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Phytochemical profile and the effect of *Paulownia elongate* root and bark on gram positive and gram negative bacterial species

Abstract

Currently, almost 80% of the world's population, primarily in Africa and other poor countries, rely entirely on traditional or herbal medicine for disease treatment. While numerous chemicals originating from traditional medicinal plants have made their way into present pharmaceutical practises as a result of considerable research and development of drugs, there are still a number of plants with potential therapeutic value that remain mainly undiscovered. The study aimed at analysing the phytochemical profile of *Paulownia elongata* root and bark extract using Gas Chromatography-Mass Spectrometry (GC-MS) and evaluating its antibacterial potential. The roots of *P. elongata* were collected, dried, and extracted with methanol. The extracted compounds analyzed by GC-MS revealed the presence of 20 chemical/bioactive constituents. The major compounds identified were theobromine, oleic acid, oxime-methoxyphenyl, and methyl stearate. The antibacterial activity of the extract was assessed against four bacterial strains: *Staphylococcus aureus, Pseudomonas aeruginosa, Clostridium bolulinum,* and *Escherichia coli*. The well method of the agar dilution was used to determine the antibacterial activity, and the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were determined. The results showed that methanolic extract of *P. elongata* roots exhibited significant antibacterial activity against the tested bacterial strains, with varying degrees of inhibition. The antibacterial potential of the roots extract showed higher activity at 300 mg/kg/bwt with 18.12+0.9 mm on *Salmonella typhi* and at 400 mg/kg/bwt with inhibition rate 20.14+ 0.0 mm on *Klebsiella pneumonia*. From the findings of this study, *P. elongata* root extract contains bioactive compounds and possesses antibacterial potential. These findings support the traditional use of *Paulownia species* in traditional medicine and highlight its potential as a source of novel antibacterial agents. Further research is warranted to isolate and characterize the active compounds and investigate their mechanisms of action.

Keywords: phytochemicals, *Paulownia elongate*, medicinal plants, gram positive bacteria, gram negative bacteria

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Introduction

Medicinal plants have been used to cure a variety of illnesses in African traditional medicine as well as other cultures throughout the world.[1,2] Currently, almost 80% of the world's population, primarily in Africa and other poor countries, rely entirely on traditional or herbal medicine for disease treatment[3] While numerous chemicals originating from traditional medicinal plants have made their way into present pharmaceutical practises as a result of considerable research and development of drugs, there are still a number of plants with potential therapeutic value that remain mainly undiscovered.[4]

Paulownia is a woody tree well renowned for its timber quality, but its medicinal benefits are just recently being discovered. The genus *Paulownia*, belonging to monogeneric *Paulowniaceae* family, comprises of nine species: *Paulownia. albiphloea (P. albiphloea), Paulownia australis (P. australis)*, *Paulownia catalpifolia (P. catalpifolia), Paulownia elongata (P. elongata)*, *Paulownia fargesii (P. fargesii)*, *Paulownia fortunei (P. fortunei)*, *Paulownia kawakamii (P. kawakamii)*, *Paulownia taiwaniana (P. taiwaniana)*, and *Paulownia tomentosa (P. tomentosa)*. Despite being extensively spread across China, most *Paulownia* species have been planted and farmed in many places throughout the world for their decorative and wood benefits.[5,6] *Paulownia* wood is light and flexible, yet it does not fracture or deform readily. It is valued for its structural resilience, textures (light to medium clay-sandy), grain, and colour[5]. The wood is very resistant to moisture and possesses flame retardant qualities.[7] Furthermore, being a short rotation rapid growing tree, *Paulownia* has already gained interest as a possible bioenergy crop capable of both carbon sequestration and transportation fuel production.[8,9]

In terms of plant components utilised in traditional medicine, *Paulownia* happens to be one of the most used medicinal plants. In traditional Chinese medicine, the bark, fruit, xylem, and leaves of *P. tomentosa* var. tomentosa have been utilised for the treatment or prevention of a wide range of diseases, such as haemorrhoid, carbuncle, inflammatory bronchitis, gonorrhoea, upper respiratory tract infection, parotitis, asthma, traumatic bleeding, erysipelas, bacteriological diarrhoea, swelling, bronchopneumonia, enteritis, conjunctivitis, hypertension, and tonsillitis.[10,11] *P. tomentosa* leaves, wood, and fruits have traditionally been used to treat tonsillitis, bronchitis, asthmatic attacks, and bacterial diseases such as enteritis or dysentery. The leaves of *Paulownia* have been used to treat frostbite and leg ulcers, thus they may offer wound-healing capabilities as

