



Research Article

Determination of Bioactive Components and Pharmacological Potential of Ethanol Extract of *Lannea egregia* Shoot

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ABSTRACT

Lannea egregia, a plant species with a rich ethnobotanical history, has garnered significant interest due to its diverse array of bioactive components. This study investigated the pharmacological potential of bioactive components derived from *L. egregia* shoot extracts. The ethanol extract of *L. egregia* shoot (EELES) was studied for secondary metabolites using high-performance liquid chromatography (HPLC). Subsequently, the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of EELES was determined. The cytotoxicity of the extract was evaluated through the brine shrimp lethality assay (BSLA). Bioactive compounds such as atropine, brucine, naringenin, caffeine, quercetin, maleic acid, saponin, glutathione and coumaric acid were detected in the ethanol extract through the HPLC analysis. The most abundant of EELES components is maleic acid (70.45 ppm), while the least abundant is atropine (3.05 ppm). Like the vitamin C C (58.06 ± 0.03 µg/mL), the EELES exhibited a noteworthy DPPH radical scavenging activity at a median inhibitory concentration (IC₅₀) of 69.03 ± 0.03 µg/mL. Moreover, both EELES and methotrexate showed considerable cytotoxic activity on nauplii at IC₅₀ of 30.08 ± 0.53 µg/mL and 0.93 ± 0.04 µg/mL, respectively. The study concluded that ethanol extract from *L. egregia* shoots contains various bioactive components with pharmacological relevance and exhibits antioxidant and cytotoxic properties, making them a promising source of new cancer drugs.

Keywords: *Lannea egregia*, Ethanol extract, Bioactive compound, Antioxidant, Cytotoxicity

INTRODUCTION

The exploration of natural products for therapeutic applications has garnered significant attention in recent years, owing to their diverse bioactive components and relatively lower toxicity than synthetic drugs. *L. egregia*, a member of the Anacardiaceae family, is a plant traditionally used in African ethnomedicine to treat various ailments,

including inflammation, infections, and gastrointestinal disorders. Previous studies have reported the presence of numerous bioactive compounds in various parts of *L. egregia*, such as phenolic compounds, flavonoids, alkaloids, saponins, terpenoids, tannins, and anthraquinones, which support its traditional medicinal use (Rafiu *et al.*, 2019). These compounds are crucial for their antioxidant, anti-inflammatory, and antimicrobial activities (Idowu *et al.*, 2020; Ogundajo *et al.*, 2021). However, there remains a paucity of detailed studies specifically focused on the

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bioactive components and pharmacological potential of *L. egregia*'s shoots.

Using a low-toxic solvent for extraction is a widely used method in preparing medicinal plants to treat diseases. Moreover, low-toxic solvents are frequently used in phytochemical studies because they efficiently extract polar and non-polar compounds (Nilamsari *et al.*, 2023). This study focused on the ethanol extract of *L. egregia* shoots (EELES), aiming to identify its bioactive components and evaluate its pharmacological potential, particularly its antioxidant and cytotoxic activities.

Antioxidant activity is crucial because oxidative stress, caused by an imbalance between free radicals and antioxidants in the body, is associated with the pathogenesis of numerous chronic diseases, including cancer, cardiovascular diseases, and neurodegenerative disorders (Lee *et al.*, 2020). Compounds with potent antioxidant properties can neutralise free radicals, thereby preventing cellular damage and disease progression.

Moreover, the cytotoxic potential of natural products is of great interest, particularly for cancer therapy. Natural compounds have been a prolific source of anticancer agents, and many plant-derived substances are currently used in clinical oncology. The brine shrimp lethality assay (BSLA) is a simple, rapid, and cost-effective method for preliminary screening of cytotoxic activity, providing an initial indication of the potential of extracts and compounds to act as anticancer agents (Atanasov *et al.*, 2021; Newman & Cragg, 2020). This study investigated the bioactive components and pharmacological potential of the ethanol extract of *L. egregia* shoots. Specifically, the study assessed the antioxidant and cytotoxic properties to determine its promise as a source of novel therapeutic agents.

MATERIALS AND METHODS

Collection and authentication of *L. egregia* shoot

Fresh shoots (immature stems consisting of leaves) of *L. egregia* were obtained from a forest in Olokemeji in Oyo State, Nigeria, in April. A sample of the plant material was deposited in the herbarium of the Forestry Research Institute of Nigeria, Ibadan, within 24 h and authenticated by a botanist.

Preparation of ethanol extract *L. egregia* shoot

The remaining portion of the shoots of *L. egregia* were washed with tap water and air dried at room temperature in the Biochemistry laboratory of Lagos State University of Science and Technology, Ikorodu, Nigeria. The dried shoots of *L. egregia* material were then ground to a fine powder. The extraction was performed by maceration, as described below. A measure of 100 g of the ground sample was weighed and extracted in a beaker containing 400 mL of 80% ethanol. After 72 h, the mixture was clarified using a muslin cloth and filter paper. The filtrate obtained was then concentrated by evaporating its liquid components at 45 °C in a water bath under controlled temperature conditions. The concentrated ethanol extract was stored in the refrigerator until use for further evaluation. The percentage

yield of *L. egregia* shoot extract was calculated using the formula below:

$$\% \text{ Yield} = \frac{\text{weight of concentrated extract}}{\text{weight of extracted plant sample}} \times 100$$

Phytochemical screening of ethanol extract of *L. egregia* shoot

The ethanol extract of shoots of *L. egregia* was qualitatively assayed for secondary metabolites such as saponins, tannins, flavonoids, glycosides, cardiac glycosides, and alkaloids using standard methods described by (Ashraf *et al.*, 2013).

