

**CHARACTERIZATION OF SYZYGIUM AROMATICUM AND ZINGIBER OFFICINALE
ESSENTIAL OILS AND THEIR INHIBITORY EFFECTS ON POSTHARVEST ROT DISEASE
OF YAM**

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Abstract

Tuber rot disease (TRD) is a serious constraint to yam cultivation and sustainability in Nigeria. This study investigated chemical constituents of the essential oils (EOs) of two botanicals, *Syzygium aromaticum* (L.) Merr. & Perr. (clove) and *Zingiber officinale* Roscoe (ginger), and their bioactivity against TRD caused by *Fusarium* species. The EOs were obtained through the process of hydrodistillation in a Clevenger-type apparatus. Chemical constituents of the EOs were determined by gas chromatography and mass spectrometry. Bioactivity of the extracted EOs against *Fusarium* species causing TRD was evaluated *in vivo* at four concentrations, 0.1, 0.2, 0.3 and 0.4 µL/mL in a CRD experiment with three replications. Results showed that *S. aromaticum* and *Z. officinale* EOs comprised 15 and 32 volatile organic compounds (VOGs), respectively. The sesquiterpenoid, eugenol and monoterpenoid, α -zingiberene were the most predominant VOGs obtained in the EOs of *S. aromaticum* (70.20%) and *Z. officinale* (52.27%), respectively. The best inhibitory effect of *S. aromaticum* EO was recorded at 0.4 µL/mL concentration when rot development was significantly ($p < 0.05$) reduced to between 9.32 and 17.33% in inoculated and treated tubers, while TRD was substantially reduced to between 9.09 and 20.62% in inoculated tubers treated with *Z. officinale* EO. These findings showed that the use of clove and ginger EOs could serve as ecologically-safe alternatives for the management of postharvest TRD in yam.

Key words: Botanicals, Essential oils, *Fusarium*, Hydrodistillation, Tuber rot disease

Introduction

White yam (*Dioscorea rotundata* Poir) constitutes an economically important staple food in tropical and subtropical regions of the world. It is the second most important root tuber crop in Africa, after cassava (Somorin *et al.*, 2021). It is a vital indigenous food crop in the humid and sub-humid regions, and is the predominant species of yam in Nigeria, which is produced mainly in three agroecological zones (AEZs) of the country: Rainforest, Derived savanna/Forest

transition and southern Guinea savanna (Dania *et al.*, 2019).

Fusarium species are important soil-borne fungal pathogens that have been associated with postharvest decay of yam (Hamzat, 2022; Hamadina and Asiedu, 2022). It had been reported that biodeterioration of white yam often occurs when the tubers are wounded during harvest (Nweke, 2021). Careful harvesting is, therefore, emphasized for tuber crops in order to prevent damage which provides entry point for rot-causing fungal organisms. Rot disease reduces the quality of yam produced thereby making the tubers unappealing to consumers. Some of these pathogenic organisms that infect yam produce mycotoxins in the affected crops which apart from causing yam deterioration may also affect the consumers thereby leading to health hazards (Gutierrez-Pozo *et al.*, 2024)).

Mohammed and Sealy (2023) reported that postharvest losses in yam production usually occurs at various stages from production, post-harvest handling, marketing, distribution to processing of tubers, which also affects quality of setts for next season's planting (Ward *et al.*, 2021). Rot fungi are among the world's most destructive plant pathogens, capable of causing diseases of several economic crops and result to damages worth billions of dollars in the global agriculture each year (Dongzhen *et al.*, 2020). As a result of the significant losses of yam tubers, adequate measures for management of the pathogens and resultant diseases are very necessary.

The use of chemicals in the management of tuber rot disease (TRD), however, is not ideal because it leaves toxic residues in the environment, which are harmful to humans and animals. Some people have resorted to the use of biological methods in the management of *Fusarium* species. However, control option is fraught with problems of toxin production and technical know-how. Due to these reasons, this study focuses on the efficacy of botanicals which involves the use of essential oils (EOs) from plants that are readily available and ecologically-safe in the management of yam rot disease.

