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Antifungal potentials of ten selected plants against fungi associated with postharvest spoilage of fruits

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Abstract

The aim of this research was to screen selected plants for their antifungal activities against some fungi commonly associated with post-harvest spoilage of fruits. Nine (9) selected fungi (Aspergillus flavus, A. fumigatus, A. niger, Colletotrichum sp., Fusarium oxysporum, Mucor sp., Penicillium digitatum, Rhizopus stolonifer and Trichoderma texanum) were isolated from some diseased fruit crops collected from local markets in Lagos, Nigeria. The antifungal potentials of ethanolic and aqueous extracts of Aframomum melegueta, Allium cepa, A. sativum, Capsicum annum, Curcuma longa, Cymbopogon citratus, Ocimum basilicum, Piper guinensis, Syzygium aromaticum and Zingiber officinale were investigated on the growth of these fungi using the agar well diffusion method. The treatments were carried out in triplicates and the antifungal activities were measured on the basis of the diameter of zone of inhibition. Sterile distilled water and ketoconazole were used as positive and negative controls respectively. Every fungus examined at varying concentrations showed different degrees of inhibitions as a result of antifungal constituents present in the plant extracts. Aqueous extracts of O. basilicum and P. guinensis showed growth inhibition against most of its tested fungi, with Colletotrichum sp. being the most inhibited by ethanolic extraction of the former. Also, ketoconazole inhibited the growth of these fungi while the negative control did not show any inhibition. Thus, the usage of these spices could help to improve food safety and reduce the risk of spoilage.

Keywords: Antifungal, Deterioration, Food safety, Post-harvest, Spoilage.

INTRODUCTION

In most developing nations, the economy is based on agriculture, and technological advancements in this sector are crucial to improving the populace standard of living. Globally, food spoilage caused as a result of pathogen interactions has a significant global impact on all food types and results in food waste and loss (Gonelimali *et al*., 2018). Fungi have been known to cause postharvest spoilage in fruits because of their availability within the immediate environment; they may conveniently infest food as it is being harvested, processed, and packaged (Hatab *et al*., 2016). Microbes such as pathogenic bacteria and fungi have the potential of causing food spoilage. The invasion by these microorganisms can be as a result of

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lack of proper handling during storage or injury to the crop during the process of harvest and storing (Lorenzo *et al.,* 2018). Over the years, food crop has been preserved using synthetic agrochemicals. The development and application of synthetic agrochemicals and food preservatives which considerably resolved a number of challenges, contributed to the current breakthrough in food production (Dayan *et al.,* 2009).

Plants are a great source of bioactive secondary metabolites, including alkaloids, flavonoids, saponins, tannins, terpenoids, and other chemical compounds; and it has been claimed that they possess *in vitro* antifungal activities (Teslim *et al.,* 2011). Some researchers (Alzoreky and Nakahara, 2003; Fernández-López *et al*., 2005; Castro *et al*., 2008; Suppakul *et al*., 2016; Clarke *et al*., 2017) have examined the likely use of some plant extracts as valuable indigenous protectants. *A. melegueta* (Alligator pepper) belongs to the family Zingiberaceae and is a perennial tropical herb. Extracts from its seed have potent antimicrobial properties and have all been identified by phytochemical study (Edeoga *et al.,* 2005). *Allium cepa* (onion) is the most commonly grown species of the genus *Allium*. It contains a variety of biologically active substances, including flavonoids, thiosulfates, and phenolic acids. Onion belongs to the family Liliaceae and also acts as a culinary and therapeutic spice. Another species of the *Allium* genus is the *A. sativum*. Garlic's antibacterial properties have been known for a long time, and the active ingredient, allicin, a diallylthiosulfinate (2-propenyl-2-propanethiol sulfonate), has been found to be responsible (Rahman *et al.,* 2006). When the plant's cells are destroyed, compounds that give garlic its pungent flavour are created. The mycelial development of plant pathogenic fungi (such as *Colletotrichum lindemuthianum*, *Fusarium solani*, *Pythium ultimum* and *Rhizoctonia solani*) has been demonstrated to be strongly inhibited by garlic extracts (Bianchi *et al*., 1997).

C. annuum (chilli) is a species of the plant genus *Capsicum* used as an ideal treatment for eliminating fungal spread. The growth of fungal strains is gradually slowed down by any concentration of capsicum extracts applied to the culture medium. *Curcurma longa* (Tumeric) is a rhizome that belongs to the Zingiberaceae family. The traditional uses of turmeric's rhizome include its usage as an insect deterrent and an antibacterial agent (Rudrappa and Bais, 2008). Due to the widespread traditional usage of turmeric in food items, numerous studies have been conducted to examine its primary phytochemicals (turmeric and curcumin) with the aim of preventing the growth of fungi and fungal infections (Soheil *et al.,* 2014). *Cymbopogon citratus* or lemongrass is a tall, stalked plant in the grass family. It has a fresh, lemony aroma and a citrus flavour. Due to the high citral concentration of lemongrass oil, several antimicrobial properties have been discovered. Also, flavonoids and tannins found in this plant may be responsible for this antimicrobial activity (Syed *et al*., 2018).