HPLC analysis of ethanol extract of *L. egregia* shoot

Sample preparation

The ethanol extract of shoots from *L. egregia* weighing 1 mg was measured and mixed with 1 mL of HPLC-grade methanol. The resulting *L. egregia* shoot-methanol mixture was vortexed for 30 seconds to ensure homogeneity. Then, 4 mL of HPLC-grade methanol was added to the mixture and vigorously shaken for 30 minutes on a shaker. Finally, the sample solutions were filtered using a micro-millipore filter with a particle size of 0.45 µm to remove the particulate matter. The HPLC sample of shoots from *L. egregia* was stored in screw-cap borosilicate glass vials in Preparation for the subsequent HPLC analysis.

Sample analysis

The HPLC analysis of the shoots from *L. egregia* was carried out using an Agilent 1260 Infinity II series consisting of an autosampler G7129A (DEAEQ22974) with a 100 µl fixed loop and a DAD UV light ionisation energy detector. The separation was performed at ambient temperature on a column 120 EC-C (18 4 µm x 4.6 mm x150 mm). The mobile phase comprised a gradient solution of 0.1 % formic acid and 0.2 % formic acid in methanol. The column used was ZORBAX ECLIPSE PLUS C18 RP 150mm X 4.6mm, 5µm at a flow rate of 1.0 ml/min. The detector was set at 210 nm at ambient temperature. The filtrates, at a volume of 20 µL, were manually injected once for HPLC analysis, and the peak areas were recorded and integrated using an enhanced ChemStation software integrator. Ferrulic acid, brucine, atropine, caffeine, gallic acid, saponin, coumaric acid, glutathione, maleic acid and quercetin were used as the internal calibration. The structures of the significant bioactive components in *L. egregia* shoots were obtained using ChemDraw Ultra-12.0.

Determination of DPPH radical scavenging activity of ethanol extract of *L. Egregia* shoot

The antioxidant activity of the ethanol extract of *L. egregia* shoots (EELES) was evaluated using the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, a widely used method for measuring the free radical scavenging ability of antioxidant compounds. DPPH (0.1 mM) solution was prepared by dissolving 3.94 mg of DPPH in 100 mL of ethanol and kept in an amber bottle before use. To

determine the antioxidant activity of EELES, an aliquot of 1 mL of the sample concentration (ranging from 10-100 µg/mL) was mixed with 1 mL of the DPPH solution in test tubes. The reaction mixtures were vigorously shaken and left in the dark at 27°C for 30 minutes. The absorbance of the resultant solutions was taken at 517 nm using a UV-Vis spectrophotometer (Shimadzu, Japan). Ethanol was used as a blank, and a solution containing 1 mL of ethanol and 1 mL of DPPH solution served as the control. All the reactions were done in triplicates. The DPPH radical scavenging activity of EELES was calculated in percentage using the formula below. The graph of the percentage scavenging of DPPH radicals was plotted against the concentrations of the test samples. Using linear regression analysis, the IC₅₀ value can be defined as the extract concentration required to scavenge 50% of the DPPH radicals.

$$\% \text{ Scavenging of DPPH radicals} = \frac{(\text{Absorbance-Cont}) - (\text{Absorbance-Test})}{(\text{Absorbance-Cont})} \times 100$$

Absorbance-cont is the absorbance of the control reaction (solution of ethanol and DPPH only) and absorbance-Test is the absorbance of the test sample.

Cytotoxicity of ethanol extract of *L. Egregia* shoot

The determination of cytotoxic potential ethanol extract of *L. egregia* shoot was conducted using Brine Shrimp Lethality Assay (BSLA).

Preparation of test solutions for BSLA

A measure of 0.2 mg of the ethanol extract of shoots of *L. egregia* was taken, dissolved in 50 µL of pure dimethyl sulfoxide (DMSO), and made up to 1 mL with seawater to produce a stock solution of 200 µg/mL. Thereafter, the stock solution was diluted to 10, 25, 50, 75 and 100 µg/mL.

Hatching of brine shrimp cysts

Dried *Artemia salina* leach cysts (brine shrimp eggs) collected from pet shops (Everlush) in Ikeja were used as the test organism. The protocol of Ogundare et al. (2023) was adopted for hatching the brine shrimp eggs (Ogundare et al., 2023). A sea salt solution (38 g/L) was made in distilled water and adjusted to pH 8.5 using 1 M NaOH for the culture. The artificial seawater (300 mL) was filtered into a small plastic tank, and brine shrimp eggs collected with the tip of a capillary tube were added to one side of the tank. This side was then covered to prevent direct sunlight. The tank containing the brine shrimp eggs was incubated for 24 h at room temperature (27 to 29 °C). At the same time, a constant oxygen supply was maintained throughout the incubation using an aerator. The newly hatched brine shrimp larvae (nauplii) were attracted to the light from egg shells, such that a pipette could collect nauplii free from egg shells from the illuminated part of the tank. Actively-swimming nauplii were selected for the cytotoxicity test.

