Review Paper:

Potential Therapeutic Arsenal: An Examination of Bioactive Compounds in the Melastomataceae Family

Umamaheswari C.[1,2] and Asha S.[1]*
1. Department of Biotechnology, VFSTR [Deemed to be University], Vadlamudi, Guntur Dt., A.P., INDIA
2. Department of Biology, RGUKT, R.K. Valley, YSR District, 516 330, Andhra Pradesh, INDIA
*sai848@gmail.com

Abstract

The objective of this review is to provide a comprehensive overview of the diverse array of bioactive compounds available in the Melastomataceae family, which is one of the most widely spread and diverse flowering plant families found in the tropical and subtropical regions. In this study, a systematic analysis of the bioactive compounds found in the Melastomataceae species including flavonoids, tannins, anthocyanins, triterpenoids, steroids, saponins and alkaloids, as well as their potential therapeutic effects, is presented. The research emphasized the significance of the presence of these compounds in a variety of traditional medicine systems based on a detailed analysis of existing literature.

Furthermore, the review emphasizes the therapeutic potential of these compounds and recommends that the exploration and research efforts be intensified to understand the pharmacological benefits and mechanisms of the bioactive constituents of the Melastomataceae family of plants which will be a significant contribution to the discovery of new natural products.

Keywords: Anti-inflammatory, Bioactive compounds, Cancers, Metabolic disorders, Phytochemicals.

Introduction

Melastomataceae, or Melastome family, comprise of flowering plants that are an important part of our global biodiversity and represent an enchanting aspect of the order Myrtales[72,81]. The Melastomataceae family, which comprises of over 4,500 species and 200 genera, is considered one of the most diverse families of flowering plants [13,35]. There is a worldwide distribution of this family, but it is mainly found in the tropics and subtropics, where the climate is conducive to its growth. As evidenced by the high diversity of species found in the Neotropics[20,37], the origin of the Melastomataceae family can be traced back to this region[63,65]. According to scientific theory, the family evolved from a common ancestor approximately 65 million years ago, contributing to the diversity of species we see today[12].

A distinctive characteristic of the Melastomataceae family is the small, four-petal flowers that have a distinctive scent and often display bright hues[48]. The role of these characteristics in attracting specific pollinators such as bees, butterflies and hummingbirds, has been studied in prior studies[30]. Its ability to adapt to a wide range of habitats, including tropical rainforests and deserts, demonstrates its ecological versatility and resilience[25]. Melastomataceae species can tolerate dry conditions and some extraordinary species can survive in alkaline or saline soils[49]. Plant ecology research in this family is fascinating because of its adaptability to diverse habitats[72].

There is a great deal of morphological diversity within the family of Melastomataceae, with leaves ranging in size, shape and texture[59]. According to extensive botanical studies, the leaves of Melastomataceae species are simple and entire, with a smooth to waxy surface[18]. Additionally, leaves can be arranged either oppositely or alternately and can be deciduous or evergreen depending on the type of plant[3]. Typically, Melastomataceae species produce small, fleshy berries containing one seed. Birds and other animals often consume these colourful fruits contributing to seed dispersal[17]. As being edible, some of these seeds have been used in traditional medicine, emphasizing the family's importance to the economy and medicine[17,23].

As a result, the Melastomataceae family contributes significantly to the floral biodiversity of our planet because of its worldwide distribution, habitat adaptability and biological diversity[44]. In addition to being ecologically important, these plants are also important sources of food and medicine for a variety of species. Even with considerable knowledge gathered about this family, many aspects remain unexplored and ununderstood, necessitating further research[1].

An overview of Melastomataceae family

In the tropical and subtropical regions of the globe, the Melastomataceae family, also known as the Melastome family, represents a large and diverse family of flowering plants[70]. The Melastomataceae consists of two significant subfamilies, the Memecyleae and the Miconieae, which comprise of over 4,000 species[47]. Known for beautiful flowers and a variety of leaf shapes and sizes, members of this family play an important role in ecology and culture.It has been documented that the Memecyleae subfamilies host over 3,000 species. They are renowned for their showy and often brightly coloured four-petal flowers, which are found in tropical and subtropical regions of the Americas, Africa and Asia. These plants usually have large leaves and have a

variety of shapes, such as heart-shaped, oval and lanceolate, contributing to their visual diversity[60,61].

