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REVIEW

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Ethnomedicinal applications, phytochemistry, and pharmacological properties of *Laggera aurita* Linn (Asteraceae): A Review

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Abstract

Background: The plant *Laggera aurita* (Asteraceae) is a commonly utilized medicinal plant growing as a weed in African countries used in the treatment of many diseases. Besides, several phytochemical and pharmacological studies were conducted to check its phytocompounds and therapeutic potentials. However, there is unavailable information on the plant documenting its ethnomedicinal uses and medicinal properties. Therefore, the current article aims to provide updated information on the ethnomedicinal values, phytochemical compounds, and therapeutic potentials of *Laggera aurita* for further studies to develop noble bioactive molecules.

Main text: Studies regarding the plant *Laggera aurita* were sourced from online academic databases such as Google Scholar and PubMed. The search terms used include *Laggera aurita*, ethnomedicinal uses, phytochemistry, pharmacological activity, and toxicology. The plant has ethnomedicinal applications against epilepsy, cancer, atherosclerosis, thrombosis, malaria, fever, pain, stomatitis, asthma, bronchitis, nasal congestion, infections, rheumatism, dyspepsia, indigestion, constipation, dysentery, and many more. Several phytochemical agents were isolated from various plant parts. Besides, pharmacological studies have shown that the plant has antipyretic, analgesic, anti-inflammatory, anticonvulsant, anxiolytic, antimicrobial, antimalarial, and antioxidant effects.

Conclusions: Various pharmacological evaluations conducted on the plant have validated the traditional values of the plant *Laggera aurita*. However, more research is paramount to validate many of the reported traditional uses. Also, the phytochemical molecules need to be screened for biological properties to develop potential therapeutic agents. The plant is relatively safe on sub-chronic administration and slightly toxic in acute studies. Hence, further toxicological studies on the plant are required to establish its safety. There is a need to also standardize doses to establish safety and efficacy.

Keywords: Ethnopharmacological uses, *Laggera aurita*, Medicinal plants, Pharmacology, Phytochemistry, Toxicology

Background

Medicinal plants are readily available sources of a wide range of phytochemical constituents for the prevention and treatment of various medical conditions (Dutra et al. 2016).These secondary metabolites have many biological actions, which give the scientific evidence for utilizing the herbal products in traditional medical practice in various communities (Kaur et al. 2021). Most people in developing nations rely on herbal

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medicines for basic treatment and other healthcare needs (Senthilkumar et al. 2018). About one-fourth of the world's population utilizes traditional treatments using herbs as a source of primary health care (Muhammad et al. 2021). In fact, herbal products are gaining more popularity due to their abundance, affordability, and presumed safety compared to orthodox medicines (Wada et al. 2019). So far, the pharmacological investigations on herbal products have encouraged the development of potent and efficient therapeutic agents for managing various diseases (Ahmad et al. 2020). The effective utilization of herbal products for medicinal purposes has obstacles, such as improper standardization, insufficient identification, characterization and isolation of the bioactive molecules, undiscovered pharmacological mechanisms, and clinical trials (Thomford et al. 2018). There have been efforts to explore alternative treatment options, particularly from natural products derived from plants due to the adverse effects of chemically synthesized drugs (Liu et al. 2020). Therefore, provision of documented information medicinal values and therapeutic potentials as a prerequisite for further development of valuable herbal products is paramount (Mao and He 2020).

Laggera aurita Linn (Asteraceae) is a shrub found around houses and farmlands (Olurishe and Mati 2014). It is an annual, erect, glutinous herbaceous plant with a pleasant aroma that grows up to 30–100 cm in height and is usually densely branched. The leaves of this plant are alternate, and the base is decurrent on the stem with glandulous points. The inflorescence reveals several involucres per head, with various white, yellow, or mauve-colored small flowers with narrow bract and usually flowers from December to February (Salisu et al. 2015; Shahwar et al. 2012). The plant grows as a weed in Nigeria and spreads throughout sub-Saharan Africa (Egharevba et al. 2010; Guragi et al. 2018). It is commonly utilized for medicinal reasons in African nations such as Senegal, Nigeria, and Ghana (Shehu et al. 2016). *Laggera aurita* is popularly known as 'Abanaadene' (meaning vulture's excrement) in Igbo (Awka), 'Eru-taba' (meaning slave of tobacco) in Yoruba (Ilorin), and 'Taba taba' in Hausa (Shehu et al. 2015). *L. aurita* (Asteraceae), also known as *Blumea aurita* Linn, belongs to the family Compositae (Olurishe and Mati 2014).

