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LEUCAENA LEUCOCEPHALA: A COMPREHENSIVE REVIEW OF ITS PHYTOCHEMISTRY, PHARMACOLOGICAL ACTIVITIES, AND NUTRITIONAL SIGNIFICANCE

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ABSTRACT
Leucaena leucocephala trees are commonly known as white lead trees. It is indigenous to Northern Central America and Southern Mexico, and it is found in many tropical and subtropical regions. It can be used for a variety of purposes, including providing shade and preventing soil erosion, as well as producing fuel, timber, greens, feed, and green manure. Its many pharmacological characteristics have led to its usage in medicine. Numerous secondary metabolites, including alkaloids, cardiac glycosides, tannins, flavonoids, saponins, and glycosides, have been found in this plant, according to studies. It is used as an abortifacient, contraceptive, and stomachache remedy in traditional medicine. The current paper discusses *Leucaena leucocephala's* worldwide distribution, classification, chemical makeup, pharmacological actions, and possible applications.

KEYWORDS: *Leucaena leucocephala*, Medicinally, Multipurpose, Pharmacological activities, Traditional medicine.

INTRODUCTION

The growing opposition against synthetic drugs has been a source of health issues in recent years and is anticipated to continue in the coming years, too. This widespread phenomenon encouraged traditional medicine to use plant-based remedies for various illnesses. It has been estimated that 75–80% of people in the world depend on herbs due to their health effects, and scientists are in search of new and potent substances.

Medicinal herbs have phytochemical compounds, which help treat various diseases in humans. In the present time, people across the globe prefer herbal medicines over synthetic medicines because of minimal side effects and affordability. An essential aspect regarding the treatment of deadly diseases includes phytochemical compounds.[1]

Leucaena leucocephala (Lam.) de. Wit is a perennial, fast-growing, multipurpose leguminous tree in the family Fabaceae (subfamily Mimosoideae). Commonly known as white lead tree, subabul, ipil-ipil, or river tamarind. *Leucaena leucocephala* is native to southern Mexico and northern Central America. The rapid growth rate, large seed production, efficient harvesting, nitrogen fixation, drought tolerance, and poor soils are major factors in the successful spread of *L. leucocephala* across its distribution.[2,3]

Based on botanical data, L. leucocephala is a small to medium-sized tree that, depending on conditions, can grow to 5-20 meters tall. The tree has an open and spreading crown, and its trunk is usually slender with smooth grey bark. With several small leaflets arranged symmetrically along the rachis, the leaves are bipinnate.

The round and cream-white flower heads with many small flowers form the inflorescences, followed by long and flat pods containing glossy brown seeds. The plant produces a huge number of highly viable seeds, which is one of the factors for the spread of the plant. By increasing root biomass, its dense root system improves soil texture and makes it more resistant to drought.[4,5] Phytochemical composition of *L. leucocephala* includes alkaloids, flavonoids, tannins, saponins, phenolic acids, terpenoids, and glycosides, which are present in various

plant parts, such as leaves, seeds, bark, and roots. The presence of mimosine acts as a toxic principle as well as a medicine. Various parts of *L. leucocephala* have been used in folk medicine for treating ailments such as infections, inflammation, intestinal worms, and dermatitis. It has many significances in agriculture, veterinary practices, pharmacology, environmental studies, and industrial biotechnology.[6-9]

Fig. 1: Leucaena leucocephala Tree.

TAXONOMICAL CLASSIFICATION[10]

Kingdom	Plantae
Subkingdom	Subkingdom
Division	Magnoliophyta
Class	Magnoliopsida
Subclass	Rosidae
Order	Fabales
Family	Fabaceae-Pea family
Genus	Leucaena Benth-lead tree
Species	*Leucaena leucocephala*

SYNONYMS[11]

- Acacia frondosa Willd.
- Acacia glauca (L.) Willd.
- Acacia leucocephala (Lam.) Link
- Acacia leucophala Link
- Leucaena glabra Benth.
- Leucaena glauca Benth.
- Mimosa glauca sensu L.1763 Misapplied
- Mimosa glauca Koenig ex Roxb.
- Mimosa leucocephala Lam.
- Mimosa leucophala Lam.

