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Review Article

ETHNOBOTANICAL USES, PHYTOCHEMISTRY AND PHARMACOLOGICAL ACTIVITIES OF *PEPEROMIA PELLUCIDA* (L.) KUNTH (PIPERACEAE)-A REVIEW

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ABSTRACT

Peperomia pellucida (L.) Kunth is a herb belonging to the family Piperaceae. In this review, an extensive literature survey was carried out to compile information available on medicinal uses, phytochemistry and pharmacological properties of *P. pellucida*. The plant is used as food, flavoring agent and as medicine. The plant is used as medicine for treating various ailments or disorders such as asthma, rheumatism, wound, fever, stomach problems, kidney infection, hemorrhoid pain, joint pain, hypertension, diarrhea, snake bite and measles. The plant contains phytochemical groups such as alkaloids, flavonoids, saponins, terpenoids, steroids and glycosides. Compounds such as dill apiole, phytol, stigmasterol, sitosterol, secolignans, tetrahydrofuran lignans, highly methoxylated dihydronaphthalenone, peperomins, sesamin and isoswertisin have been identified in the plant. Studies have shown that the plant exhibited several pharmacological activities such as antimicrobial, antioxidant, anti-angiogenic, anti-inflammatory, analgesic, antipyretic, neuropharmacological, antisickling, anticancer, enzyme inhibitory, antiulcer, hypotensive, immunostimulatory, fracture healing and antidiabetic activities which support the traditional use of the plant. Purified chemicals from the plant have also shown to exhibit certain pharmacological activities such as antiulcer, anticancer and antimicrobial activity. By this extensive literature review, it can be concluded that *P. pellucida* can be utilized as a promising candidate for developing newer drugs with potent pharmacological activities.

Keywords: *Peperomia pellucida* (L.) Kunth, Ethnomedicine, Traditional medicine, Phytochemical, Pharmacological activities

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INTRODUCTION

Throughout the world, especially developing and under-developing countries, plants have been exploited as medicine to meet primary healthcare needs. It is estimated that vast majority of population relies on medicinal plants for therapy against several diseases or disorders. Traditional medicinal practitioners utilize plants, either singly or in certain formulations, to treat ailments. Non-availability (especially for people from remote areas) and high cost of modern drugs limits their use by people from economically poor background. Nowadays, medicinal plants are used routinely in urban settings in daily healthcare and as medication against ailments. Many indigenous medicinal systems such as Ayurveda, Siddha and Unani utilize several plant species. Besides, plants provide many lead compounds for the development of modern drugs. Majority of drugs available are from natural origin, especially from plants. Drugs such as taxol, quinine, artemisinin, vincristine, vinblastine, digoxin and codeine are from plant origin [1-6].

The genus *Peperomia* Ruiz and Pavon belongs to the family Piperaceae. The genus is the second largest genus in piperaceae and includes plants that are annual or perennial, usually succulent herbs and often epiphytic. The genus encompasses a number of species found distributed in tropical and subtropical regions worldwide. The species of *Peperomia* are characterized by bisexual flowers (sessile, sunk in rachis) in spike inflorescence and lateral or terminal stigma which is usually penicillate. The genus is often considered as one of the most species rich genera of angiosperms [7-10]. *Peperomia pellucida* (L.) Kunth (fig. 1) belonging to the family Piperaceae is commonly known by names such as pepper elder, rat ear and shining bush. The plant is native to South America and is found distributed in various countries in the world including India. The plant is very common during rainy season and usually grows in clumps in loose and humid soils and is found in shaded, damp habitats. The plant occurs more or less throughout year in wet places. It is characterized by succulent stems, fleshy and heart shaped leaves, and tiny dot like seeds attached to fruiting spikes. It is called neeru kaddi gida in Kannada. The plant is known to be edible and is considered to possess cooling property [8, 10, 11]. In the present review, we presented updated information (up to 2017) concerned with the ethnobotanical uses, phytochemical composition and pharmacological properties of *P. pellucida*. An extensive literature survey on various aspects of the plant was carried out by referring flora, journals, and various search engines including Google scholar, Science Direct and Pubmed.

