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ANTIFUNGAL POTENTIAL OF *Lippia multiflora* MOLD. AND *Melaleuca leucadendron* L. ESSENTIAL OILS AGAINST SOME ROOT BORNE FUNGI OF *IPOMEA BATATAS* (L) LAM. IN CÔTE D'IVOIRE

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ABSTRACT

The objective of this study was to evaluate the antifungal activity of *Lippia multiflora* and *Melaleuca leucadendron* essential oils against three phytopathogenic fungi (*Rhizopus* sp., *Fusarium* sp., and *Aspergillus* sp.) associated with *Ipomea batatas* tuberos. Essential oils had been extracted by steam distillation method from leaves of selected plants and their chemical composition was characterized by gas chromatography-mass spectrometry (GC-MS). Essential oil composition characterization was followed by the estimation of percentage mycelial growth inhibition, minimum inhibitory concentration, and minimum fungicidal concentration of the isolated essential oils against the tested pathogens by the Sabouraud dilution medium method. Antifungal activity of different concentrations of isolated essential oils was evaluated by using the microdilution method. The most abundant compounds identified in the *M. leucadendron* essential oil are 1,8-cineole (38.2%), viridiflorol (13.4%), α -Pinene (12.5%), α -terpineol (9.2%), and geranial (22.8%) while *L. multiflora* essential oil have neral (18.7%), 1,8-Cineole (11.4%), α -Phellandrene (6.8%), sabinene (3.5%) as active ingredients. The concentration of essential oils which completely inhibited the mycelial growth and spore germination of all the tested pathogen varies and it was reported 0.33 μ L/mL and 0.66 μ L/mL for *L. multiflora* respectively while it was reported 24 μ L/mL for *M. leucadendron*, for both effect, seven days of incubation. The minimum concentration of fungicidal essential oil against *Aspergillus* sp. was 0.33 μ L/mL for *L. multiflora*. The findings of the current study confirm the fungicidal properties of the tested essential oils and their potential use in the management of economically important fungal pathogens of *Ipomea batatas*. Further, these essential oils can be used as possible alternatives to synthetic fungicides.

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1 Introduction

The economies of African countries especially Côte d'Ivoire is mainly based on livestock and agricultural production. Among agricultural products, sweet potato is the seventh most important crop in the world after wheat, rice, maize, potato, barley, and cassava because of its high yield, high adaptability, and high strength (Yan et al., 2014). Sweet potatoes are rich in vitamins, minerals (mainly potassium), dietary fiber, and protein which provide higher energy and nutrition (Ndangui, 2015). Besides, more than 80% of its composition is carbohydrates, mainly in the form of starch (Nepa, 2006). Roots and tubers, including cassava, sweet potato, potato, and yam, are the main food crops for human consumption in Africa (Zannou et al., 2017). In Côte d'Ivoire, sweet potato has recently received much attention due to its many agricultural advantages such as its adaptability to different environmental conditions and its nutritional value. The annual production, which is self-consumed, is about 50,000 tonnes and is carried out by the Central and Northern regions of the country (Anonymous, 2009).

Sweet potato crop faces many biotic and abiotic stresses, among identified biotic stress, spongy and soft root rot disease of sweet potatoes is the most damaging one. Mould contamination of these roots can lead to the loss of marketability and sanitary qualities. Indeed, the development of moulds on sweet potatoes can lead to their discoloration and poor presentation. Also, moulds can produce allergenic and toxic metabolites (mycotoxins) that can penetrate the sweet potato and affect the health of the consumer (Nasser, 2001).

To protect crops and keep harvests healthy, farmers used chemical fungicides or pesticides to reduce the microbial load or to slow down biochemical alteration reactions, as well as the action of microorganisms. However, commonly used chemicals may, in the short or long term, pose a real risk of mutagenicity, chromosomal aberrations, and cancers to the consumers (Elkaketal., 2012). The need for an alternate strategy feels by researchers and makes various efforts to develop a low-cost method that is compatible with environmental concerns and can control the spreading of disease. The control of sweet potato root rot fungi by the application of natural fungicides has taken a very important place in alternative strategies to synthetic fungicides. In this sense, the study of secondary metabolites from plants is an interesting strategy for the protection of food against fungal parasites (Tomal et al., 2015).