well.[12] The most significant plant components used in traditional herbal therapy are leaves, fruits, and flowers.[13,14] In Chinese folk medicine, mashed *Paulownia* flowers are used to cure acne vulgaris, and the decoction is used to treat fungal infections on the sole of the foot and the area between the toes.[15] Flowers have also been utilised to treat first and second degree empyrosis.[16] The goal of this study is to use Gas Chromatography-Mass Spectrometry (GC-MS) analysis to identify the phytochemical profile of *Paulownia* elongate roots extract and evaluate its antibacterial potential as a medicinal plant.

Materials and methods

Plant collection

The roots of *P. elongata* were collected from Wukari Local Government Area of Taraba State. It was washed under running water with an intensive care and was air-dried for about 5 weeks for easy grinding. Identification and authentication were done at the herbarium in the Department of Plant Sciences of Modibbo Adama University Yola, Nigeria.

Plant extraction

The air-dried roots of *P. elongata* were grinded to a smooth powdered form. Then 150g of the sample (roots of *P. elongata*) was weighed with an analytical weighing balance and put into a 1000mL container. 800mL of methanol was then added into the 1000mL container and was left for 48 hours for proper absorption. After 48 hours, the liquid sample was extracted and was evaporated in a water thermostat.

Test organisms

Clinical isolates of four bacteria (*Staphylococcus aureus, Pseudomonas aeruginosa, and Clostridium Bolulinum and Escherichia coli.*) were obtained from the Modibbo Adama University Yola Adamawa State, Nigeria. The bacteria were kept at 40°C on Nutrient agar slant. Before usage, the isolates were subcultured on new medium at regular intervals. Martins et al.[17] established a method for standardising inocula.

Antibacterial assay

The antibacterial activity of plant extracts was determined using the well technique of agar dilution. Mueller Hinton Agar (MHA) was carefully put into the petri plates and allowed to set. After punching holes (i.e. 5 wells) in the infected agar using a sterile 8mm cork borer, the agar was removed. Four wells were filled with varying concentrations of extracts and marked as follows: 100mg/ml, 50mg/ml, 25mg/ml, and 12.5mg/ml, while the fifth well contained the extractant, i.e. the solvent used for the extraction, to serve as a control. The bacterial cultures were injected on Mueller Hinton Agar (MHA) and incubated for 24 hours at 370°C. Following incubation, the diameter of the zone of inhibition around each well was measured to the approximate millimeters.

Determination of the minimum concentration of extracts (MIC)

The MIC of the plant methanolic extracts was determined using the agar diffusion method described by Baker and Breach[18]: one millilitre of each extract was added to about 14ml of nutrient agar to make a final concentration ranging from 12.5% w/v to 100% w/v of the extracts in the agar. Standardised inocula were streaked on agar in petri plates with varied extract concentrations. The plates were incubated for 24 hours at 370°C. The MIC was determined by taking the lowest dose of each extract that inhibited the growth of the test organism.

Determination of bactericidal and bacteriostatic effects of the extracts

The Minimum Bactericidal Concentration (MBC) was determined by visual observation of growth suppression in solid medium. After 24 hours of incubation at 370C, the agar plates of various extracts of varied concentrations inoculated with organisms were inspected for growth. Plates with no obvious growth were subcultured on new nutrient agar plates by selecting inocula from the streaking line. The smallest bactericidal concentration was determined to be the smallest quantity of the extract that did not generate any growth on the solid medium following incubation.

Gas chromatography-mass spectrometry (GC-MS) analysis

Phytochemical screening was done in order to detect the presence of plant constituents. 1µL of the crude extract dissolved in methanol of GC MS grade was subjected to the GC MS for the profiling of the chemical constituents. The GC-MS analysis was performed on a combined 7890A gas chromatograph system (Agilent 19091-433HP, USA) and mass spectrophotometer, which was outfitted with an HP-5 MS fused silica column (5% phenyl methyl siloxane 30.0 m250 m, film thickness 0.25 m), and interfaced with a 5675C Inert MSD with Triple-Axis detector. Helium gas was employed as the carrier gas, with a column velocity flow of 1.0 mL min-1. Other GC-MS settings include 250°C ion-source temperature, 300°C interface temperature, 16.2 psi pressure, 1.8 mm out time, and a 1 L injector in split mode with a split ratio of 1:50 and injection temperature of 300°C. The column temperature began at 36°C for 5 minutes and increased to 150 V at a rate of 4°C min-1. The temperature was increased to 250°C at a rate of 20°C min-1 and kept for 5 minutes. The entire time for elution was 47.5 minutes. The relative percent quantity of each component was computed by comparing the mean peak area with the entire areas. The supplier's MS solution software was utilised to operate the system and collect the data.