Plant description

P. pellucida is a slender herb (reaching 30-50 cm in length) with straight and succulent stem and is cosmopolitan in distribution. Leaves are opposite and alternate, up to 2.5x2 cm, ovate-deltoid, obtuse to acute at apex. Leaves are thin, fleshy, smooth, membranous when dry, 5-7 nerved from the base. Petiole is up to 1.5 cm long. Spikes are terminal and leaf-opposed, up to 5 cm long. Flowering occurs more or less throughout year. Fruits are ribbed and reticulate, minute in size and almost dry [8, 10].

Fig. 1: *Peperomia pellucida* (L.) Kunth (photograph by prashith kekuda).

Ethnobotanical uses of *P. Pellucida*

The plant *P. pellucida* is used ethno botanically as medicine, food and flavoring agent in various parts of the world. Aerial parts, young shoots, leaves and whole plant are used in the form of decoctions, juice, paste etc. to treat several diseases such as fever, cold, cough, viral diseases, rheumatic pain, asthma, vaginal infections and kidney infections. The Sumu (Ulwa) of southeastern Nicaragua and southern Miskitu uses *P. pellucida* against bites and stings (snakes, scorpions and insects), infections, venereal diseases and female disorders [12]. The plant is used as human food and medicine in Luang Prabang, Lao People's Democratic Republic [13]. In Lombok, Indonesia, the plant is used to treat fever [14]. In North-Kamrup district, Assam, India, the plant paste is applied externally to reduce pimple and white spots of the body [15]. In Trinidad and Tobago, the plant is use for cooling [16]. The whole plant is used in the treatment of measles in Ogun state, Nigeria [17]. Juice made from leaves and roots are used to treat athletes foot, decoction prepared from leaves is used in the treatment of hemorrhoid pain and kidney infection in Rondônia, Western Amazon, Brazil [18]. In Nigeria, the whole plant is used in haemmorhoids, hypertension, convulsion and bone fracture [19]. The whole plant is boiled and used to treat kidney infection and to lower hypertension in Mindanao, Philippines [20]. Table 1 depicts ethnobotanical (medicinal and non-medicinal) uses of *P. pellucida* in various parts of the world.

Table 1: Ethnobotanical uses of *P. pellucida* in various parts of the world

Region	Part used	Uses	Reference
Malappuram district, Kerala, India	Whole plant	Decoction prepared from whole plant is taken internally for treating rheumatism.	Chithra and Geetha [21]
Barpeta district, Assam, India	Plant juice, leaf paste	Plant juice is used in stomach problems, leaf paste is applied on cuts and wounds.	Kalita *et al.* [22]
East Sepik, Papua New Guinea	Leaves, whole plant	Leaves are used as antidepressant and in the treatment of pimple. Whole plant is used in the treatment of fever and headache.	Koch *et al.* [23]
Indonesia	Aerial parts	Dizziness, headache, fever, stomachache	Waty *et al.* [24]
Greater Khulna division, Bangladesh	Whole plant	Whole plant is used in the treatment of diarrhea.	Rahmatullah *et al.* [25]
Bagerhat district, Bangladesh	-	Tribal community uses plant for medicinal purposes	Mollik *et al.* [26]
Tinsukia district, Assam, India	Whole plant	Paste made from the whole plant is applied on burns for quick relief.	Buragohain [27]
Assam, India	Young shoots	Young shoots are used as flavoring agents.	Bharali *et al.* [28]
Morigaon district, Assam, India	Aerial parts	Aerial part of the plant is used to treat stomach pain, joint pain and headache.	Bordoloi *et al.* [29]
Jalpaiguri district, West Bengal, India	Whole plant	Paste made from whole plant is used against boils.	Bose [30]
Kanda community, Bangladesh	Whole plant	Paste made from the whole plant is applied by the sides of the bitten place (poisonous snake, insect or reptile bites).	Rahmatullah *et al.* [31]
Saramaccan Maroons in Suriname	Whole plant	Used as herbal bath for children for general health promotion and to get rid of evil.	Ruysschaert *et al.* [32]
Dominican Republic and New York city (Dominican traditional medicine)	Aerial parts, leaf	Aerial parts are used in the treatment of flu, leaves are used to treat vaginal infections and asthma/chest congestion.	Vandebroek *et al.* [33]
Okigwe Imo state, South Eastern Nigeria	Leaves	Leaves are used to treat athletes' foot and wound.	Uzodimma [34]
Assam, India	Leaf and stem	Stem and leaves are used in urinary disorder and fever.	Gogoi and Zaman [35]
Trinidad	Whole plant	Infusion or decoction made from whole plant is used to treat cold and cough and as cooling/cleansing agent.	Clement *et al.* [36]
Tshopo district, DR Congo	Leaves	Leaves are cooked and used as leafy vegetable.	Termote *et al.* [11]
Moulvibazar district, Bangladesh	Leaves, whole plant	Paste made from leaves and whole plant is used in the treatment of fever in children and adults respectively.	Das *et al.* [37]
Kamrup district, Assam, India	Leaves and stem	Leaves and stem are used in the treatment of fever.	Bora and Das [38]

