**ASIAN J NAT PROD BIOCHEM**
Volume 20, Number 2, December 2022
Pages: 56-62

P-ISSN: 2775-4189
E-ISSN: 2775-4197
DOI: 10.13057/biofar/f200203

# Assessment of phytochemical compositions, antibacterial effects and DPPH scavenging activities of ethanolic root extracts of *Pterocarpus erinaceus*

**EMMANUEL CHIKODIRI OKOLI♥, ISAAC JOHN UMARU, OTITOJU OLAWALE**
Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University Wukari. P.M.B. 1020, Taraba 670101, Nigeria.
Tel./fax.: +2347068385043, ♥email: emmanuelokolic@gmail.com

Manuscript received: 17 August 2022. Revision accepted: 30 September 2021.

**Abstract.** *Okoli EC, Emaru IJ, Olawale O. 2022. Assessment of phytochemical compositions, antibacterial effects and DPPH scavenging activities of ethanolic root extracts of* Pterocarpus erinaceus*. Asian J Nat Prod Biochem 20: 56-62. Pterocarpus erinaceus* Poir. serve as a medicinal plant to many populations of Nigeria and West Africa. The stem bark, leaves, and roots have been studied for their antioxidant, antimalaria, antiulcerogenic, and antibacterial properties. This study aimed to determine the phytochemical compositions, antibacterial effect and antioxidant activity of the root bark of *P. erinaceus*. A gas chromatography flame ionization detector (GC-FID) instrument was used for the analysis and quantification of phytochemicals present in the ethanolic root extract of *P. erinaceus*. The antibacterial test was carried out using the agar well method against standard bacteria: *Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa* and *Escherichia coli* while the antioxidant activity was carried out by evaluating the DPPH scavenging activity. Phytochemicals found in the extracts include: flavonoids (44.50%), alkaloids (18.87%), steroids (4.38%), tannins (1.73%), and anti-nutrients (15.12%). The ethanolic root extracts of *P. erinaceus* exhibited significant antibacterial activity against *E. coli* and *S. aureus* but exhibited no growth inhibitory effect on *B. subtilis* and *P. aeruginosa* at all tested concentrations (100 µg/mL, 150 µg/mL, and 200 µg/mL). DPPH scavenging activity was significantly high, with 97.53% at a concentration of 1000 µg/mL and 24.26% at 40 µg/mL. This study revealed that the crude ethanolic extract of *P. erinaceus* root bark contained pharmacologically active compounds and exhibited significant antibacterial activity and DPPH free radical scavenging activity in a concentration-dependent manner.

**Keywords:** Antioxidant, ethanolic extract, GC-FID, phytochemicals, *Pterocarpus erinaceus*

## INTRODUCTION

One-third of all deaths worldwide are due to infectious diseases (Tittikpina et al. 2018). Drug resistance is the current cause of this increase and is more common in less developed countries, where one in two people die prematurely from the disease, than in developed countries (Tittikpina et al. 2018). With limited access to quality medicines, people in many developing countries still use plants to treat common ailments (Tittikpina et al. 2018). About 64% of the world population still depends on traditional medicines and medicinal plants to meet their health needs (Hossain et al. 2022). According to a WHO survey, traditional medicines are prescribed for about 80% of patients in India, 85% in Burma, and 90% in Bangladesh (Hossain et al. 2022). Records indicate that the medicinal uses of the plant date back to 4000-5000 BC. AD and the Chinese were the first to use natural herbal preparations as medicine. Even modern pharmacopeias still contain at least 25% of pharmaceutical products of plant origin and, more often, synthetic compounds isolated from plants (Hossain et al. 2022). As a result, much research has been done to uncover the active ingredients in these plants. The most famous example of this approach is the discovery of artemisinin from *Artemisia annua* (a treatment for malaria), but artemisinin is not the only promising plant-based compound (Tittikpina et al. 2018). Accordingly, many authors from Asia and Africa have studied the activity of plant extracts, the purified chemicals in the extracts, against various microorganisms associated with bacterial and fungal diseases (Tittikpina et al. 2018).

*Pterocarpus erinaceus* Poir. (Leguminosae, Papilinoideae) is a species of deciduous tree in the legume family, native to the savannas and dry forests of Africa (Ahmed et al. 2017). The tree is 12-15 m high and 1.2 m in diameter. The bark is dark gray and scaly, the leaves are feathery up to 30 cm long. It flowers in yellow. The fruit has developed pink spots (Ahmed et al. 2017). Seeds are kidney-shaped to oblong, often oblong and curved at the level of small telium (Ahmed et al. 2017). Also known as African rosewood. The leaves and seeds are edible after thorough cooking (Ahmed et al. 2017). We produce the finest wood from the country of origin. At the end of the dry season, the leaves and young bark are often cut for fodder for sheep, goats, cattle and horses (Ahmed et al. 2017). According to the ethnographic findings of Saslis-Lagoudakis et al. (2011). The leaves, bark, and roots of the plant *P. erinaceus* Poir. are used in traditional Burkinabe medicine to treat inflammatory diseases such as fever, bacterial infections, malaria, ulcers, rheumatism, and inflammation. In addition, the roots of *P. erinaceus* are used to treat inflammation, ulcers, and gastric diseases (Noufou et al. 2016).