Essential oils with their wide spectrum of action against a large number of fungal species are a very promising alternative, without being a source of danger to human health or pollution to the environment (Broydé & Doré, 2013). The current study was aimed to establish the antifungal potential of two essential oils viz., *L.*

multiflora and *M. leucadendron* against three main root rot fungi (*Rhizopus* sp., *Aspergillus* sp., and *Fusarium* sp.) isolated from the tuberous roots of sweet potatoes.

2 Material and Methods

2.1 Extraction of essential oils

L. multiflora leaves were collected at Tortya (8° 46' N; 5° 41' O) in the north while *M. leucadendron* leaves from San Pedro (4° 44' 41' N; 6° 38' 23' O) regions, these two regions are located in the northern part and southern of Côte d'Ivoire respectively. The leaves of the selected plants were air-dried for seven days at room temperature under laboratory conditions (28 ± 2 °C). The essential oils were obtained from these dry leaves by steam distillation method. The essential oil yield was determined by processing 5 Kg of dry leaves matter. The percentages of essential oil yield have been calculated as follow:

$$\text{Yield (\%)} = \frac{\text{weight of essential oil}}{\text{Weight of leaves}} \times 100$$

2.2 Chemical composition of the isolated essential oils

GC-MS analyses were performed on a Hewlett-Packard gas chromatography (GC 5890, SeriesII) equipped with a HP-5 fused silica capillary column (5% phenyl 95% methylpolysiloxane :30 m x 0.25 mm i.d. 0.25 µm). The mass detector is a quadrupole type (model 5972). The temperature of the column is programmed between 70 to 200 °C at a rate of 10°C/min. The injector and transfer temperatures are 220°C and 250°C respectively. The carrier gas is Helium, the flow rate is fixed at 0.06 ml/min. 1 µL of an essential oil solution (10% essential oil in ethylether) is injected in split mode (leakage ratio: 1/100). The ionization energy is equal to 70 eV; electron multiplier 1400 eV; scanning area [35-300 (m/z)]; scanning rate 2.96 scan/s. The components were identified based on their retention index calculated by comparing retention times with those of a series of alkanes (C9-C22) and by comparing their mass spectra with those of the NBS 75 K/ NIST 98/WILEY 275 libraries (McLafferty, 1989). Some of the compounds from essential oil were confirmed by comparing their retention times with those of authentic standard substances and with data as reported by Adams (2007).

2.3 Isolation and description of fungal test pathogens

The three test pathogens were originally isolated from the naturally infected root of *Ipomea batatas*. Naturally infected tuberous roots are immersed for two minutes in a 1% potassium hypochlorite solution to remove surface saprophytic flora, it was followed by washing tubers three times by sterile distilled water. These roots segments were dried on sterile filter paper (Whatman) (Rosales & Mew, 1997) before being cut into small pieces. These surface-sterilized root fragments are transferred to the Petri dishes

supplemented with potato dextrose agar medium (PDA) (15 mL per dish) and the dishes were incubated at 25°C. To obtain pure single-spore culture, hyphal tips from the fungal cultures were subcultured onto Potato Dextrose Agar (PDA) and incubated at 25°C. Confirmation of the identity of the resultant cultures was based on cultural and morphological characteristics (Samson et al., 2004; Domsch et al., 2007).

