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(REVIEW ARTICLE)

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A comprehensive review of phytochemistry and antibacterial action of *Tectona grandis*

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Abstract

Tectona grandis L. (Teak) is one of the commercial plants which is often used in Southeast Asia. Globally, the total area of planted teaks reaches 3 million hectares, with about 31% of the land located in Indonesia. Preliminary phytochemistry showed bioactive constituents as alkaloids, tannins, flavonoids and phenolic compounds. Isolation and characterization by several methods were reported for quantifying the secondary metabolites found in the various parts of *Tectona G*, following the ICH guidelines and the following were reported, viz; Protocatechuic acid, Quinic acid, and its derivatives, Apigenin 7-O-diglucuronide, Luteolin, Luteolin 7-Odiglucuronide, Luteolin glucuronide, Diglucuronide, Apigenin glucuronide etc, which are responsible for their antibacterial action. The extractives of *Tectona grandis* were studied for antibacterial activities by agar well diffusion and disc diffusion method respectively. The test organism were isolates of nutrient broth, hospital strains, decayed food and Mueller Hinton Broth (MHB), antibacterial action of *Tectona G* were lucid as the extractives showed a maximum inhibitory effect; inhibition zone, evident by a clear zone of inhibition around the discs, minimum inhibitory concentration (MIC) and minimum bacteriocidal concentration (MBC) respectively. Accordingly, this review demonstrates the importance of the herbal plant (*Tectona grandis*) in the treatment of bacteria thus, preventing its resistance.

Keywords: *Tectona grandis*; Phytochemical; Antibacterial; Agar-well diffusion; Inhibition

1. Introduction

Herbal medicine has become an item of global importance both as medicinal and economical. The use of plant and plant products for therapeutic use is known since time immemorial. Herbs are used to treat various infectious diseases worldwide, they are most effective, cheaper and alternative sources of conventional drugs. Plants play a vital role in curing various ailments and herbal remedies are getting increasing patient compliance as they are devoid of typical side effects of allopathic medicines. The effective plant constituents can combat human and plant pathogenic bacteria, fungi and virus without any side effects and environmental hazards. Due to this favorable reason, search for plant products with antimicrobial properties intensified in recent years [1-3]. Although usage of these herbal medicines has increased, their quality, safety and efficiency are of serious concerns in industrialized and developing countries. Bacterial infections are one of the prominent causes of health problems, physical disabilities and mortalities around the world. Plants that have been used in medicine as antimicrobial agents since ancient times could provide a promising solution for drug-resistant species. The natural products are found to be more effective with least side effects as compared to

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commercial antibiotics this is why they are used as an alternate remedy for the treatment of various infections. *Tectona grandis*, the specific name, '*grandis*', is Latin for 'large' or 'great' The frontal leaves of the plant are widely used in folklore for the treatment of various kinds of wounds, especially burn wounds. They are also useful to treat haemostatic, depurative, anti- inflammatory and vulnerary and also useful in leprosy, skin disease, pruritus, microbes, stomatitis, indolent ulcer, haemorrhages and haemopstysis [4].

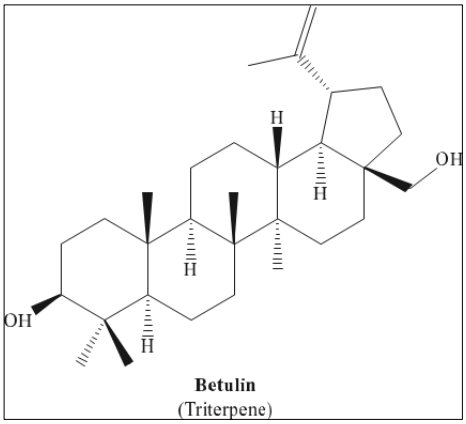
The most essential of bioactive constituents of plants are alkaloids, tannins, flavonoids and phenolic compounds which are responsible for their antibacterial action. Bioactive constituents have found applications as naturally occurring antimicrobial agents in the field of preservation, pharmaceutics, phytopathology etc. Increasing failure of chemotherapeutics and the resistance exhibited by pathogenic microbial infectious agents against antibiotics have led to the screening of medicinal plants for their potential antimicrobial activities [5,6]. There are several reports regarding the antimicrobial activity of crude extracts prepared from plants, some of the active principles of the bioactive compounds are preferred for their therapeutic purposes so as to inhibit the life processes of microbes [7,8]. The purpose of this manuscript is to elucidate a less resistant effective alternative to bacterial pathogen and finding evidence to buttress the traditional healers claim, hence this review.