Table 2: Phytochemical groups identified in *P. pellucida*

Plant part	Phytochemical group	Reference
Whole plant	Tannins, saponins, flavonoids, terpenoids, phytosterols, alkaloids, phenolics	Gini and Jothi [46]
Leaf	Alkaloids, tannins, saponins, terpenoids, flavonoids, cardiac glycosides	Ojo *et al.* [47]
Leaf	Alkaloids, flavonoids, saponins, tannins, steroids, triterpenoids	Majumder and Kumar [48]
Leaf	Alkaloid, cardiac glycoside, terpene, saponin, tannin	Omotayo and Borokini [49]
Whole plant	Alkaloids, saponins, tannins, flavonoids, anthraquinones, glycosides	Idris *et al.* [50]
Leaf	Alkaloids, tannins, flavonoids, saponins and cardiac glycosides	Abere and Okpalaonyagu [51]
Leaf	Alkaloids, flavonoids	Ibibia [52]
Stem	Alkaloids, tannins, flavonoids, steroids, triterpenoids	Majumder [53]
Whole plant	Alkaloids, flavonoids, glycosides, saponins	Sheikh *et al.* [54]
Leaf	Alkaloids, tannins, saponins	Egwuche *et al.* [55]
Aerial parts	Alkaloids, flavonoid, tannins, saponins, steroids, glycosides	Raina and Hassan [56]

Phytochemistry of *P. Pellucida*

Plants produce a range of primary and secondary metabolites. The study of chemical compounds present in plants (phytochemicals) is known as phytochemistry. The therapeutic potential of plants is ascribed to the presence of a wide range of phytochemicals, mainly secondary metabolites. Significant advancements in the technology, mainly chromatographic and spectral analyses, led to the discovery of many types of phytochemicals from plants and the pharmacological studies revealed their potential role. Techniques

such as column chromatography, Thin layer chromatography (TLC), Gas chromatography–mass spectrometry (GC-MS), Fourier-transform infrared spectroscopy (FT-IR) and Nuclear magnetic resonance (NMR) spectroscopic techniques are routinely used to identify phytochemicals present in plants [39-45]. Various researchers have identified phytochemical groups and chemical compounds in leaves and whole plant by standard phytochemical procedures and various analytical techniques.

Table 2 and 3 provides information on various phytochemical groups and chemicals identified in different parts of the plant by standard phytochemical tests and GC-MS analysis respectively.

Table 3: Chemical compounds identified in *P. pellucida* by GC-MS analysis

Sample	Compounds identified	References
Essential oil	Dillapiole, trans-caryophyllene	da Silva *et al.* [57]
Leaf extract	phytol, 2-Naphthalenol, Hexadecanoic acid and 9,12-Octadecadienoic acid	Wei *et al.* [58]
Essential oil	Dillapiole, myristicine	Francois *et al.* [59]
Essential oil	carotol, dill apiole, pygmaein, (E)-caryophyllene, germacrene D, β-elemene, camphor, daucene, apiole, β-bisabolene and bicyclogermacrene	Verma *et al.* [60]
Whole plant extract	Apiol, Phytol, n-Hexadeconoic acid, E-2-Tetradecen-1-ol, Stigmasterol, Campesterol, and Sitosterol	Narayanamoorthi *et al.* [61]
Essential oil	γ-gurjunene, 1,10-di-epicubenol, (E)-caryophyllene, dillapiole, carotol, trans-β-guaiene	de Oliveira *et al.* [62]
Essential oil	Phytol, α-terpineol, β-caryophyllene, d-limonene, linalool	Okoh *et al.* [63]