Ocimum basilicum (Family: Labiatae) commonly known as basil plant is a natural spice, which is frequently employed as a flavour in confections, baked goods and condiments (Nazzaro *et al*., 2017). It has been demonstrated that basil generally contains substances that can inhibit the growth of fungi. *Piper guinensis* popularly called Cameroon pepper is a spicy medicinal plant that is widely valued in Africa for its variety of traditional medicinal uses (Ajibesin *et al.,* 2011; Besong *et al.,* 2016). Asawalam (2006) in prior studies have demonstrated that *P. guinensis* extracts could be used as botanical fungicides by local farmers because synthetic fungicides are expensive and hazardous. *Syzygium aromaticum* (Clove) is aromatic flower buds of a tree belonging to the family Myrtaceae. About 72–90% of eugenol is present in clove, which is the substance largely responsible for the scent (Kamatou *et al*., 2012). Clove is used as food preservative as report has shown that clove essential oil showed significant inhibitory effects on *Botrytis cinerea* (Sirirat *et al.,* 2009).

Zingiber officinale (Ginger) is a member of the family Zingiberaceae and is a common ingredient used to make food. A-pinene, borneol, camphene, and linalool are a few volatile compounds that give ginger its antimicrobial properties (Nguanpuag *et al*., 2011). Touba *et al*. (2012) employed the poisoned food technique to assess the antifungal properties of crude extracts of seven spices against *Phoma exigua*, *Fusarium nygamai*, and *R. solani*. The results revealed that ginger hot water extracts had the best antifungal properties. The majority of these plant extracts have undergone testing to see how well they inhibit the growth of fungal pathogens. Although, fungicides are commonly employed to eliminate pathogens that cause post-harvest diseases, but these synthetic chemicals are harmful to human health and all other living things. Consequently, focus has shifted to the creation of effective methods of preventing plant diseases and the use of plant extracts is one of them. Thus, this study was carried out to screen selected plants for their antifungal activities against some fungi commonly associated with post-harvest spoilage of crops.

MATERIALS AND METHODS

Collection of infected crop samples: Infected samples of *Ananas comosus* (pineapple), *Carica papaya* (pawpaw), *Citrus sinensis* (sweet orange), *Cucumis sativus* (cucumber), *Daucus carota* (carrot), *Musa paradisiaca* (plantain), *Musa sapientum* (banana), *Solanum lycopersicum* (tomato), and *Solanum tuberosum* (Irish potato) were collected from local markets within the Alimosho and Ojo Local Government areas of Lagos State, Nigeria. All infected fruit samples were inspected for rotted areas and were stored in clean polythene bags. All the samples were brought to the Department of Botany Laboratory in Lagos State University (LASU), Ojo for further analysis.

Preparation and Sterilization of Media: Potato Dextrose Agar (PDA) used was prepared according to standard procedures (Fawole and Oso, 2009).

Isolation and Identification of Fungi: The method of isolation of fungi responsible for post-harvest spoilage was carried out as described by Baiyewu *et al*. (2007). A segment (3–5cm) of the contaminated fruit tissues was cut with a sterilized scalpel and placed on solidified PDA containing chloramphenicol in Petri dishes. It was then incubated at room temperature (28 ± 2°C) for five days. The resulting fungi were sub-cultured unto PDA plates until their pure cultures were obtained. Thereafter, the fungi were identified based on their morphological characteristics, colony colour, and types of sporulation with the reference to Alexopoulos and Mims (1979).

Plant Materials Collection and Identification: The plant parts screened for their antifungal potentials are majorly local spices collected from local suppliers in Igando and Mile 12 markets. Local names were also collected. More information on the plant parts is well stated on Table 1. All collected plant parts were authenticated at the Department of Botany Herbarium, LASU.

Preparation of Plant Extracts: Collected rhizome, fruits, seeds, leaves, and bulbs of the different plants were air-dried and then sliced into little pieces after being rinsed under running water. After drying for two weeks, they were pulverized into powdery form with a 1.5L blender (Binatone, China). The extracts employed in this study were aqueous and ethanol extracts.100 g of each ground plant sample was soaked separately in 1000 mL of each extraction solvents. After the third day, the resulting fluid was then filtered using Whatman filter paper No 1 (Whatman International Limited, England). The filtrates were concentrated through

evaporation to dryness, under pressure at 50°C using a water bath (Ewekeye *et al*., 2016). The crude extracts obtained were later kept in the refrigerator for further use.

Determination of yield of extracts: Dry extracts of plant parts, including rhizomes, bulbs, and fruits were weighed and stored in sterile sampling bottles before usage (Amienyo and Ataga, 2007).

Preparation of extract concentration: The crude extract was dissolved using few drops of Dimethyl sulfoxide (DMSO) and sterile distilled water. The plant extracts concentrations were prepared at 5, 10 and 15mg/mL for both the ethanol and water extracts respectively (Amjad *et al*., 2012).

Anti-fungal activity of the plant extracts: The agar well diffusion method as described by Holder and Boyce (1994) was used to assess the antifungal activity of the plant extracts. Sterile distilled water was used as a negative control and ketoconazole was used as a positive control. Five wells of diameter (8mm) were dug in each plate, 0.5 mL of concentrated extract were incorporated into each well and left for few minutes to diffuse and then sealed with the growth media. Five-millimeter mycelial discs were taken from the edge of 8 days old culture and positioned in the center of the plate. The plates were done in triplicates and were incubated at 25°C. The antifungal activity was taken on the basis of the diameter of zone of inhibition, which was measured after 5 days of incubation and the mean and standard deviation of three readings was presented.