2. Tectona grandis

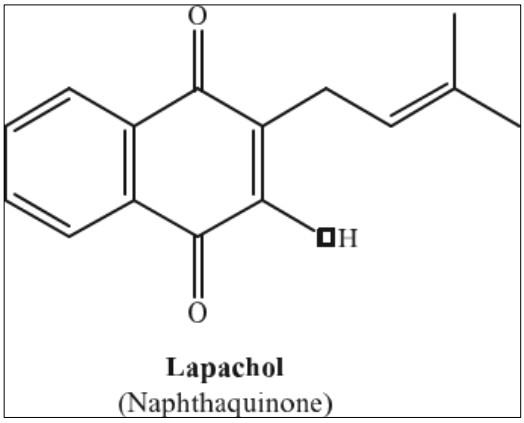
Tectona grandis Linn.(Verbenaceae) is a large deciduous tree. Branchlets are quadrangular, channeled and stellately tomentose. The tree is growing in higher situations, native to central India, Konkan, Western Deccan peninsula, South India and Burma[9]. It is commonly known as sagwan in Hindi, saka in Sanskrit and teak tree in English [10, 11]. Teak is a hardwood species of worldwide reputation [12]. *Tectona grandis* is a large, deciduous tree reaching over 30 m in height in favorable conditions. Crown open with many small branches; Bark is brown, distinctly fibrous with shallow, longitudinal fissures. The root system is superficial, often no deeper than 50 cm, but roots may extend laterally up to 15 m from the stem, leaves are 30-40 by 15-30 cm, elliptic or obovate acute or acuminate. Upper surface of leaf is rough but usually glabrous and the lower clothed with dense stellate grey or tawny tomentum. The very large, 4-sided leaves are shed for 3-4 months during the later half of the dry season, leaving the branchlets bare. Shiny above, hairy below, vein network clear, about 30 x 20 cm but young leaves up to 1 m long. Flowers are shortly pedicellate with lanceolate bracts at the forks. Flowers small, about 8 mm across, mauve to white and arranged in large, flowering heads, about 45 cm long; found on the topmost branches in the unshaded part of the crown. Fruits are 1-3 cm in diameter, subflobose; pericarp is soft with dense felted stellate hairs[9]. Fruit is a drupe with 4 chambers; round, hard and woody, enclosed in an inflated, bladder-like covering; pale green at first, then brown at maturity. Each fruit may contain 0 to 4 seeds. There are 1000-3500 fruits/kg. This family includes about 236 genera and 6900 to 7200 species [13]. The genus *Tectona* comprises 3 species viz; *T. grandis, T. hamiltoniana and T. philippinensi. T. grandis*(teak) is widely distributed in Bangladesh, Thailand, China, India, and Pakistan. *Tectona hamiltoniana* (Dahat teak) is an endangered local endemic species confined to Burma. *Tectona philippinensis* (Philippine teak) is also endangered endemic to the Philippines. Teak is a plant that has a high resistance to weather changes and termite attacks, with a worldwide reputation as a quality timber on account of its remarkable physical and mechanical properties, particularly elasticity, strength, durability and decay resistance [14]. The generic name comes from 'tekka', the Malabar name for *T. grandis*. The specific name, '*grandis*', is Latin for 'large' or 'great' The frontal leaves of the plant are widely used in folklore for the treatment of various kinds of wounds, especially burn wounds. They are also useful to treat haemostatic, depurative, anti-inflammatory and vulnerary, leprosy, skin disease, pruritus, stomatitis, indolent ulcer, haemorrhages and haemopstysis [4].

