REVIEW ARTICLE

Trametes elegans: Sources and Potential Medicinal and Food Applications

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ABSTRACT

The emergence of microfungi medicinal applications represents a turnover in the drug discovery field. These microfungi species are found in rotten woods and leaf litters collected from forests and reserves in some tropical countries during rainy seasons. Among these species is *Trametes elegans*, which shares a commensalism-based relationship with the host (plants), offering protection against external invasions. Thus, *Trametes elegans* possesses unique compositional values and gained tremendous interest in the last decade for its promising applications, such as inhibiting a wide range of bacteria and harmful fungi, reducing oxidative stresses caused by free-radicals, nitric oxide, and hydrogen peroxide, as well as extending food shelf-life. This mini-review reports the available literature on *Trametes elegans* sources, studied extracts applications, and urges the investigation of other *Trametes elegans* potential applications as antiviral and anticancer agents.
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INTRODUCTION

Trametes elegans, which Fries in 1835 formally described as Trametes (1), were previously known as Lenzites due to the convenience of recognizing them (2). T. elegans is an endophytic fungus that were found generally in hardwood forests (3). This organism is from the family Polyporaceae (4), phylum of Basidiomycete (5) and known as the genus Basidiomycota (6). However, these species were known as the most confused group of the Polyporaceae family (7). *Trametes elegans* can be identified via characteristics such as cyanophilus skeletal, skeletal hyphae, ochraceous brown basidiocarp (8), thin-walled basidiophores, poroid hymenophore, and non-amyloid (1). Even though the characteristics of this organism were listed, it is still tough to identify the Trametes species (7). Thus, the ITS region uses the molecular marker to identify *T. elegans* species.

T. elegans, which are famous for their medicinal values, and industrial uses (6), are also being used in the food production industry (9) and are commonly used for the restoration of soil, and wastewater treatment, as well as lignin biodegradation (10). In addition, these species are also widely distributed in crucial climatic zones and continents (1). A map of the regional distribution of sources of *T. elegans* is shown in Figure 1. However, studies on *T. elegans* are still lacking, particularly on its phylogenetics (10), the importance, taxonomic, and other properties that are still not fully understood (1). This mini review covers the sources of *Trametes elegans* and its potential medicinal and food preservation applications.

TRAMETES ELEGANS IN ANTIMICROBIAL APPLICATIONS

The rising cases of antibiotic-resistant bacteria such as vancomycin-resistant Enterococcus (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), and carbapenem-resistant *Acinetobacter baumannii*, is an indication that resistance towards drugs is happening fast and becoming a serious public health problem worldwide. It was reported that roughly 700,000 people die because of resistance to antibiotics every year (11). This necessitates discovering antimicrobial/antibiotics from natural resources such as fungal source. Fungal endophytes can inhibit the growth of organisms inside of the host (12) and have the potential to replace synthetic

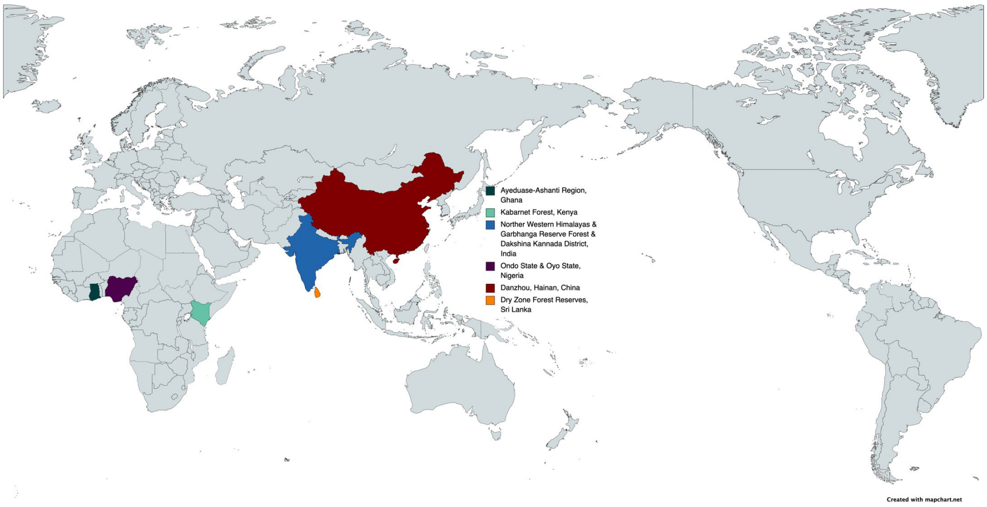

Figure 1: A map of the current reported sources of *T. elegans*.

antibiotics.