The bark, leaves, and roots of *P. erinaceus* have been studied for their anti-inflammatory, analgesic, and anti-inflammatory properties (Noufou et al. 2016), antidiarrheal, antiemetic, antimalarial, antioxidant, antifungal (Karou et al. 2003; Ezeja et al. 2012; Olaleye et al. 2013; Tittikpina et al. 2019). The evidence has confirmed the importance of this plant.

Although it is widely used in traditional medicine, little is known about its phytochemicals. Therefore, the objective of this study was to evaluate the phytochemical components and antibacterial and antioxidant activities of the ethanolic extract from the root bark of *P. erinaceus.*

## MATERIALS AND METHODS

### Study area

This study was carried out at Federal University, Wukari, Taraba State, Nigeria, between February 2022 to July 2022. Wukari town is the headquarters of Wukari Local Government Area in Taraba State, Nigeria. It lies between latitude 7.9303°N and longitude 9.8125°E of the equator.

### Materials

The root bark samples of *P. erinaceus* were collected from uncultivated farmland of Federal University Wukari, Wukari Local Government Area of Taraba State, Nigeria. The plant was taxonomically identified and authenticated in the Department of Plant Science of Modibbo Adama University of Technology, Yola, Nigeria.

### Root extraction

The root samples were rinsed with distilled water before being air-dried over a period of thirty days. It was then ground into powder by grinding in a mortar and pestle. One hundred and fifty grams (150 g) of the powdered root were cold macerated in 500 mL of ethanol inside an Erlenmeyer flask shaken at an interval of an hour and then allowed at room temperature to stand for 48hours, and filtered using Whatman's filter paper No. 1. The extract was then concentrated to dryness using a rotary evaporator. It was then stored under a frozen condition until required.

### GC-FID identification and quantification of phytochemical constituents

For the GC-FID (Gas Chromatograph/Flame Ionization Detector) analysis, 1 g of root extract of *P. erinaceus* was weighed and transferred into a test tube. Fifteen (15) mL of ethanol and 10 mL of 50% w/v potassium hydroxide were added to the crushed root bark in the test tube. The test tube was allowed to stand in a water bath at 60°C for 60 minutes. Then the content of the test tube was carefully transferred into a separatory funnel and the tube was rinsed into the same funnel with 10 mL of cold water, 10 mL of hot water, 20 mL of ethanol, and 3 mL of hexane. The extract in the test tube was washed three times with 10 mL of 10% v/v ethanol solution. The extract solution was then dried with anhydrous sodium sulfate and the solvent was evaporated. A sample of the extract was then made soluble in 100 µL of pyridine of which 20 µL was transferred into a vial on the Gas Chromatography machine for phytochemical analysis.

The GC-FID phytochemical analysis was performed on a BUCK M910 Gas Chromatograph (GC) (BUCK Scientific, USA), equipped with a flame ionization detector (FID). A RESTEK 15-meter $MXT^{-1}$ column (15 m x 250 µm x 0.15 µm) was used. The injector temperature was 280°C with a splitless injection of 2 µL of sample and a linear velocity of 30 $cms^{-1}$, Helium 5.0 Pas was the carrier gas with a flow rate of 40 $mLmin^{-1}$. The oven operated initially at 200°C, it was heated to 330°C at a rate of $3°Cmin^{-1}$ and was kept at the temperature of 320°C. Phytochemicals were determined by the ratio between the area and mass of the internal standard and the area of the identified phytochemicals (Ugoeze et al. 2020).

### Antibacterial assay

The antibacterial activity of ethanolic root bark extract of *P. erinaceus* was determined by the agar well diffusion method as adopted by Umaru et al. (2022). Twenty (20) mL of molten nutrient agar was poured into each of the Petri dishes and allowed to solidify. The 0.5 McFarland standardized bacterial broth was spread on the dry nutrient agar with a spreader pre-sterilized in ethanol and flame overnight. With the aid of a sterile cork-borer, four wells of 6 mm depth each and about 5 cm apart were made in the nutrient agar. Three wells were filled with 500 µL of the *P. erinaceus* root bark extract dissolved in sterile distilled water, one with the water only (the negative control) and the last with 1% standard antibiotic, gentamicin. The positive control was dispensed into the wells in triplicates. After incubating for 24 at 37°C, the antibacterial activities were determined by measuring the diameter of the inhibition zone. The zones of inhibition observed with the extract were compared with that of the standard antibiotic, chloramphenicol. The experiment was carried out in three sets. The measured chloramphenicol inhibition zones' diameters were subsequently matched with the respective standard zones' diameters for *Escherichia coli* (Gram -ve), *Staphylococcus aureus* (Gram +ve), *Bacillus subtilis* (Gram +ve), and *Pseudomonas aeruginosa* (Gram -ve). The *P. erinaceus* zone of inhibition from 9-14 mm in diameter was taken as a positive antibacterial activity based on the growth inhibition standard (Umaru et al. 2022).

