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# Genus Begoniaceae: A Review of Phytochemical and Pharmacological Activity

## (*Genus Begoniaceae: Kajian Review Fitokimia dan Aktivitas Farmakologis*)

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## ABSTRACT

**Background**: *Begonia* sp. (Begoniaceae) contains phytochemical compounds with significant pharmacological activities, including antioxidant, antibacterial, anticancer, and immunostimulant effect. **Objective**: Provide information about the phytochemical compounds and pharmacological activities of Begonia species. **Methods**: This narrative review was conducted by searching the literature using journal databases such as Google Scholar, PubMed, and ScienceDirect relevant from 2014 to 2024. **Results**: Nineteen articles met the inclusion and exclusion criteria of this research. The literature indicates that *Begonia* sp. exhibit various pharmacological activities influenced by phytochemical compounds. **Conclusions**: Phytochemical compounds in Begonia species support further research and present opportunities in drug development



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## INTRODUCTION

Medicinal plants have inspired the discovery of modern drugs, thereby aiding in the drug development process (Chaachouay & Zidane, 2024). The process is supported by the application of new disciplines and/or technologies that have undergone significant advancements such as computational methods, bioinformatics, pharmacogenomics, biomedical engineering, and nanotechnology (S. M. Haque & Ratemi, 2017). Information related to the phytochemical content of the Begonia genus, which has potential pharmacological activity, can further assist in the drug development process.

*Begonia* sp. (Begoniaceae) is among the largest genera of angiosperms. This genus occurs across tropical and subtropical regions, comprising ~1,870 species, primarily in Asia and to a lesser extent in Africa (Li *et al*., 2022; Maulana *et al*., 2023). Various Begonia species exhibit pharmacological activities. For example, *Begonia picta* exhibits significant antioxidant activity, evidenced by an $IC_{50}$ value of 66.72 µg/ml (Bhattarai & Rana, 2022). *Begonia malabarica* exhibits antibacterial activity against Staphylococcus epidermidis, Escherichia coli, and Pseudomonas aeruginosa (Mini Shobi & Gowdu Viswanathan, 2018). Moreover, *Begonia medicinalis* displays immunomodulatory properties, evidenced by the elevation of immune response-associated genes, such as Drosomycin (Drs), Diptericin (Dpt) (Imd pathway), and Turandot A (TotA) (JAK-STAT pathway) (Syamsidi *et al*., 2023). These activities are attributed to phytochemical compounds such as phenols, flavonoids, steroids, terpenoids, alkaloids, saponins, and tannins (Maulana *et al*., 2023). The pharmacological effects of Begonia continue to be researched, and therefore a comprehensive synthesis of these activities and the phytochemicals involved is warranted.

## METHODS

This article reviews research on the phytochemical profiles and pharmacological activities of the genus Begonia spp. using a narrative review design to inform drug development. This narrative review began with a literature search across Google Scholar, PubMed, and ScienceDirect, using the keywords “Begonia,” “phytochemicals,” and “pharmacological”. The screening procedure involved selecting studies based on their titles, abstracts, and keywords. The inclusion criteria were: (1) original, peer-reviewed research articles, (2) articles published from 2014 to 2024, and (3) studies reporting phytochemical composition and/or pharmacological activities of Begonia species. The exclusion criteria included articles that did not meet the inclusion criteria, such as non-original publications and articles without accessible full texts. The search identified 301 records, of which 19 studies met the eligibility criteria.

## RESULTS AND DISCUSSION

The following data were collected based on the literature study obtained regarding the phytochemical compounds and pharmacological activities of begonia species (Table 1).