A study conducted by Appiah et al. (2017) discovered that there was an antimicrobial activity of *T. elegans* collected from forests and farms originating from Ayeduase–Ashanti Region, Ghana, against a spectrum of Gram-negative bacteria (*Pseudomonas aeruginosa, Enterococcus faecalis, Salmonella typhi, Klebsiella pneumonia, Escherichia coli*) and Gram-positive bacteria (*Enterococcus faecalis, Bacillus subtilis, Staphylococcus aureus*, and *Streptococcus pyogenes*). The methanol extract of *T. elegans* inhibited all the organisms tested in this study. This could be due to the presence of secondary metabolites and bioactive compounds such as triterpenoids, flavonoids, and tannins that were able to react and produce the inhibition zone when tested (13). *T. elegans* that was collected from stumps and logs of rotten woods of Kabarnet forest, Kenya, was found to be able to produce compounds such as ergosta-5,7,22 trien-3-ol, Lupeol, 9,19-cycloartane-3,30-diol, 5α-8α-epidioxyergosta-6,22-dien-3β-ol, 5α,8α-epidioxyergosta-6,9 (14), and ergosta-7,22-dien-3β, 5α,6β-triol that can inhibit Gram-negative bacteria such as *Shigella, Citrobacter enterocolitica*, and Gram-positive consists of *Streptococcus pneumonia* with results of inhibition, suggesting *T. elegans* as a great source of antimicrobial agent (3).

A comparison study using hexane and methanol extract of *T. elegans* collected from the Chail area of District Solan and Morny hills, Western Himalayas was conducted to observe which extract is much more efficient as an antimicrobial agent. Methanol extract at 100mg/mL was more effective than hexane extract against Gram-positive organism (*S. aureus*) and Gram-negative organisms (*K. pneumoniae and E.coli*). Polar solvents are more efficient for extracting inorganic and organic materials from biological sources (15). Meanwhile, methanol extract at 50mg/mL was still effective against Bacillus cereus but could not inhibit *S. aureus*. This could be due to several factors such as changeable mushroom extracts for the activity of antimicrobial, type of test organisms, environment, type of media, type of solvent used for extraction as well as the chemical constituent of antibacterial from mushroom extracts (16). In another comparison study, water-ethanol extract of *T. elegans* was also effective against Gram-positive bacteria (*B. subtillis*, *S. aureus*) and Gram-negative bacteria (*S. typhi, E. coli,* and *P. aeruginosa*). Interestingly, *T. elegans* showed a higher inhibition zone in the disc-diffusion method than other microfungal species such as *Auricularia auricula-judae, Pleurotus ostreatus, Pleurotus tuber-regium, Pycnoporous sanguineus, Schizophyllum commune, Trametes versicolor* and *Tremella fuciformis*, commonly used for their antibacterial activity (17).

Fungal infections for the last 30 years have been causing diseases that threaten human lives. This is sometimes known as systemic fungal infection, leading to high mortality, morbidity, and economic burdens (18). Asia has the highest fungal diseases globally because of the tropical environment (19) and overusing antibiotics (20). An example of an infamous fungal infection is the *Candida albicans*, which has caused an estimated hospital infection of 350,000-400,000 cases with an additional 40% mortality rate (21). In a study where *T. elegans*, collected from Ilara Morkin, State of Ondo, Nigeria, was used to evaluate the potential as an antifungal compound against *C. albicans* and *Aspergillus fumigatus*. The acetone extract of *T. elegans* inhibited the tested organism, proving its potential application as an antifungal extract. Other solvents such as n-hexane and methanol from *T. elegans* were also evaluated against *Candida* sp., which inhibited the species and indicated the presence of bioactive compounds present in *T. elegans* that can be used to treat candidiasis as an antifungal product (22). In another study, acetone extract of *T. elegans* was used as antifungal agent and showed a 25.5mm inhibition zone against *Aspergillus fumigatus* (16). Altogether indicate that *T. elegans* are efficient organisms to be used as an antifungal agent against fungal infection. This also strengthens the conviction of the author to recommend researchers to further evaluate the potential of *T. elegans* as an antifungal agent against *Candida* sp., as candidiasis has been a huge threat to women, which, when left untreated, can cause congenital cutaneous candidiasis, membrane rupture, preterm delivery and membrane rupture (8). In addition, *T. elegans* were isolated from the leaves of *Amomum villosum* Lour –where the leaves were collected from Danzhou, Hainan, China and further evaluated as an antifungal compound against *Colletotrichum musae*, which causes fruit rot such as in bananas. Evaluation of *T. elegans* against C. musae indicated an excellent result as they could protect the banana rot from being spoilt and exhibited the highest activity compared to the control carbendazim (23). Table I summarizes the different sources of *T. elegans* and its potential medicinal applications.