A subfamily of Miconieae, on the other hand, encompasses over 1,000 species, most of which are found in tropical and subtropical zones[28]. The flowers of these plants are small and predominantly white or yellow, with five petals. The leaves, like those of the Memecyleae, are generally small and show a variety of shapes including ovals, lanceolates and obovates. At the genus level, there are prominent genera such as *Memecylon*, *Miconia* and *Melastoma*, which exhibit a wide range of size, shape and colour, illustrating the diversity present within the Melastome family[42].

In addition to being an essential food source for Aves, Bat and Apes species, the Melastome family has ecological significance. In addition to traditional medicinal applications, they can be used to create dyes and perfumes [6]. Some species can also be used for ornamental purposes, enriching landscapes with their striking features [31]. Among the most diverse and widely spread genera in the family is *Memecylon*, a member of the Memecyloideae subfamily. It is a tropical and subtropical plant with more than 500 species[14], these plants are usually shrubs or small trees. Typically, they have opposite leaves, often toothed or lobed, with white or pink flowers. Fruits generally contain several seeds and are small, round and opposite in shape[16].

In addition to this genus, there are three subgenera: *Memecylon*, *Eumemecylon* and *Pseudomemecylon*. *Memecylon*, the largest subgenus, contains over 400 species frequently found in disturbed habitats[5]. *Eumemecylon*, with around 100 species, prefers wetter environments like rainforests and swamps. *Pseudomemecylon*, with about 10 species, prefers arid environments like deserts and savannas[59]. Various cultures rely on the *Memecylon* genus for food and medicine. It is believed that the leaves and fruits of some species have medicinal properties. Traditional medicine employs leaves and fruits for these purported medicinal qualities[80]. A valuable timber source, *Memecylon* is also widely used in construction, furniture and other woodworking applications[14].

Bioactive compounds in Melastomataceae

As a defence mechanism against environmental stresses and herbivores, this family produces a large number of bioactive compounds and primarily secondary metabolites[51]. As a result of their diverse potential medicinal and therapeutic properties, these compounds are usually concentrated in the leaves, stems and flowers of plants. In recent years, alkaloids have been extensively studied among the secondary metabolites produced by Melastomataceae[7]. Being analgesic, anti-inflammatory and anti-cancer, these nitrogen-rich compounds also exhibit a wide range of biological activities[33].

In general, they possess complex chemical structures which contribute to their diverse biological abilities. As earlier studies revealed, alkaloids within the Melastomataceae family are also important[38].

In the family of Melastomataceae, the *Memecylon* genus is particularly noteworthy for the wide variety of bioactive compounds it contains. A promising source of medicinal substances, this genus comprises of approximately 150 species[64]. The biological activity of *Memecylonin*, a polyphenolic compound isolated from the species *Memecylon edule*, has been extensively studied[13]. Several studies have documented its anti-inflammatory, antioxidant and anti-cancer properties, supporting its potential as a therapeutic agent[29,54,75]. A range of other bioactive compounds is also produced by the *Memecylon* genus including flavonoids, terpenoids and phenolic acids[52]. These compounds, like *Memecylonin*, have anti-inflammatory, antioxidant and anticancer properties. In addition to these properties, several of these compounds also demonstrate antimicrobial, antiviral and antifungal characteristics, making them potential therapeutic agents in the management of infectious diseases[83]. According to these findings, the *Memecylon* genus within the Melastomataceae family is a valuable source of bioactive compounds with possible therapeutic applications[43].

Despite extensive research on *Memecylonin*, its exact mechanism of action remains unclear. As a free radical scavenger, it is thought to reduce the harmful effects of reactive oxygen species [ROS], by-products of metabolic processes that can damage cells and tissues[53]. As a neutralizer of ROS, *Memecylonin* may reduce inflammation and may protect against oxidative stress. Additionally, *Memecylonin* has anti-cancer properties, inhibiting the growth of breast and colon cancer cells by interfering with signaling pathways involved in cancer cell proliferation[26,82]. Another crucial aspect of its anti-cancer potential is that it induces apoptosis or programmed cell death in cancer cells[85].