Clove (*Syzygium aromaticum*) EO is known for its antimicrobial activity against several pathogenic microbes. Previous studies indicated that clove EO has the ability to inhibit spore germination, radial growth

and reduced dry weight of *Fusarium oxysporum* (Sharma and Marques, 2021). Ginger (*Zingiber officinale*) EO is widely used as antifungal and antibacterial agent, in the control of plant and human pathogens (Kalhor *et al.*, 2022). The objectives of this study were to identify EO constituents in *S. aromaticum*, and *Z. officinale* and their efficacy in the management of *Fusarium* tuber rot disease.

Materials and methods

Sampling for tuber rot disease and fungal isolation

Yam tubers showing rot symptoms were collected across nine predominantly-producing States in Nigeria using purposive sampling method. The surveyed States were Cross River, Anambra, Ondo, Edo, Ekiti, Oyo, Niger, Abuja and Kaduna. The choice of states was informed by the record on yam production obtained from the Agricultural Development Projects in the various states. Three Local Government Areas (LGAs) were sampled in each of the nine selected states, which equals to 27 LGAs. Two barns were sampled for yam rot disease in each LGA with a total of 54 farm barns and two yam tubers were randomly selected within each barn, and a total of 108 infected yam tubers were sampled for tuber rot disease. The infected tuber samples were enclosed in clearly labelled envelopes and taken to the laboratory. The samples were surface sterilized with 10% sodium hypochlorite to remove surface contaminants and rinsed with sterile distilled water. Cut tissue lesions measuring 2 mm x 2 mm dimension were plated on potato dextrose agar at four equidistant points. The medium was prepared by dissolving 39 g of dehydrated powder in 1 litre of sterile distilled water. Detailed structural features of each isolate were observed using a compound microscope and identification was done following standard manuals of fungi (Barnett and Hunter, 1998; Samson *et al.*, 2010).

Isolation and characterization of essential oils from selected botanicals

Essential oils (EOs) were obtained from two botanicals: clove (*Syzygium aromaticum*) and ginger (*Zingiber officinale*), using the method described by Silva *et al.* (2014). EOs were extracted from 250 g sample of each botanical using hydrodistillation in a Clevenger's apparatus. The volatile oils were collected at 3 hours over n-hexane at constant temperature of 80°C. The EOs were stored in dark glass bottles at 4°C for further analysis. The EOs were further solubilized in n-hexane for gas chromatographs-mass spectrometry analysis.

Gas Chromatography-Mass Spectrometry (GC-MS)

The method described by Ebadi *et al.* (2015) was used. EOs were analyzed by GC-MS analysis using 6890 A gas chromatograph coupled to 5973C inert mass

spectrometer (with triple axis detector) and electron impact source (Agilent Technologies). The stationary phase of separation of the compounds was carried out on HP-5 capillary column coated with 5% of Phenyl Methyl Siloxane (30 m length × 0.32 mm diameter × 0.25 µm film thickness). The mass spectrometer was operated in electron-impact ionization mode at 70 eV with ion source temperature of 230 °C, quadruple temperature of 150 °C and transfer line temperature of 280 °C. Scanning of possible compounds was done from 30 m/z to 550 amu at 2.62 s/scan. Scan rate was identified by comparing measured mass spectral data with those in NIST (National Institute of Standards and Technology) 14 Mass Spectral Library.

Evaluation of the efficacy of essential oils for *in vivo* management of tuber rot disease

The bioactivity of extracted EOs against *Fusarium* species was evaluated *in vivo* at four different concentrations, 0.1, 0.2, 0.3 and 0.4 µL/mL in a CRD experiment with three replications. Healthy tubers were bored at 5 mm depth using a 5mm-cork borer. Tubers were inoculated with *Fusarium* species and treated with the EOs simultaneously, while control tubers were inoculated but untreated with EO. Inoculation points were sealed with paraffilm to avoid contamination. The treated tubers were stored at room temperature for 30 days. Rot inhibition was calculated according to Dania *et al.* (2019).

Data analysis

Numerical data were analysed using generalized linear model (GLM), SAS 200 version 9/1. Means were separated using Duncan Multiple Range Test (DMRT) and standard error at 5% level of probability.

