Unveiling the Secrets of Bougainvillea: A Review of Phytochemical and Pharmacological Properties

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Abstract
This review dives into the fascinating world of Bougainvillea, exploring its chemical makeup and potential health benefits. While research encompasses 18 species, most studies (phytochemical, pharmacological, and toxicological) have focused on just four species and their cultivars, along with one hybrid. Interestingly, some Bougainvillea species already have a history of use in traditional medicine. Scientific investigations have confirmed the presence of diverse chemical compounds within Bougainvillea, including aliphatic hydrocarbons, fatty acids, volatile oils, phenolics, flavonoids, and terpenes. These studies suggest that not only the extracts but also isolated active components from Bougainvillea exhibit a wide range of pharmacological activities. This exciting potential pave the way for further exploration of Bougainvillea as a source of valuable therapeutic compounds. To unlock the full potential of Bougainvillea, future research should delve deeper into the phytochemical, pharmacological, and toxicological properties of all species, cultivars, and hybrids. Understanding mechanisms of action, safety, and efficacy is crucial for responsible development of any potential medications derived from this beautiful and promising genus.

Keywords:
Bougainvillea, Phytochemical Properties, Pharmacological Properties, Toxicological properties, Mechanism, Therapeutic Compounds

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INTRODUCTION
Spanning the globe, the Bougainvillea genus boasts a diverse family of 18 distinct species. From B. berberidifolia to B. trollii, these vibrant plants belong to the Nyctaginaceae family [1]. While only four of these species - B. buttiana, B. glabra, B. spectabilis, and B. peruviana - enjoy widespread commercial use [2], the true beauty of Bougainvillea lies in its hidden potential.
Beyond these recognized species, a hidden world of over 100 cultivars and three unique hybrids awaits exploration. These hybrids, yet to be formally acknowledged, hint at the potential for further discoveries within the Bougainvillea genus.

Ethnobotany:

Figure 1: Taxonomical Classification

Botanical Characterization and Distribution:

Born in the warmth of South America, Bougainvillea first bloomed in Brazil back in 1778 before hitching a ride to Europe with French explorer Louis Antoine de Bougainville. These captivating plants showcase their beauty in various forms, transforming from bushes into sprawling vines or even reaching for the sky as small trees [3]. Look closely, and you'll see their stems armed with straight or slightly curved thorns, offering a hint of their wild ancestry. Each leaf is carefully attached by a stalk, and their shapes dance between elliptical and wider at the base. But the true showstoppers are the bracts and flowers, bursting with vibrant colors unique to each species, cultivar, or hybrid [4].

While some botanical references claim a boundless spread for Bougainvillea, not specifying locations, distinct species, or even cultivated varieties, we wanted to offer a more precise picture. By digging deeper into scientific literature, this review presents a reliable update on the true distribution of these fascinating plants [5].

Globe-trotting Bougainvilleas:

Bougainvillea buttiana:

Embark on a journey with this species found in India, Mexico, and Thailand.

Bougainvillea glabra:

This adaptable plant thrives in Italy, Spain, France, Bangladesh, India, China, Egypt, Israel, Thailand, Philippines, Madagascar, Nigeria, Hawaii, Bolivia, and many more countries in Central and South America [6].

Bougainvillea spectabilis:

Discover its vibrant blooms in Nigeria, Bahamas, Bolivia, India, Montenegro, Pakistan, Australia, and numerous islands and countries across the Americas.

Bougainvillea spinosa:

Though shrouded in mystery, this species calls Argentina home [7].

Bougainvillea peruviana:

A rare gem, found only in China, India, and its native Peru.

Bougainvillea's Hybrid Revolution:

Since its rise to commercial fame, breeders have been busy creating stunning hybrid Bougainvilleas. Among them are three recognized beauties: B. x spectoperuviana, B. x spectoglabra, and B. glabra peruviana (also known as B. x buttiana).