Ten actively swimming nauplii were carefully selected using a Pasteur pipette and introduced to a test tube containing 5 mL of MTX or the stock extract solution. The mixture was

made up to 10 mL with seawater and incubated for 24 h. The test tubes were examined using a magnifying glass, and the number of nauplii alive in each tube was recorded. The experiment was repeated thrice. The percentages of mortality of the nauplii in each experiment were estimated by counting the number of surviving nauplii in both control and test tubes. From the data obtained, the percentage mortality at each concentration was calculated as shown in the equation below. The mean lethal concentration (LC₅₀) representing the concentration of the plant extract required to cause 50% mortality of the nauplii under the experimental conditions was determined using probit analysis of the concentrations against percentage mortality through Excel software.

$$\% \text{ Lethality} = \frac{(\text{Observed mortality} - \text{Control mortality}) \times 100}{(100 - \text{Control mortality})}$$

Statistical analysis

The mean inhibitory concentration (IC₅₀) of the antioxidant activity of EELES against DPPH was determined using linear regression analysis obtained through Microsoft Excel 16 packages. The lethal concentration (LC₅₀) of the cytotoxicity of the extract against Brine shrimp was determined using probit analysis through the IBM SPSS Statistics 23 software. The statistical analysis was tested and all graphs were plotted using the Turkey post hoc test at (p<0.05) using GraphPad Prism 5 software.

RESULTS

Bioactive components of ethanol extract of *L. egregia* shoot

Table 1 presents the percentage extraction yield of the ethanol extract of *L. egregia* shoot (EELES), which was 7.59 %, along with a qualitative screening for bioactive components. Compounds such as tannins, saponins, flavonoids, alkaloids, steroids, and terpenoids were detected, while cardiac glycosides were not.

Figure 1 shows the chromatographic profile obtained from the HPLC analysis of EELES. Each peak corresponds to a compound detected in the extract, with retention times indicating when each compound was eluted from the HPLC column.

The lists of bioactive compounds identified by HPLC, along with their retention times, concentrations (in ppm), and known biological activities from the literature, are shown in Table 2 above. Unknown compounds are noted where no clear identification or literature reference for their biological activities is available.

The chemical structures of major identified compounds, including atropine, brucine, naringenin, caffeine, quercetin, saponin, maleic acid, glutathione and coumaric acid are shown in Figure 2.

The plots the percentage scavenging activity of DPPH radicals by various concentrations of EELES and Vitamin C are presented in Figure 3. It shows dose-dependent antioxidant activity.

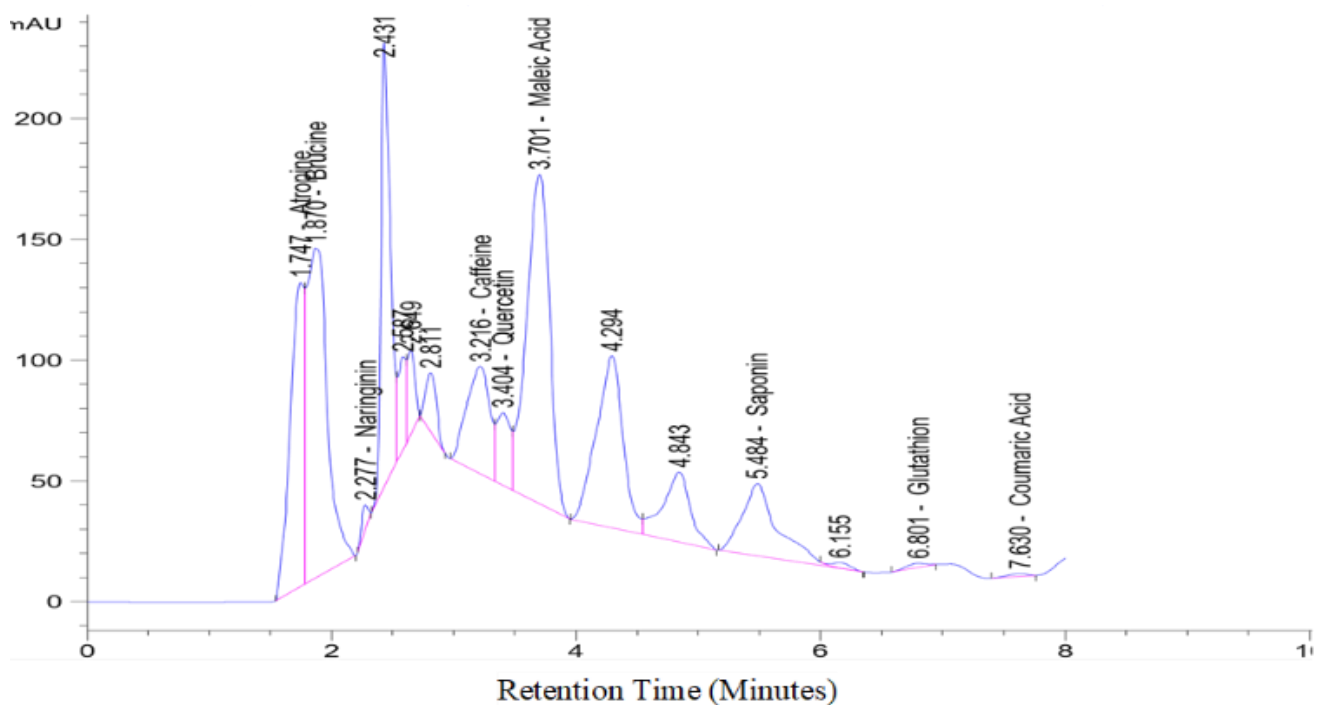


FIGURE 1: HPLC Analysis Profiles Showing Bioactive Components of *L. Egregia* Shoot