Results

The EOs of *S. aromaticum* obtained in the GC-MS analysis comprised 15 constituent compounds which varied between 1.09 and 70.20% (Table 1). The EO quality assessment showed that it varied between 82 and 98% which indicates that it was of high quality. The analytical profiling revealed the pattern of elution of the volatile organic compounds and their corresponding peaks (Figure 1). Gas chromatography-mass spectrometry of the EO obtained from ginger rhizomes showed the presence of 32 compounds which accounted for 98.01% of its constituents. Their composition varied from 0.23 to 52.27%. The monoterpeneoid α -zingiberene was the most predominant EO with a concentration of 52.27% (Table 2). Retention time of the metabolites ranged between 3.56 and 42.39 minutes, depending on their molecular weights. The quality assessment of respective constituents was relatively high varying between 83 and 98%. The chromatogram showed the pattern of elution of the constituent compounds and their corresponding peaks (Figure 2).

Table 1. Essential oil constituents of *Syzygium aromaticum* using GC-MS analysis

S/N	Compounds	RT (min)	Composition %	Quality (%)
1.	Phenol	7.974	5.42	98
2.	Vamillin	9.233	1.37	92
3.	Humulene	9.439	1.20	91
4.	Trans – Isoeugenol	9.874	1.15	86
5.	Geraniol	9.954	1.35	93
6.	Eugenol	10.160	70.20	98
7.	Isosafrole Glycol	10.296	1.42	88
8.	Benzene propanenitrile	10.469	1.09	96
9.	Caryophyllene oxide	10.520	2.68	91
10.	β -Caryophyllene	10.869	2.03	96
11.	α - Farnesene	11.007	1.30	89
12.	Cyclohexane	11.104	1.25	83
13.	2,3,4 Trimethoxyacetophenone	11.281	1.48	82
14.	Hydroxyallyl) – 2- methoxyphenol	11.607	1.82	90
15.	Anethole	18.440	3.23	86
	Total		97.99	

Table 2. Essential oil constituents of *Zingiber officinale* using GC-MS analysis

S/N	Compounds	RT (min)	Composition %	Quality (%)
1.	Gamma-terpinene	3.56	1.05	91
2.	Cyclohexane	3.79	1.09	87
3.	α -zingiberene	4.17	52.27	83
4.	2 – Carene	4.55	0.71	97
5.	Isoborneol	5.86	0.55	90
6.	Endo-Borneol	5.96	0.42	84
7.	Citronellol	6.56	0.35	95
8.	2, 6 octadienal	6.81	1.05	90
9.	Citral	7.04	0.73	92
10.	Copán	8.04	0.69	97
11.	α - Farnesene	8.36	0.61	90
12.	Germacrene D	8.67	1.64	96
13.	Naphthalene	8.95	0.61	95
14.	7 - Methane azulene	10.06	0.75	93
15.	β - Humulene	10.25	2.85	90
16.	Nonanal	10.68	0.23	87
17.	Azulene	10.89	1.76	95
18.	Cis-Thujopsene	10.94	0.98	89
19.	Squalene	11.38	1.61	98
20.	Decatronic acid	11.47	3.51	98
21.	Acetate	11.51	0.54	92
22.	Myrcenylacetate	12.03	0.67	98
23.	Sesquirosefuran	12.12	0.81	95
24.	Isobornyl acetate	12.34	1.04	95
25.	Butanoic acid	12.75	5.66	92
26.	Aminosalicyclic Acid	12.81	0.70	95
27.	Pyridine	12.99	0.52	95
28.	Methyl ester	15.53	1.09	84
29.	Hydroxy-3-methoxyphenyl oxide	16.15	2.64	98
30.	Phenol	18.10	9.48	99
31.	Hydroxy-3-methoxyphenyl octane	18.33	0.88	98
32.	Hydroxy -3-methoxyphenyl	42.39	0.50	91
	Total		98.01%	