However, information on these hybrids remains scattered. B. x spectoperuviana seems virtually NOT documented in scientific literature. B. x spectoglabra, a charming mix of B. spectabilis and B. peruviana, has only been reported in China. Thankfully, B. glabra peruviana (B. x buttiana) offers more details. Born from the union of B. glabra and B. peruviana, it’s been identified in Mexico, India, England, and China. Interestingly, our research group has taken a deep dive into its characteristics, which you can find below.

Unfortunately, information on other Bougainvillea species and hybrids beyond these three remains limited, leaving their locations, potential medicinal uses, and chemical and pharmacological properties largely unexplored [8].

Synonym[9]:

Travel the globe and discover the many names given to the vibrant Bougainvillea! In Spain, it’s known as "Buganvilia," while in Mexico, Guatemala, Cuba, and the Philippines, it dons the "Bugambilia" badge. Malaysia calls it "Pokok bunga kertas," meaning "paper flower tree," while Honduras crowns it "Napoleón." Colombians, Nicaraguans, Salvadorans, and Costa Ricans sing...
its praises as "Veranera," meaning "spring flower." Panama, Puerto Rico, Dominican Republic, and Venezuela offer the name "Trinitaria," a reference to the Trinity. Argentina, Bolivia, Brazil, Paraguay, and Uruguay share the sweet name "Santa Rita," while Brazil adds a festive bunch of other names like "Primavera" (spring), "Tres-Marias" (Three Marys), and "Sempre-lustrosa" (always shiny). In Northern Peru, it’s known as "Papelillo," meaning "little paper." This is just a taste of the diverse and delightful names this beloved flower has acquired on its journey around the world.

Traditional Uses:

Certain Bougainvillea species, like B. buttiana, B. glabra, and B. spectabilis, have traditionally been used to treat ailments like coughs and whooping cough. B. glabra even finds itself recommended for asthma, bronchitis, and dysentery. In some cases, it’s used for stomach issues and skin concerns like rust, pimples, and blackheads. B. spectabilis finds additional uses in tackling respiratory problems like snoring, lung pain, and flu.

However, research on the traditional use of other Bougainvillea species and hybrids in medicine remains scarce. Interestingly, the hybrid B. x buttiana often gets confused with B. buttiana due to their overlapping distribution in Mexico and shared use for cough and whooping cough treatment. This highlights the need for further investigation to distinguish their potential medicinal properties [10].

Phytochemistry:

Since the 1970s, scientists have been on a mission to unlock the chemical secrets of Bougainvillea. They’ve analyzed extracts from various parts of the plant, including stems, leaves, bracts with and without flowers, bark, and even roots, using different approaches to extract different types of chemical components. This meticulous detective work has led to the identification and isolation of fascinating chemical compounds present in different species and hybrids. To visualize these discoveries, scientists even use special software like Marvin to draw the structures of these intricate molecules [11].

Phytoconstituents

Alphatic Hydro Carbons

The vibrant Bougainvillea, known for its stunning blooms, might hold an unexpected secret: a potential source of energy! Scientists have discovered the presence of aliphatic hydrocarbons, like alkanes and alkenes (Figure 2), within this genus. Specifically, analysis of ethanol extracts from B. x buttiana's flower-laden bracts identified seven of these compounds (see Table 1 and Figure 2). This exciting discovery suggests that B. x buttiana could be explored as an alternative energy source, offering a sustainable and renewable option for the future [12].

Figure 2: Structure of Alkanes, Alkenes

Table 1: Alkanes, Alkenes, Cycloalkanes

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound’s Name</th>
<th>Parts used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bougainvillea</td>
<td>Pentacosane</td>
<td>Bracts</td>
</tr>
<tr>
<td>X. buttiana</td>
<td>Heptacosane</td>
<td>with Flowers</td>
</tr>
<tr>
<td></td>
<td>Nonacosane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9-Octylhexacosane</td>
<td></td>
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<tr>
<td></td>
<td>1-Nonadecene</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-Hexacosene</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cylooctacosane</td>
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</tr>
</tbody>
</table>

Fatty Acids and Fatty Alcohols [13]:

Plants are like tiny chemical factories, and Bougainvillea is no exception! These beauties are rich in fatty acids and fatty alcohols, essential compounds found throughout their aerial parts. Scientists have confirmed the presence of 13 such compounds within the Bougainvillea genus.

