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Original Article

Developing Sustainable Wood Preservatives: The Antifungal Efficiency of *Afzelia quanzensis* Welv. and *Androstachys johnsonii* Prain Sawdust Extracts from Mozambique

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Sawdust, Wood Extractives, Wood Durability, Wood Destroying Fungi, Antifungal Properties.

ABSTRACT

This study aimed to both develop and assess the antifungal efficacy of extractives derived from different sets of sawdust originating from two hardwood species, namely chanfuta (Afzelia quanzensis Welv.) and mecrusse (Androstachys johnsonnii Prain). These hardwood species possess inherent characteristics of high natural durability. The primary objective was to use these extractives to impregnate perishable wood species, enhancing their durability and augmenting their commercial value. Collected wood sawdust was initially sieved to remove residues and unwanted materials and conditioned until 12% moisture content. Subsequently, the sawdust was Soxhlet-extracted using a mixture of organic solvents, including acetone, ethanol, and toluene. After evaporating the solvents, the resulting extractives were used to prepare a preservative solution with ethanol and acetone. The extractive solutions from each wood species were mixed with malt extract agar and then diluted to various concentrations: 0.125 mg/mL, 0.25 mg/mL, 0.5 mg/mL, 1.25 mg/mL, 2.0 mg/mL, and 2.5 mg/mL. For each concentration, fungal plugs from the periphery of actively growing cultures were moved to the centre of Petri dishes and placed in controlled laboratory conditions for incubation. The antifungal efficacy was assessed against specific wood-decaying fungi, including brown rot fungi (Coniophora puteana, Postia placenta, Lentinus lapideus) and white rot (Trametes versicolor). The evaluation involved daily monitoring of the linear expansion along two perpendicular radii for each fungus expressed as a percentage of the empty Petri dish area. The results indicated that the chanfuta extractives inhibited the growth of brown rot fungi at a concentration of 0.25 mg/mL and white rot fungi at 2.0 mg/mL. Similarly, the mecrusse extractives inhibit brown rot at 0.5 mg/mL and white rot at 2.0 mg/mL. The fatty acids Oleic (C18:1) present in the chanfuta extractives solution and linoleic (C18:2) in mecrusse extractives contributed to restraining the fungal growth. These results suggest that sawdust extractives from both wood species exhibit promising potential for creating environmentally friendly wood preservatives, which, with effective treatments, could extend the lifespan of perishable wood species.

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INTRODUCTION

Fungi, bacteria, and insects play crucial roles in nature's recycling of carbon and nutrients through biodegradation processes (Uma *et al.*, 2023). They break down wood and other lignocellulosic materials into simple molecules, enriching soil fertility and increasing plant growth (Kržišnik and Gonçalves, 2023). However, this degradation also accelerates the deterioration of wood, thus reducing its lifespan. Fungi, particularly the *Basidiomycetes* group, are major contributors to wood damage, with significant economic implications.

Wood decay caused by fungi typically manifests in three main types: brown rot, white rot, and soft rot. Each type exhibits distinct decay patterns, closely linked to the fungi's capacity to degrade the primary cell wall chemical components, namely cellulose, hemicelluloses, and lignin (Randall, 2000; Woźniak, 2022; Xia and Jia, 2023). For example, brown rot fungi (e.g., *Serpula lacrymans*) target wood's cell wall carbohydrates, mainly cellulose and hemicellulose, altering the lignin structure without utilising it (Zabel and Morrell, 2020). This process leads to rapid depolymerisation of cellulose, resulting in decreased strength properties due to shortened cellulose chain molecules. Consequently, this group of fungi is relevant in the wood construction sector. Meanwhile, white rot fungi (e.g. *Trametes versicolor*) attack cellulose, hemicellulose, and lignin. In the initial stages of decay, affected wood may darken, but bleaching occurs as the decay advances. Soft rot fungi (e.g. *Chaetomium globosum*) target wood surfaces exposed to extremely wet conditions, such as being submerged in water or in contact with wet soil (Xia and Jia, 2023). The *hyphae* of soft rot fungi penetrate the cell's secondary wall, aligning longitudinally and parallel to the microfibrils of layer S2. Their enzymes break down the cellulosic components, leaving behind cylindrical-shaped cavities with pointed ends (Zabel and Morrell, 2020). According to Daniel (2016), fungi penetrate the cell wall via boreholes, with secreted enzymes degrading the cell wall to absorb nutrients for growth and development. This process results in the proteins reacting with the cell wall components, causing structural openings.