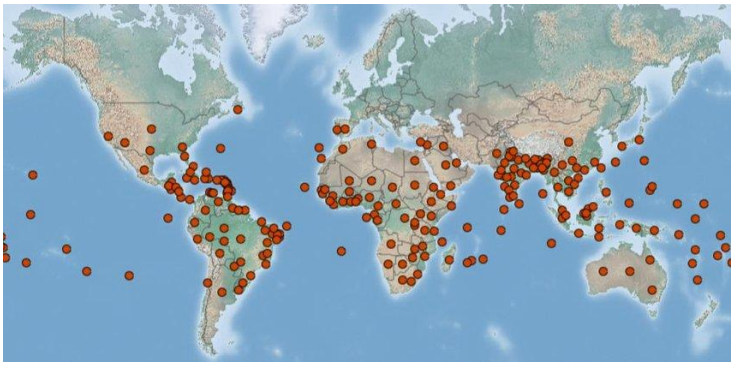
OTHER NAMES[12]

Countries	Common name
India	Kubabul, or subabul
Australia, United States	Leucaena
Indonesia	Lamtoro
Philippines	Ipil ipil
China	Yin ho huan
Hawaii	Koa haole

GLOBAL DISTRIBUTION[13]

Table 1: Global distribution of the *L. leucocephala* tree.

REGION	COUNTRIES
Asia	Bhutan, Cambodia, India, Indonesia, Iraq, Iran, Laos, Malaysia, Pakistan, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam, and Japan
Indian Ocean	Aldabra, Chagos, Archipelago, Madagascar, Mauritius, and Reunion Island. (Rodrigues Island, Seychelles, and Christmas Island.
Australasia	Australia, Papua New Guinea (New Guinea, New Britain, and Bismarck Archipelago)
Caribbean	Bahamas, Bermuda, Cayman Islands, Cuba, Dominican Republic, Grenada, Haiti, Jamaica, Puerto Rico
Central America	Costa Rica, El Salvador, Guatemala, Honduras, México, Nicaragua y Panamá.
Europe	Spain
Africa	Angola, Burundi, Cape Verde Is, Cameroon, Chad, Djibouti, Egypt, Equatorial Guinea, Ethiopia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Kenya, Liberia, Malawi, Mali, Mozambique, Niger, Nigeria, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Tanzania, Togo, Uganda, Zaire and Zimbabwe
Middle East	Saudi Arabia and Yemen.
North America	United States in Arizona, Georgia, the Virgin Islands, Texas, Florida, and Hawaii
Pacific Ocean	Caroline outer islands (Fiji), Polynesia (Tahiti, Moorea)
South America	Argentina, Bolivia, Brazil, Chile, Colombia, Guyana, Peru, Venezuela



BOTANICAL DESCRIPTION

Fig. 2: Leaves of *L. leucocephala.*

The compound pinnate leaves of *L. leucocephala* have a pinnular rachis that is 5310.2 cm long overall. They are bipinnate, with 638 pairs of pinnae that bear 9320 pairs of leaflets. The leaves are linear-lanceolate, 8315 mm long, 234.5 mm wide, slightly asymmetric, acute at the tip, linear-oblong to weakly elliptic, and glabrous except for the base of the margins, which are rounded to obtuse. The leaves of *L. leucocephala* fold up when it's hot, cold, or dry.[14]

Numerous blooms are produced, and the paired inflorescences of the axillary globose head have a diameter of 12 to 20 mm and a peduncle length of 2 to 3 cm. Each legume contains 15320 hard, shiny, brown seeds that are flat and teardrop-shaped. The axillaries are on long stalks that are white in colour and have dense globular heads that measure 1-2 cm across. The fruit pod has a raised border and is thin and flat. When it matures, it becomes dark brown and hard. It is 10315 cm long and 1.6 2.5 cm wide. It is dehiscent at both sutures. This species has 2n = 104 chromosomes, making it polyploid.[15-19]

Fig. 3: Flower of *L. leucocephala.*

Pods are linear-oblong in shape, rounded at the apex, flat, 8 to 18 seeded, mid-to orange-brown, glabrous and faintly glossy in white silky hairs, papery, and open along both borders. They are 11 to 19 cm long, 15 to 21 mm wide, and 5 to 20 per flower head. The hard, dark brown seeds have a hard, glossy testa that is transversely oriented in the pod and is 6.7 mm to 9.6 mm in length and 4 mm to 6.3 mm in width. The fruits start to grow in large quantities in the first year. Small (8 mm long), glossy, teardrop-shaped, flat, and dark brown, the seeds have a thin but somewhat resilient seed coat. A kilogram of seeds contains roughly 17,000 to 21,000 seeds.