Specifically, in B. x buttiana's colorful bracts with flowers, researchers identified eight of these fatty marvels. Interestingly, B. spectabilis, another Bougainvillea species, revealed five different fatty wonders in its leaves, branches, and roots (see Table 2 and Figure 3).

This discovery not only sheds light on the fascinating chemistry of Bougainvillea but also opens doors to potential applications in various fields. Understanding these natural building blocks could pave the way for exciting future developments.
Table 2: Fatty acids and fatty alcohols

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound’s Name</th>
<th>Parts used</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Spectabilis</td>
<td>2- Methylpropanoic acid</td>
<td>Leaves and Branches</td>
</tr>
<tr>
<td>1- Dodecanoic acid</td>
<td>Bracts</td>
<td></td>
</tr>
<tr>
<td>B. X. Buttiana</td>
<td>Hexadecanoic acid</td>
<td>Leaves and Branches</td>
</tr>
<tr>
<td>1- Octadecanoic acid</td>
<td>with flowers</td>
<td></td>
</tr>
<tr>
<td>9-Octadecenoic acid</td>
<td>with flowers</td>
<td></td>
</tr>
<tr>
<td>9,12-Octadecadienoic acid</td>
<td>with flowers</td>
<td></td>
</tr>
<tr>
<td>B. Spectabilis</td>
<td>n-Octacos-9-enoic acid</td>
<td>Roots</td>
</tr>
<tr>
<td>1,2-Diapalmitoleoyl glyceryl phosphate</td>
<td>with flowers</td>
<td></td>
</tr>
<tr>
<td>B. X. Buttiana</td>
<td>1-Triacontanol</td>
<td>Bracts</td>
</tr>
<tr>
<td>1- Dotriacontanol</td>
<td>with flowers</td>
<td></td>
</tr>
<tr>
<td>B. Spectabilis</td>
<td>n-Hentriacontanol</td>
<td>Roots</td>
</tr>
<tr>
<td>B. X. Buttiana</td>
<td>1,30-Triacontanediol</td>
<td>Bracts</td>
</tr>
<tr>
<td></td>
<td>with flowers</td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Structure of Alkanes, Alkene

Volatile Compounds:

Plants whisper their stories through their invisible messengers - volatile compounds. These fragrant molecules, with diverse chemical structures like aldehydes, ketones, and phenols, dance in the air, attracting pollinators and contributing to the plant’s unique aroma [14].

Scientists have been busy sniffing out the secrets of Bougainvillea’s scent vocabulary. In the leaves and branches of B. spectabilis, they’ve identified a whopping 35 different volatile compounds, each adding its own note to the plant’s fragrance composition. Interestingly, when examining the vibrant, flower-laden bracts of B. x buttiana, they found 9 distinct volatile compounds, hinting at a different olfactory signature.

Only one compound, ethyl hexadecanoate, seemed to be common to both species, suggesting a shared scent component amidst their unique identities (see Table 3 and figure 4). This fascinating discovery opens doors to understanding how different Bougainvillea varieties communicate with their environment and each other through their subtle chemical language [15].

Phenolic Compounds:

Plants are like tiny chemists, brimming with diverse compounds. Among these are phenolic compounds, powerful natural molecules known for their antioxidant and other beneficial properties. Within the Bougainvillea genus, researchers have identified a fascinating array of 14 such phenolics.

Intriguingly, B. x buttiana, a stunning hybrid, revealed 4 unique phenolic compounds in its vibrant flower-laden bracts. Meanwhile, B. glabra, another Bougainvillea species, surprised scientists with an impressive 11 different phenolic wonders hidden within its flowers (see Table 4 and Figure 5) [16].

But the story gets even more interesting! Two specific phenolic compounds, numbered 76 and 77, are rarely found in the plant kingdom. Yet, these elusive molecules were discovered within the hybrid B. x buttiana, suggesting a unique chemical signature for this special cultivar.

This exploration of Bougainvillea’s phenolic world not only expands our understanding of these plants’ chemical makeup but also opens doors to potential benefits these compounds might offer [17].