Table 1. Pharmacological Activity and Phytochemical Compounds of Begonia Species

| Pharmacological Activity | Begonia species | Phytochemical Compounds | Activity | Reference |
|---|---|---|---|---|
| Antioxidant | *Begonia versicolor* Irmsch. | Phenolic compounds and tamarixetin glycosides from quercetin | $IC_{50}$ value of 8.67 ppm (DPPH scavenging activity Test) | (Abriyani & Fikayuniar, 2020) |
| | *Begonia grandis* Dryand. | Alkaloids, flavonoids, glycosides, triterpenoids, and steroids | $IC_{50}$ value of 214.33 µg/ml (DPPH scavenging activity Test) | (Pendy *et al*., 2020) |
| | | | $IC_{50}$ value of 246.97 µg/ml (Superoxide scavenging activity test) | |
| | | | $IC_{50}$ value of 199.36 µg/ml (Hydroxyl radical scavenging activity test) | |
| | *Begonia picta* Smith. | Polyphenol and flavonoids | $IC_{50}$ value of 42.11 µg/mL (DPPH Scavenging Activity test) | (Khairnar *et al*., 2022) |
| | | | $IC_{50}$ value of 60.74 µg/mL (Nitric Oxide Scavenging Activity Test) | |
| | | | The Reducing Power Assay test on the extract at a dose of 100 µg/mL yielded an absorbance value of 0.102 ± 0.005 | |
| | *Begonia rex* Putz. | Polyphenol and flavonoids | An increase in antioxidant enzyme activity such as Catalase (CAT) by 44% and Glutathione Peroxidase (GPX) by 62%, as well as total antioxidant capacity (TAC) by 34%. | (Buyun *et al*., 2018) |
| | *Begonia roxburghii* | Phenols and flavonoids | $IC_{50}$ value of 158.36±0.22 µg/mL (DPPH Scavenging activity test) | (Akter *et al*., 2020) |
| | *Begonia barbata* | Phenolics | $IC_{50}$ value of 6.22 µg/mL (DPPH Scavenging activity test) | (M. R. Haque *et al*., 2020) |
| Antibacterial | *Begonia goegoensis* N.E.Br. | Flavonoids | Inhibited antibacterial agents such as *Pseudomonas aeruginosa* and β-lactamase-producing strains of *Pseudomonas aeruginosa*. | (Tkachenko *et al*., 2017) |
| | *Begonia malabarica* Lam. | Polyphenol | Inhibited the activity of gram-positive and gram-negative bacteria. | (Thilagam *et al*., 2021) |
| | | Dibutyl Phthalate | The isolation of Dibutyl Phthalate compounds inhibited the activity of pathogens such as *Staphylococcus epidermidis* and *Escherichia coli*. | (Mini Shobi & Gowdu Viswanathan, 2018) |
| | *Begonia picta* | Flavonoids and phenols | Inhibited the growth of pathogenic bacteria such as *Salmonella typhi* | (Shrestha *et al*., 2015) |