Fig. 4: Pods of *L. leucocephala.*

Fig. 5: Seeds of *L. leucocephala.*

In pastures, ruminants, non-ruminants, wind, and legumes are the seed dispersers. While still on the tree, legumes have the ability to discharge their seeds. The seeds can travel a certain distance when carried by the wind. Legumes can be consumed by both ruminants and non-ruminants, which can then spread the seeds through their faeces.[20,21]

L. leucocephala's flowering phenology differs greatly between cultivars and depending on where they are grown. On the other hand, it can bloom throughout the year. Within four to six months of seed germination, *L. leucocephala* begins to bloom. The blossoming season is typically twice a year or seasonal. They appear on young branches that are actively growing and have spherical, white flower heads that are 2 to 2.5 cm in diameter, with 100 to 180 blooms per head and 2 to 6 blooms in leaf axils in each group. The flowers, which are carried on stalks 2 to 3 cm long at the ends or edges of twigs, can be white or pale cream-white in colour.[22]

CHEMICAL COMPOSITION AND NUTRITIONAL VALUE

According to the nutritional composition analysis, leucaena seeds have the potential to be a source of both protein and energy. The seeds have an estimated metabolizable energy of 2573.26 kcal/kg and a protein content of 31.1%. 1.39% lysine, 0.36% methionine, 0.35% cystine, 2.62% arginine, 4.63% glutamic acid, 0.87% threonine, 1.38% glycine, 1.11% alanine, 1.11% valine, 0.93% isoleucine, 1.81% leucine, and 0.71% methionine + cystine were the amino acid profiles of leucaena seeds. The antinutritional factors (ANFs) were 697.50 mg/100g of phytate and 0.75% tannin.[23]

The primary chemical components of the leaves of *L. leucocephala* were 3,7,11-Tridecatrienenitrile, 4,8,12-trimethyl (25.64%), squalene (41.02%), phytol (33.80%), and 3,7,11,15-Tetramethyl-2-hexadecen-1-ol (30.86%). On the other hand, the primary chemical components of the leaf extracts of the same species from Mexico were pentadecanoic acid-14-methyl-methyl ester, 1,6-trimethyl-2-pentadecanone, a ketone, and 2,6-benzofuranone-5,6,7,7a tetrahydro-4,4,7a-trimethyl.[24]

Among the chemical components of Chinese whole plants of *L. leucocephala* were ficaprenol-11 (polyprenol), methyl-132 hydroxy-(132-S), squalene, lupeol, sitostenone, trans-coumaric acid, cis-coumaric acid, pheophytin-a, and pheophorbide a methyl ester. -pheophorbide-b coupled with aristophyll-C.[25] For many centuries, *L. leucocephala* was considered a high-potential fodder. Its high ß-carotene content makes it as nutritious as or better than alfalfa (Medicago sativa).[26]

The most popular uses for *L. leucocephala* leaves are as feed for pigs and chickens and as a pellet for freshwater fish. *L. leucocephala* had a dry matter digestibility (DMD) of 57.7% and a crude protein content of 29.5%.[27] The composition of *L. leucocephala* leaves was 9.73% ash, 22.76% crude protein, 22.29% crude fiber, 4.60% fat, and 6.70% moisture.[28] For plants that were two and four years old, respectively, the highest percentages of minerals (12.5% and 14.0%) and crude protein (33.0% and 30.9%) were found in the leaves, the highest percentages of crude fiber (31.5 and 37%) and calcium (1.9% and 2.1%) were found in the twigs, and the highest percentages of crude fat (7.2% and 10.1%) and nitrogen-free extract (55.9% and 58.8%) were found in the dry seeds.[29-33]

PHYTOCHEMICAL STUDIES:

The phytochemical screening of the leaf extract of *L. leucocephala* revealed the presence of various secondary metabolites, such as alkaloids, cardiac glycosides, tannins, flavonoids, saponins, and Glycosides.[34]

Bioactivity studies on this plant revealed its anthelmintic, antibacterial, anti-proliferative, and antidiabetic activities.[35] The *L. leucocephala* leaves possess many biological properties, such as antimicrobial, anticancer, cancer preventive, diuretic, anti-inflammatory, antioxidant, antitumor, antihistaminic, nematicide, pesticide, antiandrogenic, hypocholesterolemia, and hepatoprotective.[36]

Table 3: Phytochemical studies of *L. leucocephala* extract.