Currently, there are various documented traditional uses of the plant in the literature. Besides, many scientific investigations were conducted to investigate the bioactive molecules from *L. aurita* for therapeutic reasons. However, summarized information on the traditional values, phytochemical composition, pharmacology, and toxicology on the plant is lacking. Therefore, this review seeks to provide a comprehensive overview of the ethnomedicinal values, phytochemistry, isolated compounds, pharmacology, and toxicity of *Laggera aurita* to motivate further research for potential drug development.

Methods

A detailed search of information about the plant *Laggera aurita* was carried out and retrieved from online academic databases such as PubMed and Google Scholar from inception to April 2022. The search terms used include *Laggera aurita*, ethnomedicinal uses, phytochemistry, pharmacological activity, and toxicology.

Results

Traditional uses

The *Laggera aurita* leaves are employed in Nigeria to manage epilepsy (Malami et al. 2016). The plant's essential oils are used to treat cancer, atherosclerosis, and thrombosis. They also serve as antispasmodics and diuretic (Edris 2007; Guragi et al. 2018; Magaji and Malami 2018; Malami et al. 2016). The plant is used traditionally to treat pediatric, fever, malaria, stomatitis, pain, asthma, nasal congestion, bronchitis, and bacterial infections in Burkina Faso, Cameroon, and Nigeria. It serves as a preservative in cereal grains (Egharevba et al. 2010). It is also reported to be used traditionally in treating inflammation, rheumatic pain, dyspepsia, indigestion, constipation, and dysentery and aiding wound healing (Diabala et al. 2014). The reported ethnomedicinal uses of the plant *L. aurita* are presented in Table 1.

Reported phytochemical constituents of *Laggera aurita*

Phytochemical investigation unveiled several monoterpenoids, sesquiterpenoids, and some flavonoids (Xiao et al. 2003). Likewise, compounds such as 2,5-dimethoxy-p-cymene, β-caryophyllene, 2,3-dimethoxy-p-cymene, α-humulene, laggerol, m-menth-6-en- 8-ol, α-cadinol, and δ-cadinene were isolated from the whole plant. Hexadecenoic acid α-cadinol, 9,12-octadecadienoic acid were also isolated from the plant's aerial part (Greff et al. 2006; Shahwar et al. 2012). The summary of the documented phytochemical contents from the *L. aurita* is reported in Table 2.

Chemical compounds isolated and identified from *Laggera aurita*

A total of 44 chemical compounds from the essential oil of *Laggera aurita* obtained from Nigeria were identified and quantified using GC–MS analysis where the three major components isolated were benzene, 2-tert-butyl-1,4-dimethoxy (25.24%), caryophyllene (12.25%), and ϒ-terpinene (8.92%) (Dantanko and