Results

GC-MS chromatogram and phytochemical profile of Paviownia elongata root-bark methanol crude extract

The study determined the phytochemical profile of methanolic extracts of *paulownia elongate* roots using GC-MS as displayed in the chromatogram (Figure 1). The plant (*paulownia elongata*) was utilized in this study due to its bioactive ingredients and has proven its medicinal important. The methanolic aqueous extracts of *paulownia elongate* roots showed that the extract contains many chemicals and where varied according to their retention time, peak area, height and base (Table 1). The highest compound identified was theobromine (34.42%), oleic acid (37.87%), followed by oxime, methoxy-phenyl (3.32%) and methyl stearate (4%). The least compounds identified were ethanol, 2-(hexyloxy) and alpha-pineme (1.19%).

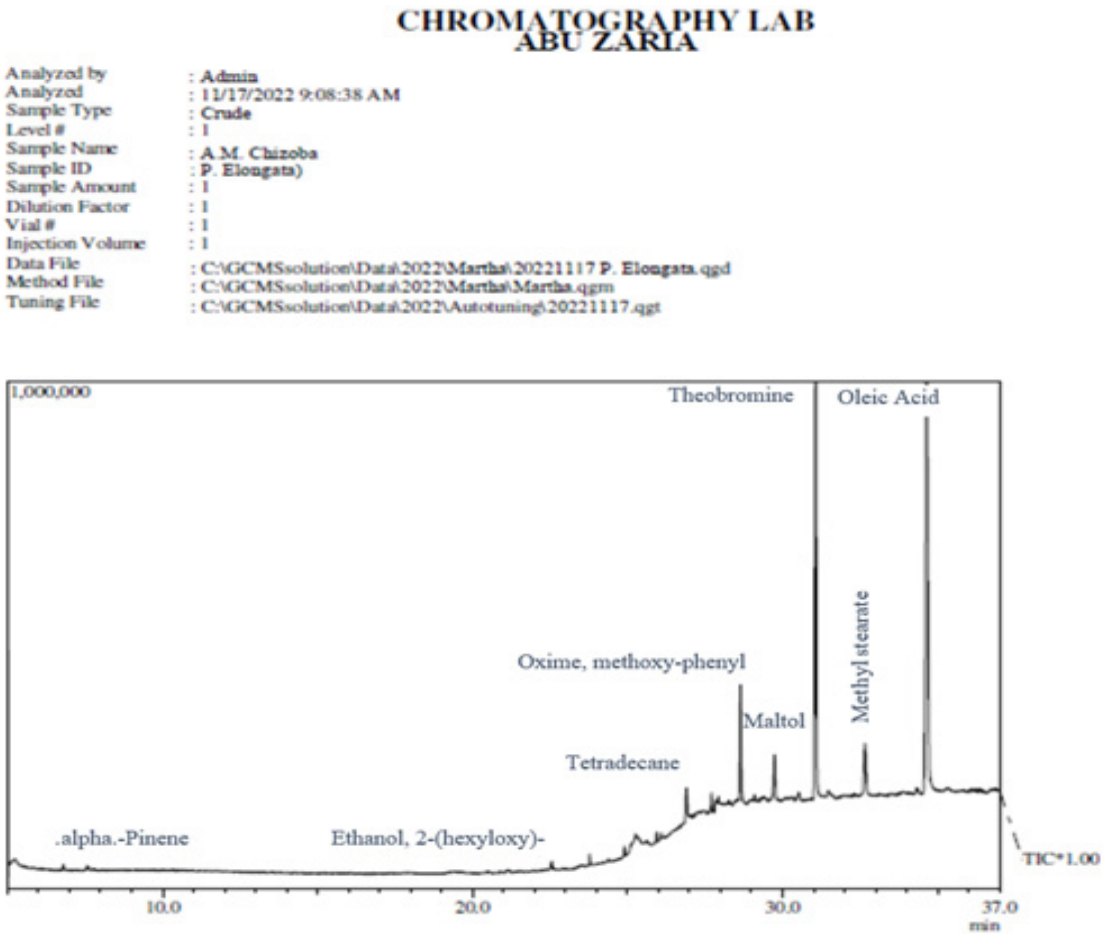

Figure 1 GC-MS chromatogram of Paviownia elongata Root-bark methanol crude extract.