TRAMETES ELEGANS IN ANTIOXIDANT APPLICATIONS

Oxidative stress occurs due to a lack of balance between antioxidant defenses and the reactive oxygen species (ROS) (24). This leads to diabetes, cancer, ageing, and atherosclerosis and other severe health issues. Antioxidants have the potential to protect the human body from such diseases (25). Antioxidants function by blocking the reactions of the oxidizing chain of free radicals in molecules and reducing the oxidative damage caused by oxidative stress (26). Belinda et al. (2019) stated that an excellent antioxidant agent should contain compounds such as tocopherols, flavonoids, polyphenols, tannins, and lignins (27). *T. elegans* and other macrofungal species were collected from the

Table I: Studies summary on the utility of Trametes elegans in various applications.

Author	Source	Type of extract	Outcome Measures	Result	Conclusion
Appiah et al. 2017 (30)	Forest and farms around Ayedu-ase-Ashanti Region, Ghana	1. Methanolic extract.	1. Gram-negative bacteria inhibition. a. *Pseudomonas aeruginosa* b. *Salmonella typhi* c. *Klebsiella pneumonia* d. *Escherichia coli* 2. Gram-positive bacteria inhibition a. *Enterococcus faecalis* b. *Bacillus subtilis* c. *Staphylococcus aureus* d. *Streptococcus pyogenes*	Inhibition of both gram-negative and gram-positive bacteria with Minimal Inhibitory Concentration (MIC) ranging from 7.5 to 30 mg/ml and zone of inhibition (ZOI) from 10 to 23.5 mm.	Trametes elegans can be used as an anti-bacterial agent.
Mayaka et al., 2019 (20)	Stumps and logs of rotten woods around Kabarnet forest, Baringo County and Kerio Valley, Elgeyo Marakwet County, Kenya	1. Ethyl acetate-hexane extract.	1. Gram-negative bacteria inhibition. a. *Shigella* b. *C. enterocolitica* 2. Gram-positive bacteria inhibition a. *S. pneumonia*	Inhibition of both gram-negative and gram-positive bacteria with MIC ranging from 2.5 to 6.5 mg/ml and ZOI from 8.0 to 9.7 mm.	Trametes elegans can be used as an anti-bacterial agent.
Singh and Tripathi 2018 (31)	Chail area of District Solan and Morny hills in District Panchkula of Norther Western Himalayas, India	1. Methanolic extract. 2. Hexane extract.	1. Gram-negative bacteria inhibition. a. *Klebsiella pneumonia* b. *Escherichia coli* 2. Gram-positive bacteria inhibition a. *Staphylococcus aureus*	Inhibition of both gram-negative and gram-positive bacteria with MIC ranging from 1.5 to 12.5 mg/ml.	Trametes elegans can be used as an anti-bacterial agent.
Deka et al., 2017 (33)	Rotten wood logs and leaf litters around Garbhanga Reserve Forest, Assam, India	1. Ethanol-water extract.	1. Gram-negative bacteria inhibition. a. *Pseudomonas aeruginosa* b. *Salmonella typhi* c. *Escherichia coli* 2. Gram-positive bacteria inhibition a. *Bacillus subtilis* b. *Staphylococcus aureus*	Inhibition of both gram-negative and gram-positive bacteria with MIC ranging from 12.5 to 50 mg/ml and ZOI less than 15 mm.	Trametes elegans can be used as an anti-bacterial agent.
Solate 2016 (38)	Ilara Morkin, from the State of Ondo, Nigeria	1. Methanolic extract. 2. Acetone extract. 3. N-hexane extract.	1. *Candida albicans* inhibition. 2. *Aspergillus fumigatus* inhibition.	Inhibition of *C. albicans* and *A. fumigatus* with MIC 25 mg/ml and ZOI ranging from 2.33 to 30 mm.	Trametes elegans can be used as an anti-fungal agent.