Statistical Analysis: Data were analysed using SPSS, version 25. Means were determined and compared using one way analysis of variance (ANOVA) and separated according to Duncan's Multiple Range Test (DMRT) at 5% level of significance.

Table 1: Information obtained from local markets

Sample plant	Part used	Locality collected	Yoruba local name	Igbo local name	Hausa local name
Curcuma longa	Rhizome	Igando market	Ata ile pupa	Mbugbo	Gangamau
Allium cepa	Bulb	Igando market	Alubosa	Yabasi	Albasa
Allium sativum	Bulb	Igando market	Atale	Ayo-ishi	Tafarnuwa
Piper guinensis	Fruit	Mile 12 market	Ata iyere	Uziza	Masoro
Syzygium aromaticum	Fruit	Mile 12 market	Kanafuru	Nchara	Kanumfari
Aframomum melegueta	Seed	Iyana Iba market	Ataare	Ose-orji	Chitta
Zingiber officinale	Rhizome	Iyana Iba market	Jinja	Chita	Ata-ile
Capsicum annuum	Fruit	Iyana Iba market	Ata wewe	Ose	Tatashi
Ocimum basilicum	Leaves	Local farm	Efirin wewe	Nchanwu	Daidoya
Cymbopogon citratus	Leaves	Local farm	Ewe tea	Acharaehi	Tsauri

RESULTS

Growth Inhibition of Isolated Fungi by Extracts: The fungi causing postharvest deterioration of selected fruit crops were *Aspergillus flavus*, *Aspergillus fumigatus, Aspergillus niger*, *Colletotrichum* sp., *Fusarium oxysporum, Muco*r sp., *Penicillium digitatum, Rhizopus stolonifer,* and *Trichoderma texanum*. The aqueous and ethanol extracts of these local spices were effective against most fungal isolates but the ethanol extracts proved highly effective as growth inhibitors for all its target fungi (Tables 2 and 3).

Table 2: Effects of various concentrations of aqueous plant extracts on the tested fungi

Extracts	Organisms	5 mg/mL	10 mg/mL	15 mg/mL
A. melegueta	*Aspergillus flavus*	-	+	+
	Mucor sp.	+	+	+
	Aspergillus niger	+	+	+
	Colletotrichum sp.	+	+	+
C. longa	*A. fumigatus*	-	+	+
	Fusarium oxysporum	-	-	-
	Penicillium digitatum	+	+	+
	Rhizopus stolonifer	+	+	+
	Trichoderma texanum	+	+	+
Z. officinale	*A. flavus*	-	+	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
C. annum	*A. flavus*	-	-	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
O. basilicum	*A. flavus*	-	+	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
Allium cepa	*A. fumigatus*	+	+	+
	F. oxysporum	-	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
Allium sativum	*A. fumigatus*	-	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
C. citratus	*A. flavus*	-	+	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
P. guinensis	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
S. aromaticum	*A. fumigatus*	+	+	+
	F. oxysporum	-	-	-
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
Ketoconazole	All isolated fungi	+	+	+
Sterile distilled water	All isolated fungi	-	-	-

Key: + = Inhibition present, - = No inhibition

Table 3: Effects of various concentrations of ethanol plant extracts on tested fungi

Extracts	Organisms	5 mg/mL	10 mg/mL	15 mg/mL
A. melegueta	*A. flavus*	+	+	+
	Mucor sp.	-	+	+
	Aspergillus niger	-	+	+
	Colletotrichum sp.	+	+	+
C. longa	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
Z. officinale	*A. flavus*	-	+	+
	Mucor sp.	-	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
C. annum	*A. flavus*	-	+	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
O. basilicum	*A. flavus*	-	+	+
	Mucor sp.	-	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
Allium cepa	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
Allium sativum	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	Penicillium sp.	+	+	+
	P. digitatum	+	+	+
	T. texanum	+	+	+
C. citratus	*A. flavus*	-	+	+
	Mucor sp.	+	+	+
	A. niger	+	+	+
	Colletotrichum sp.	+	+	+
P. guinensis	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
S. aromaticum	*A. fumigatus*	+	+	+
	F. oxysporum	+	+	+
	P. digitatum	+	+	+
	R. stolonifer	+	+	+
	T. texanum	+	+	+
Ketoconazole	All isolated fungi	+	+	+
Sterile distilled water	All isolated fungi	-	-	-

Key: + = Inhibition present, - = No inhibition

Only the aqueous extract of *P. guinensis* prevented the growth of all the target fungi at all concentrations used while the aqueous extraction of basil plant inhibited most of its tested fungi except for *A. flavus* at 5 mg/ml. The extracts of *C. longa* inhibited the growth of *R. stolonifer, P. digitatum* and *T. texanum* at all concentrations used but was not sensitive to *A. fumigatus* at 5 mg/ml and also had a negative effect on *F. oxysporum* at all concentrations. *Zingiber officinale, A. cepa* and *A. sativum* did not inhibit *A. flavus*, *F. oxysporum,* and *A. fumigatus* at 5 mg/ml respectively. Also, all aqueous plant extracts inhibited the presence of *Aspergillus* spp. at 10 and 15 mg/ml except for *C. annum* that did not inhibit *A. flavus* at 10 mg/ml.