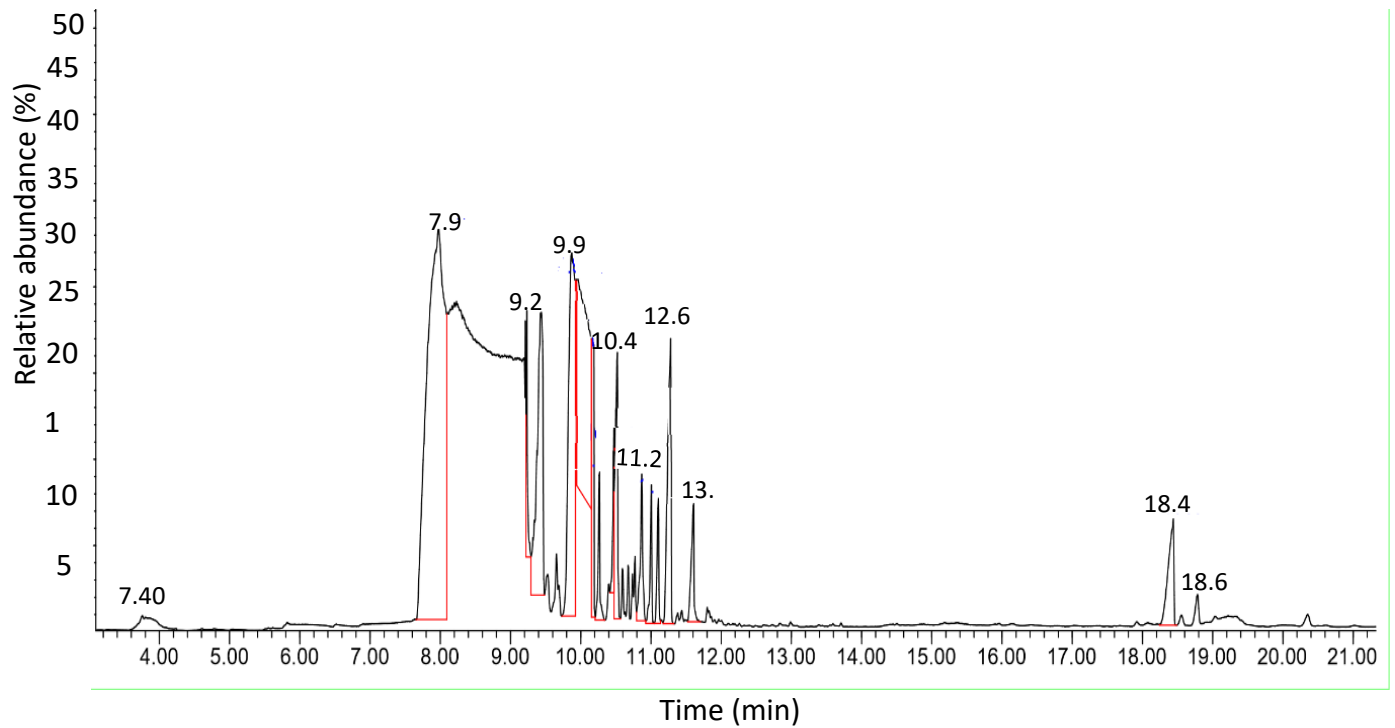


Figure 1. GC-MS analysis of the essential oil from *Syzygium aromaticum* showing pattern of elution of chemical constituents.