2.4 Determination of the antifungal activity of essential oils

The evaluation of the antifungal activity of essential oils is adopted by the direct contact method with various concentrations obtained by the addition of essential oils (dissolved in 0.5% (v/v) of Tween-80) at different doses upon 15 mL of Sabouraud with chloramphenicol (45°C) in a sterilized Erlenmeyer flask. The final concentration used for current study are C1= 0.066; C2= 0.166; C3= 0.333 and C4= 0.666 µL/mL for *L. multiflora* essential oil while it was used C1=2.66; C2= 5.33; C3= 12; C4= 24 and C5= 48 µL/mL for the essential oil of *M. leucadendron*.

Agar disque with mycelia (6 mm in diameter) were cut from the periphery of actively growing regions of 5-7days-old pure cultures using a sterile cork borer and aseptically inoculated at the center of the sabouraud Petri plate containing PDA medium with essential oil. Control plates (without the essential oil) were inoculated by following the same procedure. Three replicates were maintained for each treatment and the plates were incubated at 28 ± 2°C. The fungal colony diameter reading was taken every day and up to seven days of incubation. The percentage inhibition of the mycelial growth of the test fungi by the essential oil was calculated using the formula given by Pandey et al., (1982):

$$T(\%) = \left(\frac{dt - dT}{dt} \right) \times 100$$

T: inhibition rate

dt : average diameter of fungal colonies in the control

dT: average diameter of treated fungal colonies.

2.5 Determination of Minimum Inhibitory Concentration and Minimum Fungicidal Concentration

Minimum Inhibitory Concentration (MIC) was defined as the lowest concentration of essential oil at which fungal growth inhibited. The determination of the mycelial growth inhibition rate of each fungal strain made it possible to define the minimum inhibitory concentration (MIC). To determine the minimum fungicidal concentration (MFC) each mycelium was cut from the center of the dishes that did not show any visible fungal growth and inoculated in plates containing Sabouraud plates and these plates were incubated for 14 days at 28 ± 2°C. After 14 days of incubation at 28 ± 2°C, the readings of MFCs were carried out based on the growth controls. The minimum fungicidal

concentration was represented by the lowest essential oil concentration that hindered the visible growth of the subculture (did not yield any fungal growth on the solid medium used). MFC can be defined as the lowest concentration at which no growth was observed after sub-culturing into fresh media.

2.6 Inhibitory effect on spore germination

The evaluation of the antifungal activity was carried out using a slide germination test of spore as described by Doumbouya et al. (2012). Fungal spores were collected using sterile distilled water, from Sabouraud plates after 5 to 7 days of growth at 28 ± 2°C. Based on the preliminary results on the antifungal activity of the essential oils tested, the concentrations used for the determination of MIC and MFC were chosen for the spore germination inhibition tests. These concentrations (0.066 to 0.66 µL/mL for *L. multiflora* and 2.66 to 48 µL/mL for *M. leucadendron*) were obtained by adding different doses of essential oils to the Sabouraud medium (15 mL) melted under agitation to facilitate the dispersion of natural compounds in the medium. The medium was poured into Petri dishes and in the center of each Petri dish was inoculated 0.1 µL suspension of spores of the three activated fungal strains in the Sabouraud to obtain a concentration of 10⁵ spores/mL. The control sample consisted of a plate with culture media without essential oils. All experiments were carried out in 3 replicates.

3 Results

3.1 Essential oils yield

Characteristics and yield of essential oil varies from species to species. The essential oil from the leaves of *L. multiflora* is in light yellow, with a persistent odor and a yield of 1.2%. The essential oil obtained from the leaves of *M. leucadendron* is the blade in colour, with a pleasant odour and yield is of 0.9% (Table 1).