Problem statement

Throughout history, humans have recognised the importance of protecting wooden structures to extend their lifetime. Initially, this led to the widespread use of synthetic toxic chemicals worldwide. According to Meena (2022), toxic

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chemicals efficiently improve wood durability and increase the service life of wood structures even in hazardous conditions. Although the best performance demonstrates using toxic products (e.g. creosote), several environmental issues have been recorded, leading to restrictions and even the banning of some chemicals in the EU and the USA (Khademibami and Bobadilha, 2022). The toxic chemicals leach out from wood and negatively affect the environment and human health. For example, large areas treated with synthetic chemicals for railway cross-ties/sleepers contaminate soil and water streams, posing significant risks to aquatic life and the environment (Meena, 2022; Miranji *et al.*, 2022). In Mozambique, apart from the railway cross-ties, the vast network of chemically treated wooden transmission poles represents the primary source of contamination when leaching occurs during service life.

Moreover, developing eco-friendly wood preservatives has become an urgent need in the context of sustainable and environmentally friendly technologies. Traditionally, humans relied on naturally durable timber species such as chanfuta (*Afzelia quanzensis*) and mecrusee (*Androstachys johnsonnii*). However, the increasing demand for these species has led to overexploitation and scarcity. Eco-friendly wood preservatives are an alternative to synthetic toxic chemicals in wood protection. Therefore, some challenges in developing eco-friendly preservatives lie in their effectiveness against fungi and their fixation ability to treat wood structures. Alternatively, using plant-based extracts with biocidal properties is gaining ground to avert the reliance on toxic wood preservatives. Indeed, studies have proved that extractives from naturally durable wood species significantly inhibit fungal growth. Among several studies, Brocco *et al.* (2015) conducted research evaluating the preservative potential of teak (*Tectona grandis*) extractives against *Nasutitermes corniger* termite, showing promising results. Sablík *et al.* (2016) conducted antifungal tests using heartwood extractives sourced from Black locust (*Robinia pseudoacacia* L.) and African padauk (*Pterocarpus soyauxii* Taub.). Their preliminary results indicated a strong antifungal activity. Likewise, Özgenç *et al.* (2017) performed antifungal experiments by examining bark extracts as an organic biocide, exploring their potential as alternative wood protection materials. The bark extracts were exposed to brown rot and white rot fungi, yielding promising results.

The most common and typical extracts found in plant material comprise 1) terpenoids and steroids, 2) fats and waxes, and 3) phenolic constituents divided into four groups: stilbenes, lignans, flavonoids, and tannins (Verkasalo *et al*., 2021). The listed compounds are sourced from stems, bark, branches, knots and needles. Phenolic extracts are usually found in heartwood and protect the wood against microbiological damage or insect attack (Jansson and Nilvebrant, 2009).

Other plant extracts, such as essential oils, have also been used worldwide to protect wood against fungi and termites. For example, essential plant oils such as anise, cinnamon, and geranium have been proven to improve wood durability and increase the lifetime of treated products (Voda *et al.*, 2003; Chittenden and Singh, 2011; Broda, 2020). They have also been tried for fixing and immobilising chemical compounds in cell walls. Liebert *et al*. (2011) performed the preservative fixation by combining the wood protection agent and oil treatment, although this tends to increase the preservative cost.

Several studies determined active ingredients with potential antifungal effects of extractives. For example, Mohareb *et al*. (2010) conducted a chemical characterisation of extractives sourced from Cypress (*Cupressus lusitanica*) heartwood using GC-MS analyses. The extractive chromatogram showed the presence of benzaldehyde and terpenic compounds, including cedrol, agathadiol, epimanool, bornyl acetate, α-cedrene, and β–cedrene. Therefore, cedrol was found to represent 14.5% of all extractives and reportedly has biocide properties. Additionally, Bhat *et al.* (2010) obtained extractives from *Tectona grandis* and conducted an antifungal test

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against *Phanerochaete chrysosporium*. Furthermore, bioactive compounds were determined from the extract and 2-methyl anthraquinone, 1,4-naphthoquinone, and lapachol compounds all showed the antifungal effect.