Sl. no	Compound	Secondary metabolite	Therapeutic activity
1	Phytol	Diterpene	Antimicrobial, anticancer, cancer preventive, diuretic, anti-inflammatory
2	Squalene	Triterpene	Antibacterial, antioxidant, antitumor; cancer-Preventive, chemo preventive; immunostimulant, perfumery, pesticide, sunscreen, lipoxygenase-inhibitor
3	n-Hexadecanoic acid	Palmitic acid	Antioxidant, hypocholesterolemic nematicide, pesticide, antiandrogenic, flavor, hemolytic, 5-alpha reductase inhibitor
4	Hexadecanoic acid, 15-methyl- methyl ester	Fatty acid ester	Antioxidant, nematicide, pesticide, flavor, antiandrogenic
5	9,12,15-Octadecatrienoic acid, methyl ester	Linolenic acid ester	Anti-inflammatory, insectifuge, hypocholesterolemia, cancer preventive, nematicide, insectifuge, antihistaminic, antieczemic, antiacne, 5-alpha-reductase inhibitor, antiandrogenic, antiarthritic, anti-coronary, hepatoprotective.
6	Pentadecanoic acid, 14-methyl-methyl ester	Palmitic acid methyl ester	Antioxidant
7	Oxalic acid, allyl hexadecyl ester	Dicarboxylic acid	Acaricide, antiseptic, CNS-paralytic, fatal, hemostatic, irritant, pesticide, renotoxic, varroacide.

PHARMACOLOGICAL REVIEW

Analgesic Activity

Lamtoro leaves (*Leucaena leucocephala*) have analgesic effects. Analgesics can be used in combination, because they can provide a synergistic effect, minimise side effects and reduce the dosage of each drug. The study aims to determine the best concentration of the combination of Moringa leaf extract and lamtoro leaves as an analgesic. The writhing method was used as a test of analgesic activity in male white mice (Mus musculus L.). Testing on 7 treatment groups, namely negative control (Na-CMC 1%), positive control (paracetamol 1.3mg/20gBW), treatment group 1 (moringa leaf extract 50mg/kg BW), treatment group 2 (lamtoro leaf extract 27mg/20gBW), treatment group 3 (single dose combination), treatment group 4 (half dose combination), and treatment group 5 (quarter dose combination of each extract). The results showed that a single quarter-dose combination had the highest analgesic effect compared to other combination doses and was comparable to a single dose of the extract. The combination of small doses of the extract had the same effect as a large dose, indicating a synergistic effect.[37]

Antibacterial Activity

*E*nhancement of pathogenic bacteria such as gram-negative bacteria (Escherichia coli) and gram-positive bacteria (Staphylococcus aureus) can cause diseases such as diarrhea, nausea, abdominal pain and fever.

Utilization of medicinal plants as an herbal remedy for preventing and treating the disease continues to evolve in development of the medical field to obtain material resources as new antibiotics. The use of *Leucaena leucocephala* extracts with various solvent to determine the antibacterial activity was novelty research of leucaena. Analysis of antibacterial activity was done by two methods, inhibition zone and Total Plate Count.

In this study, two factors were used. The first factor was the type of leucaena seeds (mature and immature seeds), and the second factor was the type of solvent (water, ethanol and hexane). The results of the leucaena extract identified compounds of saponin, tannin, alkaloid and terpenoid, with a total phenol of 523.87 mg/L. The highest antibacterial activity of Escherichia coli was founded in mature seed extract with water solvent at a concentration of 100% had inhibition zone of 19 mm (positive control of 29 mm) and Total Plate Count of bacterial growth of 2.11×107 (CFU/ml) in line a negative control 7.78×105 (CFU/ml) and positive control 0.94×107 (CFU/ml).[38]

Antidiabetic activity

L. leucocephala has been reported to possess medicinal properties that control stomach diseases, facilitate abortion and provide contraception, and it is often used as an alternative, complementary treatment for diabetes.