Pharmacological Properties:

For centuries, certain Bougainvillea species have played a role in traditional medicine. But did you know that science is now exploring the pharmacological potential of these vibrant plants? Researchers have been delving into various extracts and isolated compounds across different Bougainvillea species and hybrids, uncovering exciting possibilities [18].

This journey started with four species (with their cultivars) and one intriguing hybrid known for
their traditional medicinal uses. Scientists then turned their attention to a wider scope, investigating the pharmacological activities of various crude extracts and isolated chemical compounds found within these plants.

The following sections will reveal the fascinating discoveries made so far, exploring how Bougainvillea might offer potential benefits for pain relief, inflammation management, blood sugar regulation, and many other areas. Remember, these are scientific investigations, and further research is vital before considering any plant for medicinal purposes. Always consult a healthcare professional for guidance [19].

**Analgesic [20]:**

Several studies hint at Bougainvillea's potential role in pain relief. Extracts from both B. glabra and B. x buttiana have shown impressive analgesic effects in lab animals. Researchers tested methanol extracts from B. glabra on male rats, observing a remarkable 79.88% reduction in pain using a tail-flick method. B. x buttiana, in both orange and rose varieties, also showed promising results. Ethanol extracts from the orange variety inhibited pain by 95.65% in female mice, while both varieties displayed pain-reducing effects in different testing models. These findings suggest that Bougainvillea may hold natural painkilling properties, but further research is needed to understand its full potential and safe application.

Several Bougainvillea species seem to possess natural anti-inflammatory properties, offering potential relief for conditions like arthritis and swelling. Studies have explored this potential across different species and extracts.

**Anti-Inflammatory:**

For instance, B. glabra leaves, when extracted with methanol and administered orally to male rats, showed significant anti-inflammatory activity. Similarly, B. spectabilis leaves, extracted with various solvents, reduced swelling in male rats, regardless of the extraction method. This anti-inflammatory effect was even observed in mice with induced arthritis.

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**Figure 4: Structure of volatile compounds**

The figure depicts the structure of volatile compounds found in Bougainvillea species, illustrating the chemical diversity and potential therapeutic targets.
Further studies on the hybrid B. x buttiana revealed promising results. Orange variety extracts reduced swelling in female mice, even impacting specific molecules involved in inflammation. Similar anti-inflammatory effects were seen in rose variety extracts tested on female mice.

It’s important to remember that these are scientific findings, and further research is crucial to understand the mechanisms and safe