It has also been shown that *Memecylon* may have anti-inflammatory properties. It has been shown to reduce inflammation in animal models of arthritis and other inflammatory diseases by inhibiting the production of pro-inflammatory cytokines which are implicated in inflammatory responses[83]. Melastomataceae, especially *Memecylon*, offer a promising reservoir of bioactive compounds. Among these, *Memecylonin* is particularly promising, showing a wide range of potential health benefits including antioxidants, anti-cancer and anti-inflammatory effects[52]. In order to fully understand its mechanism of action and explore its therapeutic applications in disease prevention and treatment, further research is necessary.

Flavonoids: The family Melastomataceae is mainly of shrubs or herbs and its bioactive compounds are widely recognized for their medicinal and nutritional benefits. These bioactive compounds include flavonoids whose health-promoting properties are widely recognized[37].

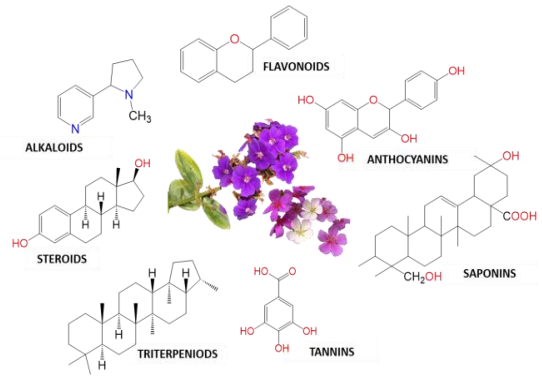

Fig. 1: Bioactive compounds observed in Melastomataceae

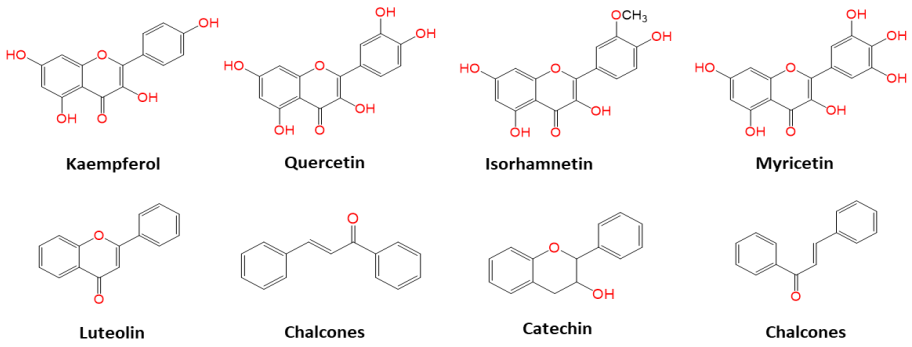

Fig. 2: Flavonoids observed in Melastomataceae

Using the Melastomataceae family as an example, the studies from Binti et al[8] research group examined the flavonoid diversity and potential bioactivities of the flavonoids and compared these findings with previous research[41]. In the family Melastomataceae, flavonoids, a class of secondary metabolites found in plants, are widely distributed[8]. In this family, a variety of flavonoids are synthesized including quercetin, kaempferol and myricetin[57]. According to Isnaini et al[34] research group, quercetin is found in species like *Melastoma malabathricum*[50]. Flavonoids have antioxidant, anti-inflammatory, anti-mutagenic and anticarcinogenic properties, in addition to modulating key cellular enzyme functions[34,77].

Recent studies from Rodrigues et al[68,69] have further demonstrated flavonoids' ability to modulate immune responses, to promote anti-aging and to reduce diabetic complications. Due to their multifaceted properties and broad spectrum of potential health benefits, flavonoids are a fascinating research topic, especially in terms of their therapeutic potential[69]. There is a wide variation in flavonoid content within the Melastomataceae family, suggesting a complex biosynthetic mechanism at work. According to studies of Bomfim et al[10] and Da Silva et al[22,23], flavonoid expression can be influenced by environmental stress, developmental stage and infection. This highlights the need for further research into flavonoid synthesis pathways, factors affecting flavonoid synthesis and plant diversity.

The Melastomataceae family has a strong reputation for flavonoids, according to Singh et al[73] research group[20]. Despite this, relatively little work has been conducted on the identification and understanding of specific flavonoid compounds across the family's different species. More extensive phytochemical research is required to fill the current knowledge gaps.The bioactivities of flavonoids have also been extensively studied in these plants, however, information about the bioactivities of flavonoids in the Melastomataceae family is relatively limited [68]. The potential health benefits of these flavonoids need to be comprehensively characterized and understood through more focused studies. Hence, the Melastomataceae family exhibits a fascinating array of flavonoids that contribute to its reputation as a valuable source of nutritional and medicinal compounds.