The plots shown in Figure 4 indicate the concentrations required to scavenge 50% of DPPH radicals (IC_{50} values) for EELES ($69.03 \pm 0.03 \mu\text{g/mL}$) compared to Vitamin C ($58.06 \pm 0.03 \mu\text{g/mL}$) with a significant value at $p < 0.05$. Figure 5 compares the cytotoxic effects of EELES and MTX

on the brine shrimp larvae using the BSLA. EELES demonstrated significant cytotoxicity with an IC_{50} value of $30.08 \pm 0.53 \mu\text{g/mL}$, indicating its potential as an anticancer agent. For comparison, MTX exhibited an IC_{50} value of $0.93 \pm 0.04 \mu\text{g/mL}$.

Table 1. Extraction Yield and the Detected Bioactive Compounds in Ethanol Extract of *L. egregia* Shoot.

Evaluated Parameters	Extraction Yield [%]	Tannins	Saponins	Flavonoids	Alkaloids	Cardiac glycosides	Steroids	Terpenoids
Presence of <i>L. egregia</i> Chemicals	7.59	+	+	+	+	-	+	+

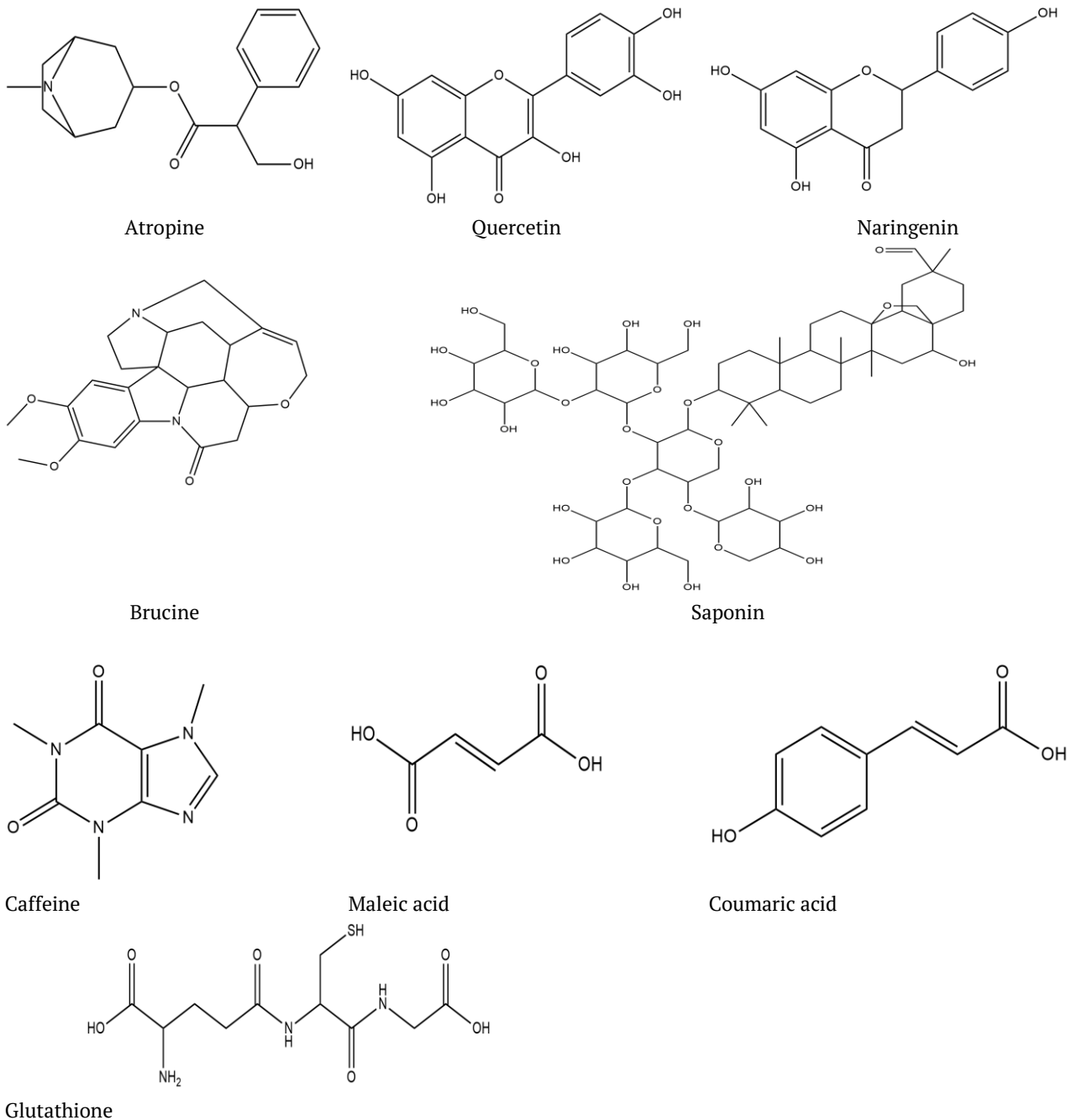
(+): Compound is detectable; (-): Compound is not detectable.