3. Detailed phytochemical profile of Tectona grandis

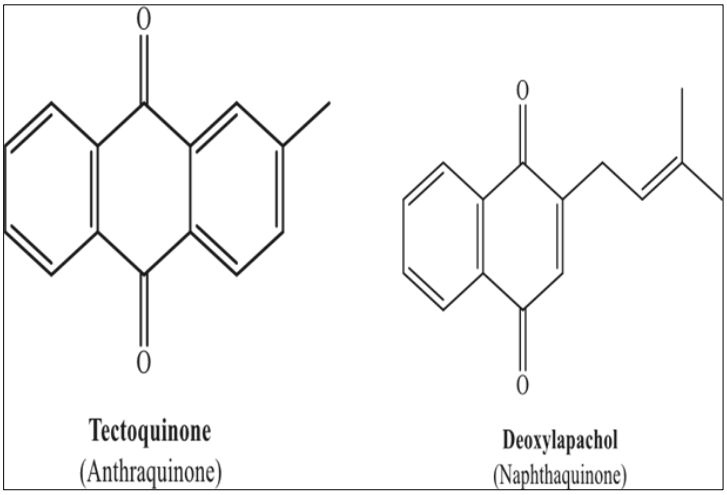
Several instrumental methods are available for identifying and quantifying the phytoconstituents in plants. The literature review describes the use of classical techniques such as high performance liquid chromatography (HPLC), high-performance thin-layer chromatography (HPTLC), gas chromatography-mass spectrometry (GC–MS), and various other methods in the field of medicinal and aromatic plants [15]. Researchers have reported an avalanche of phytoconstituents present in *T. grandis*. Several methods have been reported for quantifying the secondary metabolites found in the various parts of TG following the ICH guidelines. The chemical structures of the different constituents of *T. grandis* have been reported [16-18]. The chemical structures of some important constituents of *T. grandis* are provided below. Some preliminary phytochemicals, along with techniques of isolation and characterization are listed in table 1 and 2 respectively.



Betulin
(Triterpene)

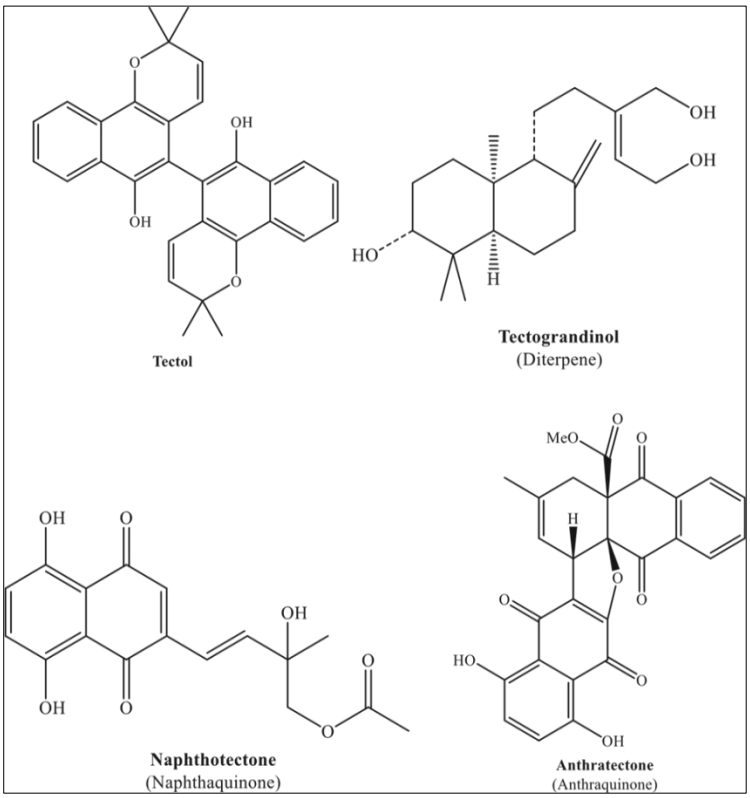


Lapachol
(Naphthaquinone)



Tectoquinone
(Anthraquinone)

Deoxylapachol
(Naphthaquinone)



Tectol

Tectograndinol
(Diterpene)

Naphthotectone
(Naphthaquinone)

Anthratectone
(Anthraquinone)