Tannins: An intriguing class of polyphenolic biomolecules known as tannins, the Melastomataceae contains an extensive array of bioactive compounds[34,67]. Comparatively, this review assesses the diversity and potential bioactivities of tannins from the Melastomataceae family. Several species in this family contain tannins, commonly divided into hydrolysable and condensed forms[84]. Proteins and various organic compounds are bound and precipitated by these compounds which are responsible for the astringent taste in some fruits as well as in the coloration of many plants within the family[58,79].

In several species of this family, soluble tannins have been identified, categorized either as gallotannins or ellagitannins[88]. Melastomataceae species also contain condensed tannins or proanthocyanidins complex structures that may offer potential health benefits[9].

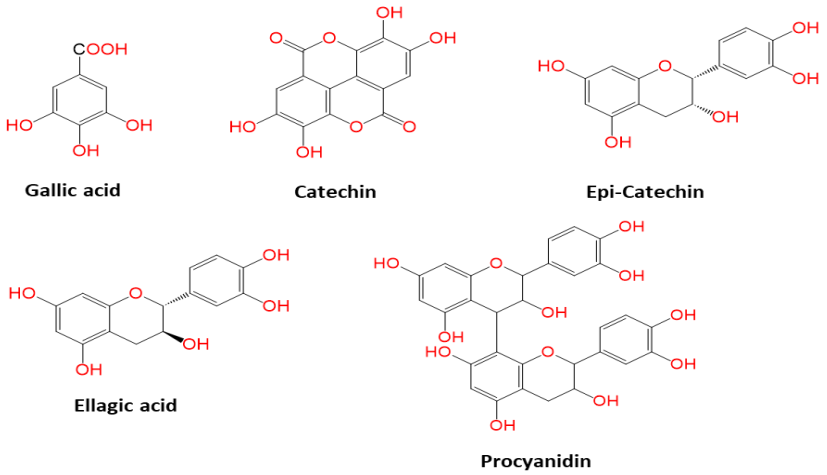

Fig. 3: Tannins observed in Melastomataceae

Species and even parts of the same plant can differ significantly in tannin content. Studies from various research groups include Nono et al[55] and Taiwo et al[78]. Tannins have been shown to have antioxidant, antimicrobial, anti-inflammatory and antitumor properties that promote health[55,65]. These biological activities highlight the therapeutic potential of tannins, making them a promising focus for future research aimed at developing novel strategies for disease prevention and treatment.

It is important to understand the biosynthesis pathways and factors influencing tannin synthesis in Melastomataceae plants, as tannin's biological activity often depends on their specific chemical structure and concentration[34]. Based on comparisons with Yıldırım and Kutlu[87] group, the presence of tannins within the Melastomataceae family is significant value[78]. Martins et al[45] group also indicates an evident knowledge gap regarding the precise identification and understanding of specific tannin compounds across various species in this family. Additionally, Melastomataceae tannins remain relatively untouched by research, compared to other plant families whose tannins have been extensively studied[20]. In order to better understand the diverse properties and potential health benefits of tannins within this family, further investigation is needed into their chemical structures, biosynthesis pathways and functions[45].

Anthocyanins: Anthocyanins, for example, contribute to the vibrant coloration of flowers and fruits. In this review we discuss the occurrence and potential bioactivities of anthocyanins within the Melastomataceae family, as well as compare them to previous research[50]. As a flavonoid, anthocyanins are a class of compounds that are beneficial to the body as antioxidants[71]. A variety of species in the Melastomataceae family produce anthocyanins which contribute to their vibrant pigmentation[4]. They are water-soluble pigments that appear red, purple, or blue depending on the pH[2].

The notable anthocyanin in this family is cyanidin which is glycosylated to form cyanidin-3-glucoside[86]. In addition to being powerful antioxidants and anti-inflammatory compounds, cyanidins have potential therapeutic applications as well. Besides their antioxidant and anti-inflammatory properties, anthocyanins have a wide range of bioactivities[71]. Research from Solarte et al[74] group has shown that they can help to prevent cardiovascular disease, cancer and other chronic diseases. Having neuroprotective effects, they could also be used to prevent neurodegenerative diseases[74]. Melastomataceae species and even different parts of the same plant can differ significantly in their anthocyanin content, suggesting complex biosynthetic regulation[19]. It has been shown that light exposure, temperature and other environmental factors can have a significant impact on the biosynthesis of anthocyanins in these plants[63].