Table 1 Phytochemical profile of *Paviownia elongata* root-bark methanol crude extract

Peak#	R.Time	Area	Area%	Height	Height%	Base m/z	Base Int.	Name
1	5.035	42000	0.41	30919	1.19	48.95	1810	.alpha.-Pinene
2	5.228	221192	2.15	14113	0.54	43.95	4337	Hydroperoxide, 1-ethylbutyl
3	22.557	46094	0.45	15412	0.59	73.00	2957	Ethanol, 2-(hexyloxy)-
4	24.893	39431	0.38	20661	0.79	73.05	3966	3-Hexen-2-one
5	25.115	60309	0.59	9763	0.38	57.05	932	.alpha.-Phellandrene
6	25.261	41490	0.40	12246	0.47	57.05	1803	p-Cymene
7	26.896	241960	2.35	69721	2.68	91.05	9847	Tetradecane
8	27.03	51043	0.50	8915	0.34	81.05	199	Dodecanal
9	27.461	47530	0.46	6293	0.24	207.05	213	Tetradecane
10	27.709	89472	0.87	39199	1.51	57.05	5947	Tetradecanoic acid
11	27.841	79277	0.77	20096	0.77	277.1	2494	E,Z-5,7-Dodecadien-1-ol acetate
12	27.926	52868	0.51	19465	0.75	73.05	2346	2,6,10-Dodecatrien-1-ol
13	28.43	44058	0.43	4458	0.17	55.00	284	Oleic Acid
14	28.644	599717	**5.84**	236177	9.07	57.05	37397	Octadecanoic acid
15	29.739	271323	2.64	86326	3.32	57.05	13448	Oxime, methoxy-phenyl
16	30.29	40112	0.39	6315	0.24	81.05	179	Maltol
17	30.519	58771	0.57	17015	0.65	73.05	901	Dodecanoic acid
18	31.059	2920111	**28.41**	895893	34.42	57.05	142681	Theobromine
19	32.657	472984	**4.60**	104133	4.000	57.05	14081	Methyl stearate
20	34.647	4857802	**47.27**	985780	37.87	57.05	154550	Oleic Acid
		10277544	100	2602900	100			

Citation: Umaru IJ, Abah MA, Ugwah EJ, et al. Phytochemical profile and the effect of Paulownia elongate root and bark on gram positive and gram negative bacterial species. *Int J Complement Alt Med.* 2024;17(3):147–154. DOI: 10.15406/ijcam.2024.17.00696

Some of the chemical composition isolated from the methanolic roots of *paulownia elongata* includes; p-Cymene, tetradecanoic acid, Maltol, Dodecanal, Hydroperoxide,1-ethylbutyl, alpha.-phellandrene, alpha-pineme, Ethanol, 2-(hexyloxy)-, Theobromine, octadecadonic acid, E,Z-5,7-Dodecatrien-1-ol acetate, 2,6,10-Dodecatrien-1-ol, methyl stearate. Some of these compounds, particularly acids, have been shown to be bioactive.

Effect of Paviownia elongata roots methanol crude extract (µg/mL) on Gram positive and Gram-negative bacteria in millimetre (mm)

The presence of phytochemicals in *Paulownia* elongate roots may indicate the plant's potential in the management of diseases associated with free radical buildup in the body, such as diabetes mellitus, as well as anticancer, anti-mutagenic, antifungal, and antibacterial properties. When compared to the test controls, the results reveal a great inhibition rate against the tested species of bacteria at 30g concentration. The antibacterial efficacy against all species, however, was decreased (Table 2). The inhibition obtained at various doses (100-300 g) was shown to be effective across all of the strains tested.

The extract showed higher significant antibacterial activity against *Escherichia coli,* and salmonella typhi at 100µg and 300µg with an inhibition rate of 18.13±i.6 and 18.12±0.9 respectively and the extract also showed a significant antibacterial activity on *klebsiella pneumonia* 100 µg and 300µg with an inhibition rate of 17.16±0.12 and 15.14±0.5.