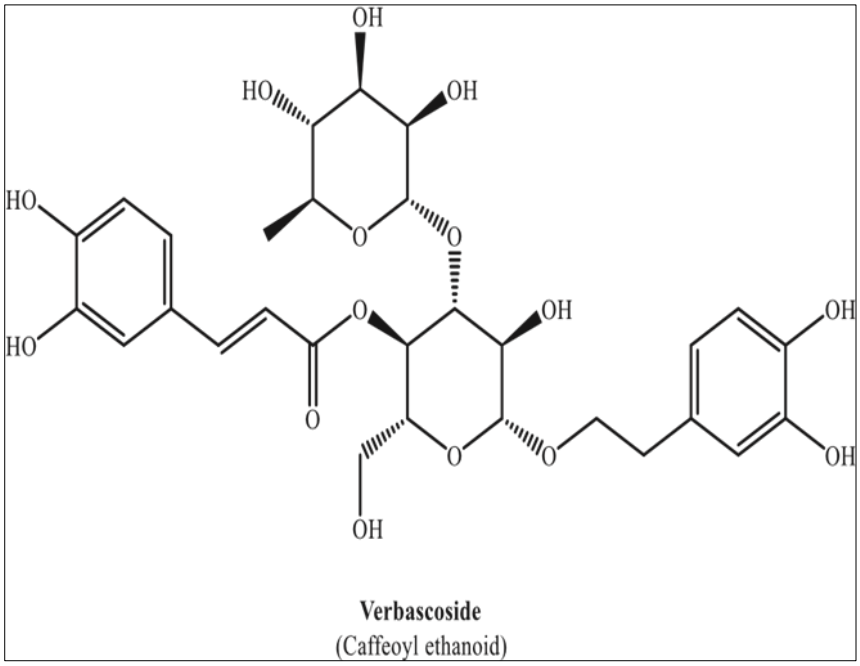


Figure 1 Chemical structures of the different constituents of T. grandi

Table 1 Basic Phytochemical analysis of *Tectona grandis,* Hexane leaf extract

Phytochemical	Qualitative	Quantitative (mg/100g)
Saponins	+	406.60
Tannins	-	1583.00
Flavonoids	+	666.60
Alkaloids	-	1778.30
Terpenoids	-	-
Carbohydrates	-	-
Reducing Sugar	-	-
Steroids	+	-
Glycosides	+	-
Phenols	-	69.50
Cardiac Glycoside	+	20.00
Resins	-	-
Balsam	-	-
volatile Oil	+	-

+ = Present, – = Absent

Table 2 Phytochemicals, their techniques of isolation and characterization are listed below

S/N.	Part (Solvent extract)	Phytoconstituents	Chemical class	Technique	Ref.
1	Stem bark (Methanol)	Betulin	Triterpenoid	HPLC	[19]
2	Roots (Methanol)	Tannic acid, Caffeic acid, Gallic acid, Ferulic acid	Phenolic acids	HPLC	[20]
3	Leaves (Methanol)	Sinapic,gallic,p-hydroxybenzoic,ferulic, p-coumarate,chlorogenic, cinnamic, vanillic acids	Phenolic compounds	RP-HPLC	[21]
4	Seed (Petroleum ether)	Linoleic acid, Octadecenoic acid methyl ester, Palmitic acid, Oleic acid.	Fatty acids	GC & GCMS	[22]
5	Heartwood, sapwood (Dichloromethane, Ethanol, and Toluene)	Lapachol, 2-Methylanthraquinone, 1,4-Naphthoquinone	Quinones	GCMS and HPLC	[23]
6	Leaves (Aqueous)	Verbascoside	Phenyl ethanoid	LCMS	[24]
7	Heart wood (Acetone)	2,3-Dimethyl-1,4,4a,9a-tetrahydro-9,10anthracenedione, Acetonyldimethylcarbinol, 4-Tertbutyl-2-phenyl-phenol, 2-Methyl-anthraquinone estriol, Lappaol, Deoxylactam, Squalene, Chloranol, Palmitic acid, 2,3-Dimethyl-1,4,4a,9a-tetrahydro-9,10nonanedione	Phenols, Quinones, Fatty acids, Triterpene	GCMS	[25]
8	Heartwood (Aqueous)	2(Hydroxymethyl)anthraquinone, 2-Anthraquinone carboxylic acid, Tectoquinone, 1 ,4 Naphthoquinone and 40,50-Dihydroxy-epiisocatalponol	Quinones	HPLC, NIR	[26]
9	Leaf (Aqueous)	Protocatechuic acid, Quinic acid, and its derivatives, Apigenin 7-O-diglucuronide, Luteolin, Luteolin 7-Odiglucuronide, Luteolinglucuronide, Diglucuronide, Apigeninglucuronide,	Flavonoids, Phenolic acids, Glucuronides	LCMS	[27]
10	Seed (Methanol)	Luteolin, Acacetin, Quercetin, Narengin, Hesperdin, Rutin, Rosmarinic, Quercetin, Naringenin, Hespertin, Kaempferol, Apigenin, Rhamnetin	Flavonoids	HPLC	[28]
11	Leaves (Nil)	4-Hydroxy-4-methyl-2-pentanone, Glycerin monoacetate, Glycerin diacetate and 1-	Aliphatic ketones, esters & alcohol, Anthocyanins	UV–Visible, GCMS, and LCMS	[29]