Table 1 Reported ethnomedicinal uses of *Laggera aurita*

Ethnomedicinal use	Plant part	Location of reported use	References	Confirmed pharmacological activity
Antibacterial	Leaf, whole plant, volatile oil, aerial part	Not specified	Egharevba et al. (2010), Greff et al. (2006), Magaji and Malami (2018), Shahwar et al. (2012)	Confirmed (Ref)
Antispasmodic	Not specified	India (Singh and Mittal (2015)	Dantanko and Malann (2020), Singh and Mittal (2015)	Not confirmed
Atherosclerosis	Essential oil	Not specified	Getahun et al. (2019), Olurishe and Mati (2014)	Not confirmed
Asthma	Not specified	Burkina Faso (Diabala et al. 2014)	Guragi et al. (2018), Magaji and Malami (2018)	Not confirmed
Bronchitis	Not specified	Burkina Faso (Diabala et al. 2014)	Magaji and Malami (2018)	Not confirmed
Cancer	Essential oil	Not specified	Edris (2007), Guragi et al. (2018), Magaji and Malami (2018)	Not confirmed
Constipation/laxative	Not specified	India (Singh and Mittal 2015)	Dantanko and Malann (2020), Getahun et al. (2019), Olurishe and Mati (2014), Singh and Mittal (2015)	Not confirmed
Diuretic	Not specified	India (Singh and Mittal 2015)	(Singh and Mittal, 2015)	Not confirmed
Dysentery	Not specified	India (Singh and Mittal 2015)	Dantanko and Malann (2020), Getahun et al. (2019), Olurishe and Mati (2014), Salisu et al. (2014), Singh and Mittal (2015)	Not confirmed
Dyspepsia	Not specified	Africa (Getahun et al. 2019)	Getahun et al. (2019), Olurishe and Mati (2014), Salisu et al. (2015)	Not confirmed
Epilepsy	Leaf	Nigeria (Malami et al. (2016)	Getahun et al. (2019), Guragi et al. (2018), Magaji and Malami (2018), Muhammad and Sani (2018)	Confirmed (Ref)
Fever	Leaf	Burkina Faso (Diabala et al. 2014)	Getahun et al. (2019), Magaji and Malami (2018)	Confirmed (Ref)
Grain preservation	Not specified	Cameroon	Egharevba et al. (2010)	Not confirmed
Indigestion	Not specified	Not specified	Julde et al. (2017)	Not confirmed
Inflammation	Whole plant	Africa (Getahun et al. 2019)	Getahun et al. (2019), Olurishe and Mati (2014), Salisu et al. (2015), Shahwar et al. (2012)	Confirmed (Ref)
Insect repellant	Essential oil	Nigeria (Dantanko and Malann (2020), Salisu et al. 2015)	Dantanko and Malann (2020), Salisu et al. (2015)	Confirmed (Ref)
Nasal congestion	Not specified	Burkina Faso (Diabala et al. 2014)	Getahun et al. (2019), Magaji and Malami (2018)	Not confirmed
Malaria	Leaf, essential oil	Burkina Faso (Diabala et al. 2014), Nigeria (Egharevba et al. 2010)	Dantanko and Malann (2020), Egharevba et al. (2010)	Confirmed (Ref)
Pain	Whole plant	Burkina Faso (Diabala et al. 2014)	Getahun et al. (2019), Julde et al. (2017)	Confirmed (Ref)
Stomatitis	Not specified	Burkina Faso (Diabala et al. 2014)	Getahun et al. (2019), Julde et al. (2017)	Not confirmed
Thrombosis	Essential oil	Not specified	Edris (2007), Guragi et al. (2018)	Not confirmed
Wound healing	Not specified	Africa (Getahun et al. 2019)	Getahun et al. (2019), Julde et al. (2017), Salisu et al. (2015)	Not confirmed

Malann 2020). Other compounds isolated include α–phellandrene, (+)-4-carene, o-cymene, ϒ-terpinene, β–linalool, 2-carene, linalool, 4-carvomenthenol, p-menthan-8-ol, thymol methyl ether, benzene, 2-tert-butyl-1,4-dimethoxy, caryophyllene, α-caryophyllene, 1,2-benzenediol, O-(4-butylbenzoyl), Cadina-1(10),4-diene, α-bourbonene, tau-muurolol and phthalic acid, and cyclobutyl tridecyl ester (Dantanko and Malann 2020). In the essential oils of *Laggera aurita* harvested in Burkina Faso, 48 compounds were identified with major components identified as 2,5-Dimethoxy-p-cymene, β-Caryophyllene, α-Humulene (Mevy et al. 2006). In addition, the essential oil of *Laggera aurita* from Nigeria and Burkina Faso has six compounds in common, namely linalool, thymol methyl ether, caryophyllene, caryophyllene oxide, α-cadinol, and α-muurolene. In the *Laggera aurita* specimen analyzed from India, seven compounds were identified, namely n-heptacosane, n-dotriacontane, laggerol, ð-cadinene, 2,3-dimethoxy-p-cymene, α-cadinol, and m-menth-6-en-8-ol; however, variations in composition are attributed to the origins of the plant (Mevy et al. 2006). The reported compounds isolated and identified from the plant *L. aurita* are presented in Table 3.

Table 2 Reported phytochemical constituents of *Laggera aurita*

Plant part	Solvent	Phytochemical	References
Whole plant, leaves	Methanol	Carbohydrate	Olurishe and Mati (2014), Salisu et al. (2015)
Whole plant, leaves	Methanol	Saponins	Olurishe and Mati (2014), Salisu et al. (2015), Shehu et al. (2016)
Whole plant, leaves	Methanol	Tannins	Olurishe and Mati (2014), Salisu et al. (2015), Shehu et al. (2016)
Whole plant, leaves	Methanol	Flavonoids	Malami et al. (2016), Salisu et al. (2015), Shehu et al. (2016)
Whole plant, leaves	Methanol	Alkaloids	Salisu et al. (2015), Shehu et al. (2016)
Whole plant, leaves	Methanol	Glycosides	Salisu et al. (2015), Shehu et al. (2016)
Whole plant	Methanol	Cardiac glycosides	Shehu et al. (2016)
Whole plant, leaves	Methanol	Phenols	Salisu et al. (2015), Shehu et al. (2016)
Whole plant, leaves	Methanol	Steroids	Salisu et al. (2015), Shehu et al. (2016)
Not mentioned	Not mentioned	Sesquiterpenoids	Malami et al. (2016)
Not mentioned	Not mentioned	Monoterpenoids	Malami et al. (2016)