### DPPH scavenging activities

Different concentrations (40-1000 µg/mL) of the root bark ethanolic extracts were taken in different test tubes. The volume was adjusted to 250 µL by adding MeOH. Two milliliters of a 0.18 mM (0.005%) methanolic solution of DPPH (2,2, -diphenyl-1-picrylhydrazyl) were added to these tubes and shaken vigorously. The tubes were allowed to stand in the dark at room temperature for 30 min (Singh et al. 2002). The control was prepared as above without any extract, and MeOH was used for the baseline correction. Changes in the absorbance of the samples were measured at 517 nm. Radical scavenging activity was expressed as the inhibition percentage and was calculated using the following formula:

% Scavenging Activity = [($A_{517}$ Ctrl - $A_{517}$ treatment)/ $A_{517}$ Ctrl] X 100

## RESULTS AND DISCUSSIONS

The result of GC-FID identification of phytochemicals in the root extract is presented in Figure 1 and Table 1. Studies have reported that medicinal plants are particularly abundant in various bioactive chemicals (Lewis and Ausubel 2006).

Flavonoids are the most abundant phytochemical in the extract (44.50%). Flavonoids are natural substances with different phenol groups found mainly in vegetables, some grains, stems, and flowers. They are well known for their valuable health benefits, especially their antioxidant, anti-mutagenic, anti-inflammatory, anti-cancer and enzyme-regulating properties. Flavonoids in the extract include: naringenin, proanthocyanin, flavone, flavan-3-ol, catechin, epicatechin, and kaempferol.

Epicatechin has the highest concentration (38.09 µg/mL or 21.98%), while the lowest concentration is proanthocyanin (2.04 µg/mL or 1.18%) (Table 1). Catechin and epicatechin are also among the flavonoids present in the ethanolic extract of the root of *P. erinaceus*. While catechins are found in various foods and herbs such as apples, grapes, berries, and tea, epicatechin is mainly found in green and black tea, with the highest levels of epicatechin found in cocoa (Isemura 2019; Prakash et al. 2019). Catechin possesses great health benefits such as anti-obesity, anti-cancer, hepatoprotective, anti-diabetic and neuroprotective effects, while epicatechin is known to have cardioprotective, anti-inflammatory activities. antioxidant, anti-diabetic and anti-cancer (Ugoeze et al. 2020). Epicatechin-rich green tea has also been shown to have antiplatelet effects in vivo and increase insulin sensitivity (Ugoeze et al. 2020).

Because of their powerful antioxidant activity, proanthocyanin and anthocyanin are widely distributed pigments in land plants, where they function as stress suppressors and health-promoting components (Ugoeze et al. 2020). Naringenin is found mostly in citrus fruits and tomatoes and is effective in treating cancer, cardiovascular disease, and osteoporosis (Galluzzo et al. 2008; Ugoeze et al. 2020). In addition, it has recently been proven to generate a considerable reduction in collagen fiber formation in rats with liver injury (Ugoeze et al. 2020). Other positive features of naringenin include its capacity to minimize oxidative stress, as well as its anti-inflammatory, anti-diabetic, anti-hyperlipidemia, antioxidant, and antidepressant properties (Ugoeze et al. 2020).