Liu et al., 2016 (39)	Leaves of *Amomum villosum Lour* around Danzhou, Hainan, China.	1. Embedded in potato dextrose agar.	1. *Colletotrichum musae* inhibition.	Inhibition of *C. musae* with ZOI ranging from 10.5 to 29.4 mm.	Trametes elegans can be used as an anti-fungal agent.
Awala et al. 2015 (32)	Rotten woods of cocoa around Osengere, Ibadan, Egbeda, Oyo State, Nigeria.	1. Methanolic extract. 2. Acetone extract.	1. *Aspergillus fumigatus* inhibition.	Inhibition of *A. fumigatus* with MIC ranging from 12.5 to 50 mg/ml and ZOI ranging from 1.5 to 25.5 mm.	Trametes elegans can be used as an anti-fungal agent.
Awala and Otetayo 2015 (45)	Rotten woods of cocoa around Osengere, Ibadan, Egbeda, Oyo State, Nigeria.	1. Methanolic extract. 2. Acetone extract.	1. Free radical detection. 2. Nitrous oxide detection. 3. Hydrogen peroxide scavenging activity	High free-radicals, nitric oxide, and hydrogen peroxide scavenging activity were also detected.	Trametes elegans has strong anti-oxidant activity.
Fernando 2015 (44)	Dry zone forest reserves, Dambulla, Minneriya, and Sigiriya, Sri Lanka	1. Methanolic extract.	1. Phenolic content detection. 2. Flavonoid content detection. 3. Hydrogen peroxide scavenging activity.	High phenolic and flavonoid content indicating strong antioxidant activity. High radical scavenging activity.	Trametes elegans has strong anti-oxidant activity.
Singh and Tripathi 2018 (46)	Northern Western Himalayas, India	1. Malt extract.	1. Free radical detection. 2. Nitrous oxide detection. 3. Hydrogen peroxide scavenging activity	High free-radicals, nitric oxide, and hydrogen peroxide scavenging activity.	Trametes elegans has strong anti-oxidant activity.
Manoj and Earanna 2017 (47)	Dakshina kannada district, Western Ghats, Karnataka, India	1. Aqueous extract.	1. Bovine herpes virus-1 cytolytic inhibition, 2. Morbili virus cytolytic inhibition.	The extract did not exhibit inhibitory effects on the cytolytic activity of Bovine herpes virus-1 nor the Morbili virus.	Trametes elegans is not suitable as an anti-viral agent.
Eniolrunda 2016 (50)	Decayed wood at the farm around Ilara Morkin from Ondo state, Nigeria.	1. Methanolic extract. 2. Acetone extract. 3. N-hexane extract.	1. Shelf-life of pawpaw 2. Shelf life of banana	Extension pawpaw and banana shelf-life.	Trametes elegans can be use to prolong food shelf life.

dry zone forest reserves, Sri Lanka, to evaluate their antioxidant activity using DPPH radical scavenging assay. The half maximal effective concentration (EC50) of *T. elegans* was 198.75 ± 0.48 (µg/ml) indicating its strong potential as antioxidant agent (28). In another study, the ability of *T. elegans* as an antioxidant agent was assessed on sample collected from the rotten woods of cocoa growing in the region of Osengere, Ibadan, Oyo State. The acetone and methanol extracts were evaluated against DPPH radical scavenging activity, nitric oxide scavenging activity, and hydrogen peroxide, where both extracts of *T. elegans* exhibited good potential as antioxidant activity. The outcome from this study can be used as a suggestion to further explore using *T. elegans* as an antioxidant agent, which can be used to protect the body from the damage done by the free radicals (29). However, in comparison to other used antioxidant micro-fungus like *Auricularia auricular-judae, Auricularia polytricha*, and *Ganoderma lucidum*, *T. elegans* extracts showed a middle-class antioxidant activity (30).