		Eicosanol, Malvidin-3-o- (6-o-acetyl)-5-o-diglucoside			
12	Wood (n-Hexane, Benzene, Chloroform, Water)	Bis(2-ethylhexyl) phthalate, n-Hexadecanoic acid, Phthalic acid, Di(2-propylpentyl) ester, Di(oct-3-yl) ester	Aromatic acids, Esters	GCMS	[30]
13	Hardwood sawdust (Hexane, methanol)	Tectol, Hemitectol, Deoxylapachol, Tectoquinone, 2Hydroxymethylanthraquinone, 30–OHdeoxyisolapachol	Quinones	Centrifugal partition chromatography	[31]
14	Sawdust (n-Hexane, methanol, water)	Abeograndinoicacid, 2-Oxokovalenic acid, 9-Hydroxyferruginol	Diterpenes	CC, HPLC	[32]
19	Heartwood (Methanol)	Rhein, Emodin, and Aloe-emodin Resveratrol, Coumestrol, Baicalein, 3-Hydroxyflavone, Rhamnetin Pinocembrin, 20-Hydroxygenistein, Anhydroglycinol, Hydroxygenkwanin, Tectorigenin, Ginkgolide A, Rhein, Piperine	Phenylpropanoids, Flavonoids, and Anthraquinone	UPLC-ESI-MS/MS	[33]
20	Bioactive extracts (Nil)	Naphthotectone and Anthratec tone	Quinones	1D and 2D NMR	[34]

4. Evidence base antibacterial activity of Tectona grandis

1. [35] Krishnananda, 2017 reported the ethanol extracts of *T. grandis, M. indica* and *A. occidentalis,* the extract was dissolved in a few drops of Dimethylsulfoxide (DMSO) and made up with distilled water to give a stock solution of 100 mg/ml separately. From this stock solution 25, 50 and 75mg/ml concentrations were prepared. The stock solutions were kept at 4-8 °C. Standard bacterial organisms were obtained in Mangalore. *S. aureus* (ATCC25923), *E. coli* (ATCC 25922) and *P. aeruginosa* (ATCC 27853) were used. The organisms were first isolated on nutrient broth for 24 h and then diluted to 1:1000 with the sterile nutrient dextrose broth. The dilutions formed were used as bacterial stock solutions for the agar-well diffusion assays. Preparation of media, direct sensitivity testing, Mueller Hinton agar media was used. Wells of 6 mm diameter and 5 mm depth were made in the solidified agar using a sterile borer. Agar-well diffusion assay Cultures of *E. coli, S. aureus* and *P. aeruginosa* were inoculated separately onto agar before solidifying, then it was transferred to each Petri dish. Prepared 1 ml extracts of concentration; 25, 50, 75, 100 mg/ml of the test and 10 µg/ml of Gentamycin Sulphate USP (positive control) were dispensed into the wells. The plates were incubated at 37 °C for 24 h. The sensitivity of the test organisms to the all the three above extracts was determined by measuring the diameters of the zone of inhibition surrounding the well. The extracts were studied for antibacterial activities by agar well diffusion method. Gentamicin sulphate USP, used as the positive control, showed sensitivity to test organisms with 25-29 mm of zone diameter, and also showed a maximum inhibitory effect compared to leaves extracts. Ethanol extract of *T. grandis* with concentration 25 mg/ml did not show any effect on the growth of microorganisms, Only 50, 75 and 100 mg/ml concentrations were effective.