Pharmacological activities of *Laggera aurita*

Different parts of the plants were reported scientifically to have different biological activities such as antinociceptive, anti-inflammatory (Olurishe and Mati 2014; Shehu et al. 2016), anticonvulsant (Malami et al. 2016), antimicrobial (Egharevba et al. 2010; Salisu et al. 2015; Shahwar et al. 2012), antimalarial (Dantanko and Malann 2020; Singh and Mittal 2015), antioxidant (Shahwar et al. 2012), and anxiolytic properties (Guragi et al. 2018). The summary of the reported biological properties of *L. aurita* is documented in Table 4.

Analgesic and anti-inflammatory studies

Pain is a disturbing and unpleasant sensation elicited after the activation of peripheral pain receptors, which is associated with real or possible tissue damage (Fan et al. 2014; Kaliyaperumal et al. 2020). Inflammation is an adaptive physiological response that happens in a particular tissue in response to tissue injury, cell death, cancer, degeneration, and ischemia (Azab et al. 2016). Even though progress has been achieved substantially in treating pain and inflammatory conditions with efficacious drugs, the conditions remain among the highest health burdens in the global healthcare system (Khan et al. 2020). The herbal products' utilization against pain and inflammation has been well reported (Borges et al. 2018; Saleh et al. 2015). In a previous experiment by Olurishe and Mati (2014), the methanol extract of *L. aurita* at 200 and 400 mg/kg elicited analgesic action against mechanically and chemically induced hyperalgesia via peripheral and central mechanisms in mice as compared with the piroxicam (5 mg/kg) (Olurishe and Mati 2014). A similar finding was documented by Shehu and team members on the acetic acid-elicited writhing test and hot plate test method (Shehu et al. 2016). The result showed an effective and dose-dependent decline in the number of acetic acid-elicited writhes than piroxicam administered at a dose of 20 mg/kg and a significant elevation in the mean reaction time at 800 mg/kg than morphine (5 mg/kg) (Shehu et al. 2016).

Furthermore, the extract unveiled a remarkable and dose-dependent decrease in the mean reaction time when it was co-administered with naloxone, as suggestive of possible participation of the opioidergic system in its antinociceptive effects (Shehu et al. 2016). The saponins- and flavonoids-rich constituents of the plant also showcased analgesic potentials in the acetic acid and thermally induced nociception (Shehu et al. 2016). The same study documented the anti-inflammatory actions of the plant in formalin-induced inflammation at 200, 400, and 800 mg/kg (Shehu et al. 2016).

Anticonvulsant properties

Epilepsy is a common serious neurological pathological condition accompanied by recurrent spontaneous seizures due to complicated neurochemical processes involving several neurotransmitters (Almeida et al. 2011). The currently available antiepileptic compounds have adverse effects and limited efficiency, necessitating alternative, potent, clinically efficacious, and safe therapeutic options against the disorder (Fisseha et al. 2021). Several herbal preparations have medicinal use against epilepsy in traditional practice (Aghamiri et al. 2020), including *L. aurita* (Malami et al. 2016). Various herbal products with potential antiepileptic effects have been documented (Zhu et al. 2014).

As per the study by Malami et al. (2016), the leaf extract of *L. aurita* at 600 mg/kg produced 40% protection against tonic hind limb extension and a significant decline in the mean recovery time in maximal electroshock (MEST)-elicited seizures. Besides, the extract