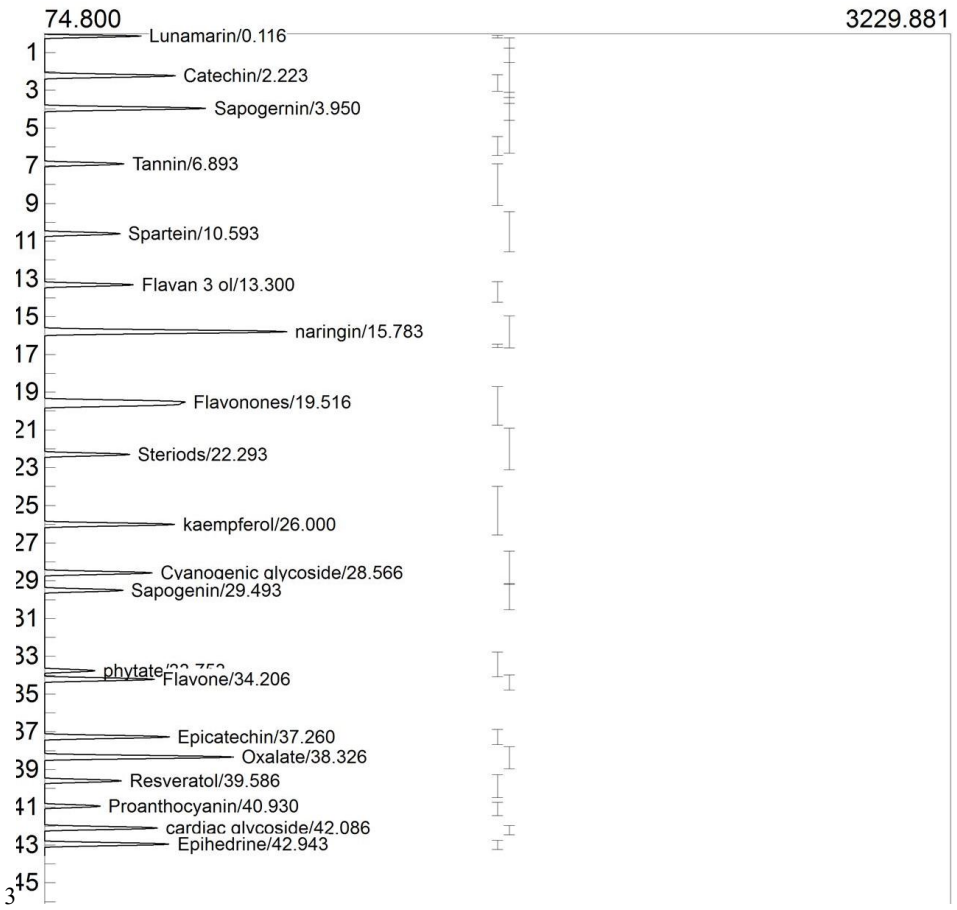


**Figure 1.** Chromatogram showing the phytochemical constituents of ethanolic root extract of *Pterocarpus erinaceus*

**Table 1.** Phytochemical components identified in root extract of *Pterocarpus erinaceus* by GC-FID

| Type of phytochemical | Phytochemical constituents | RT | Area | Height | Conc. (µg/mL) | % Composition |
|---|---|---|---|---|---|---|
| Flavonoids (44.50%) | Catechin | 2.22 | 6793.22 | 529.00 | 5.01 | 2.89 |
| | Flavone | 34.26 | 5932.53 | 458.61 | 4.42 | 2.55 |
| | Epicatechin | 37.26 | 6525.25 | 508.86 | 38.09 | 21.98 |
| | Proanthocyanin | 40.93 | 3451.57 | 270.98 | 2.04 | 1.18 |
| | Flavan-3-ol | 13.30 | 4918.61 | 385.00 | 2.91 | 1.68 |
| | Kaempferol | 26.00 | 6833.38 | 529.58 | 6.15 | 3.55 |
| | Naringin | 15.78 | 12794.39 | 919.80 | 10.56 | 6.09 |
| Alkaloids (18.87%) | Lunamarin | 0.12 | 3681.83 | 411.03 | 9.30 | 5.37 |
| | Spartein | 10.59 | 4339.04 | 337.68 | 1.83 | 1.06 |
| | Epihedrine | 42.94 | 6524.26 | 510.97 | 21.57 | 12.45 |
| Saponins (6.52%) | Sapogernin | 3.95 | 8180.04 | 637.04 | 8.17 | 4.72 |
| | Sapogenin | 29.49 | 4459.40 | 349.79 | 3.12 | 1.80 |
| Tanins (1.73%) | Tannin | 6.89 | 4491.19 | 350.85 | 3.00 | 1.73 |
| Steroids (4.38) | Steroids | 22.29 | 4749.76 | 372.51 | 7.60 | 4.38 |
| Other phenols (1.45%) | Resveratol | 39.59 | 4412.40 | 345.67 | 2.51 | 1.45 |
| Anti-Nutrients (15.12%) | Oxalate | 38.326 | 9393.732 | 732.257 | 21.985 | 12.69 |
| | Phytate | 33.753 | 3207.273 | 252.912 | 4.203 | 2.43 |
| Glycosides (7.70%) | Cardiac glycoside | 42.09 | 6000.13 | 470.14 | 7.94 | 4.58 |
| | Cyanogenic glycoside | 28.57 | 5744.95 | 450.31 | 5.41 | 3.12 |

Flavones and flavanones are other important forms of flavonoids. Flavones are found mainly in leaves, flowers, fruits, celery, parsley, and red peppers, while flavanones are found in all citrus fruits, such as lemons, grapes, and oranges (Ugoeze et al. 2020). Flavones can interact with proteins and bind to human serum albumin to facilitate plasma-mediated transport (Jiang et al. 2016). On the other hand, flavanones have antioxidant, antihyperlipidemic, and anti-inflammatory effects (Ugoeze et al. 2020). Kaempferol is another flavonoid commonly found in many other vegetables and plants, such as grapes, green tea, potatoes, onions, and cucumbers. Like other flavonoids, they may have anti-diabetic, antitumor, and anti-inflammatory activities (Calderon-Montano et al. 2011). In addition, it has been reported to regulate several key factors of cell signaling pathways involved in apoptosis, angiogenesis, inflammation and metastasis, thereby potentially inhibiting the growth of cancer cells and angiogenesis by inducing cancer cell apoptosis (Chen and Chen 2013).

These protective effects of flavonoids in organic systems are generally attributed to their ability to donate electrons to free radicals, chelate metal catalysts, activate antioxidant enzymes, reduce α-tocopherol radicals, and prevent oxidases (Ugoeze et al. 2020). Oxidative stress and inflammation are frequent response that contributes to tumor development by stimulating defective cells to promote and progress tumors, initiating direct damage to genomic nucleic acids, initiating aberrant cell proliferation, and altering intracellular signaling of the normal reaction to do (Bhattacharyya et al. 2014). The rich flavonoid content of ethanolic extract of the root of *P. erinaceus* has given it many pharmacological activities such as anti-inflammatory, antipyretic, hypoglycemic, antifungal, antibacterial, antitumor, and wound healing properties.