| | | | | |
|---|---|---|---|---|
| Antidiarrhea | *Begonia roxburghii* | Rutin | Decreased diarrhea score and interacted with the iNOS enzyme (binding energy of 64.22 kcal/mol) and the Sep A protein (binding energy of 24.47 kcal/mol) produced by *Shigella flexneri* (in silico study). | (Prasad *et al*., 2023) |
| | *Begonia rubrovenia* | Quercetin | Interacted with the EP3 prostanoid receptor (binding energy of -150.69 kcal/mol) (in silico study) and reduced diarrhea symptoms. | (Prasad *et al*., 2024). |
| Anticancer and cytotoxic | *Begonia malabarica* dan *Begonia rex-cultorum 'Baby rainbow'* | Anthocyanin (polyohenol) | Inhibited oxidative stress and promoted apoptosis in malignant cells, including HT29, MG63, HeLa, and L929. | (Madanakumar & Kumaraswamy, 2018) |
| | *Begonia roxburghii* | Alkaloids, flavonoids, saponins | The cell membranes were disrupted, and oxidative stress was induced in the Artemia salina populations. | (Mobarak *et al*., 2018) |
| | *Begonia medicinalis* | Flavonoids | The proliferation and metastasis of cancer cells, including HeLa, MDA-MB-231, and HT-2, were inhibited, and apoptosis was induced. | (Prihardina & Fatmawati, 2021) |
| Anti-diabetic | *Begonia barbata* | Flavonoids, tannin and alkaloids | A decrease in blood glucose levels was observed by 38.99%. | (M. R. Haque *et al*., 2020) |
| Antibiofilm | *Begonia multangula* Blume. | Phenolics, flavonoids, terpenoids, and alkaloids | The extracellular polymeric substances (EPS) biofilm was disrupted. | (Jabbar *et al*., 2022) |
| Anti-Inflamatory | *Begonia trichocarpa* | Flavonoids, saponins and phenolics | The high membrane stabilization activity of 79.10% | (Jeyasekhar M P & Jaslin Edward J, 2020) |
| Anti-analgesic | *Begonia roxburghii* | Flavonoids and alkaloids | Inhibited mediators such as bradykinin, prostaglandins, and serotonin | (Mobarak *et al*., 2018) |
| Anti trombolitic | *Begonia roxburghii* | Flavonoids | Inhibited the formation of blood clots (lysis) by 47.77 ± 1.80% | (Mobarak *et al*., 2018) |
| Immunostimulant | *Begonia medicinalis* | Flavonoids | Increased proliferation of lymphocyte cells (immunostimulator) | (Khumaidi *et al*., 2020) |
| | *Begonia medicinalis* | Flavonoids, phenolics and saponins | Stimulates macrophage phagocytic activity and timor cytokine production *necrosis factor alpha* (TNF-α) and *interferon-gamma* (IFN-γ). | (Sulaiman Zubair *et al*., 2022) |
| Hepatoprotector | *Begonia grandis* Dryand. | Flavonoids, glycosides, steroids, triterpenoids, and alkaloids | Reduced lipid peroxidation and protected the liver from oxidative damage. | (Pendy *et al*., 2020) |

## Phytochemical and Pharmacological Activity of *Begonia* sp.

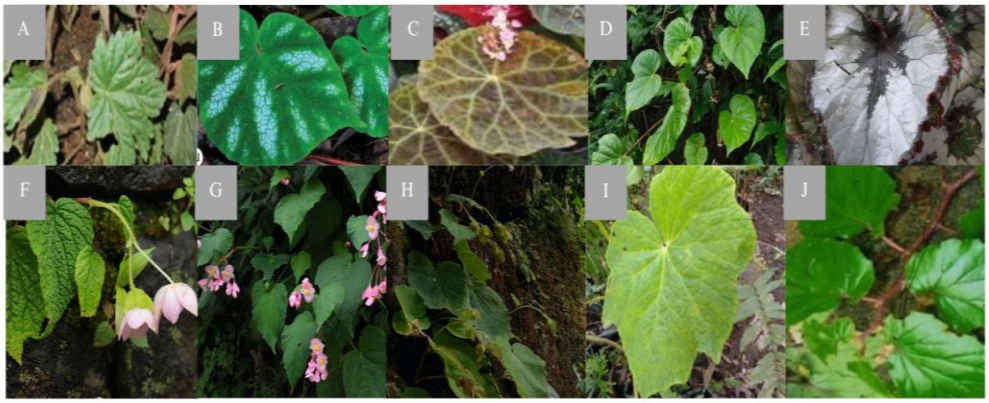


Figure 1. A. *Begonia medicinalis* (Khumaidi *et al*., 2020)., B. *Begonia versicolor Irmsch(Sheue et al., 2012).,*C. *Begonia goegoensis N.E.Br* (Siregar *et al*., 2018)., D. *Begonia roxburghii* (Gyeltshen *et al*., 2022)., E. Begonia *rex Putz.,* F. *Begonia picta.,* G. *Begonia grandis Dryand.,* H. *Begonia malabarica Lam.* (Royal Botanic Gardens, 2025)., I. *Begonia trichocarpa* (Jose & Kumar, 2016)., J. *Begonia multangula Blume* (Permata & Susandarini, 2022)