Table 3 Reported chemical compounds isolated from *Laggera aurita*

Compound	Plant part	Solvent	Activity	References
(+)-4-Carene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
(±)-Camphor	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
(2S,4R)-p-Mentha-[1(7),8]-diene 2–1	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
± Phytone	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
1-Methylpyrrole	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
1,11-Dodecadiyne	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
1,2-Benzenedicarboxylic acid	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
1,2-Benzenediol, O-(4-butylb-enzoyl)	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
10 s,11 s-himachala-3(12), 4-diene	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012), Mevy et al. (2006)
1H-Benzocycloheptene, 2,4a,5,6,9a-hexahydro-3,5,5,9-tetramethyl-, derivative	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
2-(methylthio)-Ethanamine	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
2-Carene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
2-Isopropenyl-1,3-dimethylcy-clopen	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
2,2′-Azobis [2-methyl	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
2,3-Dimethoxy-p-cymene	Volatile oil from whole plant	Not mentioned	Not mentioned	Mevy et al. (2006)
2,4-Decadienal	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
2,4-Diisopropenyl-1-methylcy-lohexane	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
2,5-Dimethoxy-p-cymene	Essential oils	Not mentioned	Not Mentioned	Mevy et al. (2006)
2,6,9,11-Dodecatetraenal, 2,6,10-trimethyl-	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
3-Allylguaiacol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
3-Buten-1-one, 2,2-dimethyl-1-phen	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
3,5-Dithiono-6-methyl-1,2,4-triazine	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
4-Carvomenthenol	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
4-Ethylformanilide	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
4-Quinolinol,2-methyl-$$ 2-Methy	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
4,8,12-Tetradecatrien-1-ol	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
5,9,13-Trimethyl-	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
6s-2,3,8,8-Tetramethyltricyclo [5.2.2.01,6] undec-2-ene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
9,12-Octadecadienoic acid	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
a-Eudesmol	Essential oils	Not mentioned	Not mentioned	Mevy et al. (2006)
Alloaromadendrene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Benzene, 2-tert-butyl-1,4-dimethoxy	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Benzenepropanoyl bromide	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Bicyclo [7.2.0]undec-4-ene, 4,11,11-trimethyl-8-methylene-derivative	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Borazine	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Cadina-1(10),4-diene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Caryophylladienol I	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)

Table 3 (continued)

Compound	Plant part	Solvent	Activity	References
Caryophyllene oxide and derivative	Essential oil from leaf	Not mentioned	Larvicidal activity	Dantanko and Malann (2020), Mevy et al. (2006)
Cedrene hydrate derivative	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Cedrol	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Decanal	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Dimethoxy-p-cymene	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012), Mevy et al. (2006)
Eicosane	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
Elemol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
ϒ-Cadinene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
ϒ-Terpinene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Geranylacetone	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Heptadecane	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
Hexadecenoic acid	Volatile oil from aerial part	Not mentioned	Antioxidant	Getahun et al. (2019), Shahwar et al. (2012)
Humulene epoxide	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Isocaryophyllene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Isopiperitenone	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Isothymol methyl ether	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Laggerol	Volatile oil whole plant	Not mentioned	Not mentioned	Getahun et al. (2019)
Linalool formate	Volatile oil	Not mentioned	Not mentioned	Dantanko and Malann (2020), Shahwar et al. (2012), Mevy et al. (2006)
Longicyclene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Longifolene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Longipinene derivative	Volatile oil	Not mentioned	Not mentioned	Mevy et al. (2006)
m-menth-6-en-8- ol	Volatile oil from whole plant	Not mentioned	Not mentioned	Getahun et al. (2019)
Mono (2-ethylhexyl) ester	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
n-Dotriacontane	Essential from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
n-Heptacosane	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Nerol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Nortricyclyl bromide	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
o-cymene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Octadecanoic acid	Volatile oil from aerial part	Not mentioned	Not mentioned	Getahun et al. (2019), Shahwar et al. (2012)
p-Cymen-8-ol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
p-Menthan-8-ol	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Patchoulane	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Pentadecane	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
Phthalic acid, cyclobutyl tridecyl ester	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
s-Triazaborane	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
s-Triazine	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Spathulenol	Essential oil from leaf	Not mentioned	Not mentioned	Dantanko and Malann (2020), Mevy et al. (2006)
T-cadinol	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012), Mevy et al. (2006)
tau-Muurolol	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Tetradecanoic acid	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
Thymol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Thymol methyl ether	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
Trans-Carveol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)

Table 3 (continued)