Like in other Tropical countries, sawmills in Mozambique process tropical wood species and generate residues, mainly sawdust. This resource is primarily accumulated in the yard and underutilised. Typically, sawdust is mostly employed for domestic energy and as litter material for the broilers' growth performance (Shao *et al*., 2019; Udokpoh and Nnaji, 2023). Therefore, large amounts of sawdust residues accumulate in sawmills across the country, posing several problems, such as fire risks and attracting nesting pests. Moreover, most of the wood species processed in sawmills possess high natural durability and represent a source of valuable bioactive molecules. This scenario presents an opportunity to come up with efficient, environmentally friendly methods to extract these compounds from the abundant sawdust by-product and utilise them to treat emerging lesser-known/used, mostly very perishable wood species.

This study aims to develop and assess the antifungal effectiveness of a potential wood preservative solution derived and formulated from the sawdust of two highly durable wood species. By repurposing potentially polluting sawmill residues as raw material, the study aims to contribute to the circular economy.

MATERIALS AND METHODS

Materials

Sawdust from two naturally durable hardwood species (*Afzelia quanzensis* Welv. and *Androstachys johnsonii* Prain); acetone (Sigma-Aldrich CAS 67-61-1 UN: 1090), ethanol (99%, Sigma-Aldrich CAS 64-17-5 UN: 1170), and Toluene.

Study area

The study took place in Maputo, south of Mozambique, where sawmills are located. The sawmill has a log yard, a building with machinery, and a saw-sharpening room. The log yard at this sawmill is used for logs unloading and as a storage area. To carry out the sawing operations, the sawmill has a simple band saw attached to the log carriage that the operator activates from the control panel. The generated sawdust is removed daily from the operation area and stocked in sisal bags. Furthermore, a large part of the generated sawdust is accumulated in an open space. The sawmill has a low level of automation, and the equipment operation depends on labour. Therefore, the sawmill operates with five employees.

Sawdust collection and further processing

The sawdust from two highly durable wood species, namely chanfuta (*Afzelia quanzensis* Welv.) and mecrusse (*Androstachys johnsonii* Prain), was collected separately from a local sawmill in Maputo, Mozambique. These two species are among the most commonly processed timbers in the country. To ensure accurate taxonomy, solid wood samples from peeled logs were collected for anatomical examination; these samples were then compared against reference xylarium specimens from the Eduardo Mondlane University in Mozambique. The results confirmed the identity of *Afzelia quanzensis* Welw and *Androstachys johnsonii* Prain. Following identity confirmation, the sawdust from each wood species was collected and stored in individual ziplock plastic bags, labelled accordingly, and taken to the laboratory for further processing. Subsequently, the sawdust from each wood species was placed in aluminium containers stored at room temperature to air dry to decrease the moisture content. Then, the samples were oven-dried, and the weight was recorded. The initial moisture content of the raw material was 94.9% for chanfuta sawdust and 70.9% for mecrusse sawdust. Before the oven dry step, the sawdust from each species underwent a gradual sieving process, passing through sieves with apertures of 1.00 mm and 0.500 mm. Subsequently, the sawdust batches were placed in a laboratory oven set at 105 ± 3 ºC for 24 hours. Once oven-dried,

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each sawdust species was allowed to cool down in a desiccator for one hour.

Extraction process

The extractives from oven-dried sawdust were obtained following standard laboratory procedures (Sluiter *et al.*, 2008). In this study, approximately 18 g of oven-dried sawdust was placed in a cellulosic thimble (33 mm inner diameter and 95 mm height). The extraction process was carried out using a Soxhlet apparatus, with successive extractions using 400 mL of a mixture of organic solvents comprising ethanol, acetone and toluene (2:1:1 v/v/v). Each extraction cycle lasted around 48 hours. Extracts were collected and dried in a rotary evaporator at 60ºC under vacuum, and 16.52% yields for chanfuta sawdust and 19.71% yields for mecrusse were obtained based on dry and unextracted wood.

Chemical characterization of extractives

This process was carried out to depict or establish the presence of potential antifungal chemical compounds in the oven-dried sawdust. The extractive samples were analysed for fatty acids and phenolic compounds. For fatty acid composition, the extractives samples were methylated with 2wt % H_2SO_4 in water-free methanol at 90 °C for 60 min. The fatty acid methyl esters were extracted into heptane and analysed by gas chromatography/mass spectrometry (Agilent 9000 gas chromatograph system, Intuvo, USA), equipped with an HP-5MS column (30 m×0.25 mm i.d., and 0.25 μm film thickness) and an Agilent 5975 mass-selective detector. Helium was used as carrier gas at a 1 mL/min flow rate. The initial temperature of the oven was set at 60 °C for 1 min, then to 220 °C at a rate of 20 °C/min, held for 2 min, and finally to 280 °C at 10 °C/min, held for 30 min.