Plant alkaloids are one of the largest groups of natural products, composed of structurally distinct and biogenetically unrelated molecules (Ugoeze et al. 2020). They have a wide range of pharmacological activities and have been used as components of many herbal remedies (Alves de Almeida et al. 2017). These include narcotic analgesics, morphine, and codeine (Ugoeze et al. 2020). They have also been shown to have potent antimalarial, antibacterial and antiprotozoal properties (Franck et al. 2004). The results of the present study indicate that ethanol extracts of *P. erinaceus* root contain significant amounts of alkaloids (23.96%), with epihedrine (Figure 2) in the extract (21.57 µg/mL or 6.09%) having the highest concentration, followed by lunamarin (9.30 µg/mL or 5.37%), then spartein (1.83 µg/mL or 1.06%) (Table 1). Lunamarin has been reported to have free radical scavenging properties (Ugoeze et al. 2020). In addition, lunamarins have anti-cancer, immunomodulatory, antiestrogenic, and antiamoebic properties8. These alkaloid levels may be attributed to some pharmacological properties of *P. erinaceus* root extract.

Saponins comprise a group of structurally related natural compounds that include either steroidal or triterpenoid aglycones (sapogenins) and are found primarily in plants and other lower marine animals (including some bacteria) (Ugoeze et al. 2020). They are found in a wide range of plants and crops, with triterpenoid saponins being more common as they are found in many legumes such as soybeans, beans and peas. Pharmacological effects attributed to saponins include immunomodulatory, anti-inflammatory, antifungal, antiviral, antibacterial, hypercholesterolemic, and anticarcinogenic properties (Ugoeze et al. 2020). Saponins accounted for 6.52% of the total phytochemicals obtained from the ethanol extract of *P. erinaceus* root (Table 1). Sapogenins are known for many beneficial properties, but other harmful properties have also been documented. For example, their hemolytic and cytotoxic effects have been observed (Ugoeze et al. 2020). It has also been observed to significantly impair protein digestion and vitamin and mineral absorption in the small intestine, causing hypoglycemia (Ugoeze et al. 2020).

Tannins are found in tea, cocoa, vegetables, legumes, and some immature fruits (Sharma et al. 2021). The extract of *P. erinaceus* root was found to contain low levels of tannins (1.73%), accounting for 1.73% of total phytochemicals (Table 1). Tannins play an important role in traditional Asian medicine, and tannin-rich plant extracts are used as astringents and diuretics (Ugoeze et al. 2020). It is also used to treat diarrhea, gastrointestinal ulcers, and tumors. It also has anti-inflammatory and antioxidant properties (Ugoeze et al. 2020). However, tannin-rich diets have been reported to be responsible for reduced feed intake and efficiency in experimental animals and are, therefore, usually considered low nutrient density. In addition, it is thought to inhibit their conversion into bodily substances (Chung et al. 1998; Ertop and Bektas 2018). The formation of tannin-protein complexes can lead to the inactivation of digestive enzymes and reduced protein digestibility caused by interactions with protein substrates and ionized iron (Ugoeze et al. 2020).

Anti-nutrients are not considered beneficial because they interfere with mineral absorption. Blockage of nutrient absorption is known to cause headaches, rashes, nausea, bloating, and malnutrition (Popova and Mihaylova 2019). Anti-nutrients are mostly organic or synthetic structures that are highly reactive and thus can have toxic effects. Phytates and oxalates are anti-nutrients found in the ethanolic extract of *P. erinaceus* root (Figure 2). Phytic acid (myo-inositol hexaphosphate) is found in various foods, including nuts, seeds, and whole grains. It also contains significant amounts of roots and tubers. Phosphorylated inositol, especially phytic acid, has been suggested to be involved in insulin secretion by pancreatic beta cells (Ugoeze et al. 2020). It has also been suggested that phytic acid inhibits plaque development and lowers serum cholesterol and triglycerides (Schlemmer et al. 2009; Ugoeze et al. 2020). Oxalates, on the other hand, are known to interfere with the absorption and utilization of calcium by forming calcium oxalate crystals that lead to the formation of kidney stones. They also irritate and swelling in the mouth and throat (Ugoeze et al. 2020).

The ethanolic stem bark extract of *P. erinaceus* exhibited different levels of antibacterial activity against the tested bacterial strains. The bacterial strains used were clinical and laboratory isolates. All these bacterial species are known to cause serious human infections. From a clinical point of view, *E. coli* causes septicemias and can infect the gall bladder, surgical wounds, skin lesions and the lungs (Seeram et al. 2002). The *S. aureus* causes dermatitis and sialadenitis (Mastroeni 2002). The *B. subtilis* is known to cause disease in severely immune-compromised patients (Seeram et al. 2002), and *P. aeruginosa* typically infects the pulmonary tract, urinary tract, burns, wounds and also causes other blood infections. All assayed bacteria were sensitive to the extract.

The results shown in Table 2 depict that the ethanolic root extract of *P. erinaceus* exhibited significant growth inhibition of *E. coli* and *S. aureus* but exhibited no growth inhibition of *B. subtilis* and *P. aeruginosa*.

The extract showed an increasing inhibitory activity across all concentrations (100 µg/mL, 150 µg/mL, and 200 µg/mL) in a dose-dependent manner in the two bacteria in which it was found active. The highest inhibition was observed in *S. aureus* with a mean growth inhibition zone of 6.10 mm at a concentration of 200 µg/mL, while the lowest inhibition was observed in *E. coli* with a mean growth inhibition zone of 2.23 mm at 100 µg/mL concentration.