Compound	Plant part	Solvent	Activity	References
Tricyclo [4.1.1.0(2,5)] octane	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Tridecanoic	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
Trifluoromethyl peroxynitrate	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
Valencene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Himachalene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Methyl-3-phenylallyl alcohol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Terpineol	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Bourbonene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
α-Phellandrene	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
α-Amorphene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Cadinol	Volatile oil from whole plant and aerial part	Not mentioned	Not mentioned	Dantanko and Malann (2020), Shahwar et al. (2012), Mevy et al. (2006)
α-Calacorene	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012)
α-Caryophyllene	Volatile oil	Not mentioned	Larvicidal and insecticidal activity	Dantanko and Malann (2020), Getahun et al. (2019), Shahwar et al. (2012)
α-Humulene	Volatile oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
α-Muurolene or its enantiomers: 1x,6x,7x-Cadina-4,9-diene	Essential oil from leaf	Not mentioned	Not mentioned	Dantanko and Malann (2020), Mevy et al. (2006)
β-Linalool	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
β-Caryophyllene	Volatile oil from leaf	Not mentioned	Larvicidal and insecticidal activity	Dantanko and Malann (2020), Getahun et al. (2019), Shahwar et al. (2012), Mevy et al. (2006)
β-Farnesene	Volatile oil	Not mentioned	Not mentioned	Shahwar et al. (2012), Mevy et al. (2006)
β-Himachalene	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
β-Ionone	Essential oil from leaf	Not mentioned	Not mentioned	Mevy et al. (2006)
B-Methyl mercapto ethylamine	Essential oil	Not mentioned	Not mentioned	Dantanko and Malann (2020)
δ-Cadinene	Volatile oil from whole plant	Not mentioned	Not mentioned	Getahun et al. (2019), Mevy et al. (2006)

Table 4 Pharmacological activities of *Laggera Aurita*

Activity	Solvent	Plant part	Assay	References
Analgesic	Methanol/fractions	Whole plant	In vivo	Olurishe and Mati (2014)
Anticonvulsant	Methanol	Leaf	In vivo	Malami et al. (2016)
Anti-inflammatory	Methanol/fractions	Whole plant	In vivo	Shehu et al. (2016)
Antibacterial	Methanol, ethanol	Leaf, whole plant, volatile oil, aerial part	In vitro	Egharevba et al. (2010), Salisu et al. (2015), Shahwar et al. (2012)
Antioxidant	Methanol, ethanol, steam distilled	Leaf, whole plant, volatile oil	In vitro	Egharevba et al. (2010), Shahwar et al. (2012)
Antiplasmodial	Methanol, hydrodistillation	Leaf, essential oil	In vivo	Magaji and Malami (2018)
Antipyretic	Methanol	Leaf	In vivo	Magaji and Malami (2018)
Anxiolytic	Methanol	Leaf	In vivo	Guragi et al. (2018)
Mosquito repellent and oviposition deterrent	Acetone	Whole plant	In vivo	Singh and Mittal (2015)

conferred 50% protection against pentylenetetrazol (PTZ)-produced seizures and significantly elevated the seizures onset. In the strychnine-provoked seizure model, the highest protection of 50% against seizure was seen when the animal was administered 300 mg/kg of the extract (Malami et al. 2016). In fact, a remarkable elevation in the seizure's latency was observed at all the tested doses. About 33.3% protection was recorded against the clonic convulsion in the picrotoxin-elicited seizure (Malami et al. 2016).

When subjected to a chronic model of epilepsy, the extract significantly produced a dose-dependent delay in the seizure for all the treatment days, showcasing its action at 600 mg/kg comparable to sodium valproate at 100 mg/kg in the PTZ-induced kindling test (Malami et al. 2016). When the extract (600 mg/kg) was co-administered with flufenamic acid (5 mg/kg), there was a 70% synergistic effect as against the respective 40% and 20% protection recorded when the individual agents were administered, respectively (Malami et al. 2016). About 80% protection was also observed when the extract was administered together with phenytoin against respective 40% and 60% protection recorded with individual administrations (Malami et al. 2016). It was postulated that the possible mechanisms of antiepileptic actions of the extract could be attributed to its interaction with serotonergic and histaminergic pathways following pretreatment with cyproheptadine before the extract administration (Malami et al. 2016).