The ethanol extracts of *C. longa, A. cepa, A. sativum, P. guinensis*, and *S. aromaticum* inhibited the growth of all their tested fungi at different concentrations similarly as Ketoconazole while the growth of the fungi on the negative control (sterile distilled water) was sporadic. The ethanol extracts of *C. annum* and *O. basilicum* inhibited the growth of all targeted fungi but both concentrations at 5 mg/ml was observed to show negative effects on *A. flavus.*

For the ethanol extract, *Allium sativum* had the highest antifungal activity with mean of 32.00±0.15 mm while for the aqueous extract for *A. cepa* had the highest (33.5±0.00 mm) inhibitory effect on *T. texanum*, same for *S. aromaticum* on *T. texanum* with the same value. The lowest inhibitory effects for aqueous extracts of all the plants on the test fungi was 0.00±0.00 mm at 5 mg/ml (Table 4a).

The ethanolic extract of *C. Ionga* at 10 mg/ml on *P. digitatum* showed the highest inhibitory effect with the mean value of 35.03±0.17, higher than the positive control. For the aqueous extract, *P. guinensis* recorded the highest inhibitory effect on *Penicillium digitatum* (Table 4b). From Table 4c, *C. longa* showed the highest (37.20±1.61) inhibition on *A. fumigatus* for ethanol extract while for aqueous extract, both *A. cepa* and *P. guinensis* recorded the highest zone of inhibition against *Penicillium digitatum* and *T. texanum* respectively. In Table 4d, *S. aromaticum* had the highest (20.20±0.23) inhibition against Mucor sp. for the ethanol extract while *A. sativum* had the highest value (22.00±0.60) against *Penicillium* sp. for aqueous extract. *C. longa* recorded the highest inhibition of 22.37±0.48 mm against *Mucor* sp. for ethanol extract while *P. guinensis* against *Colletotrichum* sp. had the highest effect for aqueous extract (Table 4e).

P. guinensis had the maximum inhibitory effect on *Colletotrichum* sp. with 24.00±0.00 mm for ethanol extract whereas, *A. cepa* had the highest (22.43±0.47) inhibition against *Mucor* sp. for the aqueous extract (Table 4f).

Table 4a: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm)

Treatments	*Aspergillus fumigatus*	*Fusarium oxysporum*	*Penicillium digitatum*	*Rhizopus stolonifer*	*Trichoderma texanum*
	5 mg/ml	5 mg/ml	5 mg/ml	5 mg/ml	5 mg/ml
C. longa EE	20.13±1.06^{b}	18.00±0.15^{d}	27.97±1.19^{c}	19.00±0.10^{f}	20.00±0.10^{d}
C. longa AE	0.00±0.00^{c}	0.00±0.00^{f}	25.00±1.19^{de}	20.00±0.10^{ef}	24.00±0.10^{c}
A. cepa EE	20.00±0.79^{b}	15.00±0.55^{e}	26.00±0.10^{d}	30.00±0.00^{a}	28.00±0.67^{b}
A. cepa AE	25.00±2.76^{ab}	0.00±0.00^{f}	20.00±0.21^{f}	19.00±0.21^{f}	30.00±0.00^{a}
A. sativum EE	25.00±3.13^{ab}	20.00±0.40^{c}	32.00±0.15^{a}	23.00±0.60^{d}	25.00±0.76^{c}
A. sativum AE	0.00±0.00^{c}	21.00±0.40^{b}	25.00±0.15^{de}	23.00±0.21^{d}	25.00±0.21^{c}
S. aromaticum EE	20.00±0.66^{b}	15.00±0.26^{e}	30.00±0.00^{b}	25.00±0.21^{b}	25.00±0.15^{c}
S. aromaticum AE	0.00± 0.000^{c}	0.00±0.00^{f}	24.00±0.21^{e}	15.00±0.55^{g}	30.00±0.55^{a}
P. guinensis EE	30.00±3.41^{a}	18.00±0.26^{d}	30.00±0.00^{b}	28.00±0.55^{b}	25.00±0.70^{c}
P. guinensis AE	22.20±0.91^{b}	22.50±0.44^{a}	30.00±0.00^{b}	21.00±0.60^{e}	28.00±0.70^{b}
Negative control	0.00±0.00^{c}	0.00±0.00^{f}	0.00±0.00^{g}	0.00±0.00^{h}	0.00±0.00^{e}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

Table 4b: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm

Treatments	*Aspergillus fumigatus*	*Fusarium oxysporum*	*Penicillium digitatum*	*Rhizopus stolonifer*	*Trichoderma texanum*
	10 mg/ml	10 mg/ml	10 mg/ml	10 mg/ml	10 mg/ml
C. longa EE	27.07±3.35^{ab}	19.00±1.08^{d}	35.03±0.17^{a}	25.00±0.56^{c}	25.00±0.15^{c}
C. longa AE	22.00±.95^{bcd}	0.00±0 .00^{e}	30.00±0.46^{b}	21.00±0.21^{f}	25.00±0.25^{c}
A. cepa EE	30.00±4.31^{a}	19.00±0.72^{d}	30.00±0.79^{b}	30.50±0.38^{a}	30.00±0.00^{ab}
A. cepa AE	25.50±2.08^{abc}	19.00±0.55d	28.33±3.28^{b}	22.50±0.30de	30.00±0.00^{ab}
A. sativum EE	30.00±1.50^{a}	19.00±0.26^{d}	32.00±1.07^{ab}	30.00±0.00^{a}	29.00±0.82^{b}
A. sativum AE	20.00±1.63^{cd}	29.00±0.46^{a}	30.00±0.21^{b}	23.00±0.40^{d}	26.00±0.55^{c}
S. aromaticum EE	28.00±1.11^{ab}	19.00±0.75^{d}	30.00±0.00^{b}	27.50±0.35^{b}	29.00±0.26^{b}
S. aromaticum AE	18.00±1.08^{d}	0.00±0.00^{e}	30.00±0.00^{b}	21.00±0.55^{f}	30.00±0.00^{ab}
P. guinensis EE	30.50±0.66^{a}	22.50±0.80^{c}	30.50±0.35^{b}	28.50±0.00^{b}	30.50±0.49^{a}
P. guinensis AE	27.50±0.90^{ab}	26.00±1.37^{b}	30.50±0.21^{b}	21.50±0.38^{ef}	29.83±0.24^{ab}
Negative control	0.00±0.00^{e}	0.00±0.00^{e}	0.00±0.00^{c}	0.00±0.00^{g}	0.00±0.00^{d}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