Discussion

The investigation of chemical compounds of the genus *Paulownia* began in the early 1930s. The initial researchers in this discipline were Japanese. Investigations on herbal remedies from the genus *Paulownia* strive to uncover novel compounds using methodologies and current spectroscopic techniques (Table 3). Iridoid glycosides, phenyl-propanoid glycosides, lignin glycosides, flavonoids, sesquiterpenes, and triterpenes are the most prominent. A majority of the aforementioned substances have been shown to exhibit some level of bioactivity.[19] Recently, phenylethanoid derivatives integrated via ether or ester link to iridoid glycosides have been discovered.[20] Campneosid I phenylethanoid glycosides isolated from *P. tomentosa* exhibit strong biological activity. Campneosid I was shown to exhibit considerable antibacterial action against a variety of pathogenic *Streptococcus* and *Staphylococcus* species, including *S. aureus*.[21]

Table 2 Effect of *Paviownia elongata* roots methanol crude extract (µg/mL) on Gram positive and Gram-negative bacteria in millimetre (mm)

Conc. (µg/mL)	Organism	Tetracycline (30 µg/mL)	Methanol
50	Salmonella typhi	20.71+ 0.5	12.12 + 0.2
	Escherichia coli	20.47± 0.5	10.13 ± 0.2
	Staphylococcus aureus	20.64± 0.5	10.12 ± 0.3
	Klebsiella pneumonia	20.34± 0.5	11.11 ± 0.5
	Salmonella typhi	20.65± 0.5	10.15 ± 0.7
100	*Escherichia coli*	20.34± 0.5	18.10 ± 1.6*
	Staphylococcus aureus	20.61± 0.5	18.13 ± 0.3
	Klebsiella pneumonia	20.62± 0.5	13.11 ± 0.1
	Salmonella typhi	20.33 ± 0.5	12.21 ± 0.00
200	*Escherichia coli*	20.34 ± 0.5	16.11 ± 1.12
	Staphylococcus aureus	20.32 ± 0.5	10.12 ± 3.11
	Klebsiella pneumonia	20.34 ± 0.5	15.14 ± 0.5*
	Salmonella typhi	20.36 ± 0.5	**18.12 ± 0.9**
300	*Escherichia coli*	20.31 ± 0.5	15.13 ± 0.11
	Staphylococcus aureus	20.33 ± 0.5	13.15 ± 0.13
	Klebsiella pneumonia	20.32 ± 0.5	17.11 ± 0.12
400	*Salmonella typhi*	20.22 ± 0.0	16.16 ± 0.15
	Escherichia coli	20.18± 0.0	12.11± 0.13
	Staphylococcus aureus	20.16 ± 0.0	11.13± 0.11
	Klebsiella pneumonia	20.14± 0.0	**17.16± 1.4**

Result is Mean + SD. N = 3

*, significant activity was observed when compared to the control ($p<0.05$); Concentration of standard is 30 µg/mL of tetracycline, Conc, concentration

Table 3 A list of chemical compounds that have been isolated from different parts/tissues of various *Paulownia species*

#	Species	Plant part	Compound	Reference
1	*P. tomentosa*	Immature fruit surface	Nine geranylated flavanones:	Asai et al.[55]
			6-geranyl-5,7-dihydroxy-3',4'-dimethoxyflavanone;	
			6-geranyl-3',5,7-trihydroxy-4'-methoxyflavanone; 6-geranyl-4',5,7-trihydroxy-3',5'-dimethoxyflavanone; 6-geranyl-4',5,5',7-tetrahydroxy-3'-methoxyflavanone;	
			6-geranyl-3,3',5,7-tetrahydroxy-4'-methoxyflavanone;	
			4',5,5',7-tetrahydroxy-6-[6-hydroxy-3,7-dimethyl-2(E),7-octadienyl]-3'-methoxyflavanone;	
			3,3',4',5,7-pentahydroxy-6-[6-hydroxy-3,7-dimethyl-2(E),7-octadienyl]flavanone;	

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Table 3 Continued...