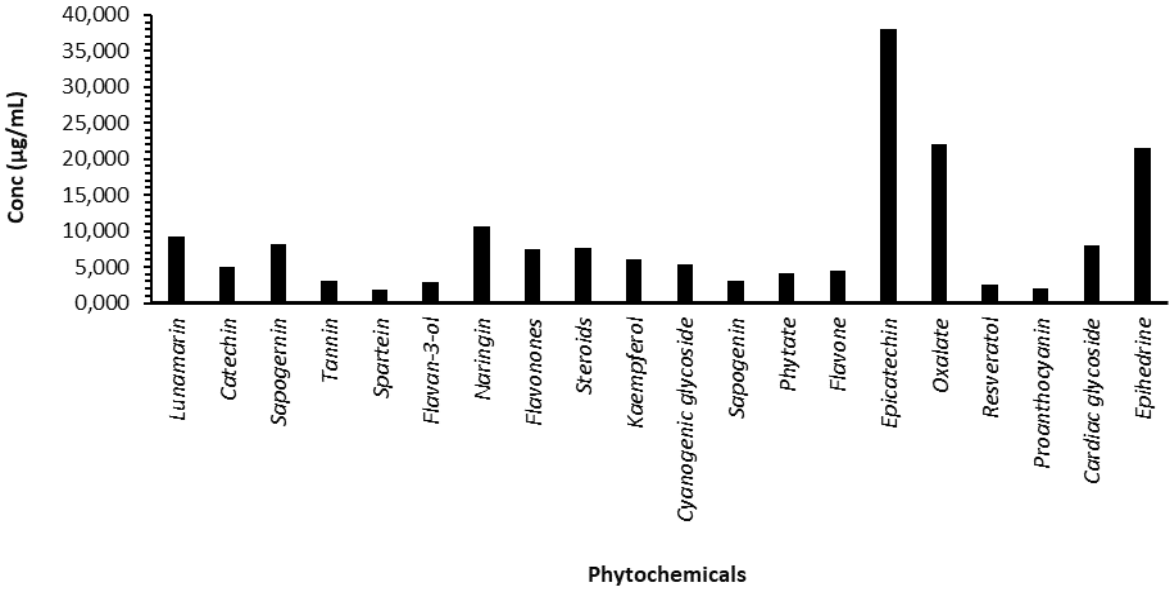


**Figure 2.** Concentrations of phytochemicals in ethanolic root extract of *Pterocarpus erinaceus* identified by GC-FID

**Table 2.** Effect of ethanol root extract of *Pterocarpus erinaceus* on bacteria

| Extract (µg/mL) | *Bacillus subtilis* (Gram +ve) Inhibition zone (mm) | *Escherichia coli* (Gram -ve) Inhibition zone (mm) | *Pseudomonas aeruginosa* (Gram -ve) Inhibition zone (mm) | *Staphylococcus aureus* (Gram +ve) Inhibition zone (mm) |
|---|---|---|---|---|
| Gentamicin (µg/mL) | $20.67 \pm 0.31^{a}$ | $20.47 \pm 0.21^{a}$ | $30.20 \pm 0.26^{a}$ | $23.90 \pm 0.17^{d}$ |
| 100 | - | $2.23 \pm 0.25^{a}$ | - | $3.13 \pm 0.15^{a}$ |
| 150 | - | $4.03 \pm 0.15^{b}$ | - | $4.40 \pm 0.36^{b}$ |
| 200 | - | $6.06 \pm 0.15^{c}$ | - | $6.10 \pm 0.10^{c}$ |

Note: Result is Mean ± SD. Value with same superscript within a column are statistically not significant, while values with different superscripts within a column are statistically significant (P<0.05)

**Table 3.** DPPH scavenging activity of various concentrations of ethanol root extract of *Pterocarpus erinaceus*

| Extract conc (µg/mL) | Control | Average | % RSA | $IC_{50}$ |
|---|---|---|---|---|
| 40.00 | 0.65 | 0.41 | 36.48 | 1.38 |
| 100.00 | 0.65 | 0.45 | 44.63 | 10.66 |
| 200.00 | 0.65 | 0.31 | 51.83 | 26.12 |
| 400.00 | 0.65 | 0.28 | 56.47 | 57.03 |
| 1000.00 | 0.65 | 0.24 | 62.91 | 149.78 |

When compared to the standard drug's mean inhibition zone, the values of the two organisms (*E. coli* and *S. aureus*) are found to be statistically significant when compared to the mean inhibition zone of the standard drug (gentamicin). This result is not in trend with the study of Tittikpina et al. (2018), who reported that the methanolic-dichloromethane extracts of *P. erinaceus* root exhibited inhibitory effects ranging from 42-77% against all selected bacteria strains (*Enterococcus faecalis, S. aureus, P. aeruginosa, Acinetobacter baumannii, E. coli* and *Klebsiella pneumoniae)* at the concentrations of 256 µg/mL. However, they obtained MICs (minimum inhibitory concentrations) with individual fractions (Butanol, petroleum ether, ethyl acetate, dichloromethane, and water) against *E. faecalis*, *S. aureus* and *P. aeruginosa*. The MICs values obtained were ranging from 64 to 256 µg/mL, depending on the individual fraction and the bacteria tested.