<table>
<thead>
<tr>
<th>Species</th>
<th>Compound's Name</th>
<th>Parts used</th>
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</thead>
<tbody>
<tr>
<td>B. Spectabilis</td>
<td>Butyl formate</td>
<td>Leaves and branches</td>
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<td></td>
<td>Butyl acetate</td>
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<td></td>
<td>Methy 2 methybutanoate</td>
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<td></td>
<td>Methyl hexadecanoate</td>
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<td></td>
<td>Ethyl hexadecanoate</td>
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</tr>
<tr>
<td></td>
<td>Isopropyl Palmitate</td>
<td></td>
</tr>
<tr>
<td>B. Spectabilis</td>
<td>Propyl hexadecanoate</td>
<td>Leaves and branches</td>
</tr>
<tr>
<td></td>
<td>Hexanal</td>
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<td></td>
<td>Heptanal</td>
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<tr>
<td></td>
<td>Ethyl 3-hydroxy-hexanoate</td>
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<tr>
<td>B. x buttiana</td>
<td>9,12-Octadecadienoic acid, ethyl ester</td>
<td>Bracts with flowers</td>
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<tr>
<td></td>
<td>9,12,15-Octadecatrienoic acid, ethyl ester</td>
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<tr>
<td>B. Spectabilis</td>
<td>Methyl linolenate</td>
<td>Leaves and branches</td>
</tr>
<tr>
<td>B. x buttiana</td>
<td>Diisoctyl Maleate</td>
<td>Bracts with flowers</td>
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<td></td>
<td>1,2-Benzenedicarboxylic acid, diisoctyl ester</td>
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<tr>
<td>B. Spectabilis</td>
<td>Ethyl-crotonate</td>
<td>Leaves and branches</td>
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<tr>
<td></td>
<td>2-Hexenal</td>
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<td></td>
<td>Linaool</td>
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<td></td>
<td>2-Heptadecanone</td>
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<td>Toluene</td>
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<td></td>
<td>o-Xylene</td>
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<td>2-Furfural</td>
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<td></td>
<td>Terpinolene</td>
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<td>Terpinen-4-ol</td>
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<tr>
<td></td>
<td>Methyl salicylate</td>
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<td></td>
<td>Transdihydrocarvone</td>
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<td></td>
<td>Verbenone</td>
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<td></td>
<td>Pulegone</td>
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<td></td>
<td>Dihydroedulan II</td>
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<td></td>
<td>Theaspirane B</td>
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<td></td>
<td>Dehydroionene</td>
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<td></td>
<td>α-Copaene</td>
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<td></td>
<td>β-damascenone</td>
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<td></td>
<td>α-Ionone</td>
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<tr>
<td></td>
<td>2,5-Dimethyl-4-hydroxy-392H) furanone</td>
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<tr>
<td></td>
<td>Aromadendrene</td>
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<td></td>
<td>Cadina-1,4-diene</td>
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<td>3-Hexenyl salicylate</td>
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<td></td>
<td>α-santalol</td>
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<td></td>
<td>(ZZ)-Farnesol</td>
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<tr>
<td>B. x buttiana</td>
<td>4-H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6methyl</td>
<td>Bracts with flowers</td>
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<tr>
<td></td>
<td>2-(Phenyl-piperdin-1yl-methyl)-cyclohexanol</td>
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<td></td>
<td>Oxirane, heptadecyl</td>
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</tbody>
</table>
application of these properties. However, these initial studies paint an exciting picture of Bougainvillea's potential as a natural source of anti-inflammatory compounds [21].

**Anti Diabetic:**

Several Bougainvillea species show promise in managing blood sugar levels, potentially offering benefits for conditions like diabetes. Studies have explored this potential in different parts of the plant and across various species.

B. spectabilis flowers, extracted with different solvents, showed similar blood sugar management benefits in diabetic rats and mice, regardless of the extraction method. Even steam bark from B. spectabilis displayed positive results. The hybrid B. x buttiana also holds promise. Extracts from its flowers and bracts lowered blood sugar levels in both male and female mice.

While these findings are encouraging, it’s crucial to remember that further research is necessary to understand the mechanisms and safe application of these properties. However, these initial studies suggest that Bougainvillea may possess natural compounds with potential benefits for blood sugar management [22].

<table>
<thead>
<tr>
<th>Table 4: Phenolic Compounds</th>
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</thead>
<tbody>
<tr>
<td>Species</td>
</tr>
<tr>
<td>B. x Buttiana</td>
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<tr>
<td>B. Glabra</td>
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<tr>
<td>B. x Buttiana</td>
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</tr>
</tbody>
</table>
Antipyretic:
B. glabra leaves, extracted with methanol and administered orally to rats, exhibited significant antipyretic activity, suggesting potential fever reduction.

Anti-Hyperlipidemic:
Several Bougainvillea species might hold the key to managing cholesterol levels, potentially aiding heart health. Studies have investigated this potential in different species and extracts.

B. glabra extracts, both in diabetic and healthy rats, led to reductions in "bad" cholesterol (LDL and VLDL) and triglycerides, while increasing "good" cholesterol (HDL). Similarly, B. spectabilis leaves, extracted with ethanol, significantly lowered various cholesterol markers in rats with high cholesterol.

While these findings are promising, it's important to note that further research is crucial to understand the mechanisms and safe application of these properties. However, these initial studies suggest that Bougainvillea may offer natural compounds with potential benefits for cholesterol management [23].

Antidiarrhoeal:
Extracts from B. glabra leaves showed promise in reducing diarrhea in male rats. This suggests potential for addressing digestive issues.

Antiulcer:
The same B. glabra extract exhibited antiulcer activity in male rats, offering hope for protecting the stomach lining.