### 1) Antioxidant

Antioxidant activity can prevent and protect against a wide range of disorders, including neuroprotective, anti-inflammatory, anti-tumor, anti-aging, and anti-diabetic (Carpena *et al*., 2022). Phytochemical compounds influence the antioxidant activity of the Begonia genus, as shown in Table 1. The antioxidant activity of phenolic compounds and their derivatives, such as flavonoids, is capable of disrupting oxidative stress in biological systems by capturing free radicals such as hydroxyl radicals (OH) and hydrogen peroxide ($H_2O_2$), as a result of the presence of hydroxyl groups (M. R. Haque *et al*., 2020). *Begonia picta* Smith and *Begonia rex* Putz. possess flavonoid and polyphenol components (Buyun, 2018; Khairnar *et al*., 2022) *Begonia picta* exhibits antioxidant activity as evidenced by DPPH Scavenging Activity tests ($IC_{50}$: 42.11 µg/mL) and Nitric Oxide Scavenging ($IC_{50}$: 42.11 µg/mL). The Reducing Power Assay of the extract at a concentration of 100 µg/mL produced an absorbance value of 0.102 ± 0.005. The findings demonstrate that the extract of *Begonia picta* exhibits potent antioxidant activity, as evidenced by an $IC_{50}$ value of less than 50 µg/mL (Khairnar *et al*., 2022). *Begonia rex* Putz. exhibits antioxidant activity, as evidenced by the 44% increase in the activity of the Catalase (CAT) enzyme and the 62% increase in the Glutathione Peroxidase (GPX) enzyme in response to the addition of *Begonia rex* Put extract. The efficacy of this plant is demonstrated by a 34% increase in total antioxidant capacity (TAC) (Buyun, 2018). In a DPPH assay, *Begonia barbata*'s phenolic components exhibit significant antioxidant activity, evidenced by an $IC_{50}$ value of 6.22 µg/mL (M. R. Haque *et al*., 2020).

**2) Antibacterial activities**

Phytochemical compounds in medicinal plants have a wide potential for antibacterial activity, making them an alternative to address antibiotic resistance (Vaou *et al*., 2021). Several species in the genus Begonia are known to contain bioactive compounds related to this activity, such as *Begonia picta* which contains flavonoids and phenols (Shrestha *et al*., 2015). *Begonia goegoensis* which contains flavonoids (Thilagam *et al*., 2021), and *Begonia malabarica* which is known to contain polyphenols and dibutyl phthalate (Mini Shobi & Gowdu Viswanathan, 2018). Flavonoids and other phenolic compounds disrupt bacterial cell membranes, obstruct efflux pumps (EP), and interfere with cell wall biosynthesis by inhibiting urease, sortase A, and dihydrofolate reductase enzymes (Angelini, 2024). Dibutyl phthalate, initially extracted from *Begonia malabarica*, exhibits significant antibacterial activity against various pathogenic bacteria, including *Staphylococcus epidermidis, Streptococcus pneumoniae, Escherichia coli, Micrococcus luteus, Klebsiella pneumoniae, Shigella flexneri, Vibrio cholerae*, and *Pseudomonas aeruginosa* (Mini Shobi & Gowdu Viswanathan, 2018).

**3) Anti-diarrhea**

Diarrhea is defined by the occurrence of three or more bowel movements and the presence of watery stool consistency. Diarrhea treatment is frequently unsafe and ineffective, which has prompted research on compounds found in medicinal plants (Gahamanyi *et al*., 2021). Table 1 illustrates that Begonia genus plants, including *Begonia roxburghii* and *Begonia rubrovenia*, exhibit antidiarrheal properties. *Begonia roxburghii's* Rutin compound possesses antidiarrheal properties, as demonstrated by the decrease in the diarrhea score of the Shigella flexneri control group from 65.66 ± 3.49 to 16.33 ± 0.66. The results of the In Silico study demonstrate that the iNOS enzyme (binding energy of -64.22 kcal/mol) and the Sep A protein (binding energy of -24.47 kcal/mol) produce by Shigella flexneri have a significant affinity for interaction. As a result, these enzymes' activity is suppressed, perhaps leading to a reduction in diarrhea symptoms such as oxidative stress and inflammation (Prasad *et al*., 2023). *Begonia rubrovenia* contains quercetin compounds that can relax the smooth muscles of the intestines by inhibiting the process of defecation by reducing the discharge of $Ca^{2+}$ ions through the sarcoplasmic reticulum. In silico testing results indicate that the compound forms a bond with the EP3 receptor with a binding energy of -150.70 kcal/mol, which supports its activity (Prasad *et al*., 2024).