Antifungal efficiency assessment

The antifungal activity of the obtained extracts was assessed following the method outlined by Chang *et al.* (1999), with minor adjustments. In this experiment, the growth medium composed of 2% malt extract and 1.5% agar was sterilised for 20 minutes. The extracts from the two wood species were separately added to the media to achieve concentrations ranging from 0.125 to 2.5 mg/ml, each in four replicates (Figure 1). Plugs of common wood-destroying fungi, namely (i) brown-rot fungi (*Coniophora puteana* - Cp), (*Postia placenta* - Pp), *Lentinus lapideu* (Ll), and (ii) white-rot Fungus (*Trametes versicolor*-Tv) from actively growing cultures were placed at the centre of Petri dishes and then incubated at 22°C with 70% relative humidity. Control Petri dishes containing only culture media or solvent were included. The diameter of fungal growth was measured when mycelia reached the edges of the control dishes. The fungal growth was evaluated daily by measuring the Petri dishes in the two perpendicular diameters of the colony's linear, radial expansion, and it was expressed as a percentage of the occupied Petri dish area. The growth inhibition corresponded to the unoccupied petri dish area and was calculated according to formula 2, geometrically explained in Figure 2. This evaluation of antifungal activities was conducted in four replicates.

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Figure 1: Diagram of the experiment showing different final concentrations and fungi (Tv-*Trametes versicolor*; Pp-*Postia placenta*; Cp-*Coniophora puteana* and Ll-*Lentinus lapideu*) in four replicates along with control Petri dishes.

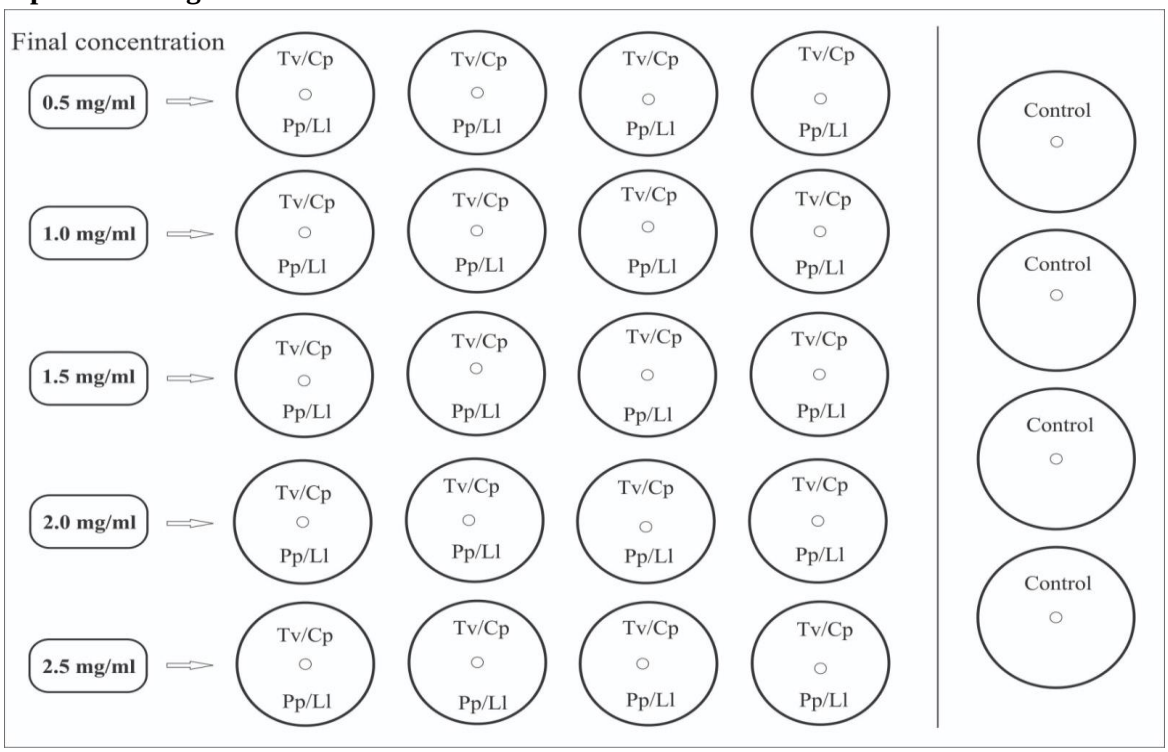
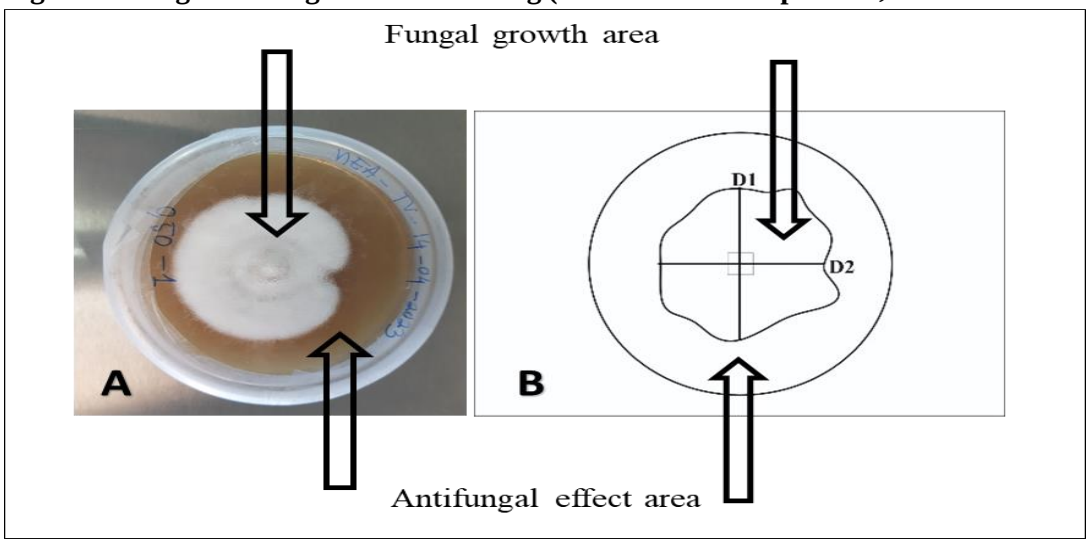