Ragasa *et al.* [39] isolated dill-apiol, aurantiamide acetate and pachypophyllin from leaf extract of *P. pellucida* and elucidated their structure by NMR studies. Pellucidin A, a novel dimeric ArC2 compound, along with dill-apiol has been isolated by Bayma *et al.* [64] from the aerial parts of *P. pellucida*. The structure of pellucidin A was established by spectral analyses. The study carried out by Xu *et al.* [65] revealed isolation of compounds such as secolignans, tetrahydrofuran lignans, highly methoxylated dihydro-naphthalenone, peperomins, sesamin and isoswertisin from the whole plant of *P. pellucida*. Khan *et al.* [66] recovered a xanthone glycoside from leaves of *P. pellucida* and characterized the compound as Patuloside A (3-β-D-glucopyranosyloxy-1,5,6-trihydroxy-9H-xanthene-9-one) by performing various chromatographic and spectral analyses. Leena and Annam [67] isolated a flavone glycoside from whole plant of *P. pellucida* and characterized the compound as vitexin by chromatographic and spectral analyses. The study carried out by Hartati *et al.* [41] identified compounds viz. stigmasterol, analogue of pheophytin and β-sitosterol-D-glucopyranoside in the solvent extract of *P. pellucida*. Susilawati *et al.* [68] isolated a compound namely 8,9-dimethoxy ellagic acid from the ethyl acetate fraction of leaf of *P. pellucida* by column chromatography and the structure was elucidated by chromatographic and spectral analyses. A compound by name 3',4', dihydroxy-3-5-dimethoxy flavone-7-O-β-rhamnose was isolated from ethyl acetate fraction of crude methanolic extract of aerial parts of *P. pellucida* and the structure was elucidated by the spectral data [43]. The study carried out by Ahmad *et al.* [69] revealed a total alkaloid content of 29.59 mg/g piperine in the dichloromethane fraction of plant material. Fig. 2 shows the structure of some of the compounds identified in the plant.

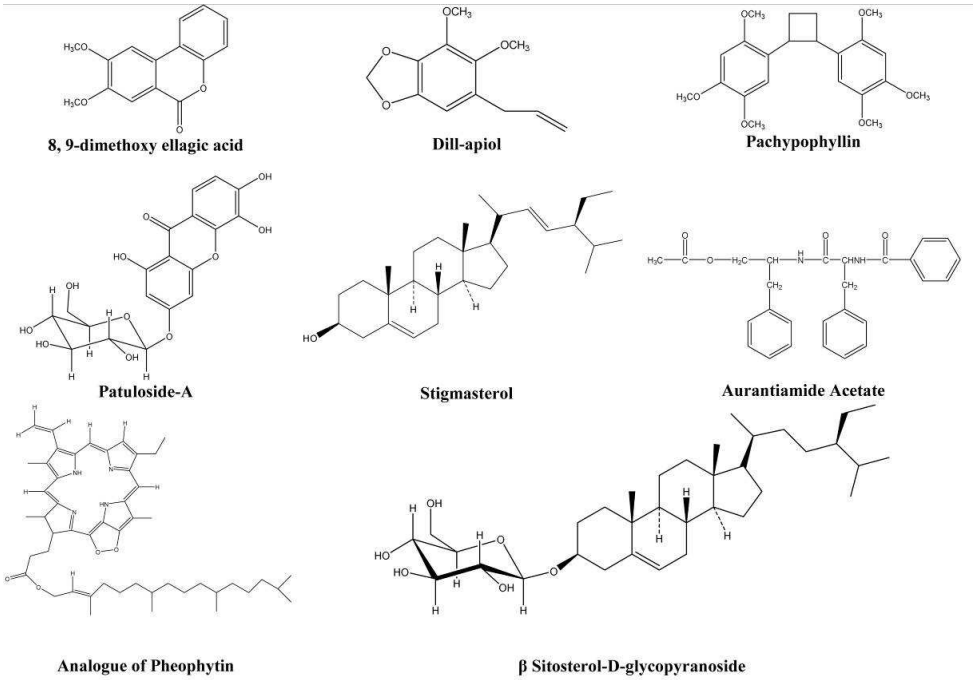

Fig. 2: Structures of some compounds identified in *P. pellucida* [39, 41, 66, 68]

Pharmacological activities of *P. Pellucida*

Many studies have been carried out to investigate pharmacological properties of *P. pellucida*. The plant is reported to exhibit several bioactivities such as hypotensive, immunostimulatory, antioxidant, antimicrobial, analgesic, anti-inflammatory, fracture healing, gastroprotective and antidiabetic activity.