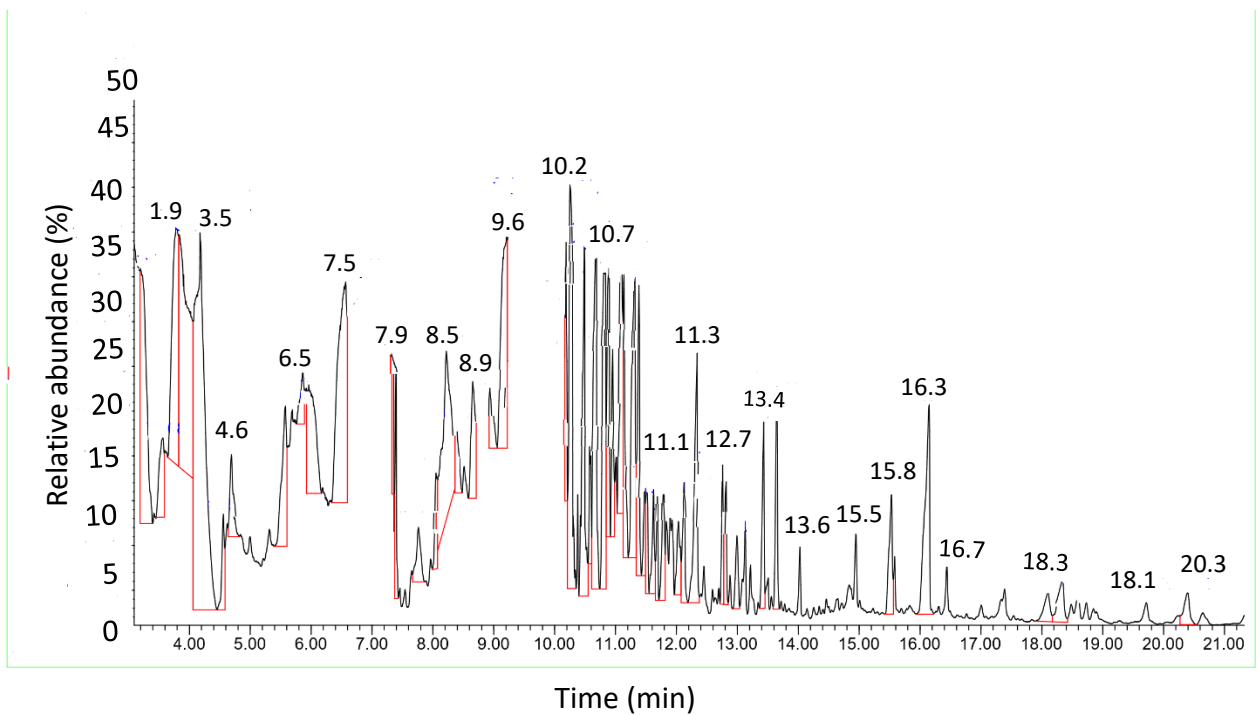


Figure 2. GC-MS analysis of the essential oil from *Zingiber officinale* showing pattern of elution of chemical constituents.

Evaluation of the efficacy of essential oils from botanicals for *in vivo* management of *Fusarium* yam tuber rot disease

Rot development was reduced to between 20.33 and 32.33% in yam tubers that were inoculated with *Fusarium oxysporum* and treated with *Syzygium aromaticum* EO at 0.1 $\mu\text{L/mL}$ (Table 3). This was significantly ($p<0.05$) lower than rot values recorded in control tubers that were not treated with the EO. The efficacy of the EO in reducing rot development increased when the concentration was doubled to 0.2 $\mu\text{L/mL}$ as tuber decay was reduced to between 16.02 and 30.27%. The lowest rot value was recorded in yam tuber samples obtained from Ekiti State, while the highest value was recorded in Anambra State. However, at 0.3 $\mu\text{L/mL}$ EO concentration, tuber samples from Kaduna State recorded the lowest rot of 14.33%, while the highest was 25.55% in Ondo State. Rot reduction was significantly ($p<0.05$) lower in treated tubers than those in control tubers without EO application. The best inhibitory effect was achieved at the highest EO concentration of 0.4 $\mu\text{L/mL}$ with rot development ranging from 9.09 to 20.62%. These values were also

significantly ($p<0.05$) lower than those recorded in control tubers.

At 0.1 $\mu\text{L/mL}$ EO concentration, the decay in yam tubers that were inoculated and treated with *Zingiber officinale* EO was reduced to between 23.05 and 31.03% and this was significantly ($p<0.05$) lower than the recorded rot range of 26.33 to 40.05% in the control without treatment (Table 4). The efficacy of the EO increased with higher levels of the EO application with rot development varying between 17.77 and 26.23% in treated tubers relative to 24.13 to 40.09% in the control at 0.2 $\mu\text{L/mL}$ concentration. Rot development was considerably lower (12.57 to 22.33%) when the EO concentration was increased to 0.3 $\mu\text{L/mL}$ in inoculated tubers and this was also significantly ($p<0.05$) lower than the control which varied from 23.22 to 34.24%. The best inhibitory effect of the EO was obtained at 0.4 $\mu\text{L/mL}$ concentration when reduction in rot development ranged from 9.32 to 17.33% compared to the control tubers without extract application (14.32 to 38.03%). Generally, rot initiation was significantly ($p<0.05$) lower in inoculated tubers with extract application than the control.