2. [36] Krishna and Nair also investigated antibacterial activity of all extracts from *Tectona grandis* against *Staphylococcus aureus* (ATCC 25923), *Klebsiella Pneumoniae* (ATCC 700603), hospital strains of *Salmonella paratyphi* and *Proteus mirabilis* by disc diffusion assay [37]. Samples were tested at 25, 50, 100, 250 and 500 µg concentration per disc of 5mm diameter (Whatman No.1). Carrier soaked discs were also kept as negative control. Result expressed as diameter of inhibition zone and compared with standard antibiotic i.e ciprofloxacin. Out of the four cultures tested, it showed good activity against *S. aureus* (14 mm) and *K. Pneumoniae* (8 mm) at the highest concentration checked (500 µg). Methanol extract of leaf and ethyl acetate extract of wood was also able to show fairly good activity against gram

positive and negative species. Comparatively, only chloroform extract of leaf was able to produce activity even at least concentration tested.

[38,39] also reported data on antimicrobial activity of aqueous extract of teak against *S. aureus* and *K. Pneumonia.* According to reviews, extracts or phytochemicals with activity against gram positive and negative organisms (broad spectrum activity) are rare. So the presence of a compound(s) with broad spectrum activity against both types of organisms has to be explored by further purification.

3. [40] unraveled the antimicrobial activities of *tectona grandis* leaf and bark extracts. Test organisms include: *P. aeruginosa, S. aureus* and *B. subtilis*- the strains were procured from local Government hospital. Antimicrobial activity of ethanol, methanol, ethyl acetate and water extracts of leaf and bark were tested for the antimicrobial activities against test bacteria mentioned above. Antimicrobial activity was carried out by Disc diffusion method. Whatman filter paper (No.1) was cut into small discs and the discs were incubated in the corresponding extract for 1 hour before been placed on the petriplate. The plates were incubated for overnight to study antibacterial activities and for a period of 72 hrs. Leaf and bark extracts of *Tectona grandis* prepared in solvents (ethanol, methanol, ethyl acetate and water) were tested for the antibacterial activity against test bacteria. The antibacterial activity of the extract was assessed for the presence or absence of zone of inhibition. Both leaf and bark extracts of *Tectona grandis* exhibited significant antibacterial activity as is evident by a clear zones of inhibition around the discs, the study also showed that there is an antibacterial compound in teak leaf, namely 5-hydroxy-1,4- naphthalendion (juglone). In the same vein [41] opined the antibacterial activity of *T. grandis* bark extracts towards *S. aureus* and other bacterial strains.

4. [42] Maishera et al., 2019 reported the synthesis of MgO nanorods, using *Tectona grandis* leaves extract alongside its antibacterial potential against selected enteric bacterial pathogens. Nanorods on clinical isolates of *Escherichia coli* Acj 213, *Salmonella typhi* strain T8 and *Pseudomonas. A* strain DMI. MgO nanorods (at 200 mg/ml, 300 mg/ml, 400 mg/ml and 500 mg/ml) were screened for their antibacterial effect in comparison with leaves extract, $MgCl_2$ salt solution and 30 µg/ml standard antibiotics (Ampiclox- beecham). This was done in vitro by agar well diffusion method [43]. Twenty milliliter (20 ml) of sterilized nutrient agar was dispensed into each of 12 sterile petri dishes. The agar was allowed to set, inoculated (with a loop full standardized inocula), and in each of the plate, 6 mm wells were bored on each of the plate using a sterile cork borer [44]. The wells were filled with 160 µl MgO nanoparticles. This was allowed to diffuse at room temperature for two hours and incubated at 37 °C for 18 hours. The diameters of each inhibition zone formed around the wells were measured.