Studies conducted on the free radical scavenging activity of medicinal plants have shown that the efficiency of each plant species differs depending on the particular assay methodology, reflecting the complexity of mechanisms involved in total antioxidant capacity. The DPPH method was used to study the antioxidant activity of the root extract of *P. erinaceus*. Revealed that *P. erinaceus* has a relatively strong radical scavenging activity, which is dose-dependent. For example, the highest activity of 62.91% at a concentration of 1000 µg/mL with $IC_{50}$ of 149.78 (Table 3), while the lowest activity of 36.48% at a concentration of 40 µg/mL with $IC_{50}$ of 1.38.

In conclusion, this plant part could represent a potential source of lead molecules with pharmacological activities for developing new novel pharmaceutical products for treating malaria and other diseases. Also, the presence of compounds with biological activities justifies the traditional use of the root of *P. erinaceus* for treating malaria and other diseases. However, further studies are needed into the isolation and identification of the individual bioactive compounds responsible for their therapeutic activity and elucidating their mechanism(s) of action.

Not all bacterial strains used were sensitive to the root extract of *P. erinaceus.* Hence the root is not a promising therapeutic agent that can be used in combating infectious diseases caused by drug-resistant microorganisms. Furthermore, the root extract of *P. erinaceus* proved to have a moderate DPPH-scavenging antioxidant potential. Further study is needed to isolate and structurally characterize the pure compounds and evaluate their antimicrobial activity against multidrug-resistant microbial strains.

## ACKNOWLEDGEMENTS

We like to thank Professor Otitoju Wale for initiating concept of this research and spearheading it.

## REFERENCES

Ahmed MU, Modibbo AA, Zaruwa MZ, Sudi IY. 2017. Phytochemical and nutrient composition of *Pterocarpus erinaceus* stem bark. Intl J Biochem Res Rev 19: 1-6. DOI: 10.9734/IJBCRR/2017/36546.

Alves de Almeida AC, de-Faria FM, Dunder RJ, Manzo LPB, Souza-Brito ARM, Luiz-Ferreira A. 2017. Recent trends in pharmacological activity of alkaloids in animal colitis: Potential use for inflammatory bowel disease. Evid Based Complement Altern Med 2017: 1-24. DOI: 10.1155/2017/8528210.

Bhattacharyya A, Chattopadhyay R, Mitra S, Crowe SE. 2014. Oxidative stress: An essential factor in the pathogenesis of gastrointestinal mucosal diseases. Physiol Rev 94 (2): 329-354. DOI: 10.1152/physrev.00040.2012.

Calderon-Montano J, Burgos-Morón E, Pérez-Guerrero C, López-Lázaro M. 2011. A review on the dietary flavonoid kaempferol. Mini Rev Med Chem 11 (4): 298-344. DOI: 10.2174/138955711795305335.

Chen AY, Chen YC. 2013. A review of the dietary flavonoid, kaempferol on human health and cancer chemoprevention. Food Chem 138 (4): 2099-2107. DOI: 10.1016/j.foodchem.2012.11.139.

Chung KT, Wong TY, Wei CI, Huang YW, Lin Y. 1998. Tannins and human health: A review. Crit Rev Food Sci Nutr 38 (6): 421-464. DOI: 10.1080/10408699891274273.

Ertop MH, Bektaş M. 2018. Enhancement of bioavailable micronutrients and reduction of antinutrients in foods with some processes. Food Health 4 (3): 159-165. DOI: 10.3153/FH18016.

Ezeja IM, Ezeigbo II, Madubuike KG, Udeh NE, Ukweni IA, Akomas SC, Ifenkwe DC. 2012. Antidiarrheal activity of *Pterocarpus erinaceus* methanol leaf extract in experimentally-induced diarrhea. Asian Pac J Trop Med 5 (2): 147-150. DOI: 10.1016/S1995-7645(12)60014-5.

Franck X, Fournet A, Prina E, Mahieux R, Hocquemiller R, Figadère B. 2004. Biological evaluation of substituted quinolines. Bioorg Med Chem Lett 14 (14): 3635-3638. DOI: 10.1016/j.bmcl.2004.05.026.

Galluzzo P, Ascenzi P, Bulzomi P, Marino M. 2008. The nutritional flavanone naringenin triggers antiestrogenic effects by regulating estrogen receptor α-palmitoylation. Endocrinology 149 (5): 2567-2575. DOI: 10.1210/en.2007-1173.

Hossain MM, Uddin MS, Baral PK, Ferdus M, Bhowmik S. 2022. Phytochemical screening and antioxidant activity of *Ipomoea hederifolia* stems: A potential medicinal plant. Asian J Nat Prod Biochem 20 (2): 41-47 DOI: 10.13057/biofar/f200201.

Isemura M. 2019. Catechin in human health and disease. Molecules 24 (3): 1-5. DOI: 10.3390/molecules24030528.

Jiang N, Doseff AI, Grotewold E. 2016. Flavones: From biosynthesis to health benefits. Plants 5 (2): 1-25. DOI: 10.3390/plants5020027.