Table 4c: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm)

Treatments	*Aspergillus fumigatus* 15 mg/ml	*Fusarium oxysporum* 15 mg/ml	*Penicillium digitatum* 15 mg/ml	*Rhizopus stolonifer* 15 mg/ml	*Trichoderma texanum* 15 mg/ml
C. longa EE	37.20±1.61^{a}	19.50±1.01^{ab}	32.00±0.25^{bcd}	26.00±0.26^{c}	30.00±0 .00^{d}
C. longa AE	26.50±4.36	0.00±0.00^{c}	32.00±0.74^{bcd}	25.00±0.15^{c}	26.00±0.15
A. cepa EE	33.50±4.36^{ab}	20.00±0.93^{ab}	33.50±0.57^{a}	25.50±1.50^{c}	30.50±0.38^{cd}
A. cepa AE	26.50±3.14^{de}	24.00±1.69^{a}	33.50±0.38^{a}	20.00±0.26^{e}	32.30±0.61^{b}
A. sativum EE	31.00±1.49^{bcde}	25.00±1.34^{a}	33.00±0.15^{ab}	32.50± 0.21^{a}	30.00±0.00^{d}
A. sativum AE	31.00±2.09^{bcde}	25.00±0.57^{a}	31.03±0.71^{de}	25.00±0.74^{c}	28.00±0.55
S. aromaticum EE	33.00±2.89^{abc}	21.10±0.30^{ab}	30.00±0.00^{e}	22.00±0.74	30.00±0.00^{d}
S. aromaticum AE	27.50±1.93^{cde}	0.00±0.00^{c}	30.00±0.00^{e}	22.03±0.55^{d}	30.00±0.57^{d}
P. guinensis EE	31.40±2.74^{bcd}	19.50±0.83^{ab}	32.50±0.00^{abc}	30.50±0.58^{b}	31.50±0.80^{bc}
P. guinensis AE	25.50±4.49^{de}	19.50±0.91^{ab}	31.50±0.35^{cd}	20.50±0.52^{de}	33.50±0.23^{a}
Negative control	0.00±0.00^{c}	0.00±0.00^{f}	0.00±0.00^{g}	0.00±0.00^{h}	0.00±0.00^{e}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

Table 4d: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm

Treatments	*Aspergillus flavus* 5 mg/ml	*Penicillium* sp. 5 mg/ml	*Mucor* sp. 5 mg/ml	*Aspergillus niger* 5 mg/ml	*Colletotrichum* sp 5 mg/ml
C. longa EE	12.06±0.29^{a}	18.23±0.48^{b}	0.00±0.00^{f}	0.06±0.07^{e}	12.80±0.10^{d}
C. longa AE	0.00±0.00^{b}	10.00±1.74^{d}	15.00±0.00^{e}	12.00±0.58	20.00±0.00^{ab}
A. cepa EE	0.00±0.00^{b}	13.43±0.36^{c}	0.00±0.00^{f}	5.93±1.27^{d}	10.00±0.00^{d}
A. cepa AE	0.00±0.00^{b}	7.00±1.37^{e}	21.60±0.64^{a}	19.00±0.00^{ab}	20.00±0.00^{ab}
A. sativum EE	0.17±0.17^{b}	18.17±0.38^{b}	0.00±0.00^{f}	6.00±0.00^{d}	12.66±0.88^{d}
A. sativum AE	0.00±0.00^{b}	22.00±0.60^{a}	21.00±0.57^{ab}	20.00±0.00^{a}	21.33±0.88^{a}
S. aromaticum EE	0.00±0.00^{b}	18.10±0.65^{b}	20.20±0.23^{bc}	18.00±0.00^{b}	10.00±0.57
S. aromaticum AE	0.00±0.00^{b}	4.17±2.29^{f}	19.50±0.29^{cd}	12.00±0.00^{c}	19.00±0.00^{bc}
P. guinensis EE	0.00±0.00^{b}	17.57±0.81^{b}	0.00±0.00^{f}	5.00±0.00^{d}	19.16±0.88^{bc}
P. guinensis AE	0.00±0.00^{b}	9.33±3.22^{d}	18.50±0.76^{d}	20.00±0.00^{a}	18.00±0.00^{c}
Negative control	0.00±0.00^{b}	0.00±0.00^{g}	0.00±0.00^{f}	0.00±0.00^{e}	0.00±0.00^{e}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