Figure 2: Fungus radial growth monitoring (A-actual radial expansion; B-measurement scheme).



$$GI\ (\%) = \left(1 - \frac{D1}{D}\right) x100 \quad (2)$$

Where:

D1 = fungi radial expansion in the petri dish and

D2 = radial growth in the solvent control dish;

GI = percentage of unoccupied area.

Data analysis

The data were analysed using Stata, a statistical package software. The effect of the extractives sourced on fungal growth in culture media was evaluated using an ANOVA (One-way analysis of variance) in a completely random design. The collected data were checked for a normal distribution. Teste Turkey was conducted to

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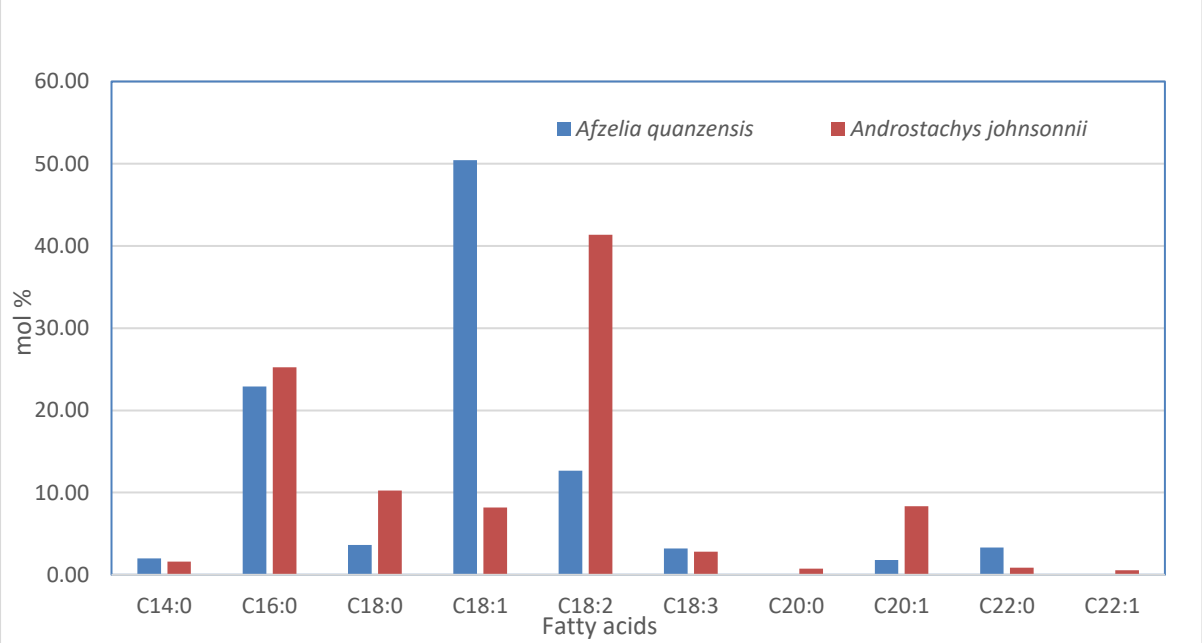
compare the mean values of a fungus's growth inhibition based on different concentrations.