Karou D, Dicko MH, Sanon S, Simpore J, Traore AS. 2003. Antimalarial activity of *Sida acuta* burm. F. (Malvaceae) and *Pterocarpus erinaceus* Poir. (Fabaceae). J Ethnopharmacol 89 (2-3): 291-294. DOI: 10.1016/j.jep.2003.09.010.

Lewis K, Ausubel FM. 2006. Prospects for plant-derived antibacterials. Nat Biotechnol 24 (12): 1504-1507. DOI: 10.1038/nbt1206-1504.

Mastroeni P. 2002. Immunity to systemic *Salmonella* infections. Curr Mol Med 2 (4): 393-406. DOI: 10.2174/1566524023362492.

Noufou O, Andre T, Richard SW, Yerbanga S, Maminata T, Ouedraogo S, Anne EH, Garcia I, Pierre GI. 2016. Anti-inflammatory and anti-plasmodial activities of methanol extract of *Pterocarpus erinaceus* Poir. (Fabaceae) leaves. Intl J Pharmacol 12 (5): 549-555. DOI: 10.3923/ijp.2016.549.555.

Noufou O, Wamtinga SR, André T, Christine B, Marius L, Emmanuelle HA, Jean K, Marie-Geneviève D, Pierre GI. 2012. Pharmacological properties and related constituents of stem bark of *Pterocarpus erinaceus* Poir. (Fabaceae). Asian Pac J Trop Med 5 (1): 46-51. DOI: 10.1016/S1995-7645(11)60244-7.

Olaleye MT, Akinmoladun AC, Crown OO, Ahonsi KE, Adetuyi AO. 2013. Homopterocarpin contributes to the restoration of gastric homeostasis by *Pterocarpus erinaceus* following indomethacin intoxication in rats. Asian Pac J Trop Med 6 (3): 200-204. DOI: 10.1016/S1995-7645(13)60023-1.

Popova A, Mihaylova D. 2019. Antinutrients in plant-based foods: A review. Open Biotechnol J 13 (1): 68-76. DOI**:** 10.2174/1874070701913010068.

Prakash M, Basavaraj BV, Murthy KC. 2019. Biological functions of epicatechin: Plant cell to human cell health. J Functional Foods 52: 14-24. DOI: 10.1016/j.jff.2018.10.021.

Saslis-Lagoudakis CH, Klitgaard BB, Forest F, Francis L, Savolainen V, Williamson EM, Hawkins JA. 2011. The use of phylogeny to interpret cross-cultural patterns in plant use and guide medicinal plant discovery: An example from *Pterocarpus* (Leguminosae). PloS One 6 (7): e22275. DOI: 10.1371/journal.pone.0022275.

Schlemmer U, Frølich W, Prieto RM, Grases F. 2009. Phytate in foods and significance for humans: Food sources, intake, processing, bioavailability, protective role and analysis. Mol Nutr Food Res 53 (S2): 330-375. DOI: 10.1002/mnfr.200900099.

Seeram NP, Schutzki R, Chandra A, Nair MG. 2002. Characterization, quantification, and bioactivities of anthocyanins in *Cornus* species. J Agric Food Chem 50 (9): 2519-2523. DOI: 10.1021/jf0115903.

Sharma K, Kumar V, Kaur J, Tanwar B, Goyal A, Sharma R, Gat Y, Kumar A. 2021. Health effects, sources, utilization and safety of tannins: A critical review. Toxin Rev 40 (4): 432-444. DOI: 10.1080/15569543.2019.1662813.

Singh RP, Chidambara Murthy KN, Jayaprakasha GK. 2002. Studies on the antioxidant activity of pomegranate (*Punica granatum*) peel and seed extracts using in vitro models. J Agric Food Chem 50 (1): 81-86. DOI: 10.1021/jf010865b.

Tittikpina NK, Nana F, Fontanay S, Philippot S, Batawila K, Akpagana K, Kirsch G, Chaimbault P, Jacob C, Duval RE. 2018. Antibacterial activity and cytotoxicity of *Pterocarpus erinaceus* Poir extracts, fractions and isolated compounds. J Ethnopharmacol 212: 200-207. DOI: 10.1016/j.jep.2017.10.020.

Tittikpina NK, Sandjo LP, Nana F, Vaillant V, Fontanay S, Philippot S, Diop YM, Batawila K, Akpagana K, Kirsch G, Duval RE. 2019. Investigation of the antifungal activity of *Pterocarpus erinaceus* led to the identification of two new diarylpropanoids from its stem barks. Phytochem Lett 32: 110-114. DOI: 10.1016/j.phytol.2019.05.013.

Ugoeze KC, Oluigbo KE, Chinko BC. 2020. Phytomedicinal and nutraceutical benefits of the GC-FID quantified phytocomponents of the aqueous extract of *Azadirachta indica* leaves. J Pharm Pharmacol Res 4 (4): 149-163. DOI: 10.26502/fjppr.039.

Umaru IJ, Ale EM, Kenneth I, Habibu B, Ismail MZ, Emmanuel OC, Dawoye Y, Chizaram BC. 2022. Antidiarrheal and antibacterial actions of methanol extract of *Cassia fistula* (Linn) leaves. J Appl Sci 22 (6): 279-287. DOI: 10.3923/jas.2022.279.287.