#	Species	Plant part	Compound	Reference
			3,3',4',5,7-pentahydroxy-6-[7-hydroxy-3,7-dimethyl-2(E)-octenyl]flavanone;	
			3,4',5,5',7-pentahydroxy-3'-methoxy-6-(3-methyl-2-butenyl)flavanone	
2	*P. tomentosa*	Unripe fruit	Diplacone, Mimulone	
3	*P. tomentosa*	Fruit	Acteoside; Isoacteoside; Mimulone; Diplacone	Šmejkal et al.,[13]
			Mimulone; Diplacone	Jiang et al.,[9]
			Tomentomimulol; Mimulone B (C-geranylated flavonoids)	Schneiderová et al.,[45]
			5,7-dihydroxy-6-geranylchromone; Acteoside; Isoaceteoside; 3'-O-Methyldiplacol; 3'-O-methyl-5'-methyldiplacone; 3'-O-methyl-	Šmejkal et al.[56]
			5'-hydroxydiplacone; Taxifolin; 5,7,4'-trihydroxyflavanone; Tomentodiplacone; Tomentodiplacone B; Cisplatinum; Ara-C	Navrátilová et a.,[46]
			Tomentodiplacol; 3'-O-methyl-5'-methoxydiplacol;	Šmejkal et al.,[13]
			6-isopentenyl-3'-O-methyltaxifolin; dihydrotricin; 3'-O-Methyldiplacone	
			Acid; Fatty oil; Flavanon; Alkaloid	Ayan et al.,[57]
				Zhu et al.,[5]
			C-6 geranylated flavanones	Šmejkal et al.,[54]
4	*P. tomentosa*	Flower	Diplacone	
5	*P. tomentosa*	Flower	Paulownin; Isopaulownin	
			Furanoquinone	Kang et al.,[14]
			Apigenin; Methanol	Ji et al.,[41]
			Glycerides	
			Abscisic acid; T-abscisic acid; Luteolin; Apigenin; Tricin; 4',5,7-trihydroxy-3'-methoxyflavone; Paulownin; 3'-methyldiplacol;	
			Diplacone	
		Essential oil of the flower	Geranyl Geraniol; Nonanal; Heptadecane; Nonadecane; Pentacosane; Hexatriacontane; 1-octen 3-ol; Cis-methyl isoeugenol; Anethole; Neryl acetone; Stearyl aldehyde; Nerolidol	Ibrahim et al.,[42]
6	*P. tomentosa*	Hop	Naringenin	Šmejkal et al.,[54]
7	*P. tomentosa*	Bark	Apigenin	Si et al.,[43]
8	*P. tomentosa*	Leaf	Syringin; Catalpinoside	Ayan et al.,[57]
			Ursolic acid; Matteucinol	Zhu et al.,[5]
8	*P. tomentosa*	Xylem	Paulownin; D-Sesamin	
		Leaf	Glycerides	
			Flavonoids	Zima et al.,[35] Šmejkal et al.,[13]
9	P. tomentosa	Extract	Ursolic acid; Oleanolic acid	Liu et al.,[50]
			Paulownioside	
			Tomentoside; 7-hydroxytomentoside	
10	P. tomentosa	Extract	(+)-Piperitol; Daphneside	
			Phenylethanoid glycosides Campneosid I	Radev[20]
11	*P. tomentosa* var.	Bark	Eight phenolic compounds: glucodistylin, luteolin, ellagic acid, cistanoside F, campneoside II, isocampneoside II, verbascoside, and isoverbascoside	Si et al.,[43]
			Nine phenolic extractives: two flavonoids (naringenin, and quercetin), two phenolic acids (cinnamic acid, and gallic acid), and five phenylpropanoid glycosides (cistanoside F, acteoside, isoacteoside, campneoside II, and isocampneoside II	
12	*Paulownia imperialis*	Extract	Azulene; Bisabolols; Apigenin; Glycosides; Flavonoids; Uvzymestm	
13	*P.imperialis*;	Extract	Chlorophyll a; Chlorophyll b; β-Carotene; Violaxanthin; Proline	
14	*P. fortunei*			
15	*P. tomentosa*	Fruits	C-geranyl flavonoid: Mimuline	An et al.,[47]
16	*P. tomentosa*	Extract	C-geranylated flavanone: Tomentodiplacone B (TOM B)	Kollár et al., [26]
17	*P. coreana*	Leaf	Isoatriplicolide Tiglate (PCAC)	Jung et al.,[37]
18	*Paulownia sp.*	Wood	Cellulose; Hemicellulos Pentozan; Lingin	
		Xylem	Paulownin and d-sesamin	Zhu et al.,[5]
		Seed	Sterols and tocopherols	Angelova et al.,[58]
		Bark and leaf	Glycoside	Kazi et al.,[49]
20	*Paulownia sp.*	Extract	Iridoid glycosides; Phenyl- propanoid; Lignin glycosides; Flavonoids; Sesquiterpene; Triterpenes	Cao et al.,[18]
			Syringin	