Antidiabetic activity testing was carried out by giving *L. leucocephala* seed extract at an oral dose of 250 mg/kg body weight to streptozotocin-induced diabetic rats daily for 6 wk. The results revealed that *L. leucocephala* seed extract significantly ($p < 0.05$) reduced the fasting blood glucose and the blood chemistry consisting of: albumin, alkaline phosphatase (ALP), total protein and red blood cells in the diabetic-treated rats compared to those in diabetic-untreated rats. *L. leucocephala* seed extract slightly increased the serum insulin level in the diabetic-treated rats.[39]

Among the three extract concentration levels used, 50% level was found to be most effective in reducing blood glucose levels (BGL) in the experimental animals, while the pure extract (100% concentration) was the least effective. Thus, it is clear that *Leucaena leucocephala* Linn has anti-diabetic potentials which are comparable to the commercial anti-hyperglycemic drug Metformin.[40]

Anti-diarrheal

L. leucocephala seed of the ethanol extract decreased the onset of diarrhea, frequency of diarrhea, consistency, and weight of stool and duration of diarrhea in rats induced by castor oil.

The *L. leucocephala* groups that received doses of 200 and 400 mg/kg BW decreased the duration of diarrhea; however, there was no discernible difference between them and the loperamide group. *L. leucocephala* seed ethanol extract exhibits activity that decreases stool weight by altering stool consistency in a dose-dependent manner. The activity of 400 mg/kg BW in the dosage group was similar to that of loperamide.[41]

Anticancer Activity

Oral cancer is one of the most common cancers worldwide, and metastasis is recognized as a major factor causing its low survival rate. The inhibition of metastasis progress and the improvement of the survival rate for oral cancer are critical research objectives. Leucaena leucocephala from the mimosa branch Leucaena genus is native to Central and South America and has been used as a traditional remedy for treating various disorders. Previous studies have demonstrated antioxidant, anti-inflammatory as well as anticancer properties of L. leucocephala plant materials.

However, the molecular mechanism underlying the anticancer effect induced by L. leucocephala remains unclear. In this study, we investigated the effect of L. leucocephala extract (LLE) on SCC-9 and SAS oral cancer cells and examined the potential inhibitory mechanisms involved. The results indicated that LLE attenuated the migration and invasion abilities of both SCC-9 and SAS cells by reducing the activity and protein expression of matrix metalloproteinases-2 (MMP-2). Regarding mitogen-activated protein kinase (MAPK) pathways, the phosphorylation of ERK1/2 and p38 exhibited a significant inhibitory effect in the

presence of LLE. The application of ERK inhibitor and p38 inhibitor confirmed that both signalling transduction pathways were involved in the inhibition of cell metastasis.

These data indicate that L. leucocephala could be a potent therapeutic agent for the prevention and treatment of oral cancer and a prominent plant source for anticancer research in the future.[42]

Anthelmintic Activity

Helminthic infections are chronic illnesses in both human beings and cattle. The petroleum ether extract shows maximum activity at all the tested concentrations. Thus, the wormicidal activities of the plant extract against earthworms suggest that it can be effective against parasitic helminths of humans and animals.

At the measured concentrations, some *Leucaena leucocephala* leaf extracts exhibit strong in vitro anti-worm action. At every measured concentration, the petroleum ether extract exhibits the highest level of activity. Therefore, the plant extract's wormicidal properties against earthworms imply that it may also be useful against parasitic helminths that affect both humans and animals.

Exposure of C. elegans to different concentrations of *L. leucocephala* extract and mimosine significantly decreased the head thrashing, egg-laying and mean pump amplitude of pharyngeal pumping activity.[43]

Antioxidant Activity

Antioxidant activity of the solvent fractions obtained from a 20% aqueous methanol dried leaf extract of Leucaena leucocephala was evaluated using a 1, 1-diphenyl-2-picrylhydrazyl (DPPH) TLC assay. The more polar fractions ethyl acetate and butanol fractions demonstrated strong activity. A DPPH activity-guided fractionation procedure was used to isolate the antioxidant constituents of these active fractions.