Concise information on pharmacological activities of extracts and purified compounds of *P. pellucida* is discussed below.

Hypotensive activity

Nwokocha *et al.* [70] evaluated hypotensive activity of aqueous extract from whole plant of *P. pellucida* in rat model. Intravenous administration of extract showed a dose dependent reduction in systolic and diastolic blood pressure, heart rate and mean arterial pressure. It was shown in the study that the extract induces bradycardia and hypotension in normotensive rats via mechanisms that are nitric oxide dependent. The study carried out by Fasola and Adeboye [71] also revealed anti-hypertensive activity of *P. pellucida* in normotensive rats. Intravenous administration of methanol extract resulted in marked decrease in mean arterial blood pressure and heart rate.

Neuropharmacological activity

The study carried out by Khan *et al.* [72] indicated that the petroleum ether and ethyl acetate fractions of ethanol extract of leaves of *P. pellucida* possess central nervous system depressant effect as the fractions were shown to possess dose dependent effects on duration of diazepam-induced sleep, nikethamide-induced toxicity, light-dark test and force swimming test.

Immunostimulatory activity

In a study, Lee *et al.* [73] revealed the potential of leaf extract of *P. pellucida* (mixed with fish pellets) as an immunostimulator in controlling motile aeromonad septicemia caused by *Aermomonas hydrophila* in *Oreochromis* spp. (red hybrid tilapia). It was observed that the mortality rate was considerably lesser in fishes that were fed with diet which was mixed with leaf extract.

Antimutagenicity activity

Ragasa *et al.* [39] evaluated antimutagenic activity of dill-apiol and pachypophyllin isolated from leaf extract of *P. pellucida* by micronucleus test. The compounds were not effective as the study did not indicated significant reduction in micronucleated polychromatic erythrocytes induced by mitomycin C.

Anti-angiogenic activity

The study carried out by Camposano *et al.* [74] revealed anti-angiogenic activity of methanol extract of *P. pellucida* in terms of inhibition of angiogenesis in chorioallantoic membrane assay. The extract was shown to inhibit angiogenesis with an activity of 26%.

Fracture healing activity

Ngueguim *et al.* [75] evaluated the potential of ethanol extract of *P. pellucida* on bone regeneration following bone and marrow injury in rats, and determined the mode of action. The extract dose-dependently induced bone regeneration at the fracture site and significantly increased mineral deposition. The extract was also found to improve microarchitecture of the regenerating bone. It was shown that the extract accelerates fracture repair via stimulatory effects on osteoblast differentiation and mineralization. Recently, Florence *et al.* [76] revealed the potential of aqueous extract of *P. pellucida* to accelerate fracture healing in Wistar rats. Radiological tests revealed a dose dependent formation of callus at the level of the fracture gap and was evidenced by formation of a highly dense and compact fibrocartilagenous callus.

Antiulcerogenic/gastroprotective activity

Roslida and Aini [77] evaluated gastroprotective (antiulcerogenic) activity of ethanolic extract of aerial parts of *P. pellucida* in indomethacin and necrotizing agent induced models in rats. The result revealed that the extract at all doses produced significant inhibition of gastric mucosal damage induced by necrotizing agents and indomethacin. Rojas-Martínez *et al.* [78] determined gastroprotective activity of solvent extracts and Dillapiole from *P. pellucida*. Dichloromethane extract of leaf and stem displayed marked gastroprotective activity in rats with ethanol induced gastric ulcer. Dillapiole also exhibited marked gastroprotection.

Analgesic activity

Aziba *et al.* [79] determined analgesic activity of methanol extract of aerial parts of *P. pellucida* by acetic acid induced writhing in mice. It was observed that oral administration of extract (70-210 mg/kg) exhibited a significant analgesic activity in mice. Arrigoni-Blank *et al.* [80] evaluated analgesic activity of aqueous extract prepared from aerial parts of *P. pellucida* by abdominal writhing and hot plate tests. The extract displayed significant analgesic activity at extract concentration of 400 mg/kg and 100 mg/kg in abdominal writhing and hot plate test respectively. The study carried out by Sheikh *et al.* [54] revealed analgesic potential of ethyl acetate extract of whole plant by acetic acid-induce writhing in mice.