Antimicrobial properties

Infectious diseases form part of the top 10 causes of global death, disability, and morbidity (Etame et al. 2019; Nair et al. 2017). Even though there has been advancement in antimicrobial therapy, resistance causes serious drawbacks in curtailing infectious diseases (Etame et al. 2019). Natural products, including plants, form a new hub for treating infectious diseases (Blondeau et al. 2020). The crude extract of *L. aurita* and its fractions were reported to have anti-tubercular activity in the broth micro-dilution method (BMM) (Egharevba et al. 2010). The crude extract's minimum inhibitory concentration (MIC) was determined to be625u/ml compared to several fractions ranging between 1000-3000u/ml (Egharevba et al. 2010). It was proposed that the observed antimicrobial effect shown by the crude extract might result from several compounds' synergistic action (Egharevba et al. 2010). In another experiment by Shahwar and c0-researchers, the antibacterial properties of the volatile oil of *L. aurita* elicited the effective antimicrobial actions against *Proteus mirabilis* as compared to *Bacillus subtilis, Escherichia coli,* and *Nocardia asteroides* using the agar well diffusion test (Shahwar et al. 2012).

The antibacterial action of *L. aurita* was further supported by Diabala et al. (2014), where the MIC and minimum bactericidal concentration (MBC) of the bioactive fractions revealed the highest efficacy in the ethyl acetate fraction (EAF) than dichloromethane fraction (DCMF) in the broth microdilution method. The inhibitory effects of the ethyl acetate containing-flavonoid fractions combined with gentamycin against the food bacterial strain multi-resistant showed a synergistic and additive effect (Diabala et al. 2014; Salisu et al. 2015).

Antiplasmodial properties

Malaria is a disease that causes rampant death and complications globally, where more than 50% of the population is affected by the disease. The most affected region is sub-Saharan Africa (Habte and Assefa 2020). Besides, the *Plasmodium* species, notably *P. falciparum,* have developed resistance to the currently available antimalarial agents, posing obstacles to malaria prevention and treatment (Fenta and Kahaliw 2019). In developing areas, people rely on herbal preparations for treating malaria (Okokon et al. 2017). The plant *L. aurita* exhibited significant repellent properties against *A. stephensi* and oviposition deterrence against *A. stephensi* vector of malaria (Singh and Mittal 2015). It was reported by Dantanko and Malann (2020) that the essential oil of *L. aurita* possesses potential larvicidal activity against *Anopheles gambiae* (Dantanko and Malann 2020). The *L. aurita* extract unveiled an effective and dose-dependent decline in the elevated parasitemia level in 4-day suppressive, prophylactic, and curative in vivo test models against chloroquine-sensitive *Plasmodium berghei* in mice (Magaji and Malami 2018).

Antioxidant properties

Antioxidants moderate the generation of reactive oxygen species (ROS) such as free radicals from various bodily metabolic activities. However, an irregularity that increases the ROS level and oxidative stress results in many disorders, including cardiovascular diseases, diabetes mellitus, inflammation, and neurodegenerative disorders associated with oxidative stress (Aldoghaci et al. 2021). Medicinal plants are a great source of antioxidant compounds (Link et al. 2016).

The antioxidant effect of the volatile oils obtained from *L. aurita* elicited significant xanthine oxidase inhibitory effects against 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activities comparable to allopurinol (Shahwar et al. 2012). In another work by Diabala et al. (2014), the DPPH radical method, 2,2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic Acid (ABTS) radical cation decolorization assay and the ferric reducing antioxidant power (FRAP) assay were carried out on ethyl

acetate fraction (EAF), oil ether fraction (OEF), dichloromethane fraction (DCMF), and ethyl acetate fraction (EAF) (Diabala et al. 2014). The strongest scavenging actions against DPPH radicals were observed in the EAF fraction, followed by the DCMF, and the lowest activity was seen in the OEF fraction (Diabala et al. 2014). The strongest ABTS activity was seen in EAF, followed by DCMF, and the lowest activity in OEF (Diabala et al. 2014).In addition, the strongest FRAP activity was obtained by DCMF, followed by EAF and the lowest activity was obtained by OEF (Diabala et al. 2014). According to the study, the EAF and DCMF have the highest polyphenol than other fractions and, therefore, might be the reason for the high antioxidant activities seen in the two fractions (Diabala et al. 2014).

Antipyretic activity

Pyrexia is an elevation in the body temperature beyond the physiological level due to conditions including ovulation, increased thyroid hormone secretion, strenuous exercise, and microbial agents (Sultana et al. 2015). The body's immune is stimulated to remove the microbes in case of infections (Sultana et al. 2015). Various medicinal plants were reported to have antipyretic actions (Nock et al. 2022; Rauf et al. 2014). Another research unveiled a significant ($p < 0.05$) reduction in the Brewers' yeast-induced fever model as an indication of the antipyretic effect of the plant (Magaji and Malami 2018).