Separate fractionation of the fractions led to the isolation of epicatechin-3-O-gallate (1) along with two quercetin glycosides: quercetin-3-O-arabinofuranoside (2) and quercetin-3-O-rhamnoside (3) together with apigenin (4).

The structures of the isolated compounds were elucidated using spectroscopic techniques NMR (1D and 2D) and mass spectrometry. Compounds 1 and 4 are reported for the first time from this species. In the qualitative antioxidant TLC assay, isolated compounds instantly bleached the DPPH (0.2% in MeOH) purple colour indicating strong antioxidant activity. The antioxidant quercetin glycosides were not cytotoxic at the highest concentration tested (200 ìg/ml), and apigenin was not isolated in sufficient quantity to test for cytotoxicity.

Epicatechin-3-O-gallate showed slight cytotoxicity against Vero cells (LC50 = 92 µg/ml).[44]

Larvicidal Activity

L. leucocephala leaves contain saponins, which can be used as larvicides. The purpose of this study was to determine the effectiveness of the ethanol extract of *L. leucocephala* as a natural larvicide against the death of larvae of Aedes aegypti instar III. This type of research is an experiment with a post-test only research design with a control group design, where there are two groups: the treatment and control groups. A sample of 25 larvae for each group was repeated four times. So that the total sample is 700 Aedes aegypti larvae. The results showed that at a concentration of 0 % (control), ethanol extract of *L. leucocephala* leaves could kill 0 Aedes aegypti larvae, a concentration of 4 % could kill seven larvae (28 %), a concentration of 6 % could kill 18 larvae (72 %), and a concentration of 8 % could kill. kill 21 larvae (84 %), 10 % concentration can kill 25 larvae (100 %), 12 % concentration can kill 25 larvae (100 %), and 14% concentration can kill 25 larvae (100 %). Based on the Kruskal-Wallis test, it can be concluded that there is an effect of giving ethanol extract of *L. leucocephala* leaves (Leucaena glauca, Benth) on the mortality of larvae of Aedes aegypti instar III, with a significant value of $p = 0.000$ ($p < 0.01$). The ethanol extract of *L. leucocephala* leaves (Leucaena glauca, Benth) at a concentration of 10 % is the smallest concentration that can kill 100 % of Aedes aegypti instar III larvae.[45]

Anti-microbial activity

Condensed tannins (CTs) are one of the promising compounds due to their potentially health-promoting qualities. In this study, CTs were extracted from a *Leucaena leucocephala* hybrid-Rendang and subjected to various biological studies including antioxidant (using Ferric reducing antioxidant power (FRAP), DPPH and ABTS radical scavenging assay), anti-microbial (against different pathogens) and cytotoxic activities (toward human breast adenocarcinoma (MCF-7), human colon carcinoma (HT29), human cervical carcinoma (HeLa) and human liver carcinoma (HepG2) cell lines) in cancer cells through *in vitro* experiments. The structural characteristics and purity of the CTs extract were determined using ^{13}C NMR. The results showed that CTs exhibited higher *in-vitro* antioxidant activities (2257.12 ± 80.55 mg TEAC/g extract, 605.3 ± 1.82 mg TEAC/g extract and 1014.03 ± 1.20 mg TEAC/g extract in FRAP, ABTS and DPPH assays, respectively) and demonstrated anti-microbial activities toward selected Gram-positive and Gram-negative bacteria tested with MIC and MBC values at 6.25–50 mg/mL.

Furthermore, among other selected cancer cells, CTs also demonstrated cytotoxic activity toward human breast cancer cells (MCF-7) ($IC_{50} = 38.33 \pm 2.08$ µg/mL). Characteristics of apoptosis, such as cell shrinkage, nuclear condensation and apoptotic bodies, were shown in MCF-7. These preliminary investigations have provided scientific rationale to use CTs as an alternative therapy for various oxidative and inflammatory-associated diseases.[46]

Anti-inflammatory activity
In a rat model in vivo study, the rich n-butanol and ethyl acetate fractions demonstrated a novel anti-inflammatory activity; the plant fractions were highly effective and exhibited robust activity when compared to the NSAID diclofenac sodium and the positive control.