Table 4e: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm

Treatments	*Aspergillus flavus* 10 mg/ml	*Penicillium* sp. 10 mg/ml	*Mucor* sp. 10 mg/ml	*Aspergillus niger* 10 mg/ml	*Colletotrichum* sp 10 mg/ml
C. longa EE	15.40±0.31^{ab}	11.73±1.37^{a}	22.37±0.48^{a}	0.00±0.00^{f}	10.03±0.15^{e}
C. longa AE	14.50±0.68	0.00±0.00^{d}	15.56±0.99^{bc}	7.00±0.44^{f}	20.00±0.00^{a}
A. cepa EE	14.50±1.32^{ab}	11.13±0.38^{a}	11.43±0.47^{ef}	11.16±0.00^{c}	10.93±0.78^{e}
A. cepa AE	10.90±1.35^{cd}	6.17±0.60^{c}	16.77±0.76^{b}	15.00±0.00^{b}	18.00±0.00^{bc}
A. sativum EE	12.87±0.99^{bc}	8.57±0.92^{b}	11.77±0.43^{e}	17.00±0.29^{a}	17.50±0.69^{c}
A. sativum AE	0.00±0.00^{e}	5.16±0.44^{c}	13.33±0.33^{de}	10.00±0.01^{d}	20.00±0.00^{a}
S. aromaticum EE	16.70± 0.67^{a}	8.76±0.72^{b}	21.43±0.47^{a}	10.00±0.00^{d}	14.36±0.69^{d}
S. aromaticum AE	9.50±0.29^{d}	0.00±0.00^{d}	14.50±0.28^{cd}	9.00±0.00^{e}	19.00±0.00^{ab}
P. guinensis EE	16.17±1.05^{a}	0.16±0.17^{d}	22.23±0.65^{a}	6.00±0.00^{g}	10.00±0.87^{e}
P. guinensis AE	11.33±0.02^{cd}	0.00±0.00^{d}	9.67±1.20^{f}	6.00±0.00^{g}	20.00±0.00^{a}
Negative control	0.00±0.60^{e}	0.00±0.00^{d}	0.00±0.00^{g}	0.00±0.00^{f}	0.00±0.00^{f}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

Table 4f: Antifungal activities of plant extracts on some post-harvest fungal isolates causing spoilage in selected fruits (mean of zone of inhibition ± Standard Deviation in mm)

Treatments	*Aspergillus flavus*	*Penicillium* sp.	*Mucor* sp.	*Aspergillus niger*	*Colletotrichum* sp
	15 mg/ml	15 mg/ml	15 mg/ml	15 mg/ml	15 mg/ml
C. longa EE	22.53±0.66^{a}	9.23±0.15^{c}	14.27±0.54^{c}	12.00±0.00^{d}	22.26±0.26^{b}
C. longa AE	12.33±0.00^{d}	14.33±0.44^{ab}	22.33±0.44^{a}	9.43±0.58^{e}	10.33±1.17^{f}
A. cepa EE	19.17±0.99^{abc}	15.00±0.00^{ab}	19.57±0.52^{b}	16.00±0.00^{c}	13.00± 0.00^{e}
A. cepa AE	15.13±0.76^{cd}	15.93±1.11^{ab}	22.43±0.47^{a}	19.60±1.33^{b}	6.26±1.03^{g}
A. sativum EE	19.40±0.78^{abc}	14.00±3.49^{ab}	18.83±1.01^{b}	16.00±0.00^{c}	20.00±0.00^{c}
A. sativum AE	16.67±0.58^{bcd}	15.67±2.45^{ab}	21.43±0.47^{a}	20.60±0.46^{ab}	15.30±0.17^{d}
S. aromaticum EE	20.23±0.46^{ab}	13.00±.00^{abc}	19.60±0.67^{b}	10.00±0.00^{e}	22.00±0.00^{b}
S. aromaticum AE	19.87±0.44^{ab}	16.83±2.14^{ab}	21.66±0.33^{a}	21.33±0.73^{a}	11.16±0.37^{f}
P. guinensis EE	20.43±1.34^{ab}	18.00±0.00^{a}	22.10±0.38^{a}	11.00±0.00^{de}	24.00±0.00^{a}
P. guinensis AE	20.33±0.60^{ab}	12.67±0.73^{bc}	22.16±0.88^{a}	10.33±0.33^{e}	19.50±0.50^{c}
Negative control	0.00±0.00^{e}	0.00±0.00^{d}	0.00±0.00^{d}	0.00±0.00^{f}	0.00±0.00^{h}

Means with different superscripts in the same column are significantly different at 5% probability level according to Duncan's multiple range test
Key: EE = Ethanol Extract, AE = Aqueous Extract

DISCUSSION

The isolated fungi in this study were responsible for postharvest deterioration of the selected crops collected from local markets within Alimosho and Ojo, Lagos State, Nigeria. Also, these organisms have been reported to cause extensive rot of fruit crops during storage by gaining entry into them through natural openings and wounds created during harvesting, transportation, handling and marketing (Obayelu *et al.,* 2021). The different plant extracts at varying concentrations were used to prevent the growth of these organisms *in vitro*. This shows the presence of antifungal substances in the ethanol and aqueous extract of plant parts used, this is in consonance with the earlier reports of several researches but on different fungal organisms (Ameinyo and Ataga, 2007; Suleiman, 2010; Ewekeye *et al.,* 2016).