Antipyretic activity

The study carried out by Khan *et al.* [81] revealed the antipyretic potential of petroleum ether and ethyl acetate soluble fractions of ethanol extract of leaves of *P. pellucida* in boiled milk induced pyrexia in albino rabbits. Administration of solvent fractions at a dose of 80 mg/kg body weight showed a significant reduction in elevated body temperature in albino rabbits.

Anti-inflammatory activity

Arrigoni-Blank *et al.* [82] evaluated anti-inflammatory activity of aqueous extract of leaves of *P. pellucida* by carrageenan induced paw edema test in rats. It was observed that the extract obtained from plants in all seasons displayed antiedematogenic activity with significant activity observed in phenophases of winter and spring. Arrigoni-Blank *et al.* [80] evaluated anti-inflammatory activity of aqueous extract prepared from aerial parts of *P. pellucida* by paw edema induced by carrageenan and arachidonic acid. It was observed that oral administration of 200 and 400 mg/kg of the extract showed an anti-inflammatory activity in the carrageenan test, which was based on interference with synthesis of prostaglandin, as confirmed by the arachidonic acid test. The study carried out by Mutee *et al.* [83] indicates the anti-inflammatory potential of petroleum ether, chloroform and methanol extract of *P. pellucida* in carrageenan induced rat paw edema. Among extracts, petroleum ether extract displayed significant activity when compared to chloroform and methanol extracts.

Antimicrobial activity

Ragasa *et al.* [39] isolated dill-apiol and pachypophyllin from leaf extract of *P. pellucida* and determined their antimicrobial activity. These compounds were selectively effective against *Trichophyton mentagrophytes* while other test microbes were not affected. In a study, Khan and Omoloso [84] screened antimicrobial activity of crude methanolic extract and petrol, dichloromethane, ethyl acetate and butanol fractions of methanolic extract of *P. pellucida*. Crude extract and fractions displayed broad spectrum antibacterial activity. Butanol fraction of crude extract was more active. Patuloside A isolated from leaves of *P. pellucida* was shown to display concentration dependent inhibition of Gram positive and Gram negative bacteria. Patuloside A showed weak activity against *Aspergillus flavus* and *Candida albicans* while *A. niger* and *Rhizopus oryzae* were unaffected [66]. Further details on the antimicrobial potential of *P. pellucida* described by other researchers are shown in table 4.

Antidiabetic activity

Humzah *et al.* [93] showed that diet containing *P. pellucida* (10% and 20%) possess antidiabetic effect in alloxan-induced diabetes in rats. A considerable reduction in the blood glucose level was observed in the study. The levels of aspartate transaminase (AST), alanine transaminase (ALT) and alkaline phosphate (ALP) were lesser in rats fed with diet containing *P. pellucida*. Moreover, the concentration of total cholesterol, triglycerides (TG), high-density lipoprotein (HDL) and low-density lipoprotein (LDL) content were also lesser in rats fed with diet containing *P. pellucida*. The levels of superoxide dismutase (SOD), catalase and glutathione were also increased. Sheikh *et al.* [54] evaluated antidiabetic activity of ethyl acetate extract of whole plant of *P. pellucida* in alloxan-induced diabetic mice. A significant hypoglycemic effect was observed in mice administered with extract. 8,9-dimethoxy ellagic acid, isolated from leaf extract of *P. pellucida*, was evaluated for antidiabetic activity by alloxan-induced hyperglycemia in mice [68]. The compound was shown to exhibit 33.74% blood glucose lowering in normoglycemic model at 100 mg/kg dose.