Table 1 Physical characteristics and yields of essential oils

Essential oil	<i>L. multiflora</i>	<i>M. leucadendron</i>
Color	Light yellow	Blade
Odour	Persistent and pleasant	pleasant
Yield (%)	1.2	0.9

3.2 Chemical composition of essential oils

The results of the chemical analyses of *M. leucadendron* and *L. multiflora* essential oils samples are presented in table 2. According to the obtained results, both essential oils are characterized by their richness in oxygenated monoterpenes. The essential oil of *M. leucadendron* consists of compounds divided into three terpene groups viz., 47.7% oxygenated monoterpenes, 16.3% hydrocarbon monoterpenes, and 13.4% oxygenated sesquiterpenes. In the group

Table 2 Majority compounds of the essential oils studied

Compounds	IR ^a	IR ^b	<i>M. leucadendron</i>	<i>L. multiflora</i>
<i>Hydrocarbon monoterpenes</i>			16.3	11.8
α -pinene	936	1011	12.5	1.0
Sabinene	975	1044	-	3.5
β -pinene	982	1104	2.8	
Myrcene	991	1132	-	0.5
α -phellandrene	1004	1154	-	6.8
Limonene	1030	1187	1.0	
<i>Oxygenated monoterpenes</i>			47.7	63.6
1,8 cineole	1036	1209	38.2	11.4
γ -terpinene	1060	1232	0.3	
Linalol	1097	1552	-	6.5
α -terpineol	1194	1696	9.2	4.2
Neral	1242	1699	-	18.7
Geranial	1272	1715	-	22.8
<i>Oxygenated sesquiterpenes</i>			13.4	-
Viridiflorol	1614	1817	13.4	-

IR^a= RetentionIndex on non polar HP5column ; IR^b= CalculatedRetentionIndex

Table 3 Macroscopic and microscopic characteristics of isolated strains

Colonies aspects	Macroscopic characteristics			Microscopic characteristics			Identified Genera
	Colony shape	Back color of the back	Reverse	Hyphae	Spore shape	Organization of conidial heads	
<i>Fluffy</i>	Invasive	Whitish	Does not penetrate agar	Not partitioned with rhizoids	Spherical	Brush shape	<i>Rhizopus</i> sp.
<i>Powdery</i>	Invasive but slow	Greenish	Does not penetrate agar	Partitioned	Spherical	Brush shape	<i>Aspergillus</i> sp.
<i>Pastey</i>	Invasive but very slow	Pink white with age	Does not penetrate agar	Partitioned	Fusiformity	Crescent shape	<i>Fusarium</i> sp

of oxygenated monoterpenes, 1,8-cineole with a content of 38.2% and α -terpineol (9.2%) were the most represented terpenic elements. α -Pinene (12.5%) is the most important hydrocarbon monoterpene. This essential oil is also composed of sesquiterpenes such as viridiflorol (13.4%).

Similarly, the essential oil extracted from *L. multiflora* also revealed the predominance of oxygenated monoterpene compounds (63.6%) such as 41.5% citral (18.7% neral and 22.8% geranial) and 1,8-Cineole (11.4%). However, it is relatively unlikely to be composed of hydrocarbon monoterpenes. α -Phellandrene (6.8%) and sabinene (3.5%) were also the most representative hydrocarbon components identified from these two essential oils.

3.3 Identification of fungal strain

The macroscopic and microscopic characteristics of the different fungal strains isolated from sweet potato roots grown on Sabouraud are grouped in Table 3.

3.4 Antifungal activity of isolated essential oils

The antifungal activities of isolated essential oils were recorded as mycelial growth inhibition and spore germination inhibition against all three selected three fungal pathogens viz., *Rhizopus* sp., *Aspergillus* sp., and *Fusarium* sp. Both essential oils exhibited significant antifungal activities against the isolated pathogens and it varies against the essential oil concentration.

