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The Content of Compounds and Bioactivity of the *Eucalyptus* sp species

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ABSTRACT

Eucalyptus sp. is one of the plant genera from the Myrtaceae family which is widely known for its diverse secondary metabolite content and high biological activity. This study aims to systematically examine the diversity of active compounds and potential bioactivity of various *Eucalyptus species*, especially in the leaves, bark, seeds, and essential oils. Various compounds such as 1,8-cineole, citronellal, flavonoids, and phenolic compounds have been shown to contribute to pharmacological activities such as antioxidants, antimicrobials, anti-inflammatory, immunomodulators, anticancer, as well as natural insecticides and repellents. The results of the review indicate that these activities have great relevance in the development of biopharmaceutical products, cosmetics, and other health applications. The diversity of compounds and broad pharmacological effects place *Eucalyptus* as a very potential source of natural materials to be developed sustainably.

Keywords: *Eucalyptus* sp, Secondary Metabolites, Bioactivity

I. INTRODUCTION

Plants from the genus *Eucalyptus* are a group of woody plants belonging to *the Myrtaceae family* and are widely distributed in the Australian region, but are now cultivated globally, including in Asia, Africa, and South America (Chandorkar et al., 2021). This genus includes more than 700 species, including *Eucalyptus globulus*, *Eucalyptus camaldulensis* , and *Eucalyptus citriodora* , which are well known for their abundance of secondary metabolites content (Hayat et al., 2015). Over the past few decades, *Eucalyptus species* have become important subjects of numerous phytochemical and pharmacological studies, due to their potential as sources of natural bioactive compounds (Mierza et al., 2023).

Eucalyptus species contain various active compounds, such as essential oils (especially 1,8-cineole or eucalyptol), flavonoids, tannins, triterpenoids, and other phenolic compounds (Fauzi et al., 2021). These chemical compounds play an important role in their biological activities, ranging from antioxidants, antimicrobials, anti-inflammatories, to anticancer (Ardilla et al., 2023). This diverse phytochemical profile varies depending on the species, but also on the part of the plant used (leaves, bark, or essential oils), the extraction method, and the geographical conditions of the growing area (Metboki, 2018).

In the context of developing natural materials as biopharmaceutical candidates, a systematic study of the compound content and bioactivity *of Eucalyptus sp* . is very relevant.

This article aims to comprehensively review the current scientific literature on the chemical composition and pharmacological potential of various *Eucalyptus species* . By summarizing the findings of previous studies, this review is expected to provide an in-depth understanding and become a basis for further research and development of sustainable plant-based products.

II. METHODS

The approach used in this study is descriptive qualitative. This literature review was conducted by collecting data from various indexed national journals, Sinta, and Scopus. The data collected includes the results of laboratory studies examining the compound content and bioactivity of eucalyptus sp. The studies analyzed were selected based on relevance and scientific validity.

III. RESULTS AND DISCUSSION

Diversity of Active Compound Content in *Eucalyptus* sp.

Species of the genus *Eucalyptus* are known to contain a wide range of secondary metabolites that contribute significantly contribute to their biological activities (Suarantika et al., 2024). The most widely studied main content is essential oils stored in the secretory glands of leaves (Irvan et al., 2015). These essential oils generally consist of main components in the form of monoterpenes and sesquiterpenes, such as 1,8-cineole (eucalyptol), α -pinene, limonene, p-cymene, and γ -terpinene (Taufik et al., 2022). The relative proportions of each of these compounds depend greatly on the species, leaf age, harvest season, and geographical conditions of the plant habitat (Wahyudiono et al., 2022).

Several species that have been widely studied, such as *Eucalyptus globulus* , *E. camaldulensis* , and *E. citriodora* , show distinctive chemical profiles. *E. globulus* , for example, is dominated by 1,8-cineol up to 85% of the total essential oil (Sudrajat, 2016), while *E. citriodora* produces citronellal as the main component with strong antimicrobial activity (Syafii et al., 2020). In addition to terpenoids, *Eucalyptus leaves* are also rich in flavonoid compounds such as quercetin, kaempferol, and luteolin (Prado et al., 2015). Phenolic compounds such as gallic acid, caffeic acid, and chlorogenic acid have also been identified in various polar extracts of this plant (Kurniansyah, 2021).