The abundance of secondary metabolic substances, including flavonoids, stilbene, and phenolic acids (rutin, resveratrol, quercetin, isorhamnetin, luteolin, caffeic acid, and coumaric acid), that were identified and characterised to be present in plant n-butanol and ethyl acetate fractions using TLC and HPLC chromatographic analysis, made the N-butanol and ethyl acetate fractions extremely valuable.[47]

Anti – Lipidemic activity
The leaf extract of *Leucaena leucocephala* exhibited a moderate hypolipidemic effect in diabetic induced rats, and this can be attributed to the triterpenoids, which are the phytochemical constituents in this plant. Thus, it may be considered one of the major constituents causing hyperlipidemia.[48]

Reproductive activity
In separate experiments, mature rats were either given a ration containing L. leucocephala leaf meal at 15% or 7 3% level, or dosed each day orally with water extract of the leaf meal before and during the breeding period.

At the 15% level, the food intake of the rats was greatly reduced, and they showed general symptoms of inanition. All the females were infertile and the males showed reduced libido and fertility. In the other experiments the majority of the females conceived, but on autopsy it was observed that they had a significantly larger proportion of foetuses dead and undergoing resorption as compared with those of the control group.

The results suggested that the toxic material in *L. leucocephala*, probably mimosine, produced infertility in the rat by reducing the food intake; when food consumption was adequate for reproductive function, the toxic material caused a high incidence of foetal death and resorption.[49]

Anti-Proliferative
The research shows that the ethanolic extract from *Leucaena leucocephala* (LL) has notable antioxidant, anti-proliferative and anti-migration capabilities against the human cervical cancer cell line, HeLa. The ethyl acetate fraction of *Leucaena leucocephala* had the highest total phenolic and flavonoid content, which was associated with the strong antioxidant activity reported - 319.289 ± 10.934 µg GAE/mg extract (phenolics) and 399.572 ± 10.905 µg QE/mg extract (flavonoids). Cell viability analysis showed that LL extract was effective in reducing the viability of HeLa cells in a dose-dependent manner (cytotoxic effects observed at 2503500 µg/ml).

The *Leucaena leucocephala* extract also effectively reduced the migration rate of HeLa cells, suggesting potential cancer metastasis inhibition. Overall, these data suggest that *Leucaena leucocephala* may be used as a source of natural chemotherapeutic agents.[50]

Effects on the Estrous Cycle
The investigation of the effects of *Leucaena leucocephala* leaf extract suggests it may act as a natural phytoestrogen with notable results on the estrous cycle and uterine weight of ovariectomized rats. *Leucaena leucocephala* leaf extract not only increased uterine weights but also helped to modulate the estrous cycle, implying that the extract may have the potential to restore the reproductive function of females experiencing estrogen deficiency. This can contribute to the proposed application of *Leucaena leucocephala* leaf extract as a less hazardous and economical alternative to synthetic hormone replacement therapy (HRT), attributing decreased risks of cancers and cardiovascular risks associated with the chronic use of estrogens, as well as reduced costs and medical evaluations required for HRT.[51]

CONCLUSION

Leucaena leucocephala is a highly versatile leguminous tree with significant ecological, pharmacological, and industrial applications. Despite its widespread adaptability to diverse climatic conditions, this species remains underutilised in many regions. The plant is a rich source of bioactive compounds, including alkaloids, flavonoids, saponins, tannins, and glycosides, which contribute to its broad pharmacological activities, such as antimicrobial, anticancer, antidiabetic, anti-inflammatory, and anthelmintic properties.

Additionally, its high nutritional value and sustainable biomass production make it an important resource for animal feed, biofuel, and the pulp and paper industries.

Given its multifaceted applications, further research should focus on optimising its cultivation, enhancing its medicinal utilisation, and exploring innovative industrial applications. Advances in biotechnological interventions and sustainable harvesting practices could unlock its full potential, paving the way for its integration into modern pharmacological and agro-industrial sectors. Recognising and promoting *L. leucocephala* as a valuable natural resource could contribute to environmental sustainability, economic development, and public health.

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