ± 0.20	15.00 ± 0.00	15.00 ± 0.08	16.00 ± 0.05	16.00 ± 0.30
Trichophyton rubrum	11.00 ± 0.05	13.00 ± 0.08	15.00 ± 0.19	17.00 ± 0.16	11.00 ± 0.03	14.00 ± 0.00	17.00 ± 1.20	20.00 ± 0.15
Aspergillus fumigatus	18.00 ± 0.06	19.00 ± 0.13	20.00 ± 0.05	20.00 ± 1.00	9.00 ± 0.10	9.00 ± 0.15	10.00 ± 0.08	11.00 ± 0.20
Cladosporium sp.	15.00 ± 0.10	18.00 ± 0.06	20.00 ± 0.00	21.00 ± 0.12	10.00 ± 0.05	13.00 ± 0.10	15.00 ± 0.00	18.00 ± 0.06

Table 8: Percentage mycelial growth inhibition of aqueous extracts of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger) on mycelia growth of test fungi

Test fungi	***Allium sativum* (Garlic) %**				***Zingiber officinale* (Ginger) %**			
	1000 mg/ml	**500 mg/ml**	**250 mg/ml**	**125 mg/ml**	**1000 mg/ml**	**500 mg/ml**	**250 mg/ml**	**125 mg/ml**
Mucor mucedo	91.25	68.75	56.25	50.00	96.25	93.75	87.50	83.75
Penicillium cyclopium	66.25	43.75	31.25	27.13	87.13	85.88	85.88	85.00
Penicillium oxalicum	93.75	93.75	92.50	92.50	93.75	93.75	92.50	92.50
Microsporum sp.	63.43	57.14	53.43	51.43	92.86	91.43	85.71	79.57
Aspergillus nidulans	56.25	43.75	31.25	27.13	94.93	93.38	93.00	90.88
Aspergillus flavus	85.00	85.00	85.00	85.00	86.25	86.25	85.00	85.00
Aspergillus tamari	68.94	58.94	53.19	44.68	95.75	90.85	90.85	88.72
Aspergillus niger	68.75	67.50	62.50	62.13	91.25	85.00	77.50	75.00
Trichophyton rubrum	75.39	72.31	67.69	63.08	90.77	87.69	84.62	81.54
Aspergillus fumigatus	78.57	78.57	77.14	75.71	81.43	80.00	78.57	78.57
Cladosporium sp.	85.71	85.71	82.86	81.43	85.71	81.43	78.57	77.14

Table 9: Percentage mycelial growth inhibition of the ethanolic extracts of *Allium sativum* (Garlic) and *Zingiber officinale* (Ginger) on mycelia growth of test fungi

Test fungi	***Allium sativum* (Garlic) %**				***Zingiber officinale* (Ginger) %**			
	1000 mg/ml	**500 mg/ml**	**250 mg/ml**	**125 mg/ml**	**1000 mg/ml**	**500 mg/ml**	**250 mg/ml**	**125 ml/ml**
Mucor mucedo	87.50	81.25	75.00	75.00	66.25	62.50	62.50	60.00
Penicillium cyclopium	83.75	79.63	73.38	68.75	90.25	89.63	88.00	87.50
Penicillium oxalicum	83.75	73.75	68.75	68.75	91.25	90.00	88.75	88.75
Microsporum sp.	78.57	65.29	52.43	41.43	78.57	71.00	67.14	65.71
Aspergillus nidulans	81.25	75.00	61.25	50.00	88.75	88.75	85.00	85.50
Aspergillus flavus	87.50	87.50	86.25	83.75	80.00	77.50	75.00	75.00
Aspergillus tamari	70.21	59.58	53.19	34.04	70.21	61.06	53.19	65.96
Aspergillus niger	68.75	58.75	52.50	47.12	87.50	87.50	86.25	86.25
Trichophyton rubrum	76.92	76.92	76.92	76.92	90.77	86.15	81.54	76.92
Aspergillus fumigatus	77.14	77.14	74.29	74.29	94.29	94.29	92.86	91.43
Cladosporium sp.	90.00	90.00	88.57	88.57	92.86	88.57	85.71	81.43

4.0. Conclusion

Extracts of ginger produced stronger antifungal activity against most test fungi. Different extraction procedures result in varying antifungal efficiency, with aqueous extracts having the greatest inhibitory capacity against most test fungi's mycelia growth. However, aqueous and ethanolic extraction of ginger produces stronger antifungal activity against most test fungi, when compared to the garlic extraction.

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Conflict of Interest

No competing interests is recorded from the authors.

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