RESULTS AND DISCUSSION

Extraction process and sawdust chemical composition

During the oven-drying of the sawdust before extraction, certain volatile elements of the extracts might have been lost. Following concentration in the rotary evaporator, the solvent extracts from both wood species appeared oily with high viscosity and strong brown colouration. The yields of *Afzelia quanzensis* and *Androstachys johnsonnii* extracts were 16.52% and 19.71%, respectively, calculated based on dry wood sawdust. The extractives contain chemical compounds that inhibit the growth of microorganisms in wood material (Mburu *et al*., 2007; Kilic and Niemz, 2010). Phenolic compounds and fatty acids are reported to possess antifungal properties and are available in wood extractives (Vek *et al*., 2021; Clausen *et al*., 2010). Figure 3 presents the fatty acid composition and distribution of both sawdust species, carried out by the Gas Chromatograph technique.

Figure 3: Sawdust extractives fatty acids composition of *Afzelia quanzensis* and *Androstachys johnsonnii* extractives.



Fatty acids such as myristic (C14:0), palmitic (C16:0), stearic (C18:0), oleic (C18:1), linoleic (C18:2), linolenic (C18:3), arachidic (C20:0), behenic (C22:0) were found in both wood species extractives with relative quantities. Based on Figure 3, palmitic (C16:0), oleic (18:1), and linoleic (C18:2) were the most abundant fatty acids for both wood extractive species. *Afzelia quanzensis* extractives showed relatively higher oleic (18:1) fatty acid (50 mol%) than *Androstachys johnsonnii* extractives; meanwhile, *Androstachys johnsonnii* extractives showed higher content in linoleic (C18:2) (42 mol%) than *Afzelia quanzensis* extractives. Other fatty acids such as myristic (C14:0), linolenic (C18:3), arachidic (C20:0), and behenic (C22:0) were found in the lowest proportion. However, extractives sourced from wood with abundant fatty acids content are reported to act as a barrier to water owing to their hydrophobic long carbon chain and possess inhibition properties against microbiological organisms (fungi, bacteria and insects) (Movahed, 2012). Therefore, according to Guimarães and Venâncio (2022), unsaturated fatty acids show more excellent inhibitory properties than saturated ones because of double bonds. Fatty acids with double bonds and cis configuration exhibit stronger antifungal properties.

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However, oleic (C18:1) and linoleic (C18:2) fatty acids are formed by a straight carbon chain with double bonds in their molecule structure arranged in cis configurations where both hydrogen atoms are on the same side of the double bond.

These fatty acids were dominant in both wood extractive species, which indicates a prospective antifungal effect. Clausen *et al.* (2010) tested a fatty acid-based formulation against mould growth on wood. The authors found that propionic (C3) and pentanoic (C5) acids restrained the fungi's growth at 6% concentration. Yin *et al*. (2018) performed a chemical analysis of wood extractives from *Dalbergia melanoxylon* using GC-MS, and the results revealed the presence of five relevant chemical compounds, which are 10,11-dihydro-10-hydroxy-2,3-dimethoxy dibenzo (b,f) oxepin (peak 12, 4.57%), 2-(4-methoxy-2.5-dimethyl phenyl)-9-methyl-9methyl-2H-benzo [g] indazole (peak 13, 3.14%), 10,11-dihydro-10-hydroxy-2,3,6-trimethoxydibenzo-2,3,6-trimethoxydibenzo (b,f) oxenpin (peak 14, 37.30%), 10,11-dihydro-2,3,6-trimethoxydibenzo (b,f) oxygen-10-one (peak 15, 8.32%) and pillion (peak 16, 7.77%). These chemical compounds inhibit the attacks of microorganisms and protect the heartwood. Further studies are needed to characterise phenolic compounds in *Afzelia quanzensis* and *Androstachys johnsonnii* wood extractives.