Minimum inhibitory concentration (MIC) and minimum bacteriocidal concentration (MBC) of the MgO nanorods were determined [45]. Serial dilution of the synthesized MgO nanorods was done using 2 ml of nutrient broth in six (6) test tubes to obtain varied concentrations (500, 250, 125, 62.5, 31.25 and 15.125 µg/ml). The tubes were inoculated with 0.2 ml of standardized inocula of the bacterial isolates and incubated over night at 37 °C. The tubes containing broth and MgO nanorods without inocula served as positive control, while tubes containing broth and inocula served as negative control. Thereafter, the tubes were examined for visible growth. Culture tube with lowest concentration of the MgO nanorods which did not show any visible sign of growth was taken as the MIC value. The antibacterial activity of the MgO nanorods at various concentrations (200 mg/ml, 300 mg/ml, 400 mg/ml and 500 mg/ml) showed remarkable activities against *P. aeruginosa* strain DMI, *S. typhi* strain T8 and *E. coli* Acj 213 with zones of inhibition ranging from 22.75 to 14.25. The MIC of MgO nanorods against *P. aeruginosa* strain DMI, *S. typhi* strain T8 and *E. coli* Acj 213 were 125 mg/ml, 62.5 mg/ml and 125 mg/ml respectively, while that of the MBC were 250 mg/ml, 125 mg/ml and 250 mg/ml respectively. The absolute values for MIC and MBC of the MgO nanorods were 250 mg/ml and 500 mg/ml respectively.

5. Furthermore, [46] Ogunmefun et al.,2017 conducted a study on antibacterial activities of *Tectona grandis* L. f. leaves on microorganisms isolated from decayed food samples. In his investigation, eight bacteria were isolated from decayed food samples. The bacterial isolates were identified as *Bacillus cereus* and *B. siamensis* from rice sample; *Klebsiella oxytoxa, Salimicrobium halophilium* and *Norcardia brasiliensis* from beans sample; *Bacillus subtilis, Enterobacter taylore,* and *Brevibacillus agri* from tomatoes, A sterile swab stick was placed into the broth bacterial culture corresponding to Mac Farland standard of a specific organism and then spread on already prepared sterile nutrient agar plate. The plates were allowed to dry for approximately 5 minutes. The wells were then filled with dilutions of 50 mg/ml, 100 mg/ml, 150 mg/ml, 200 mg/ml, 250 mg/ml, 300 mg/ml, 350 mg/ml and 400 mg/ml with *T. grandis* extract reconstituted with 10 % Dimethyl sulphoxide (DMSO) and sterilized by 0.45 µm membrane filter. The DMSO was used as a negative control while streptomycin was used as the positive control. The plates were incubated 37 °C for 24 hours. The diameters of the inhibitory zones were measured in millimeters.

The leaf extracts obtained with chloroform and methanol were used as antibacterial agents against the bacterial isolates. The results showed that the extracts exhibited weak antibacterial activities on the isolates. The antibacterial activities

of streptomycin used as positive control ranged from 11.00–30.00 mm respectively and were without a doubt effective against food pathogens than the extract. All the bacterial isolates were resistant to DMSO used as negative control. At concentrations of 50, 100, 150 and 200 mg/ml, the extracts were not effective likely because of sub-optimal doses related reason, however at concentrations of 250, 300, 350 and 400 mg/ml there were clear zones of inhibition, the extract's antibacterial action were dose dependent.

6. Additionally, [47] Singh, 2022 investigated Pharmacological effect of heartwood of *Tectona grandis Linn*. for antibacterial activity by Agar-Well Diffusion method. This same method was also used previously to study antibacterial activity of *Acacia raddiana* against some selected test bacterias [48]. By pouring 20 ml of molten media into sterile petri plates, the plates were allowed to solidify for 8 min and then, 30 µl suspension was spread uniformly with the help of a sterile glass spreader. After that, the plates were allowed to dry for 5 min. By using a sterile stainless steel borer, the wells of 6 mm diameter were punched in the plates. The test sample was allowed to diffuse for 30 min after loading the test extract and control in the wells. The plates were kept for incubation at 37 °C for 24 hours. At the end of incubation, inhibition zones formed around the well, which were measured in millimetres with a transparent scale.

All the test extracts from the selected plant species were found to be moderate and most active against mostly test bacterias. The ethanolic extract of heart wood of *Tectona grandis Linn*. Exhibited moderate activity against selected bacteria. The various fractions of the heart wood of *Tectona grandis Linn*. Exhibited significant activity against *E. aerogenes, E. coli* and *S.aureus*. The ethyl acetate fractions of the heart wood of *Tectona grandis Linn*. Exhibited significant activity against all test becterias. All the fractions exhibited effect against *S. aureus* but ethyl acetate fraction showed better effect against *S. aureus*.