The bark, flowers, and seeds of *Eucalyptus* also contain important metabolites, although they are less frequently studied. The bark often contains high amounts of tannins (Awaliyan et al., 2017), while the seeds are rich in lipid and phenolic compounds (Suarantika et al., 2024). Phytochemical studies have also shown the presence of alkaloid and triterpenoid compounds in several parts of the plant (Abubakar & Khaerah, 2022). The complex combination of these compounds makes *Eucalyptus* a potential source of active ingredients in natural medicine formulations and raw materials for the phytopharmaceutical industry (Tofiana, 2020).

Antioxidant Activity

One of the most dominant biological activities in *Eucalyptus* sp. is its ability as an antioxidant. This activity mainly comes from the content of phenolic and flavonoid

compounds that function as free radical scavengers (Abubakar & Khaerah, 2022). The DPPH (2,2-diphenyl-1-picrylhydrazyl) test (Lumbantoruan et al., 2023), ABTS (Gullón et al., 2019), and FRAP (Ferric Reducing Antioxidant Power) (Moges et al., 2024), are widely used to evaluate the antioxidant capacity of *Eucalyptus extracts* .

Methanol and ethanol extracts of *Eucalyptus camaldulensis leaves* have been reported to have significant antioxidant activity, equivalent to butylated hydroxytoluene (BHT) as a positive control (Wang et al., 2022). The combination of flavonoids and phenolic acids in *Eucalyptus globulus leaves* has a synergistic effect in stabilizing cell membranes against oxidative stress (Park et al., 2023). This activity is very important in preventing cell damage by free radicals that play a role in various degenerative diseases such as cancer, atherosclerosis, and premature aging (Suarantika et al., 2024).

The high antioxidant power of *Eucalyptus* also has the potential to be applied in the cosmetic field as an active anti-aging ingredient (Almeida et al., 2022), as well as in the food industry as a natural preservative (Awaliyan et al., 2017). The stability of phenolic compounds during storage and processing is also an important factor that supports the practical application of *Eucalyptus extract* in various fields (Obenu et al., 2025).

Biochemically, the antioxidant activity of phenolic and flavonoid compounds in *Eucalyptus* occurs through the ability of their hydroxyl (-OH) groups to donate hydrogen atoms or electrons to various types of free radicals, such as DPPH, ABTS, and ROO, thereby converting these radicals into more stable and non-reactive forms (Lumbantoruan et al., 2023). In addition, these compounds play a crucial role in chelating transition metal ions, such as Fe^{2+} and Cu^{2+}, which participate in the Fenton reaction responsible for generating highly reactive hydroxyl radicals (OH), thus inhibiting their formation. Flavonoids also contribute to the regeneration of endogenous antioxidants, including glutathione (GSH) and vitamin E, which help maintain the cellular redox balance (Obenu et al., 2025). The synergistic interaction of these mechanisms effectively suppresses lipid peroxidation, preserves membrane stability, and protects essential biomolecules from oxidative damage, thereby maintaining cellular homeostasis under oxidative stress conditions (Gullón et al., 2019).

Antimicrobial Activity

Another quite prominent bioactivity of *Eucalyptus* sp. is antimicrobial activity (Putri et al., 2024). Essential oils from the leaves of various species have shown effectiveness in inhibiting the growth of gram-positive and gram-negative bacteria, as well as several types of pathogenic fungi. Components such as eucalyptol, α -terpineol, and citronellal are thought to play a role in damaging microbial cell membranes, increasing permeability, and causing cell lysis (Wibowo et al., 2023).

Research by (Oriola & Oyedeji, 2022) showed that *E. citriodora essential oil* has a significant inhibition zone against *Staphylococcus aureus* , *Escherichia coli* , and *Candida albicans* . The activity is comparable to or even exceeds standard antibiotics at certain concentrations. In addition, synergistic activity between essential oils and antibiotics has been studied, resulting in increased effectiveness of inhibition of resistant bacteria, such as *Pseudomonas aeruginosa* .