TRAMETES ELEGANS AS ANTIVIRAL AGENT

Viral disease has been a significant threat to humankind. In the threat of a health emergency, it is crucial to identify a suitable treatment to stop a pandemic. This is because antiviral treatments are crucial as they can reduce the issues faced by healthcare systems worldwide. Not only that but the vulnerable population can also be protected using antiviral if they are infected with a virus. *T. elegans* collected from Western Ghat in Dakshinakannada (Karnataka district) were tested as an antiviral agent against Petitsruminant virus (PPR) and Bovine herpes virus-1. Even though the extracts of *T. elegans* exhibited inhibitory effects on the host cells, no effects were shown on the cells indicating that *T. elegans* are not suitable as candidates to be antiviral compounds against the tested virus in this study (31). However, this should not be a stopping point as *T. elegans* could be used as antiviral compounds against many viruses globally, estimated to be ten noni million (1031) viruses worldwide (32).

TRAMETES ELEGANS AS FOOD PRESERVATION NATURAL AGENT

The primary purpose of food preservation is to extend shelf-life and ensure quality and safety, which has been the main aim of the government agencies and food industries worldwide. Shelf life is defined as how long the product remains safe, retaining its taste, physical, microbiological, and chemical characteristics, and the nutritional data when stored in suitable conditions (33). In a study to evaluate the potential of *T. elegans* as a food natural preservation agent, the sample was isolated from decayed wood at the farm of Ilara Morkin from Ondo state, Nigeria, and was soaked in different extracts such as methanol, n-hexane, and acetone and was coated on paw-paw and banana. All three extracts of *T.elegans* coated on paw-paw and banana exhibited an extended duration of shelf-life (34), proving that *T. elegans* can be an excellent agent of natural preservation. Despite exhibiting good results as a natural food preservative. This is the first-ever study conducted; thus, it should be extended to other fruits and foods as research involving *T. elegans* is limited. Doing so will increase the shelf life of food and fruits naturally and does not involve using chemicals such as the preservative using nitrite that could lead to the risk of carcinogenic (35).

DISCUSSION

Overall, this review found that the most common Trametes species reported were *Trametes hirsuta* and *Trametes versicolor*. However, studies related to the potential applications of *T. elegans* were limited; therefore, not much information was obtained. For example, in studies related to antimicrobial, despite having such an astonishing result from previous research indicating *T. elegans* can be an excellent antimicrobial agent – we believe that studies on *T. elegans* as an antimicrobial activity are limited. Therefore, more studies need to be conducted. Studies involving multi-drug resistant (MDR) need to be the focus of future studies conducted by the researchers as MDR organisms severe public health crisis (36). It has been a significant obstacle faced by the healthcare system and has caused 700,000 deaths worldwide, and without serious intervention, the death case can increase up to 10 million by 2050 (37). Therefore, it is crucial to develop a new strategy to overcome this issue related to MDR-causing diseases (38) using *T. elegans*. This will reduce the mortality and morbidity rate caused by MDR organisms. As for its potential to combat candidiasis, a previous study indicates that *T. elegans* is very efficient against human pathogens and fruit pathogens. However, research involving *T. elegans* is very little explored; thus, more studies need to be done to further evaluate the capability of this organism as an antifungal compound against other fungal causing infections such as the *Aspergillus niger, Aspergillus flavus*, and *Aspergillus tamarii*.

The same goes for the antioxidant compounds, where the lack of literature on *T. elegans* has been an obstacle to describing more on the potential as an antioxidant agent in this write-up. Thus, more studies need to be conducted on the potential of *T. elegans* as an antioxidant agent.

In order to identify the potential of *T. elegans* as an antiviral compound, more studies need to be conducted against many viruses out there. For example, from 2013-to 2016, the Ebola outbreak terrorised West Africa bringing about 28,000 cases of infection while causing 11,000 deaths (39). Another example of a virus that can be studied using *T. elegans* is the Acquired immunodeficiency syndrome (AIDS), the largest pandemic in public health. In 2017, WHO stated that 37 million individuals have HIV globally, and almost one million individuals die every year (40).

CONCLUSION

In conclusion, for researchers to explore the untapped potential of *T. elegans*, we recommend that additional studies related to antimicrobial, antioxidant, antiviral, and food preservation be conducted to benefit human well-being. Studies involving *T. elegans* as an anticancer agent need to be conducted because cancer has been a major threat to humans and carries the highest amount of morbidity and mortality worldwide, estimated to cause 11 million deaths in 2030 (41). Therefore, it is imperative to conduct this study to explore the potential of *T. elegans* as an anticancer agent.

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