Table 3. Effect of *Syzygium aromaticum* essential oil on rot development in inoculated tubers

State	Concentration ($\mu\text{L/mL}$)			
	0.1	0.2	0.3	0.4
Ekiti 5	20.36±1.4e	16.02±0.3g	15.63±2.9f	13.05±0.2f
Control	27.32±1.7c	25.08±0.9d	30.04±3.3b	29.11±2.4b
Kaduna 5	22.23±0.5e	19.61±0.5f	14.33±1.7f	12.01±0.1f
Control	30.17±0.1b	25.18±1.4d	33.31±2.5a	28.73±3.1b
Edo 1	21.14±0.1e	19.33±0.1f	18.66±1.6e	14.46±0.3f
Control	25.14±1.5d	26.01±0.1d	28.12±2.2b	30.17±2.7b
Niger 2	30.32±1.1b	26.41±1.5d	21.72±2.1d	17.86±0.5e
Control	31.04±0.8b	24.57±0.7d	23.77±0.1d	26.70±0.1c
Abuja 5	25.20±1.5d	20.01±0.6f	16.31±0.7e	15.74±0.7e
Control	26.04±0.3d	27.32±0.5d	25.88±1.3c	25.32±1.3c
Oyo 1	28.55±1.2c	25.70±1.2d	22.04±1.0d	16.22±0.5e
Control	30.33±0.5b	34.11±2.3b	26.32±0.5c	39.03±3.8a
Abuja 4	30.08±0.8b	26.33±1.5d	20.71±0.3d	17.77±1.0e
Control	32.09±2.0b	34.12±1.8b	31.33±1.8b	28.75±2.3b
Ondo 1	24.13±0.1d	20.51±0.1f	25.83±1.3b	19.44±1.0d
Control	27.17±0.1c	25.09±2.1d	18.70±0.1e	14.21±0.1f
Anambra 1	31.92±1.3b	27.18±0.7d	24.80±0.1c	19.27±0.3d
Control	36.92±1.1a	30.04±3.2c	25.55±1.3c	28.77±3.2b
Niger 6	21.34±0.5e	17.08±1.5g	13.40±0.8f	9.07±1.7g
Control	32.06±0.2b	30.21±0.8c	21.60±0.5d	19.21±0.4d
Cross River 1	27.29±1.8c	25.01±0.1d	18.16±0.3e	13.07±1.3f
Control	31.66±1.5b	41.23±2.8a	28.70±2.1b	29.04±2.4b
Cross River 5	30.32±0.1b	26.08±1.3d	20.33±1.3d	16.04±0.7b
Control	24.20±0.1d	28.66±0.1d	25.11±0.6c	30.16±0.3b
Oyo 2	22.30±1.5e	19.44±0.2f	16.30±2.0e	13.81±0.7f
Control	32.33±2.3b	25.09±1.7d	30.15±2.3b	29.16±2.3b
Ekiti 2	20.33±1.2e	30.07±2.2c	22.14±1.3d	20.62±0.1d

Control	27.06±1.7c	23.90±1.0e	26.32±0.8c	30.11±3.1b
Anambra 4	31.52±0.9b	25.88±0.8b	21.18±1.1d	14.85±0.1e
Control	23.77±0.1e	23.66±1.4e	34.51±0.2a	30.42±2.4b

Values are means of three replicates. Means with same letter along the column are not significantly different. ($p>0.05$), using Duncan Multiple Range Test (DMRT)

Table 4. Effect of *Zingiber officinale* essential oil on rot development in inoculated tubers