Table 2: Reported Biological Activities of Some Extractable Components of *L. egregia* Shoot.

Extractable Components	Retention time [min]	Amount [ppm]	Reported biological activity	Reference
Atropine	1.747	0.31	antidepressant effect and vasodilation properties Acetylcholine inhibitor	(Edo & Ogheneoruese, 2022)
Brucine	1.870	0.84	Antitumor, anti-inflammatory, anticancer, and analgesic activities.	(Lu et al., 2020)
Naringenin	2.277	4.36×10^{-3}	Cardioprotective, anti-inflammatory, antioxidant, anticancer and antiulcer	(Ravetti et al., 2023)
Unknown	2.431	$< 0.01 \times 10^{-3}$	Not reported	Not reported
Unknown	2.687	Not quantified	Not reported	Not reported
Unknown	2.811	Not quantified	Not reported	Not reported
Unknown	2.849	Not quantified	Not reported	Not reported
Caffeine	3.216	30.70	psychoactive	(Cappelletti et al., 2014)
Quercetin	3.404	2.20	Antioxidant and anticancer	(Khater et al., 2019)

Table 2. *Continue*

Extractable Components	Retention time [min]	Amount [ppm]	Reported biological activity	Reference
Saponin	5.484	5.59	Antioxidants, anticancer, anti-inflammation, antimicrobial, antiviral, and antiparasitic	(Timilsena et al., 2023)
Maleic acid	3.701	70.45	Anticancer and antioxidant	(Arslan, 2021)
Unknown	6.155		Not reported	Not reported
Glutathione	6.801	1.07	Antioxidant	(Hasanuzzaman et al., 2017)
Coumaric acid	7.630	3.08×10^{-2}	Anticancer, antioxidant and antimicrobial	(Aliyazcoglu et al., 2013; Tehami et al., 2023)

**Figure 2.** Structures of some of the bioactive components of ethanol extract of *L. egregia* shoot.

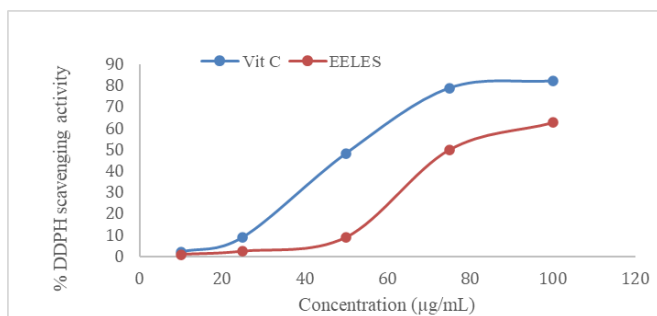


Figure 3. Percentage scavenging of 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical of ethanol extract of *L. egregia* shoot and Vit C.

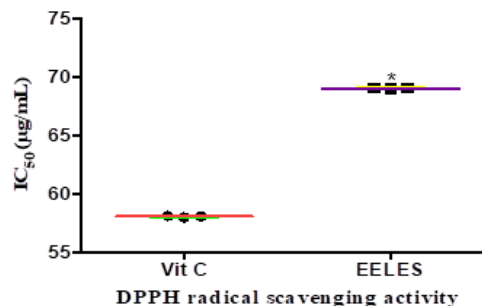


Figure 4. Radical scavenging activity of ethanol extract of *L. egregia* shoot.

Values are mean \pm SEM of triplicate analyses. (*) indicates a significant value at $p < 0.05$ when compared with Vitamin C using Student's t-test.

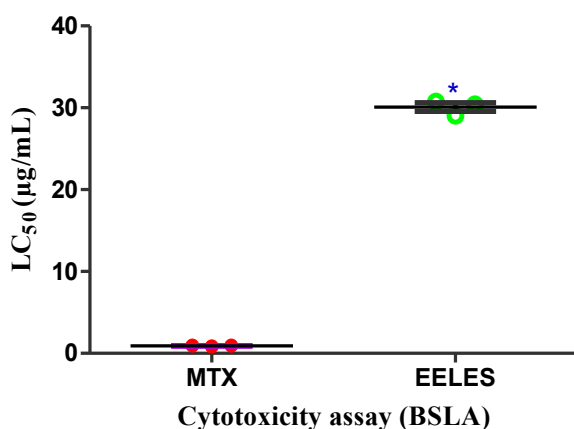


Figure 5. Cytotoxic activity using BSLA of ethanol extract of *L. egregia* shoot and MTX.

Values are mean \pm SEM of triplicate analyses. (*) indicates a significant value at $p < 0.05$ when compared with Vitamin C using Student's t-test.