7. Moreover, the antibacterial activity of hexane extract of the leaves of *Tectona grandis* and mistletoe were evaluated on *Salmonella typhi, Escherichia coli, Staphylococcus aureus, Klebsiella Pneumonia* and *Pseudomonas aeruginosa* by agar well diffusion method [49-51]. The isolates were allowed to grow for 24 hours at 37 °C on Mueller Hinton Broth (MHB). Wells were bored into the agar media using a sterile 6 mm cork borer, the wells were then filled up with 0.2 ml of the various concentration of the extract. The plates were allowed to stand in the lamina flow hood for 30 seconds to allow proper diffusion of the extract. The bacteria plates were incubated at 37 °C for 24 hours. Streptomycin was used as a positive control and Dimethyl sulphoxide (DMSO) as a negative control.

Table 3 Antibacterial action of *Tectona grandis*

S/N	Bacteria Source/ Strain	Assay	Doses(mg/ml)	Bacterial action	Ref
1	Nutrient broth/ *S. aureus, E. coli* and *P. aeruginosa*	Agar well diffusion	25, 50, 75, 100	Minimum inhibition	35
2	Hospital/*S. aureus*, *K. Pneumoniae*, *Salmonella. P* and *P. mirabilis*	Disc diffusion	25, 50, 100, 250 & 500	Inhibition	36
3	Hospital/*P. aeruginosa, S. aureus* and *B. subtilis*	Disc diffusion	_	Inhibition	40
4	Clinical isolates/*E. coli*, *Salmonella. T* and *Pseudomonas. A*	Agar well diffusion	200, 300, 400 & 500	Inhibition	42
5	Decayed food/ *Bacillus cereus. B. siamensis, Klebsiella. O, Salimicrobium. Norcardia. B, B. subtilis, E . taylore,* and *B. agri*	Agar well diffusion	50, 100, 150, 200, 250, 300, 350 & 400	Inhibition	46
6	Nutrient broth/ *E. aerogenes, E. coli* and *S. aureus*	Agar well diffusion	40	Inhibition	47
7	Mueller Hinton broth/ *Salmonella typhi, E. coli, S. aureus, K. Pneumonia* and *P. aeruginosa*	Agar well diffusion	20	Inhibition	49-51

The result revealed that the hexane extract of mistletoe leaves exhibited the following zone of inhibition against *Staphylococcus aureus* (24mm), *Escherichia coli* (26mm), *Salmonella typhi* (20mm) and *Pseudomonas aeruginosa* (12mm), while the hexane extract of *Tectona grandis* leaves exhibited the following zone of inhibition against *Staphylococcus aureus* (16mm), *Escherichia coli* (13mm), *Salmonella typhi* (18mm) and *Pseudomonas aeruginosa* (10mm). The activities of the extracts was based on the zone of inhibition. The greater the zone of inhibition the more

active the extract was. The extract of the mistletoe has greater zone of inhibition against *Staphylococcus aureus*, *Escherichia coli*, *Salmonella typhi* and *Pseudomonas aeriginosa* than *Tectona grandis*. This indicated that the former had greater antibacterial action to the latter. The range of inhibition of the hexane extract was between 10mm to 26mm. The degree of antibacterial activity of the hexane extract of mistletoe compared favorably well with that of the standard antibiotics (Streptomycin) [52]. [53] also affirm to the antibacterial action of *T. grandis* against *Staphylococcus aureus*, *E. coli*, *P. aeruginosa*, *Klebsiella*, *Pneumonia*, *Escherichia* and aerogenes by the method of Disc diffusion and broth microdilution respectively.

5. Conclusion

Herbs are widely used for the treatment of various diseases. *Tectona grandis* (Teak) is known for its natural resistance, which is associated with the chemical composition of its extractives. This study highlight the research work done so far in order to isolate and characterize the compounds present in teak and their influence on defense against degradation agents. Teak phytoconstituents have been shown to exhibit a wide range of significant medicinal value with more emphasis on the antibacterial action as thus, so far proven. Additionally, *T. grandis* extractives are a promising source of drug (antibacterial), and as such further studies are still required to examine the mechanism of action and subsequently project their use in clinical settings.

Compliance with ethical standards

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Disclosure of conflict of interest

None of the authors declared conflicting interest

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