Antifertility:
B. spectabilis extracts reduced testosterone and estrogen levels, sperm count, and sperm motility in mice. While further research is needed, this highlights potential fertility-related impacts.

Neuroprotective:
B. glabra leaves, extracted with ethanol, showed neuroprotective effects in fruit flies. This suggests potential for protecting brain health and reducing damage [24].

Thrombolytic:
Extracts from both B. glabra leaves and B. spectabilis green leaves were found to break down blood clots in lab tests using blood from healthy volunteers. This suggests potential for preventing or dissolving harmful blood clots.

Cardiotonic:
An aqueous extract of B. glabra was studied for its effects on isolated frog hearts. The extract increased heart rate and output, suggesting potential benefits for heart health, although further research is needed.

Anthelmintic:
Extracts from B. glabra leaves showed effectiveness against different worm species, including Pheretima posthuma, Eudrilus eugeniae, and Eisenia fetida. These extracts caused paralysis and death of the worms, suggesting potential anthelmintic properties.

Antimicrobial:
Traditional methods like agar diffusion and dilution were used to test various Bougainvillea extracts against bacteria and fungi. While results are promising, further research is crucial to understand the mechanisms and safe application of these properties [25].

Tackling Viral Foes:
Studies explored the antiviral potential of proteins from B. x buttiana against RNA viruses like tobacco mosaic virus. These proteins showed an ability to degrade viral RNA, offering hope for controlling plant viruses and protecting crops. Further research is needed to explore the mechanisms and applications of this activity.

Exploring Cancer Potential:
Extracts from B. glabra leaves and stems have shown antiproliferative activity against cancer cell lines in lab tests. This suggests potential in cancer research, but extensive studies are crucial to understand the mechanisms, safety, and efficacy of such extracts before any therapeutic applications can be considered.

Several studies have explored the antiproliferative and cytotoxic potential of Bougainvillea extracts against various cancer cell lines [26]:

B. Spectabilis:
Stem and leaf extracts showed varying cytotoxic activity depending on the solvent used.
Dichloromethane extract had the lowest activity among hexane, dichloromethane, acetonitrile, ethyl acetate, methanol, and butanol extracts against U373 cells.

Isolated compounds bougainvinones 79, 80, and 84 exhibited cytotoxicity against different cancer cell lines, with 84 showing the broadest activity on KB, HeLa S-3, HT-29, MCF-7, and HepG2 cells.

New flavones bougainvinones 86-90 isolated from ethyl acetate extract displayed cytotoxic activity against all tested cell lines including KB, HepG2, HeLa, S-3, HT-29, and MCF.

**B. X Buttiana:**

Orange-1 and Orange-2 flower extracts in ethanol showed higher cytotoxic activity against HeLa cells compared to pink, violet, and white ones.

Dichloromethane extract of bracts and flowers was the most cytotoxic among various solvent extracts (aqueous, methanol, ethanol, acetone, ethylacetate, dichloromethane, and hexane) against L-929 cells.

**Overall:**

Bougainvillea extracts from different species and parts (stems, leaves, flowers) exhibit promising antiproliferative and cytotoxic activity against various cancer cell lines. Specific activity varies depending on the extraction solvent and tested compounds. Dichloromethane extracts seem less active compared to others in some cases.

Further research is needed to understand the mechanisms of action, identify the most potent compounds, and evaluate their safety and efficacy for cancer treatment [27].

**Immunomodulatory Effects [28-29]:**

An ethanol extract of B. x buttiana showed potential to activate macrophages in mice, indicating potential for modulating the immune system. Further research is needed to understand its implications and applications.

**Antioxidant Powerhouse:** Numerous Bougainvillea species and parts (leaves, bracts, flowers) have demonstrated antioxidant activity in various studies. Here are some key findings:

**B. Buttiana:** Ethanol extracts displayed antioxidant activity and inhibited lipid peroxidation. Butanol and methanol extracts had the highest activity.

**B. Glabra:** Leaves and bracts extracted with methanol showed high antioxidant activity. Activity was detected by several techniques (FRAP, ORAC).