Only the aqueous extract of *P. guinensis* inhibited the growth of all its tested fungi at varying concentrations. This shows that the efficiency of ethanol and water-based plant extracts in inhibiting the growth of the fungal pathogens are really different from one another. Ethanol extracts gave higher inhibition in most plants (*C. longa, A. cepa, A. sativum, P. guinensis* and *S. aromaticum*) than the aqueous extracts. This suggests that water used in the extraction process was probably not able to dissolve all the principal compounds present in the plants. A similar study by Enyiukwu *et al*. (2014) who highlighted how the active ingredient(s) in plant extracts are soluble in different extraction solvents. It was also observed in this study that greater concentrations of the plant extracts caused higher inhibition of the fungal growth which aligns with the work of Babu *et al*. (2008). The inhibitory effect exerted by 10 and 15 mg/mL concentrations on the growth of these fungi was higher than that caused by 5 mg/mL concentration. For *Aspergillus* spp., *A. niger* was more susceptible to the inhibitory activity of the aqueous and ethanolic plant extracts when compared to *A. flavus* and *A. fumigatus*. Thus, this work validates the claim of several researchers that plant extracts could serve as potent disease-control agents.

CONCLUSION

Aqueous and ethanol extracts of our local spices possess potentially useful fungitoxic properties such as phyto-fungicides against fungi commonly associated with post-harvest

crop spoilage. Hence, the best concentration of the extracts can be considered to replace synthetic preservatives with these natural antifungal agents (spices). More research is needed to identify and purify the active principles responsible for the observed antifungal activities of the extracts. Then, attention will be required to determine how to acquire these extracts in significant amounts and package them in a manner that can be accessible by farmers. Additionally, this research may in some little way assist in addressing the issue of chemical pollution and toxicity caused by the use of synthetic chemicals in disease prevention.

REFERENCES

Ajibesin, K. K., Bala, D. N. and Umoh, U. F. (2011). The use of medicinal plants to treat sexually transmitted disease in Nigeria: Ethnomedical survey of Niger Delta region. *International Journal of Green Pharmacy*, 3(5):181-191.

Akande, T. A. and Yahaya, S. A. (2011). Phytochemical screening and antimicrobial activity of pumpkin (Ugwu) leaf (*Telferia occidentalis*). *J. Inter. Sci. Tech*., 5: 54-57.

Alexopoulos, C.J. and Mims, C.W. (1979). *Introductory Mycology,* 3rd ed. John Wiley and sons, New York, 613pp.

Alzoreky, N. S., and Nakahara, K. (2003). Antibacterial activity of extracts from some edible plants commonly consumed in Asia. *International Journal of Food Microbiology.* 80**:**223–230.

Amienyo, C. A. and Ataga, A. E. (2007). Use of indigenous Plant extracts for the production of mechanically injured sweet potato (*Ipomoea batatas* (L) Lam) tubers. *Scientific Research and Essay*.2(5):167-170.

Amjad, L., Mousavidehmourdi, K. and Saghazadeh, M. (2012). Antifungal potential of *Achillea wilhelmsii* flowers methanolic extract on different strains of *Candida albicans*. *International Journal of Biological and Medical Research.* 3(3):2107-2110.

Asawalam, E. F. (2006). Insecticidal and repellent properties of *Piper guineense* seed oil extract for the control of maize weevil, *Sitophilus zeamais*. *Electronic Journal of Environmental, Agricultural and Food Chemistry*, 5(3): 1389-1394.

Babu, J., Muzafar, A.D. and Vinod, K. (2008). Bioefficacy of Plant Extracts to Control *Fusarium solani* f. sp. *melongenae* incitant of Brinjal Wilt. *Global Journal of Biotechnology and Biochemistry*. 3(2): 56- 59.

Baiyewu, R.A., Amusa, N. A., Ayoola, O.A. and Babalola, O. O. (2007). Survey of the post-harvest diseases and aflatoxin contamination of marketed pawpaw fruits (*Carica papaya* L) in south western Nigeria. *African Journal of Agricultural Science*. 2(4):178-181.

Besong, E.E., Balogun, M.E., Djobissie, S.F., Mbamalu, O.S. and Obimma, J. N. (2016). A review of *Piper guineense* (African Black Pepper). I*nternational Journal of Pharmacy and Pharmaceutical Research.* 6**:** 368-384.

Bianchi, A., Zambonelli, A., ZechiniD'Aulerio, A., and Bellesia, F. (1997). Ultrastructural studies of the effects of *Allium sativum* on phytopathogenic fungi *in vitro. Plant Disease*. 81:1241-1246.

Castro, S. B. R., Leal, C. A., Freire, F. R., Carvalho, D. A., Oliveira, D. F., and Figueiredo, H. C. P. (2008). Antibacterial activity of plant extracts from Brazil against fish pathogenic bacteria. *Brazilian Journal of Microbiology.* 39**:** 756–760.

Clarke, D., Tyuftin, A. A., Cruz-Romero, M. C., Bolton, D., Fanning, S., Pankaj, S. K. *et al*. (2017). Surface attachment of active antimicrobial coatings onto conventional plastic-based laminates and performance assessment of these materials on the storage life of vacuum packaged beef sub-primals. *Food Microbiology*. 62:196-201.

Dayan, F. E., Cantrell, C. L. and Duke, S. O. (2009). "Natural products in crop protection", *Bioorganic & Medicinal Chemistry.* 17(12):4022-4034.

Edeoga, H.O., Okwu, D.E. and Mbaeble, B.O. (2005). Phytochemical Constituents of some Nigerian Medicinal Plants. *African Journal of Biotechnology*. 4**:**685-688.