DISCUSSION

Screening for bioactive compounds is crucial in identifying and characterising botanical chemical compounds. The extraction yield of 7.59% observed in the study for the ethanol extract of *L. egregia* shoot indicates the effectiveness of ethanol in extracting polar and other compounds from the plant material. The result is consistent with prior findings on ethanol's extraction efficiency (Ashraf et al., 2013; Hajlaoui et al., 2022). Moreover, it showcases ethanol's potential in extracting bioactive compounds with antioxidant properties. This finding aligns with studies on other plant extracts, such as the stem of *Anthocleista djalensis*, which demonstrated cytotoxic potential and antioxidant properties compared to the N-hexane and the ethyl acetate extracts (Ogundare et al., 2017). Similarly, the anti-tumour activity of *Lupinus angustifolius* ethanolic extracts has been reported (Stapel et al., 2015). The results of this study highlight the significant pharmacological potential of the ethanol extract of *L. egregia*

shoots (EELES), characterised by a rich array of bioactive compounds. These compounds, including flavonoids, saponins, phenolics, alkaloids, and glycosides, were identified through phytochemical screening and are well known for various pharmacological properties, including antioxidant, anti-inflammation, cytotoxicity, anticancer, antidiabetic, antimicrobial and pesticidal properties. Furthermore, HPLC analysis revealed specific bioactive constituents such as atropine, brucine, naringenin, caffeine, quercetin, maleic acid, saponin, glutathione, and coumaric acid. The diversity and presence of these bioactive components underpin the observed pharmacological activities of the extract. The HPLC analysis indicated that maleic acid is the most abundant compound in the EELES, with a concentration of 70.45 ppm, while atropine is the least abundant at 3.05 ppm. The prevalence of maleic acid is noteworthy as it participates in several biochemical pathways and has been associated with various therapeutic effects, including antioxidant and anticancer properties (Arslan, 2021; Dilshad et al., 2020). Additionally, detecting compounds such as quercetin—a well-known flavonoid with potent anticancer, antioxidant and anti-inflammatory activities, further supports the pharmacological potential of EELES (Khater et al., 2019; Zhang et al., 2022). The presence of other bioactive compounds like naringenin, caffeine, and saponin also contributes to the extract's bioactivity profile, given their recognised antioxidant, anti-inflammatory, and anticancer properties (Al-Dhabi et al., 2015; Arafah et al., 2020).

The antioxidant activity of EELES, evaluated using the DPPH radical scavenging assay, demonstrated strong radical scavenging activity with an IC₅₀ value of 69.03 ± 0.03 µg/mL. This significant antioxidant activity suggests that ethanol extract of *L. egregia* shoots has the potential to neutralise free radicals, which are implicated in the pathogenesis of various chronic diseases, including cancer. Likewise, the ethanolic extract of medicinal plants such as *Arthrocnemum indicum* reportedly demonstrated potent antioxidant activity by effectively scavenging free radicals (Hajlaoui et al., 2022). The antioxidant activity is likely attributable to the high phenolic

content, particularly compounds like quercetin and coumaric acid, known for donating hydrogen atoms to free radicals, thereby stabilising and neutralising them (Ashraf et al., 2013; Elansary et al., 2020; Rodrigues et al., 2019).

Interestingly, the cytotoxic potential of EELES was evaluated using the brine shrimp lethality assay (BSLA), a preliminary screening method for assessing the cytotoxicity of bioactive compounds. Most importantly, the BSLA is a preliminary toxicity screening for future experiments on mammalian or animal models (Naher et al., 2019). Scientific reports showed that the protocol significantly correlates with cytotoxic and antitumor properties (Anderson et al., 1991; Ogundare et al., 2020). In this study, the ethanol extract demonstrated significant cytotoxicity with an IC₅₀ value of 30.08±0.53 µg/mL, indicating its potential as an anticancer agent. For comparison, methotrexate, a well-established chemotherapeutic agent, exhibited an IC₅₀ value of 0.93±0.04 µg/mL. Although methotrexate showed superior potency, the considerable cytotoxicity of EELES suggests the presence of compounds with substantial anticancer activity.

Compounds such as quercetin, naringenin, and brucine likely contribute to the cytotoxic effects of EELES. Quercetin and naringenin have been extensively studied for their anticancer properties, including the induction of apoptosis, cell proliferation inhibition, and disruption of cell cycle progression in various cancer cell lines (Srimathi & Vijayalakshmi, 2017; Khater et al., 2019; Zhang et al., 2022). Brucine, an alkaloid, has also exhibited cytotoxic effects against cancer cells (Lu et al., 2020). The combination effects of these bioactive compounds in EELES might exert a synergistic effect, enhancing the overall cytotoxicity of the extract.

Moreover, the observed antioxidant and cytotoxic properties of EELES underscore its potential as a source of new cancer drugs. Antioxidants are important in protecting cells from oxidative stress-induced damage, a common feature in cancer development. By neutralising free radicals, antioxidants can help prevent DNA damage and subsequent initiation of carcinogenesis. Additionally, the cytotoxic effects observed in the brine shrimp lethality assay suggest that EELES contains compounds capable of triggering cell death in cancer cells, making it a suitable candidate for further exploration in cancer therapy.

CONCLUSION

The ethanol extract of *L. egregia* shoots contains diverse bioactive components with significant pharmacological importance. The extract's potent antioxidant and cytotoxic properties highlight its potential as a source of new anticancer drugs. This study paves the way for further research into the therapeutic applications of *L. egregia*, potentially contributing to the development of novel treatments for cancer and other oxidative stress-associated diseases.