**4) Anticancer and cytotoxic activity**

Cancer remains a global problem due to the continuously increasing number of deaths. Treatment using synthetic drugs is often accompanied by side effects, highlighting the need to develop medications using medicinal plants (Ohiagu *et al*., 2021). Researchers had proven the potential anticancer properties of *Begonia malabarica*, *Begonia rex-cultorum* 'Baby Rainbow,' *Begonia roxburghii*, and *Begonia medicinalis*. *Begonia malabarica* and *Begonia rex-cultorum* 'Baby Rainbow' contained anthocyanin compounds, part of the flavonoid group, which inhibited oxidative stress and induced apoptosis in cancer cells like HT29, MG63, and HeLa. These compounds had been shown to be cytotoxic to fibroblast L929 cells in the MTT assay (Madanakumar & Kumaraswamy, 2018). Additionally, in Artemia salina bioassays, Begonia roxburghii was found to contain secondary metabolites, such as alkaloids, flavonoids, and saponins, which disrupt cell membranes and induce oxidative stress (Mobarak *et al*., 2018). Alkaloid compounds inhibit cancer cell proliferation by promoting apoptosis and limiting tumor invasion and metastasis (Ohiagu *et al*., 2021). Saponins have show**n** anticancer effects by increasing oxidative stress, thereby triggering apoptosis (Elekofehinti *et al*., 2021). *Begonia medicinalis* has demonstrated antitumor activity in MTT assay assessments. The flavonoid compounds present in the extract have been reported to induce apoptosis, inhibit proliferation, and impede metastasis in cancer cells, including HeLa, MDA-MB-231, and HT-29 (Prihardina & Fatmawati, 2021).

**5) Anti-diabetic**

The extract from *Begonia barbata* reduced blood glucose levels by 38.99% within 3 hours at a dosage of 200 mg/kg. The results were comparable to glibenclamide (2 mg/kg), which demonstrated a decrease of 39.79%. This occurrence developed as a result of enhanced insulin sensitivity or the suppression of glucose absorption in the intestines. Flavonoids, polyphenols, and alkaloids were the compounds that were implicated in this activity (M. R. Haque *et al*., 2020). Flavonoid compounds demonstrated anti-diabetic properties by enhancing glucose metabolism, inhibiting α-glucosidase, and regulating carbohydrate metabolism in pancreatic β cells, hepatocytes, adipocytes, and skeletal muscle myofibers (Hussain *et al*., 2020). Alkaloid substances decreased postprandial hyperglycemia by inhibiting the enzymes α-glucosidase and α-amylase, thus obstructing the conversion of carbohydrates into glucose (Rasouli *et al*., 2020). Tannin compounds inhibited the production of advanced glycation end products (AGEs), which are associated with vascular problems like nephropathy and diabetic retinopathy (Laddha & Kulkarni, 2019).

**6) Antibiofilm**

The polymicrobial antibiofilm properties of *Begonia multangula* Blume extract were demonstrated on catheters, which enabled the prevention or treatment of infections associated with these devices. The phytochemical components of this extract were phenolics, flavonoids, terpenoids, and alkaloids. Biofilm formation was significantly inhibited by this compound during the mid-phase and the maturation phase, with a maximum inhibition of 65.23% and 60.44%, respectively. The results were comparable to those of the control drugs, chloramphenicol and nystatin. This activity disrupted the biofilm's extracellular polymeric substances (EPS), thereby hindering the bacteria's ability to form complex structures (Jabbar *et al*., 2022). The significant lipophilic characteristics of phenolic compounds and their derivatives, such as flavonoids, have been shown to impede biofilm formation, thereby compromising bacterial membranes (Samrot *et al*., 2021). Terpenoid compounds also increased biofilm activity, although their efficacy was inferior to that of flavonoids. These compounds prevented the growth of biofilm by enhancing membrane permeability and modifying ion transport mechanisms in both gram-negative and gram-positive bacteria (Samrot *et al*., 2021). Alkaloid compounds disrupted the synthesis of nucleic acids, reduced the synthesis of cell walls, and damaged bacterial cell membranes in gram-positive, gram-negative, and antibiotic-resistant bacteria (Yan *et al*., 2021).