The antifungal effects of *Eucalyptus* are also promising, especially against fungal species that cause plant diseases and dermatophyte infections in humans (Metboki, 2018). The phenolic and tannin contents in the water and ethanol extracts showed fungistatic and fungicidal effects against *Aspergillus niger* , *Fusarium spp.* , and *Trichophyton rubrum.* These activities support the use of *Eucalyptus* as an active ingredient in antiseptic, antifungal, and environmental sanitation products (Sukhikh et al., 2022).

Anti-inflammatory and Immunomodulatory Activity

Terpenoid and flavonoid compounds from *Eucalyptus* also contribute to anti-inflammatory activity (Mierza et al., 2023). The main mechanism involves inhibition of the synthesis of inflammatory mediators such as prostaglandins and leukotrienes, as well as inhibition of enzymes such as cyclooxygenase (COX) and lipoxygenase (LOX) (Polanunu, 2024). This study showed that *E. globulus leaf extract* was able to reduce carrageenan-induced edema, indicating strong anti-inflammatory activity.

(Maulidiyah et al., 2025) also found that essential oils and phenolic compounds from *Eucalyptus* have immunomodulatory effects by reducing the expression of proinflammatory cytokines such as TNF- α and IL-6. This shows that *Eucalyptus* is not only anti-inflammatory, but also has the potential to selectively stimulate the immune system.

These effects have important implications for the development of plant-based therapies for chronic inflammatory diseases, including rheumatoid arthritis (Maftuchah et al., 2020), asthma (Suudi & Mustikawati, 2024), and autoimmune conditions (Mitayani et al., 2021). Several traditional herbal formulations containing *Eucalyptus* have also been used empirically in the treatment of cough, bronchitis, and respiratory disorders, scientifically justified by the anti-inflammatory and mucolytic activities of eucalyptol.

Anticancer Activity

Although not as intensive as antimicrobial and antioxidant research, several studies have shown the potential of *Eucalyptus* as an anticancer agent. Cytotoxic activity against cancer cells has been associated with flavonoid compounds, triterpenoids, and phenolic derivatives that can induce apoptosis and inhibit cell proliferation (Tanalp et al., 2023). Ethanol extract of *E. camaldulensis leaves* showed antiproliferative activity against breast cancer cells (MCF-7) and cervical cancer cells (HeLa). The mechanisms include cell cycle disruption, increased intracellular ROS, and caspase activation (Huang et al., 2022).

Insecticide and Repellent Activity

Eucalyptus essential oil has also been widely studied as a natural insecticide and repellent against insects, including disease-carrying mosquitoes. Compounds such as citronellal (Sakalli et al., 2022), eucalyptol (Mączka et al., 2021), and limonene (Fernandes, 2022) have been shown to be effective in repelling or killing insects through neurotoxic or irritant mechanisms. *Eucalyptus -based products* have been widely commercialized as mosquito repellent lotions and air fresheners (Daud et al., 2023). Its effectiveness against

Aedes aegypti, a dengue vector, has been shown to inhibit oviposition and increase larval mortality (Kaihena & Ukratalo, 2021).

IV. CONCLUSION

Eucalyptus sp. is rich in secondary metabolites, including essential oils, flavonoids, phenolic compounds, and terpenoids, which play important roles in its various biological activities. These active compounds exhibit high antioxidant activity, antimicrobial ability against various pathogens, and anti-inflammatory and immunomodulatory effects, which support its use in the treatment of long-term diseases. In addition, several studies have shown that eucalyptus extracts have anticancer properties in addition to functioning as insecticides and natural repellents for disease-causing insects. Eucalyptus is a very potential source of natural materials for development in the pharmaceutical, health, cosmetic, and phytopharmaceutical industries due to the diversity of its bioactive compounds.

Future research should focus on bioassay-guided isolation of active compounds, elucidation of molecular mechanisms, and the development of standardized formulations for clinical or industrial applications.

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