Antifungal performance of extracts from both wood species against wood-destroying fungi

Table 2 summarises the growth inhibition of all tested fungi at different extract concentrations. The results indicate that fungal growth inhibition increased with higher extract concentrations for all wood decay fungi tested. This trend is consistent with findings reported by Sablík *et al*. (2016), Özgenç *et al.* (2017) and Manan *et al*. (2022). For instance, Manan *et al*. (2022) evaluated the antifungal activities of extractives sourced from *Neobalanocarpus heimii* (Cengal) heartwood against *Coniophora puteana* and *Trametes versicolor* in a mixed culture medium at concentrations of 10, 25, and 50 mg/mL. They reported that the antifungal index of 81.22% at 10mg/mL increased with rising concentrations to 100% at 50mg/mL, demonstrating the extract's effectiveness in inhibiting white rot fungi, *Trametes versicolor*. To calculate the antifungal index, the authors placed a fresh fungal plug in the centre of a Petri dish, allowed it to incubate for a few days, measured the colony diameter, and then computed the antifungal index accordingly. Sablík *et al*. (2016) assessed the antifungal efficacy using extractives extracted from the heartwood of Black locust (*Robinia pseudoacacia* L.) and African padauk (*Pterocarpus soyauxii* Taub.) and exhibited strong antifungal properties.

Table 2: Fungal growth inhibition (%) for each concentration extractive formulation of both wood species sawdust

Concentration	*Coniophora puteana*		*Postia placenta*		*Lentinus lapideus*		*Trametes versicolor*	
(mg/mL)	AQ	AJ	AQ	AJ	AQ	AJ	AQ	AJ
0.125	8.2 (5.39)	13.0 (7.84)	19.3 (5.62)	7.1 (4.20)	8.7 (3.14)	8.8 (2.31)	21.15 (4.23)	4.4 (3.68)
0.25	28.2 (3.52)	26.1 (4.69)	61.7 (6.21)	17.6 (3.74)	25.0 (3.58)	47.2 (1.30)	29.05 (2.52)	30.6 (2.63) a
0.5	66.2 (2.41)	48.9 (2.25) a	76.1 (3.52)	40.1 (2.85)	42.9 (2.74)	60.0 (2.41)	38.5 (3.25)	39.2 (1.52) a
1.25	75.7 (2.20)	58.4 (2.41) ab	100.0 (2.41) a	60.6 (2.20)	63.0 (1.23)	69.5 (1.63) a	50.3 (2.35)	52.4 (1.54)
2.0	94.2 (1.23) a	66.7 (1.85) bc	100.0 (2.02) a	75.3 (2.96)	92.3 (1.10) a	71.3 (1.28) a	61.8 (1.85) a	65.7 (2.20)
2.5	100.0 (1.08) a	74.9 (1.02) c	100.0 (2.08) a	83.3 (3.10)	100.0 (2.52) a	82.8 (1.32)	67.4 (1.53) a	78.1 (1.41)

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Note: Means of growth inhibition variable followed by the same letters do not statistically differ using the Tukey test ($p<0.05$). The means comparison is made within each fungus, either chanfuta (AQ) extractives or mecrusse (AJ) extractives.

Legend: AQ - *Afzelia quanzensis*; AJ - *Androstachys johnsonnii*.

The results in Table 2 reveal contrasting effects between the chanfuta and mecrusse extracts at a 2.5 mg/mL concentration. While chanfuta extract effectively suppressed the growth of *Coniophora puteana, Postia placenta,* and *Lentinus lapideus* fungi, it failed to inhibit *Trametes versicolor* entirely. In comparison, mecrusse extract exhibited less potent inhibition overall, with the highest recorded inhibition (83.3%) observed against *Postia placenta*. Interestingly, *Postia placenta* required a lower concentration of chanfuta extract (1.25 mg/mL) to be entirely suppressed, with inhibition starting at 0.25 mg/mL. Conversely, mecrusse extract demonstrated superior performance against *Trametes versicolor* across all concentrations tested (0.125 – 2.5 mg/mL), although complete inhibition was not attained even at the highest concentration.