**7) Anti Inflamatory and anti analgesic**

The antioxidant activity of *Begonia trichocarpa* extract and the stabilization of human red blood cell (HRBC) membranes exhibited its anti-inflammatory potential. The activity value of 79.10% was greater than that of the control, sodium diclofenac, which was 69.26%. These results indicated the extract's potential for use in the development of new medications. The compounds that were involved in this activity were phenolics, saponins, and flavonoids. The compounds involved in this activity were flavonoids, saponins, and phenolics. These three compounds exhibited excellent antioxidant properties, which protected the body from oxidative stress and inhibited lipid peroxidation that could damage cell membranes (Jeyasekhar M P & Jaslin Edward J, 2020).

Anti-analgesic activity referred to a pain-relieving effect induced by activation of the central nervous system (CNS) and peripheral nervous system (PNS) (Silva-Correa *et al*., 2021). The extract of *Begonia roxburghii* exhibited analgesic properties by suppressing mediators, including bradykinin, prostaglandin, and serotonin, as demonstrated in the acetic acid-induced writhing test. A dosage of 400 mg/kg yielded a 55.42% inhibition, but the positive control sodium diclofenac (10 mg/kg) attained a 68.33% inhibition. In the formalin-induced pain test,

the 400 mg/kg dose of the extract exhibited a 56.52% inhibition in the early phase and a 62.52% inhibition in the late phase, while the positive control sodium diclofenac exhibited a 73.52% inhibition in the early phase. The active chemicals were flavonoids and alkaloids (Mobarak *et al*., 2018) Flavonoid compounds provided analgesic effects by activating the Nrf2/HO-1 pathway and interacting with prostaglandins and the 5-HT2 and 5-HT3 receptors in the central nervous system. Alkaloid substances interacted with receptors, including μ-opioid, TRPA1, and purinergic (P2X3, P2X7), which were involved in pain regulation (Silva-Correa *et al*., 2021).

**8) Anti trombolitic**

Thrombolysis problems could have influenced the development of cardiovascular diseases (CVD) and other illnesses. Phytochemical compounds derived from plants were regarded as an alternative to synthetic thrombolytic agents, including streptokinase, urokinase, and antistreplase, which had substantial adverse effects (Jain *et al*., 2023). Through blood clot lysis testing, *Begonia roxburghii* revealed thrombolytic activity with an activity result of 47.77 ± 1.80%, whereas streptokinase, the positive control, showed an activity of 73.13 ± 2.80%. The activity was affected by the flavonoid components found in the extract of *Begonia roxburghii* (Mobarak *et al*., 2018). Flavonoids reduced platelet activity by decreasing the activation of the GPIIb/IIIa receptor induced by agonists (Sharifi-Rad *et al*., 2022).

**9) Immunostimulant**

IImmunostimulant activity is a system to enhance the immune system in the body as an organism's defense to prevent and eliminate harmful pathogens (Fristiohady *et al*., 2020). One of the begonia species that has this activity is *Begonia medicinalis*. The extract from this plant can enhance macrophage phagocytosis activity, production of tumor necrosis factor alpha (TNF-α) and interferon-gamma (IFN-γ) cytokines, as well as increase lymphocyte proliferation activity (immunostimulator) (Khumaidi *et al*., 2020; Sulaiman Zubair *et al*., 2022). The compounds that were involved in these activities were saponins, phenolics, and flavonoids. Flavonoid compounds significantly improved innate immunity by increasing the activity of NK (natural killer) cells, inhibiting the maturation of dendritic cells (DC), and modulating the polarity of macrophages from the pro-inflammatory phenotype (M1) to the anti-inflammatory phenotype (M2). In addition, flavonoids also regulated adaptive immunity through the proliferation of T-regulatory (Treg) cells, CTLs, and B cells (Han *et al*., 2022). Phenolic compounds in immunostimulants worked by inhibiting the NF-kB and MAPK signaling pathways, thereby reducing the release of inflammatory mediators. These drugs modulated cytokine balance, augmented Th1, inhibited Th2, and promoted Treg proliferation