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Glycosides are a broad and important family of carbohydrate molecules that are distinguished by the substitution of another substituent for the anomeric hydroxyl group.[22] Research on plant-based substances from the genus *Paulownia* promise to disclose novel compounds as chromatographic procedures and advanced spectroscopic techniques progress. Iridoid glycosides, phenyl-propanoid glycosides, lignin glycosides, flavonoids, sesquiterpenes, and triterpenes are the most prominent. Many of these compounds have been shown to exhibit some level of bioactivity.[19] Recently, phenylethanoid derivatives integrated via ether or ester link to iridoid glycosides have been discovered.[20] Campneosid I phenylethanoid glycosides isolated from *P. tomentosa* exhibit strong biological activity. Campneosid I was shown to exhibit considerable antibacterial action against a variety of pathogenic *Streptococcus* and *Staphylococcus* species, including *S. aureus*.[21]

Lignin study of *Paulownia* wood revealed the presence of syringin, a bioactive chemical.[21] Syringin is a phenylpropanoid glycoside derived from eleutheroside. Free radical harvesting, neuronal cell damage preventative measures, apoptosis suppression, antidiabetic impact, anti-inflammatory prospects, antinociceptive impact, and anti-allergic effects are among the pharmacological features of syringin.[18] Furthermore, *Paulownia* has been shown to be insect-resistant, neuroprotective, antioxidant, and hemostatic.[19]

Flavonoids are a class of hydroxylated polyphenolic chemicals with a benzo--pyrone structure that are abundant in plants. The phenylpropanoid pathway produces these. Secondary phenolic metabolites, including flavonoids, are synthesised in response to diverse stress circumstances and have a variety of pharmacological actions[22,23,24]. Flavones, flavanones, catechins, and anthocyanins are the four major types of flavonoids.[25] *P. tomentosa* geranylated flavanone has been demonstrated to reduce nitrite oxide levels in LPS-stimulated rat macrophages.[26] Tomentodiplacone B (TOM B), on the other hand, suppressed the growth of human moncytic leukaemia cells.[27]

The flowers appear to be the most utilised plant component among diverse sections of the *Paulownia* tree, with many uses in traditional medicinal products.[28,29] Because of the presence of flavonoids, notably Apigenin, extracts of *P. tomentosa* flowers have piqued the interest of researchers. Apigenin is hypotensive,[30] antispasmodic,[31] antiinflammatory,[32] vasorelaxant[33] and antioxidant.[34] Furthermore, apigenin has been shown to have anti-tumorigenic properties both in vitro and in vivo, not only by inhibiting tumour cell proliferation but also by impairing tumour cell invasiveness.[35,36]

Flavonoids extracted from *P. tomentosa* leaves are being shown to exhibit antiradical and cell protecting properties.[37] In vitro antibacterial activity of fresh *P. elongata* leaves and silage extracts against *Pseudomonas aeruginosa, Salmonella enterica, Candida albicans, Staphylococcus aureus, Streptococcus pyogenes* and *Paenibacillus alvei*. Popova and Baykov (2013) found that the inhibitory impact is stronger against gram-negative bacteria. In in vitro tests on cervical and breast cancer cell lines, the leaves of *P. tomentosa* (misidentified as *P. coreana*) contained isoatriplicolide tiglate (PCAC), which triggered apoptosis.[38] Varlyakov et al.[39] investigated the effect of *P. elongata* leaf consumption on blood parameters in three yearling sheep, Stara Zagora x Pleven Blackhead hybrids. Their findings demonstrated a considerable decline in erythrocyte and leukocyte counts, with the most marked decrease occurring in the postprandial hours. Furthermore, their research revealed that the leaves of *P. elongata* had the capacity to drastically lower blood glucose levels.