For *Coniophora puteana,* chanfuta extract showed a concentration-dependent effect, with increased concentrations resulting in greater growth inhibition. Notably, significant inhibition (66.2%) was observed at 0.5 mg/mL, with subsequent concentrations slowing down fungal growth further. Interestingly, there was no statistical difference between the 2.0 mg/mL (94.2%) and 2.5 mg/mL (100.0%) concentrations, suggesting a threshold concentration to inhibit total fungal growth. Similarly, *Lentinus lapideus* displayed behaviour comparable to *Coniophora puteana,* achieving complete inhibition at 2.0 mg/mL.

Figure 4 shows the performance of wood extractives from chanfuta and mecrusse against brown rot fungus *Coniophora puteana* at 0.5 mg/mL and 2.5 mg/mL concentrations. *Coniophora puteana* was completely inhibited from growing under chanfuta wood extractives at the highest concentration (2.5 mg/mL) because it effectively stopped the fungal growth. However, mecrusse wood extractives at the same concentration showed a sign of growth as the mycelia slightly expanded, which means that it did not stop but restrained the fungal growth.

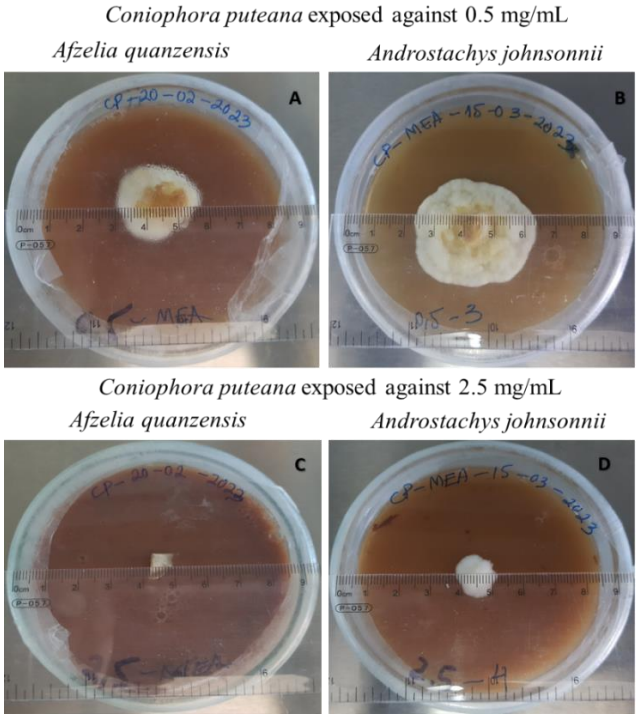

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Figure 4: Antifungal performance of extractives from chanfuta and mecrusse against brown rot fungus *Coniophora puteana*; A-Fungal expansion in culture medium under *Afzelia quanzensis* extractives at 0.5 mg/mL; B-Fungal expansion in culture medium under *Androstachys johnsonnii* at 0.5 mg/mL; C- Fungal expansion in culture medium under *Afzelia quanzensis* extractives at 2.5 mg/mL; D- Fungal expansion in culture medium under *Androstachys johnsonnii* extractive solution at 2.5 mg/mL. Scale division in millimetres.

CONCLUSION

Based on the study results, it could be concluded that the extractives obtained from chanfuta sawdust restrained the fungal growth with increased concentrations from 0.125 to 2.5 mg/mL. Furthermore, the same trend was observed for the mecrusse extractive solution, even though it could not stop the fungal growth in all concentrations against all tested fungi. The effectiveness of both sources of extractives was observed at higher concentrations (2.0 and 2.5 mg/mL) against all fungi except *Postia placenta* and *Lentinus lapideus*, in which significant inhibition was achieved at relatively low concentrations (0.25 mg/mL and 0.5 mg/mL respectively).

Both phenolic compounds and fatty acids had active compounds with antifungal effect. Phenolic compounds are reported to be the active chemicals. The fatty acids Oleic (C18:1) present in the chanfuta extractives solution and linoleic (C18:2) in mecrusse extractives contributed to restraining the fungal growth.

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Ethical approval: The research was conducted without regard to human or animal use. All rights, safety, dignity, and well-being of research participants were observed.

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