(Simões *et al*., 2024). Additionally, saponin compounds enhanced macrophage phagocytosis and the release of cytokines including IL-6 and TNF-α. These compounds activated CD4+ and CD8+ T cells, promoted the release of cytokines including IL-2 and IFN-γ, and enhanced the production of antigen-specific antibodies such as IgG, IgA, and IgM (Shen *et al*., 2024).

**10) Hepatoprotector**

The hepatoprotective activity of *Begonia grandis* in experimental animal models, caused by the hepatotoxin $CCl_4$, correlated with its antioxidant properties. The antioxidant activity protected the organism from free radicals, such as trichloromethyl and trichloromethyl peroxide produced from $CCl_4$, which triggered lipid peroxidation. Substantial destruction of liver plasma, including SGOT, SGPT, SALP, and total bilirubin levels, was induced by this procedure. The extract of *Begonia grandis* decreased that activity due to the presence of phytochemical compounds such as glycosides, alkaloids, steroids, triterpenoids, and flavonoids (Pendy *et al*., 2020). Flavonoid molecules and their derivatives, including glycosides, acted as radical scavengers for superoxide, lipid peroxides, and hydroxylated substances. These compounds inhibited free radicals by providing them hydrogen atoms from hydroxyl groups (Hassanpour & Doroudi, 2023) Triterpenoid and alkaloid compounds have the capacity to protect the liver by preventing oxidative stress (Zhou *et al*., 2021).

## Drug Development Potential

The identification of bioactive compounds and the prediction of their pharmacological activities are facilitated by advances in technology**,** which present significant opportunities for the development of medicinal plants (Noor *et al*., 2022). The stages of natural substance drug development include molecular model drug development, biological screening, extraction/isolation, and selection/authentication (Nasim *et al*., 2022). In addition, targeted drug-delivery systems such as nanoparticles, bioadhesive microspheres, and liposomes are being developed (Nasim *et al*., 2022). Herbal drug development has also involved the genus Begonia (Begoniaceae), such as the extraction of Begonia malabarica, from which dibutyl phthalate was isolated as an antibacterial compound using column chromatography. The compound was identified using HPTLC, UV-Vis, FTIR, NMR, and GC–MS analyses (Mini Shobi & Gowdu Viswanathan, 2018). Begonia roxburghii contains marker compounds such as rutin**,** which has been evaluated in silico for antidiarrheal activity against the target proteins secreted extracellular protein A (SepA) and inducible nitric oxide synthase (iNOS)**.** Docking results indicated a stable interaction between the target proteins and rutin molecules (Prasad *et al*., 2023). The extract of B*egonia medicinalis*, which contains immunomodulatory compounds such as flavonoids and saponins, was successfully formulated as SNEDDS-based nanoparticles**,** combined with moringa leaf extract (Moringa oleifera). The formulation met characterization and stability standards, and it

significantly enhanced macrophage phagocytic activity, lymphocyte proliferation and leukocyte counts. These findings highlight its potential as an innovative drug delivery system for plant-based immunostimulants (Asita *et al*., 2024;Zubair *et al*., 2025)

## CONCLUSION

The phytochemical profile of the genus Begonia (Begoniaceae) is highly promising for drug development, as it contributes to a variety of pharmacological effects, including antioxidant, antimicrobial, anticancer, antidiabetic, and immunostimulant activities. Opportunities for innovation in plant-derived pharmaceutical products are enabled by the application of advanced technologies, which substantially enhances this development.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest

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