State	Concentration ($\mu\text{L/mL}$)			
	0.1	0.2	0.3	0.4
Ekiti 5	31.03±1.3b	26.22±0.3d	19.77±0.8d	14.08±0.1d
Control	39.21±2.0a	34.27±1.8b	31.41±1.6b	38.03±2.3a
Kaduna 5	26.77±1.5c	25.17±0.7d	20.71±0.5d	15.33±0.1d.
Control	28.77±0.8c	29.17±1.5c	30.71±0.5b	33.33±1.3b
Edo 1	23.05±1.2d	20.41±2.5e	17.38±1.2e	14.78.5d
Control	39.68±2.8a	31.13±1.7c	30.12±0.1b	34.09±1.5b
Niger 2	27.31±1.3c	23.44±0.1e	21.32±0.1d	11.98±0.3e
Control	26.33±2.0c	29.11±0.1c	30.81±0.1b	27.18±0.1c
Abuja 5	28.07±1.0c	26.22±1.1d	21.08±1.3d	15.77±0.1d
Control	32.60±2.5b	24.13±1.0d	27.67±2.0c	25.96±0.8c
Oyo 1	24.20±0.8d	24.10±1.2d	20.80±1.5d	12.06±0.5e
Control	30.30±2.9b	27.08±0.5d	31.44±0.7b	24.60±0.5c.
Abuja 4	33.49±1.6b	26.01±0.5d	22.33±0.6d	15.02±10d
Control	38.20±3.5a	29.54±1.3c	28.80±1.5c	33.27±1.6b
Ondo 1	30.11±0.7b	24.09±0.8d	19.88±1.1d	12.07±1.0e
Control	40.05±2.4a	32.19±1.9c	34.24±2.0a	27.13±2.2c
Anambra 1	28.04±1.7c	26.23±0.1d	20.51±1.3d	14.33±0.1d
Control	32.22±0.3b	30.77±1.5c	25.90±1.3c	31.31±1.5b
Niger 6	30.83±2.3b	26.03±0.7d	16.20±0.1d	10.17±0.5e
Control	31.22±0.1b	40.09±1.6a	26.13±0.3c	28.07±0.1c
Cross River 1	27.30±0.1c	21.36±0.3e	14.55±1.2e	9.32±0.1e
Control	28.18±2.0c	31.11±0.3c	27.22±2.0c	30.87±2.1b
Cross River 5	25.07±1.1d	24.66±1.3d	15.04±1.1e	12.76±3.1e
Control	32.08±1.2b	35.80±3.4b	27.82±1.3c	30.33±1.7b
Oyo 2	24.16±1.5d	22.09±0.5e	17.24±0.3e	11.11±0.1e
Control	31.08±1.9b	25.64±1.2d	30.89±2.1b	26.18±1.3c
Ekiti 2	25.55±0.5d	20.33±0.8e	12.57±0.9f	10.34±0.8e
Control	32.01±2.1b	29.16±0.8c	31.17±3.2b	25.62±1.6c
Anambra 4	24.75±0.7d	17.77±0.3f	14.87±1.1e	11.46±0.7e
Control	30.71±1.5b	26.04±1.5d	23.22±1.8d	14.32±0.7d

Values are means of three replicates. Means with same letter along the column are not significantly different. ($p>0.05$), using Duncan Multiple Range Test (DMRT)

Discussion

In this study, several bioactive compounds were obtained from each of the botanicals, *Syzygium aromaticum* and *Zingiber officinale*. Eugenol was the most abundant organic compound (70.20%), while Trans-isoeugenol was the lowest (1.15%) in *S. aromaticum* EO. This result is consistent with the findings of previous authors who had reported eugenol as the most predominant volatile organic constituent of clove EO (Xing *et al.*, 2012; Hiwandika *et al.*, 2021; Dania and Esiobu, 2022). GC-MS analysis of the EO

obtained from ginger rhizomes showed the presence of 39 compounds which accounted for 99.97% of its constituents. The monoterpenoid α -zingiberene was the most predominant constituent with a concentration of 52.27%. Several authors have reported zingiberene as the major and bioactive principle in the EO composition of *Z. officinale* (Yeh *et al.*, 2015; Mao *et al.*, 2019; Shalaby *et al.*, 2023). Although each of the EOs contains an inherent major active constituent, it is believed that some of the other secondary metabolites may act in synergy towards the enhancement of antimicrobial

activity and suppression against *Fusarium*-induced tuber rot disease of yam. Dania and Esiobu (2022) hypothesized that the antifungal activity of EOs may be primarily due to their major compounds and the possibility of a synergistic or masking effect with other micro constituents exists.