**B. Peruviana:** Ethanol extracts exhibited antioxidant activity.

**B. Spectabilis:** Both methanol and water extracts showed antioxidant activity. Leaf extracts also increased antioxidant enzymes in diabetic rats.

**B. X buttiana:**

All colored bract extracts demonstrated antioxidant activity, with varying effectiveness based on color and solvent used.

**Overall:**

Bougainvillea offers promising antioxidant potential against free radical damage. Different species, parts, and extraction methods can influence the activity.

More research is crucial to identify the most potent compounds, understand their mechanisms, and ensure safe and effective applications.

**Toxicity:**

While Bougainvillea captivates with its vibrant colors, its potential toxicity requires careful consideration:

**B. Glabra:** Aqueous extracts from leaves did not show toxicity in rats.

**B. Spectabilis:** Ethanol extracts from leaves can significantly reduce red blood cell count and hemoglobin levels in rats, potentially leading to anemia (20,80). Aqueous extracts from leaves also reduced red blood cell and hemoglobin levels in mice. Methanol extracts from leaves proved toxic in male rats. (50) However, oral administration of a methanol extract in mice didn't cause kidney or liver damage (59). Ethanol extracts from root bark did not show toxicity in rats.

**Overall:**

- While some Bougainvillea species and parts seem non-toxic, others, especially B. spectabilis leaves, warrant caution.
• Oral ingestion, particularly of specific extracts, can harm red blood cells and potentially cause anemia.

• Toxicity varies depending on the species, part used, and extraction method.

• More research is needed to fully understand the risks and safe limits of various Bougainvillea extracts.

Previous information revealed varying toxicity levels within Bougainvillea species. Here’s what we learned about additional parts and colors:

B. Spectabilis Flowers: Methanol extracts of flowers in various colors (white, orange, pink, red, and violet) showed no toxicity towards brine shrimp.

B. X Buttiana Bracts [28]: Ethanol extracts of bracts demonstrated no toxicity in two different mouse strains.

Overall:

These findings suggest that different parts and colors of Bougainvillea may have varying toxicity profiles.

While some extracts appear non-toxic, it’s crucial to exercise caution as different species and extraction methods can significantly impact toxicity.

More research is necessary to comprehensively understand the safety of consuming or using various Bougainvillea extracts [30].

CONCLUSION

This review delves into the intriguing world of Bougainvillea, where vibrant colors might mask fascinating properties that benefit our health. We explore traditional uses, chemical constituents, and scientific studies to understand the potential of this genus in various domains:

1. Rooted in Tradition:

Indigenous communities have long employed Bougainvillea for various ailments, including cough, asthma, stomach pain, and even wounds. These practices offer valuable clues for further research.

2. Unveiling the Chemistry:

Studies reveal a diverse range of phytochemicals within Bougainvillea, including betalains, flavonoids, and terpenes. Understanding these compounds is crucial to unlock their potential benefits.

3. Exploring Pharmacological Activities:

Research suggests Bougainvillea might possess properties that could be harnessed for various health concerns:

Anti-inflammatory: Studies hint at potential to combat inflammation, a key factor in many diseases.

Antioxidant: Bougainvillea may offer protection against free radical damage, linked to aging and chronic diseases.

Immunomodulatory: Evidence suggests possible modulation of the immune system, potentially aiding in immune defense or autoimmune disorders.

Antimicrobial: Some studies indicate potential effectiveness against bacteria and fungi, though further research is needed.

4. Safety Considerations:

While promising, potential toxicity requires careful consideration. While some species and parts seem safe, others, like B. spectabilis leaves, warrant caution. Different extraction methods can also impact toxicity.

5. The Road Ahead:

Though initial explorations are encouraging, the field of Bougainvillea research is still young.

Extensive studies are needed to: Validate traditional uses through rigorous scientific investigations. Isolate and characterize the active compounds responsible for observed effects. Conduct pre-clinical and clinical trials to assess safety and efficacy for specific health conditions. Bougainvillea, with its stunning beauty and potential health benefits, offers an exciting avenue for further research. As we delve deeper into its secrets, we might unlock novel therapeutic possibilities for a healthier future.

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