Enyiukwu, D. N., Awurum, A. N., and Nwaneri, J. A. (2014). Efficacy of plant-derived pesticides in the control of myco-induced postharvest rots of tubers and agricultural products: A review. *Net Journal of Agricultural Science*. 2(1):30-46.

Ewekeye, T. S., Oke, O. A. and Emoh, A. G. (2016). Antifungal activities of crude extracts of some Nigerian chewing sticks. *Journal of Medicinal Plants Research.* 10(36), 626-630.

Fawole, M. O. and Oso, B. A. (2009). Laboratory manual of Microbiology. 5th edition. Spectrum Books Ltd, Ibadan, Nigeria.

Fernandez-Lopez, J., Zhi, N., Aleson-Carbonell, L., Perez-Alvarez, J. A., and Kuri, V. (2005). Antioxidant and antibacterial activities of natural extracts: application in beef meatballs. *Meat Science*. 69: 371-380. Doi: 10.1016/j.meatsci.2004.08.004.

Gonelimali, F. D., Lin, J., Miao, W., Xuan, J., Charles, F., Chen, M. *et al*. (2018). Antimicrobial properties and mechanism of action of some plant extracts against food pathogens and spoilage microorganisms. *Frontiers in Microbiology*. 9:389103. Doi: 10.3389/fmicb.2018.01639.

Hatab, S., Athanasio, R., Holley, R., Rodas-Gonzalez, A., and Narvaez-Bravo, C. (2016). Survival and reduction of shiga toxin-producing *Escherichia coli* in a fresh cold-pressed juice treated with antimicrobial plant extracts. *Journal of Food Science*.81**:**1987–199.

Holder, I. A and Boyce, S. T. (1994). Agar well diffusion assay testing of bacterial susceptibility to various antimicrobials in concentrations non-toxic for human cells in culture. *Burns*. 20(5):426-429.

Kamatou, G. P., Vermaak, I. and Viljoen, A. M. (2012). Eugenol—From the Remote Maluku Islands to the International Market Place: A Review of a Remarkable and Versatile Molecule. *Molecules*. 17(6):6953-6981. https://doi.org/10.3390/molecules17066953

Lorenzo, J. M., Munekata, P. E., Gomez, B., Barba, F. J., Mora, L., Perez-Santaescolastica, C. *et al*. (2018). Bioactive peptides as natural antioxidants in food products–A review. *Trends in Food Science & Technology*. 79:136-147.

Moghadamtousi, S. Z., Kadir, H. A., Hassandarvish, P., Tajik, H., Abubakarc, S. and Zandi, K. (2014). A review on antibacterial, antiviral, and antifungal activity of curcumin. *BioMed Research International.* doi: 10.1155/2014/186864.

Nazzaro, F., Fratianni, F., Coppola, R., and De Feo, V. (2017). Essential oils and antifungal activity. *Pharmaceuticals*.10(4):86.

Obayelu, O. A., Adegboyega, O. M., Sowunmi, F. A., and Idiaye, C. O. (2021). Factors explaining postharvest loss of hot pepper under tropical conditions. *International Journal of Vegetable Science*. 27(6):526-535. https://doi.org/10.1080/19315260.2021.1879342

Rahman, M.S., Al-Sheibani, H.I. Al-Riziqi, M.H. Mothershaw, A. Guizani, N. and Bengtsson, G. (2006). Assessment of the anti-microbial activity of dried garlic powders produced by different methods of drying. *International Journal of Food Production*. 9**:**503–513.

Rudrappa, T. and Bais H. P. (2008). Curcumin, a known phenolic from *Curcuma longa*, attenuates the virulence of *Pseudomonas aeruginosa* PAO1 in whole plant and animal pathogenicity models. *Journal of Agricultural and Food Chemistry*. 56(6):1955–1962.

Sa-Nguanpuag, K., Kanlayanarat, S., Srilaong, V., Tanprasert, K., Techavuthiporn, C. (2011) Ginger (*Zingiber officinale*) oil as an antimicrobial agent for minimally processed produce: A case study in shredded green papaya. *International Journal of Agriculture and Biology*. 13**:**895–901.

Sirirat, S., Rungprom, W., and Sawatdikarn, S. (2009). Antifungal activity of essential oils derived from some medicinal plants against grey mould (*Botrytis cinerea*). *Asian Journal of Food and Agro-Industry.* 2:S229-S233.

Suleiman, M.N. (2010). Fungitoxic activity of neem and paw-paw leaves extracts on *Alternaria solani*, casual organism of yam rots. *Advances in Environmental Biology*.4(2):159-161.

Suppakul, P., Thanathammathorn, T., Samerasut, O., and Khankaew, S. (2016). Shelf life extension of "fios de ovos", an intermediate-moisture egg-based dessert, by active and modified atmosphere packaging. *Food Control*. 70:58-63.

Syed, I., and Sarkar, P. (2018). Ultrasonication-assisted formation and characterization of geraniol and carvacrol-loaded emulsions for enhanced antimicrobial activity against food-borne pathogens. *Chemical Papers*. 72:2659-2672.

Touba, E. P., Zakaria, M., and Tahereh, E. (2012). Anti-fungal activity of cold and hot water extracts of spices against fungal pathogens of Roselle (*Hibiscus sabdariffa*) in vitro. *Microbial Pathogenesis*. 52(2):125-129.