3.5 Effect of *L. multiflora* essential oil on isolated fungal strains

The effects of different essential oil concentrations on the inhibition percentage of fungus are shown in figure 1. In the case of *L. multiflora* essential oil, the highest inhibition (100%) for all the isolated pathogen was observed at concentration C3 (0.33 μ L/mL) after 7 days of incubation. Similar results were observed for concentration C4 (0.666 μ L/mL) while the lowest inhibition was obtained with C1 (0.066 μ L/mL). These results

Figure 1 : Inhibition rate of mycelial growth of *Rhizopus* sp., *Aspergillus* sp. and *Fusarium* sp. at different concentrations of *L. multiflora* essential oil : C1= 0.066 μL/mL; C2= 0.166 μL/mL; C3= 0.333 μL/mL ; C4= 0.666 μL/mL

Figure 2 : Inhibition rate of mycelial growth *Rhizopus* sp., *Aspergillus* sp., *Fusarium* sp. at different concentrations of *M. leucadendron* essential oil : C1= 2.66 μL/mL; C2= 5.33 μL/mL; C3= 12 μL/mL; C4= 24 μL/mL; C5= 48 μL/mL

Table 4 Minimum inhibitory and fungicidal concentrations of essential oils of *L. multiflora* and *M. leucadendron*

Strains	<i>Lippia multiflora</i>		<i>Melaleuca leucadendron</i>	
	MIC (μL/mL)	MFC (μL/mL)	MIC (μL/mL)	MFC (μL/mL)
<i>Rhizopus</i>	0.33	-	24	nd
<i>Aspergillus</i>	0.33	0.33	24	nd
<i>Fusarium</i>	0.33	-	24	nd

MIC: minimum inhibitory concentration; **MFC:** minimum fungicide concentration

indicate that the percentage inhibition of mycelia growth increased with increasing concentration of *L. multiflora* essential oil for all fungus tested.

3.6 Effect of *M. leucadendron* essential oil on isolated fungal strains

The effects of different concentrations of *M. leucadendron* essential oils on the inhibition percentage of fungus are shown in figure 2. The highest inhibition (100%) of mycelial growth for all the isolated pathogen was observed at concentration C4 (24 μL/mL) after 7 days of incubation. However, in the case of various fungal isolates, highest (78.17%) inhibition was observed for *Rhizopus* sp. at the lowest concentration C1 (2.66 μL/mL). The results of the study revealed that *Rhizopus* sp. showed high sensitivity to *M. leucadendron* essential oil at all concentrations. The lowest inhibition was observed in the concentration of C1 (2.66 μL/mL), C2 (5.33 μL/mL), and C3 (12 μL/mL) on *Aspergillus* sp. and *Fusarium* sp.

3.7 Minimum inhibitory and fungicidal concentration of essential oils

The results of study showed that both tested essential oils have varied degrees of inhibition in mycelial growth. The minimum inhibitory concentration (MIC) for *Aspergillus* sp., *Rhizopus* sp., and *Fusarium* sp., was 0.33 μL/mL and 24 μL/mL for *L. multiflora* and *M. leucadendron* respectively (Table 4). The minimum fungicidal concentration (MFC) for *Aspergillus* sp., was 0.33 μL/mL and this concentration was fatal for *Aspergillus* sp., (Table 4). This indicated that this oil has a fungistatic effect on *Aspergillus* sp.

3.8 Inhibition of spore germination

Data presented in table 5 revealed that the reduction in spore germination was reported with the increasing essential oil concentration. The highest essential oil concentration of both oils tested caused the most profound reduction of spore germination. The highest reduction in spore germination was reported in *L. multiflora* oil which completely inhibited the spore germination of all test fungal strains at 0.66 μL/mL concentration. Conversely, *M. leucadendron* essential oil gave a moderate reduction in spore germination at the lowest concentration of oil. Total inhibition of

Table 5 Inhibition of spore germination by essential oils

Strains	<i>L. multiflora</i> (μL/mL)					<i>M. leucadendron</i> (μL/mL)					
	Control	0.06	0.16	0.33	0.66	Control	2.66	5.33	12	24	48
<i>Rhizopus sp</i>	+	+	+	-	-	+	+	+	+	-	-
<i>Aspergillus sp</i>	+	+	+	+	-	+	+	+	+	-	-
<i>Fusarium sp</i>	+	+	+	-	-	+	+	+	+	-	-

+ germination of spore

-: inhibition of germination

spore germination was reported at 24 $\mu\text{L/mL}$. These results show that *L. multiflora* essential oil has a higher fungitoxicity against all three fungal strains.