AUTHORS' CONTRIBUTIONS

OCO, MAO and SMA conceptualized the research and contributed to both the writing and editing of the manuscript. AAO, AOA, SPO and OMA conducted the research. VIO and AA analyzed the results. SPO and AOA assisted with laboratory analysis, and AOA and OCO contributed to result analysis and manuscript preparation and submission for publication. All authors confidently read and approved the final version for publication.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest

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REFERENCES

- Al-Dhabi, N. A., Arasu, M. V., Park, C. H., & Park, S. U. (2015). An up-to-date review of rutin and its biological and pharmacological activities. *EXCLI Journal*, 14, 59–63. <https://doi.org/10.17179/excli2014-663>
- Aliyazcoglu, R., Sahin, H., Erturk, O., Ulusoy, E., & Kolayli, S. (2013). Properties of phenolic composition and biological activity of propolis from Turkey. *International Journal of Food Properties*, 16(2), 277–287. <https://doi.org/10.1080/10942912.2010.551312>
- Arafah, A., Rehman, M. U., Mir, T. M., Wali, A. F., Ali, R., Qamar, W., Khan, R., Ahmad, A., Aga, S. S., Alqahtani, S., & Almatroudi, N. M. (2020). Multi-therapeutic potential of naringenin (4',5,7-trihydroxyflavonone): experimental evidence and mechanisms. *Plants*, 9(12), 1784. <https://doi.org/10.3390/plants9121784>
- Arslan, M. E. (2021). Anticarcinogenic properties of malic acid on glioblastoma cell line through necrotic cell death mechanism. *MANAS Journal of Engineering*, 9(1), 22–29. <https://doi.org/10.51354/mjen.848282>
- Ashraf, M. F., Aziz, M. A., Stanslas, J., Ismail, I., & Kadir, M. A. (2013). Assessment of antioxidant and cytotoxicity activities of saponin and crude extracts of *Chlorophytum borivilianum*. 2013.
- Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., Orhan, I. E., Banach, M., Rollinger, J. M., Barreca, D., Weckwerth, W., Bauer, R., Bayer, E. A., Majeed, M., Bishayee, A., Bochkov, V., Bonn, G. K., Braidy, N., Bucar, F., Cifuentes, A., D'Onofrio, G., Bodkin, M., ... Supuran, C. T. (2021). Natural products in drug discovery: advances and opportunities. *Nature Reviews Drug Discovery* 20(3).
- Cappelletti, S., Daria, P., Sani, G., & Aromatario, M. (2014). Caffeine: cognitive and physical performance enhancer or