There is evidence that the occurrence and variety of anthocyanins within the family of Melastomataceae are relatively well studied when compared to previous research[75]. It remains unclear, however, which biosynthetic pathways and environmental influences influence anthocyanin production in different species [2]. While anthocyanins have been extensively studied for their potential health benefits in some plants, their specific bioactivities were emphasised by several research groups [36,76]. The bioavailability and bioactivity of these compounds in the human body need further research. A valuable source of bioactive compounds with potential health benefits is the Melastomataceae family which is rich in anthocyanins.

Triterpenoids: As a result of their diverse bioactivities, triterpenoids have emerged as one of the most significant groups of these compounds. A comparison with prior research was made by Nzogong et al[56] group between the occurrence and potential bioactivities of triterpenoids in the family Melastomataceae[40]. There are six isoprene units in triterpenoids and they generally have a molecular formula of $C_{30}H_{48}$[34]. Many species within the Melastomataceae family have been identified as possessing these compounds as part of their defence mechanisms[50]. This family contains one such triterpenoid, ursolic acid, which is well known for its anti-inflammatory, antifungal and antitumor properties[39].

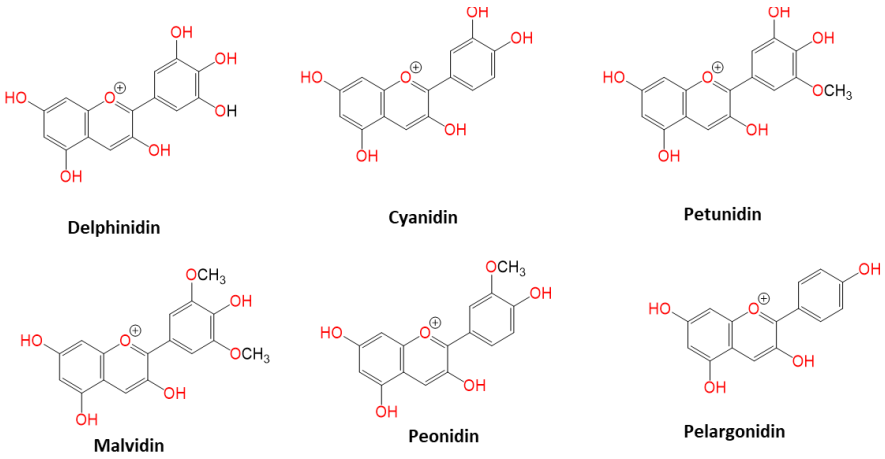

Fig. 4: Anthocyanins observed in Melastomataceae

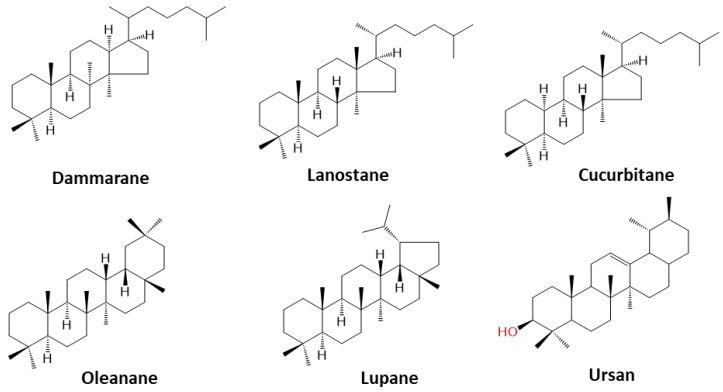

Fig. 5: Triterpenoids observed in Melastomataceae

Regarding their defensive functions, triterpenoids in the Melastomataceae family also demonstrate promising bioactivities that are beneficial to human health[21]. In addition to their antimicrobial, anticancer, anti-inflammatory and hepatoprotective properties[56], triterpenoids have a wide range of potential health benefits[66]. As a result of a complex biosynthetic process within the Melastomataceae family, triterpenoid content varies between species[23].