4 Discussion

The average yield of *L. multiflora* leaves essential oil after extraction is 1.2%, which is similar to the report of Tia (2012) those who obtained a similar yield (1.2%) from *L. multiflora* leaves. Similarly, Kouamé et al. (2008) reported the yield of *L. multiflora* leaves between 0.8-1.3%. Also, a higher essential oil yield (0.9%) was obtained with *M. leucadendron*. Rokhaya et al. (2017) obtained a similar essential oil yield from *Senegalese* species. In this study, the components of *M. leucadendron* essential oil were identified. Among various reported compounds, 1,8 cineole, α -terpineol, α -pinene, and viridiflorol were the major components. In a recent report on the chemical composition and biological activity of the essential oil of *M. leucadendron*, various authors confirm the high terpenoids contents (Pino et al., 2010; Pujiarti et al., 2012; Tia et al., 2013; Rokhaya et al., 2017). The oil of *L. multiflora* was characterized by the high proportion of oxygenated monoterpenes with a predominance of citral. These results are contradictory to the findings of Tia et al. (2011) and Soro et al. (2015), those who reported predominance of oxygenated terpenes such as linalol, (E)-Nerolidol and thymol in the essential oil of *L. multiflora* from Yamoussoukro and Bondoukou respectively. Also, 1,8 cineole at a rate of 60.5% was previously detected by Owolabi et al. (2009). In addition, in this study, citral and 1,8 cineole, with respective proportions of 41.5% and 11.4% were the main molecules of *L. multiflora* oil. Similar results were obtained by Soro et al. (2015) on the same species from Abidjan and Toumodi in Côte d'Ivoire. The variations in composition observed in the essential oil of *L. multiflora* can be justified by the geographical origin and physiological state of the plant.

The results of the sanitary analysis of sweet potato roots showed the presence of several types of mould fungus such as *Fusarium*, *Rhizopus* and *Aspergillus* colonize the roots. Concerning the main genera identified, the results of the current study are in agreement with those obtained by Dao (2013), who worked on 116 seed samples of local maize cultivars collected from farmers in Burkina Faso in different locations. These cosmopolitan fungi, especially in tropical and subtropical regions, are the most common and frequently isolated from stored foods (Laouid & Neftia, 2007).

In this study, antifungal effects of two essential oils including *L. multiflora* and *M. leucadendron* was evaluated against three root-borne fungi of *Ipomea batatas* and determined their mycelial growth inhibition rate, minimum inhibitory concentration, and minimum fungicidal concentration.

It was observed that *L. multiflora* oil completely inhibited the mycelial growth of the selected fungi at 0.33 $\mu\text{L/mL}$ concentration. Furthermore, this essential oil also inhibited complete spore germination of all isolated fungal strain. The inhibitory activity of *L. multiflora* essential oil against fungal pathogens was also reported by various authors (Bassolé & Juliani, 2012; Tiendrebeogo et al., 2017; Cissé et al., 2019). This antifungal activity of *L. multiflora* oil probably depends on the major components citral (41.5%) and 1,8-Cineole (11.4%).

As result, the essential oil of *M. leucadendron* also has acceptable antifungal properties against the isolated pathogens. The efficacy of these essential oils was positively correlated with the concentration. *M. leucadendron* oil has complete inhibition and highly effective against the mycelial growth and spore germination at 24 $\mu\text{L/mL}$ concentration. These results are in agreement with those reported by Doumbouya et al. (2012) which show that the essential oil of the genus *M. leucadendron* has a weak action on *F. oxysporum* and *Pythium* sp. Similar results have been reported by Camara et al. (2010) when they tested a high concentration of *M. leucadendron* essential oil against *Deightoniella*. Indeed, the strains studied do not have the same sensitivity to the essential oils tested. This could be explained by the diversity of membrane components of each microorganism and by the chemical composition of each plant species (Yen & Chang, 2008).