- psychoactive drug? *Current Neuropharmacology*, 13(1), 71–88.
<https://doi.org/10.2174/1570159x13666141210215655>
- Dilshad, E., Bibi, M., Sheikh, N. A., Tamrin, K. F., Mansoor, Q., Maqbool, Q., & Nawaz, M. (2020). Synthesis of functional silver nanoparticles and microparticles with modifiers and evaluation of their antimicrobial, anticancer, and antioxidant activity. *Journal of Functional Biomaterials*, 11(4). <https://doi.org/10.3390/jfb11040076>
- Elansary, H. O., Szopa, A., Kubica, P., Ekiert, H., El-Ansary, D. O., Al-Mana, F. A., & Mahmoud, E. A. (2020). Polyphenol content and biological activities of *Ruta graveolens* L. and *Artemisia abrotanum* L. in Northern Saudi Arabia. *Processes*, 8(5), 1–18. <https://doi.org/10.3390/PR8050531>
- Hajlaoui, H., Arraouadi, S., Mighri, H., Ghannay, S., Aouadi, K., Adnan, M., Elsbali, A. M., Noumi, E., Snoussi, M., & Kadri, A. (2022). HPLC-MS profiling, antioxidant, antimicrobial, antidiabetic, and cytotoxicity activities of *Arthrocnemum indicum* (Willd.) Moq. Extracts. *Plants*, 11(2). <https://doi.org/10.3390/plants11020232>
- Hasanuzzaman, M., Nahar, K., Anee, T. I., & Fujita, M. (2017). Glutathione in plants: biosynthesis and physiological role in environmental stress tolerance. *Physiology and Molecular Biology of Plants*, 23(2), 249–268. <https://doi.org/10.1007/s12298-017-0422-2>
- Idowu, P. A., Ekemezie, L. C., & Olaiya, C. O. (2020). Phytochemical, antioxidant and antimicrobial studies of *L.egregia* Engl. & *K. Krause* (Anacardiaceae) extracts and chromatographic fractions. *Journal of Phytomedicine and Therapeutics*, 19(1), 348–363. <https://doi.org/10.4314/jopat.v19i1.4>
- Srimathi P. K., & Vijayalakshmi, K. (2017). Investigation of antioxidant potential of quercetin and hesperidin: An in vitro approach. *Asian Journal of Pharmaceutical and Clinical Research*, 10(11), 83–86. <https://doi.org/10.22159/ajpcr.2017.v10i11.20260>
- Khater, M., Ravishankar, D., Greco, F., & Osborn, H. M. I. (2019). Metal complexes of flavonoids: their synthesis, characterisation and enhanced antioxidant and anticancer activities. *Future Medicinal Chemistry*, 11(21), 2845–2867. <https://doi.org/10.4155/fmc-2019-0237>
- Lee, K. H., Cha, M., & Lee, B. H. (2020). Neuroprotective effect of antioxidants in the brain. *International Journal of Molecular Sciences*, 21(19), 1–29. <https://doi.org/10.3390/ijms21197152>
- Lu, L., Huang, R., Wu, Y., Jin, J. M., Chen, H. Z., Zhang, L. J., & Luan, X. (2020). Brucine: A review of phytochemistry, pharmacology, and toxicology. *Frontiers in Pharmacology*, 11(April), 1–6. <https://doi.org/10.3389/fphar.2020.00377>
- Naher, S., Aziz, Md. A., Akter, Mst. I., Rahman, S. M. M., Sajon, S. R., & Mazumder, K. (2019). Anti-diarrheal activity and brine shrimp lethality bioassay of methanolic extract of *Cordyline fruticosa* (L.) A. Chev. leaves. *Clinical Phytoscience*, 5(1), 4–9.
- Newman, D. J., & Cragg, G. M. (2020). Natural Products as Sources of New Drugs over the Nearly Four Decades from 01/1981 to 09/2019. In *Journal of Natural Products*, 83(3).
- Ogundajo, A. L., Ewekeye, T., Sharaibi, O. J., Owolabi, M. S., Dosoky, N. S., & Setzer, W. N. (2021). Antimicrobial activities of sesquiterpene-rich essential oils of two medicinal plants, *L. egregia* and *Emilia sonchifolia*, from Nigeria. *Plants*, 10(3), 1–11. <https://doi.org/10.3390/plants10030488>
- Ogundare, O., Akoro, S., Ogunfowora, A., & Oladunni, A. (2017). Investigation of antioxidant activity and cytotoxic effect of stem of *Anthocleista djalensis*. *European Journal of Medicinal Plants*, 20(1), 1–8. <https://doi.org/10.9734/ejmp/2017/33803>
- Ogundare, O. C., Adedosu, O. T., Afolabi, O. K., Adeleke, G. E., Akinboro, T., Daniel, A. A., Akoro, S. M., & Oludare, V. I. (2023). Ethnobotanical survey, physiochemical composition and preliminary cytotoxic evaluation of some medicinal plants with anticancer potential from certain areas in South-West Nigeria. *Annual Research & Review in Biology*, X, 27–42. <https://doi.org/10.9734/arrb/2023/v38i130566>
- Ogundare, O. C., Saibu, G. M., Adu, O. B., Akinyemi, T. V., & Adepoju, A. O. (2020). A study of cytotoxic potential and antioxidant activity of fruit of *Annona muricata*. *International Journal of Zoology and Applied Biosciences*, 5(3), 139–148. <http://www.ijzab.com>
- Rafiu, B. O., Sonibare, A. M., & Adesanya, E. O. (2019). Phytochemical screening, antimicrobial and antioxidant studies of *L. egregia* Engl. and *K. Krause* (Anacardiaceae) stem bark. *Journal of Medicinal Plants for Economic Development*, 3(1), 81–90. <https://doi.org/10.4102/jomped.v3i1.62>
- Ravetti, S., Garro, A. G., Gaitán, A., Murature, M., Galiano, M., Brignone, S. G., & Palma, S. D. (2023). Naringin: Nanotechnological strategies for potential pharmaceutical applications. *Pharmaceutics*, 15(3), 1–20. <https://doi.org/10.3390/pharmaceutics15030863>
- Rodrigues, A. B., De Almeida-Apolonio, A. A., Alfredo, T. M., Da Silva Dantas, F. G., Campos, J. F., Cardoso, C. A. L., De Picoli Souza, K., & De Oliveira, K. M. P. (2019). Chemical composition, antimicrobial activity, and antioxidant activity of *Ocotea minarum* (Nees & Mart.) mez. *Oxidative Medicine and Cellular Longevity*, 2019. <https://doi.org/10.1155/2019/5736919>
- Stapel, J., Oppermann, C., Richter, D. U., Ruth, W., & Briese, V. (2015). Anticarcinogenic effects of ethanolic extracts from root and shoot of *Lupinus angustifolius* on breast carcinoma cell lines MCF-7 and BT20. *Journal of Medicinal Plants Research*, 9(17), 561–568. <https://doi.org/10.5897/jmpr2014.5392>
- Tehami, W., Nani, A., Khan, N. A., & Hichami, A. (2023). New insights into the anticancer effects of p-coumaric acid: Focus on colorectal cancer. *Dose-Response*, 21(1), 1–9. <https://doi.org/10.1177/15593258221150704>
- Timilsena, Y. P., Phosanam, A., & Stockmann, R. (2023). Perspectives on saponins: Food functionality and applications. *International Journal of Molecular Sciences*, 24(17). <https://doi.org/10.3390/ijms241713538>
- Zhang, J., Li, H., Wang, W., & Li, H. (2022). Assessing the anti-inflammatory effects of quercetin using network

pharmacology and in-vitro experiments. *Experimental
and Therapeutic Medicine*, 23(4).

<https://doi.org/10.3892/etm.2022.11230>

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