Anxiolytic activities

Anxiety is a severe psychological situation associated with negative emotional experiences (Mani et al. 2021). This disorder is one of the most common community illnesses affecting about 2–6% of the world population (Mani et al. 2021). Previous studies reported the anxiolytic actions of medicinal plants (Doukkali et al. 2015; Elakhal et al. 2021; Lobina et al. 2018). The methanol leaf extract of *L. aurita* (150, 300, and 600 mg/kg) exhibited anxiolytic potentials in the hole-board, elevated plus maze, staircase, beam walk assay, open field, and diazepam-induced sleep models (Guragi et al. 2018).

Toxicological studies

Traditional medicine has been getting attention globally with medicinal plant products to treat diseases and improve health (Joung et al. 2019). Because herbal products are obtained from natural sources and utilized for prevention and disease curation, they are generally presumed safe (Abraham and Ahmad 2021). Nevertheless, studies have cautioned about the safety of the herbal preparations, particularly their possible liver and kidney toxicity (Ahmad et al. 2022; Teschke et al. 2014). Therefore, scientific documentation on plant safety information is necessary for drug development (Reduan et al. 2020).

An experiment by Shehu et al. (2016) reported the acute toxicological effects of the *L. aurita* extract at 2000 and 5000 mg/kg (Shehu et al. 2016). The histopathological result showed specific toxicity of the extract on the kidney and liver at 2000 mg/kg. The liver, kidney, spleen, lungs, and stomach were all affected at 5000 mg/kg, except for the heart (Shehu et al. 2016).

Evaluation of the serum biomarker of Wistar rats following the 28-day oral treatment of the *L. aurita* showcased that the extract has some level of safety (Julde et al. 2017). However, there was an elevation in alkaline phosphatase (ALP) level at the tested doses (75, 150, 300, and 600 mg/kg), while aspartate transaminase (AST) and alanine transaminase (ALT) levels were lowered (Julde et al. 2017). The results of the kidney parameters showed no significant alteration in creatinine concentration at all the doses. Besides, a substantial reduction in the urea level was observed at 600 mg/kg. The study also showed no significant change in the oxidative stress markers (superoxide dismutase, catalase, and malondialdehyde) except in glutathione peroxidase, where a remarkable increase was observed at 300 and 75 mg/kg (Julde et al. 2017). Besides, there were no substantial changes in the food and water consumption, weights of the animals, organ weight, and blood glucose level. The hematological indices evaluated were also not affected by the extract (Julde et al. 2017).

Conclusions

The plant *Laggera aurita* possesses promising therapeutic values. Previous experiments on the plant have established some of its ethnopharmacological indications in traditional medicine as evidence for its potential therapeutic activity against various disorders. However, more research is needed to provide documented proof for many of its traditional uses. The literature has shown that several compounds have been isolated and identified from *Laggera aurita* from different locations, although there are variations in the compounds isolated. Therefore, there is a need to screen the compounds responsible for potential pharmacological effects and toxicities. The toxicological evaluation of *Laggera aurita* has also shown relative safety in sub-chronic administration and signs of toxicity in acute studies. In addition, there is a need for further detailed long-term toxicological evaluation, such as chronic, mutagenic, teratogenic, and genotoxic toxicity studies of the plant, to establish its safety fully. Furthermore, there is a need to standardize doses that could be used for subsequent clinical trials in humans. This will

further establish safety and efficacy of *Laggera aurita* in the treatment of various diseases.

Abbreviations

ABTS: 2,2-Azino-bis-3-ethylbenzothiazoline-6-sulfonic acid; ALP: Alkaline phosphatase; ALT: Alanine transaminase; AST: Aspartate transaminase; BMM: Broth microdilution method; DCMF: Dichloromethane fraction; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; EAF: Ethyl acetate fraction; FRAP: Ferric reducing antioxidant power; MBC: Minimum bactericidal concentration; MEST: Maximal electroshock test; MIC: Minimum inhibitory concentration; OEF: Oil ether fraction; PTZ: Pentylenetetrazol; ROS: Reactive oxygen species.

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Author contributions

SMJ contributed to conceptualization, writing original draft, review, and editing. SBB and ASW performed literature review and wrote the original draft of the manuscript. MHA contributed to literature review, writing original draft, review, and editing. SM edited and critically reviewed the manuscript. LAB critically reviewed the manuscript for intellectual content. All authors reviewed and approved the final version of the manuscript.

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