The fungitoxicity of *M. leucadendron* oil can be accredited to the most abundant components 1,8-cineole, α -Pinene, α -terpineol. These monoterpenes had been earlier reported for their antifungal properties as part of many essential oils (Sartorelli et al., 2007; Liu et al., 2008; Gudrun & Gerhard, 2012; Tabassum & Vidyasagar, 2013).

The essential oil of *L. multiflora* and *M. leucadendron* have a particular chemical composition. It contains a high proportion of oxygenate compounds. Several previous studies have shown that essential oils rich in terpenoids may have antifungal properties (Tiendrebeogo et al., 2017; Ouoba et al., 2018;). Monoterpenes could act on permeability but also other functions in cell membranes, thereby disrupting membrane exchanges (Cristani et al., 2007; Russo et al., 2013). This gives them different modes of action on several types of fungi that cause food spoilage (Aoudou et al., 2010). 1,8-cineole was found to be highly capable of eliminating the fungal pathogens by altering the structure and moisture of mucous membranes of fungal cells and interrupting the respiratory processes (Andriole, 1994). Various monoterpenes with antimicrobial potencies such as α -pinene, α -terpineol, and citral have antifungal and antibacterial activities (Zhou et al., 2014; Mahizan et al., 2019). These components seem to be contributing to the total efficiency. According to Grbic et al. (2011), the constituents of essential oils interact with the absorption of nutrients from the environment, which affects the mycelial growth of fungi. They operate on mycelial hyphae, loss of rigidity, and

integrity of the hyphae cell wall, resulting in the death of the mycelium (Sharma & Tripathi, 2008).

The essential oils of *L. multiflora* and *M. leucadendron* have shown the potential to inhibit spore germination. Complete inhibition (100%) of spore germination was obtained with *L. multiflora* (0.66 µL/mL) and *M. leucadendron* (24 µL/mL). The results of the present study are in agreement with the previous findings which indicate that essential oils can inhibit fungal spore germination (Grbic et al., 2011; Doumouya et al., 2012). According to Chitarra (2003), the active metabolism that occurs during spore germination is respiration, RNA, and protein synthesis. These vital mechanisms can be inhibited by essential oils that can penetrate, disrupt fungal cell walls and cytoplasmic membranes (Grbic et al., 2011). This will damage and permeate mitochondrial membranes (Akthar et al., 2014).

Major components are usually found to be responsible for the antimicrobial activities of essential oils. But sometimes the minor and trace components may also play a significant role in synergistic and antagonistic interactions to influence the total activity of the oil (Ismail et al., 2013). Referring to the values of the minimum fungicidal concentrations of each of these oils used, the study revealed that *L. multiflora* oil is the most toxic. Tests should be considered under actual tuberous root storage conditions to assess its biological efficacy on the major fungal strains that colonize these roots. This could lead to the practical use of these essential oils as an alternative solution in integrated systems for the protection of sweet potato tuberous roots in Côte d'Ivoire.

Conclusion

The investigation of the antifungal activity of the tested of *L. multiflora* and *M. leucadendron* essential oils against three phytopathogenic fungi (*Rhizopus* sp., *Fusarium* sp., and *Aspergillus* sp.) associated with *Ipomea batatas* tuberous showed that both oils have antifungal effects. The results of this study indicate the high effect was observed with *L. multiflora* oil which provides complete inhibited on mycelial growth of *Fusarium* sp., *Rhizopus* sp. and *Aspergillus* sp. at 0.33 µL/mL concentration strains tested. This antifungal activity of *L. multiflora* oil probably depends on the major components. In this case of *Melaleuca* oil, a higher concentration was needed for inhibition. Both essential oils could be used as food preservatives in some food products where fungal strain can grow and can spoilage the product. Further research is needed on safety issues namely, on the effect of natural antifungal in field condition.

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Conflicts of interest

We have no conflict of interest to declare.

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