The number of compounds extracted from the botanicals differed depending on the plant material and other extraneous factors. Several authors have reported significant variation in the EO constituents of botanicals depending on location, plant material, time of harvesting and extraction method (Wang *et al.*, 2019). The method and time of EO application could, to a large extent, determine the level of success to be achieved in the use of EO for plant disease management (Mao *et al.*, 2019). It has been substantiated that extraction yield and chemical composition of EOs can vary with extrinsic and intrinsic factors such as age of plant organ and agro-ecological origin (Braga *et al.*, 2005). The efficacy of EOs as antimicrobial agents primarily depends on their chemical composition and intrinsic interactions between the components. Although, the efficacy of EOs had been attributed to the presence of volatile organic compounds such as those recorded in the GC-MS analyses in this study, other secondary metabolites such as alkaloids, flavonoids, terpenoids and tannins from plant materials are also capable of inhibiting growth of different fungal pathogens (Aidah *et al.*, 2014). The constituents of EOs are generally hydrophobic and could accumulate in the lipid-rich environments of the cell membrane structures causing structural and functional damage (Tang *et al.* 2018; Dania *et al.* 2019; Yang *et al.*, 2023).

The best inhibitory effect of *S. aromaticum* EO was recorded at 0.4 µL/mL concentration when rot development was reduced to between 9.32 and 17.33% which was significantly ($p < 0.05$) higher than rot reduction obtained in the control tubers without extract application (14.32 to 38.03%). This result is consistent with previous findings of Xing *et al.* (2012) that reported the efficacy of clove EO in the suppression of mycelial growth of *Rhizopus stolonifer*, *Aspergillus flavus* and *Penicillium citrinum* *in vitro* and fruit rot disease incidence. In a similar research, Moghaddam *et al.* (2019) reported that clove EO effectively inhibited growth of *A. ochraceus* strains causing ochratoxin production and contamination in groundnut. According to Cox and Markham (2007) and Sameza *et al.* (2014), eugenol may inactivate essential enzymes, react with the cell membrane or disrupt the genetic material functionality. It could be inferred, therefore, that this compound may be the main active ingredient in clove EO, because of its inherent efficacy against plant pathogens. However, bioactivity could also be due to less abundant or trace components that act essentially through additive or synergistic interactions. In addition, the lipophilic property of the EO that readily diffuses

into plant tissue across membranes and acts on mycelia and conidia could justify the reduction of the necrotic lesion (Xing *et al.*, 2012)

The highest inhibitory effect of *Z. officinale* EO was recorded at 0.4 µL/mL concentration with rot development reduced to between 9.09 and 20.62%. Several authors have reported the effectiveness of ginger EO in the management of plant pathogens. Kalhor *et al.* (2022) reported the fungicidal activity of *Z. officinale* EO against *Phytophthora colocasiae* causing taro blight disease. In a related research, Xi *et al.*, 2022 found EO obtained from ginger rhizome to be effective against the soilborne pathogen, *Fusarium solani*, in citrus orchard. Ginger EO has been projected as potential biocontrol product against plant pathogens and bioherbicide for the control of noxious weeds (Raveau *et al.*, 2020).

Conclusion

This study has revealed that rot initiation and subsequent development was significantly inhibited in yam tubers that were inoculated with *Fusarium* species, but treated with *S. aromaticum* and *Z. officinale* EOs. These findings imply that the EOs have the prospects of being formulated and deployed as biofungicides in the management of postharvest rot disease of yam. However, further study is required in nanoformulation of the EO to surmount volatility constraint and facilitate efficient field delivery.

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