Steroids: Apart from its rich variety of phytochemicals, this family contains steroids which have a wide range of biological effects. The purpose of this review is to provide an overview of the existence and potential bioactivities of steroids within the Melastomataceae family[57]. There are many biological functions of steroids, derivatives of triterpenes [45]. They are essential to signaling, structure of cell membranes and metabolic functions[55]. It has been found that many plant steroids are present in the Melastomataceae family that are capable of being anti-inflammatory and antioxidants[32].

Research reports from Desire et al[27] commented that the plant steroids belonging to the Melastomataceae family possess a wide range of bioactivities including anti-inflammatory, antifungal, antimicrobial and cytotoxic effects. These properties make steroids of this family ideal for treating various ailments, warranting further investigation into their biome dical potential.

Saponins: As Melastomataceae family, one of the most important tropical flowering plant families[1], its many bioactive compounds are saponins. A review of the occurrence and potential bioactivities of saponins in the family Melastomataceae is presented here. Known as a crucial defense mechanism against herbivores and microbes, saponins are a diverse group of plant glycosides that have distinctive foaming characteristics. The ecological and pharmacological importance of saponins have been highlighted by the discovery that several members of the Melastomataceae family produce them[79].

The saponins possess a wide range of bioactivities including anti-inflammatory, antitumor, antimicrobial and immunomodulatory effects. These saponins could thus serve as potent therapeutic compounds for the family of Melastomataceae. Among Melastomataceae species and even within the same plant, saponin concentrations and compositions can vary significantly, as they do with many other plant metabolites[67].

Alkaloids: As one of the largest families within angiosperms, the Melastomataceae has diverse bioactive constituents. Alkaloids have emerged as particularly notable[50]. This review focuses on the presence of alkaloids in the Melastomataceae family, their bioactivities and compares them to previous research[1]. There is a wide range of pharmacological activities associated with alkaloids,

which are naturally occurring organic compounds mainly with basic nitrogen atoms. There are numerous species of Melastomataceae that contain alkaloids[66] contributing to their medicinal value. Alkaloids in the Melastomataceae family are potent as they are diverse. Samad et al[71] review discussed the anticancer, antimicrobial, antiviral and anti-inflammatory activities with the alkaloids.

Medicinal and traditional uses: *Memecylon* is known for its beautiful flowers, edible fruits and many traditional uses. Among the many species of *Memecylon* indigenous to tropical and subtropical climates, its medicinal, culinary and other uses have been documented for centuries[80]. In the past, *Memecylon* was extensively used to treat illnesses such as fevers, headaches and digestive problems. In addition to being used to treat diuretics, certain species leaves and bark were also used to treat skin conditions like eczema and psoriasis[1]. The leaves of *Memecylon* have also been used to relieve inflammation and treat wounds in several cultures[38]. Aside from being edible both raw and cooked, the fruits of *Memecylon* species are used to make jams and jellies, which give dishes a distinctive flavour. A variety of cultures have fermented the fruits into wine, demonstrating their culinary versatility[65].

Memecylon use extends beyond medicinal and culinary applications. Leaves of some species are used to make paper, while others are used to make dyes and inks. Some species of wood have been used to make furniture while others have been used to make musical instruments. Its bark, flowers, roots and fruits are used for a wide array of medicinal purposes[21].