Paulownia flower extracts limit the development of some bacteria, with the highest impact reported on *Staphylococcus aureus* and having a smaller impact on *Penicillium chrysogenum, Saccharomyces cerevisiae,* and *Aspergillus niger*.[40] Methanol extracts of *P. tomentosa* dried flowers have been demonstrated to exhibit antiviral activity over *Coxsackie virus* A16 (CAV 16) and e*nterovirus* 71 (EV 71), the two primary pathogens causing hand, foot, and mouth disease (HFMD).[41] Ibrahim et al.[42] discovered that essential oils extracted from *P. tomentosa* flowers have broad range antibacterial action against *Escherichia coli* NRRL B-210, *Staphylococcus aureus* NRRL B-313, and *Bacillus subtilis* NRRL B-543.

Certain chemicals found in *Paulownia* fruits have been shown to have strong inhibitory effect towards Staphylococcus epidermidis, a pathogenic gram-positive bacterium.[43] According to one research, the fruits of *P. tomentosa* can be a viable source of naturally occurring antioxidant compounds.[44] Purification of the methanol extract of *P. tomentosa* fruits resulted in potent butyrylcholinesterase (BChE) and acetylcholinesterase (hAChE) inhibitory flavonoids, which have been linked to the amelioration of Alzheimer's symptoms, as well as a rich source of many different geranylated flavonoids.[45] The antibacterial activity of compounds 3'*O*-methyldiplacol, mimulone D, tomentodiplacone D, tomentodiplacone G, 3'-*O*methyl-5'-hydroxydiplacone, mimulone C, tomentodiplacone B, diplacone, 3'-*O*-methyl-5'*O*-methyldiplacone, tomentodiplacone E mimulone, and tomentodiplacone C against different Methicillin-resistant *Staphylococcus aureus* (MRSA) stains have been reported.[46,47] Several geranylated flavonoids from methanolic extract of *P. tomentosa* fruits show remarkable inhibitory activity against SARS viral protease because of an unusual 3, 4-dihydro-2H-pyran motif, which targets the cysteine residues on the RNA virus's replicase protein: the papain-like protease[48]. Furthermore, anti-microbial efficacy and synergistic action with conventional antibiotics of six geranylated flavonoids extracted from *P. tomentosa* fruits have been found.[49] Mimulone, a C-geranyl flavonoid derived from the fruits of *P. tomentosa*, has been demonstrated to activate autophagy in human lung cancer cell lines via p53-mediated control of AMPK/mTOR signalling, resulting in tumour cell apoptosis.[50] The fruits of *P. tomentosa* (misidentified as *P. coreana*) were reported to contain eleostearic acid, flavonoids, fatty oil, and alkaloids.[51]

Campneoside-I identified from the species *Paulownia* inhibits Staphylococcus aureus, *S. pyogenes*, and *S. faecium*.[51] Eight C-6geranylflavonoids were extracted from an ethanol extract of *P. tomentosa* fruits and their antibacterial and yeast inhibitory properties were reported.[52] According to experimental research on the pharmacological activity of *paulownin*, the molecule provides considerable health advantages such as antiinflammatory and analgesic effects, increasing immunity, and reducing blood glucose; and has little toxicity.[53]

Conclusion

Paulownia elongate is a medicinal plant that contains some bioactive ingredients. The roots of *paulownia elongate* was used in this research to investigate the phytochemical profile of its methanol extracts and the antibacterial activity of the extract on some bacterial organisms. The study found a large number of organic compounds in the roots of *Paulownia* elongata, and these chemicals account for a large portion of the plant's claimed and documented ethno medicinal and bioactive potential. The methanol aqueous extracts of *paulownia elongata* roots when displayed on the chromatogram showed the different retention time, peak area and height as it accounts for certain

compounds. The highest compound identified was theobromine (34.42%), oleic acid (37.87%), followed by oxime, methoxy-phenyl (3.32%) and methyl stearate (4%). The least compounds identified were ethanol, 2-(hexyloxy) and alpha-pineme (1.19%).

The results of phytochemical screening revealed the extract's potential, which led to its antibacterial activities as reported in this study. When compared to the test controls, the anti-bacterial activity generated a substantial reduction in growth rate against the tested species of microorganisms at 30g provided concentration. *Salmonella typhi* and *Escherichia coli* likewise demonstrated substantial activity ($p<0.05$) at 30g when compared to the scontrol. More research is needed to assess the prospective effectiveness of the crude extracts of *paulownia elongate* as antimicrobial, antimalarial and anticancer agents. And, more research aimed at isolating and elucidating the structure of antibacterial active constituents from the plant, is well recommended.

Conflicts of interest

The authors declare that there have no conflicts of interest associated with this publication.

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