Table 4: Antimicrobial potential of *P. pellucida*

Extract	Part	Activity against	References
Aqueous and ethanol extract	Leaf	Gram negative bacteria	Akinnibosun *et al.* [85]
Methanol extract	Whole plant	*Bacillus subtilis* and *Candida albicans*	Wiart *et al.* [86]
Methanol extract	Leaf	Gram positive and Gram negative bacteria	Wei *et al.* [58]
Methanol extract, solvent fractions	Leaf	Gram positive and Gram negative bacteria; Fungi namely *Aspergillus*, *Rhizopus*, *Candida* and *Penicillium*	Oloyede *et al.* [87]
Solvent extracts	Leaf	*Pseudomonas aeruginosa*, *Salmonella typhii* and *Shigella dysenteriae* and *Aspergillus niger*	Ibibia *et al.* [52]
Aqueous and organic extracts	Leaf	Gram positive and Gram negative bacteria	Ojo *et al.* [47]
Alcohol extract		Gram positive and Gram negative bacteria	Mensah *et al.* [88]
Essential oil	Leaf	*Fusarium moniliforme*, *Rhizopus stolonifer*	Francois *et al.* [59]
Ethanol extract	Leaf	Gram positive and Gram negative bacteria	Igwe and Mgbemena [89]
Ethanol	Leaf	*Shigella dysenteriae*	Uddin *et al.* [90]
Solvent extracts	Leaf	Gram positive and Gram negative bacteria	Zubair *et al.* [91]
Aqueous and methanol extract	Aerial parts	*Aeromonas hydrophila*, *Enterobacter cloacae*, *Streptococcus agalactiae*	Raina and Hassan [56]
Solvent extracts	Whole plant	Gram positive and Gram negative bacteria	Idris *et al.* [50]
Essential oils	Leaf and stem	Gram positive, Gram negative bacteria, *Mycobacterium smegmatis*	Okoh *et al.* [63]
Ethanol extract	Leaf	*Candida albicans*	Hastuti *et al.* [92]

Acaricidal activity

In a study, de Oliveira *et al.* [62] evaluated the activity of the essential oils from leaf and stem against *Tetranychus urticae*. It was observed that the stem oil was fourfold more toxic than the leaf oil however the activity of essential oils was lesser than eugenol, the positive control.

Anticancer/cytotoxic activity

Peperomin E, isolated from whole plant of *P. pellucida*, was found to exhibit cytotoxicity against cell lines viz. HL-60, MCF-7 and HeLa cell lines [65]. Khan *et al.* [66] determined cytotoxic activity of Patuloside A, isolated from leaves of *P. pellucida*, against brine shrimp nauplii. The compound exhibited cytotoxicity with an LC_{50} value of 18.24µg/ml and the activity observed was lesser when compared to standard drug. Wei *et al.* [58] determined cytotoxic potential of methanolic extract of *P. pellucida* leaf against MCF-7 cell line by 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. The extract displayed concentration dependent cytotoxicity with an IC_{50} value of 10.4±0.06µg/ml. Oloyede *et al.* [87] screened cytotoxicity of crude methanol extract and fractions such as hexane, ethyl acetate, butanol and aqueous fractions of leaves of *P. pellucida* by brine shrimp lethality assay. Crude extract, hexane and ethyl acetate fractions were shown to be effective while butanol and aqueous fractions were not effective in causing mortality of brine shrimp larvae.

Antioxidant activity

Mutee *et al.* [83] determined antiradical activity of chloroform, petroleum ether and methanol extract of *P. pellucida* by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay. Methanol extract was shown to display marked scavenging of free radicals when compared to other extracts. Wei *et al.* [58] screened methanolic extract of *P. pellucida* leaf for radical scavenging potential by DPPH assay. The extract was shown to display concentration dependent scavenging of radicals but the activity observed was considerably lesser than that of quercetin. Oloyede *et al.* [87] determined antioxidant potential of crude methanolic extract and hexane, ethyl acetate, butanol and aqueous fractions of leaves of *P. pellucida* by DPPH scavenging, hydrogen peroxide scavenging and ferric thiocyanate method. Extract and fractions were shown to exhibit marked activity in all methods. The study carried out by Beltran-Benjamin *et al.* [94] revealed an increase in the levels of antioxidant enzymes viz. superoxide dismutase and catalase on administration of crude methanolic extract of *P. pellucida* in rats. Phongtongpasuk and Poadang [95] evaluated antioxidant potential of butanol, ethyl acetate and methanol extracts of *P. pellucida* obtained by maceration and reflux method. Extracts obtained by reflux method displayed marked DPPH scavenging activity and reducing power. Phenolic content was also higher in extracts obtained by reflux method. The study carried out by Okoh *et al.* [63] showed the antioxidant potential of essential oil of leaf and stem of *P. pellucida*. The essential oils exhibited concentration dependent scavenging of DPPH, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid (ABTS) and nitric oxide radicals.