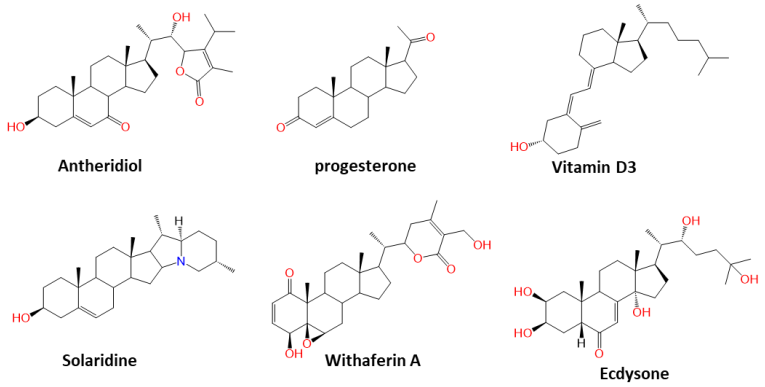

Fig. 6: Steroids observed in Melastomataceae

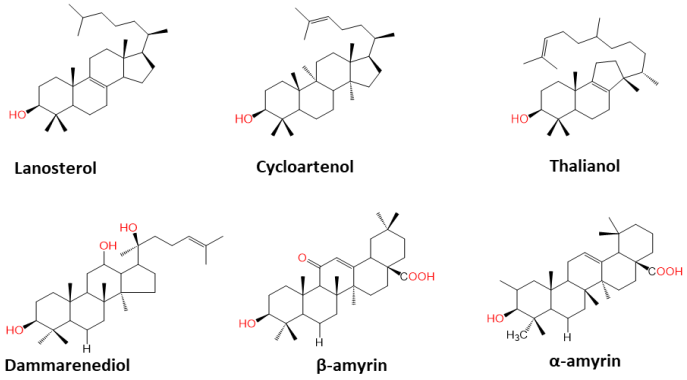

Fig. 7: Saponins observed in Melastomataceae

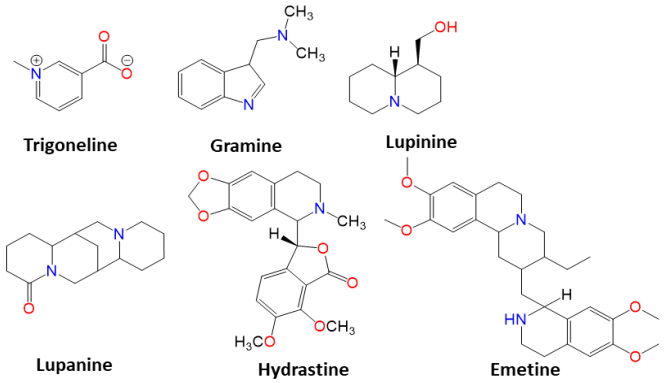

Fig. 8: Alkaloids observed in Melastomataceae

Besides treating fever, headaches and other illnesses, these plants also function as antiseptics, aiding in the treatment of skin diseases. In addition to treating snake bites, these parts have also been used as diuretics, reduce inflammation and treat skin conditions. Some cultures have even used them for snake bites[19].

Memecylon is traditionally prepared in different ways across cultures. Some prepare tea by boiling the leaves, bark, fruits, flowers and roots. Others grind these parts into powder, mix it with water and drink it. Some cultures also boil these parts in oil for topical application. Powders, oils, creams, extracts and ashes are commonly used for these preparations[44]. Traditionally, *Memecylon* bark is used to treat skin conditions such as eczema and psoriasis in India whereas in Africa, it is used for fever, diarrhea and dysentery[24]. The roots are used to treat digestive disorders and reduce inflammation in South American cultures[27].

There has been an increase in the commercial value of *Memecylon* in recent years. Some species are used to make herbal teas which are available at health food stores. In addition to preparing extracts and tinctures, *Memecylon* is also used to produce essential oils, which are used for aromatherapy and other natural health treatments. In addition to making incense, the leaves can also be used for making soaps and dyes [11,62].

Conclusion

As a defence mechanism against stress and herbivores, the Melastomataceae family produces a wide range of bioactive compounds, mainly in leaves, stems and flowers. A variety of secondary metabolites, including alkaloids, have been extensively researched in Melastomataceae due to their analgesic, anti-inflammatory, anti-cancer and other biological properties. Among the *Memecylon* genus within the Melastomataceae, its bioactive compounds are particularly noteworthy.

Memecylonin, a polyphenolic compound found in *Memecylon edule* species, has shown significant anti-inflammatory, antioxidant and anti-cancer effects, making it an excellent therapeutic agent. It is exhibiting antimicrobial, antiviral and antifungal properties as well. Other bioactive compounds such as flavonoids, terpenoids and phenolic acids, may also be used in infectious disease management.It is believed that *Memecylonin* scavenges free radicals and protects against oxidative stress, but the exact mechanism of action is not fully understood.

It inhibits cancer cell proliferation and induced programmed cell death. *Memecylonin* has also been shown to reduce pro-inflammatory cytokines, which are responsible for anti-cancer effects. Research suggests that *Memecylon*, specifically *Memecylonin*, is a valuable source of bioactive compounds useful for a variety of therapeutic purposes. It is still necessary to investigate its potential for disease prevention and treatment as well as to uncover its complete mechanism of action. It is believed that the *Memecylon* genus can offer a wide range of health benefits as a reservoir of bioactive compounds.

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