Enzyme inhibitory activity

In a study, Ong *et al.* [96] evaluated porcine pancreatic lipase inhibitory activity of methanolic extract of leaves of *P. pellucida* and observed lesser potential of leaf extract to cause inhibition of lipase activity when compared to standard. Kurniawan *et al.* [43] isolated a compound by name 3',4', dihydroxy-3-5-dimethoxy flavone-7-O-β-rhamnose from aerial parts of *P. pellucida* and evaluated its inhibitory activity against Angiotensin converting enzyme (ACE). The compound was found to inhibit ACE dose dependently with an IC_{50} value of 7.72µg/ml. Ethyl acetate fraction was more potent than the compound. The study carried out by Parawansah *et al.* [97] showed the potential of ethanol extract of leaves of *P. pellucida* to inhibit the activity of xanthine oxidase. Extract was shown to exhibit inhibition of xanthine oxidase with an IC_{50} value of 19.5 ppm.

Antisickling activity

Abere and Okpalaonyagu [51] evaluated antisickling activity of leaves of *P. pellucida* on the inhibition of sodium metabisulphite-induced sickling of the HbSS red blood cells. Leaf extract was found to significantly inhibit sickling of red cells with maximum inhibition of sickling (57.5%) at 500 mg/ml of the extract.

Anti-ostioporesis activity

The study carried out by Putri *et al.* [98] revealed the potential of ethanol extract of *P. pellucida* (100 mg/kg body weight [b. w]) to prevent osteoporosis in ovariectomized (OVX)-induced osteoporotic rats. At 100 mg/kg concentration, the extract treated rats showed improvement on three-dimensional image of the trabecular bone compared with the OVX-control group. Also, the trabecular cavity formation in 100 mg/kg extract-treated group was minimal.

Fibrinolytic activity

The study of Ebenezer *et al.* [99] showed a weaker fibrinolytic activity of *P. pellucida* extract. The *in vitro* clot lysis activity was

considerably lesser when compared to extracts from other plants. In another study, Zubair *et al.* [91] revealed the potential of ethyl acetate, hexane, chloroform and aqueous soluble fractions of *P. pellucida* to cause lysis of clot indicating thrombolytic activity. Marked activity was displayed by ethyl acetate soluble fraction.

Antidiarrhoeal activity

The ethanolic extract of *P. pellucida* leaves was evaluated for antidiarrhoeal activity in castor oil-induced diarrhoea in mice. The extract was shown to display concentration dependent anti-diarrhoeal activity [91].

Hair growth promotion activity

The study carried out by Kanedi *et al.* [100] revealed the potential of crude extract of *P. pellucida* in a topical gel formulation to promote hair growth in rabbits dose dependently. The mean hair length increased on increasing the concentration of extract in the gel.

Proximate and nutritive attributes of *P. Pellucida*

Egwuche *et al.* [55] evaluated nutritive attributes of *P. pellucida* leaves from Nigeria. The leaves were shown to contain carbohydrates (38.97%), proteins (7.68%), crude fibre (22.35%) and fat (1.08%). The leaves were also shown to contain appreciable quantity of calcium, magnesium, potassium and sodium. The study carried out by Ooi *et al.* [101] revealed the nutritive composition of *P. pellucida* from Malaysia. The plant was shown to contain an appreciable quantity of carbohydrates (about 45%) and proteins (about 10%) however the lipid content was low (about 3%). The plant is also shown to possess considerable quantity of potassium, calcium, iron and sodium.

CONCLUSIONS

The plant *P. pellucida* is a well-known medicinal plant being used ethnomedicinally for treatment of various diseases worldwide. *In vitro* and *in vivo* studies have shown many pharmacological activities of the plant which supports the traditional use of the plant. Literatures have shown the potential of isolated compounds to exhibit bioactivities such as antimicrobial, anticancer, gastroprotective and antidiabetic activities. The presence of phytochemicals such as alkaloids, flavonoids, saponins, tannins and glycosides in the plant could be responsible for the pharmacological activities of the plant. The plant *P. pellucida* appears to be suitable for developing drugs that can be used to treat several diseases or disorders. Utilization of the plant in suitable form can be beneficial in terms of promotion of health and disease therapy.

SOURCES OF SUPPORT

None

AUTHORS CONTRIBUTIONS

Both the authors namely Dr. Prashith Kekuda T. R and Dr. Raghavendra H. L were involved equally in literature survey, framing contents, writing draft paper and finalizing the review paper.

CONFLICTS OF INTERESTS

Authors declared that there are no potential conflicts of interest

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