Agrobiodiversity for Improving Nutrition, Health and Life Quality

Literature Review

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Traditional uses, Phytochemistry, and Pharmacological Potential of *Myroxylon peruiferum* L.f and *Myroxylon balsamum* (L.) Harms in Bolivia

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Considering the systemic toxicity and limited efficacy associated with conventional antidiabetic medications, there is an increasing demand for plant-based therapeutic alternatives. Herbal medicines have gained significant global attention due to their natural origin and reduced side effects. South American countries, including Bolivia, have a rich ethnobotanical heritage that plays a fundamental role in traditional medicine. This review focuses on *Myroxylon peruiferum* L.f and *Myroxylon balsamum* (L.) Harms, are two medicinal species from the Fabaceae family widely used in Bolivia for the treatment of malaria, respiratory infections (including bronchitis and laryngitis), rheumatism, and other inflammatory conditions. The study aims to provide a comprehensive overview of their geographical distribution, ethnobotanical relevance, phytochemical composition, and pharmacological properties, with an emphasis on their potential for future scientific investigation, sustainable collection, and commercialization. Both species are rich in bioactive secondary metabolites, including flavonoids, phenolics, fatty acids, aldehydes, and terpenoids, which contribute to their diverse biological activities. Previous *in vitro* and *in vivo* studies have reported their antiseptic, antibacterial, antimicrobial, antifungal, antimalarial, antileishmanial (*Leishmania amazonensis*), and antiviral properties. These pharmacological effects are attributed primarily to compounds present in their leaves, bark, wood, and fruits. Despite promising therapeutic potential, a substantial gap remains between traditional ethnomedicinal knowledge and pharmacological research. Further interdisciplinary studies integrating

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ethnopharmacology, phytochemistry, and clinical research are essential to validate the efficacy and safety of these species. This review underscores the need for scientific exploration of Bolivian medicinal plants, not only to support traditional healthcare practices but also to promote the development of bioactive natural products with economic and industrial significance.

Keywords: Bolivian traditional medicine, bioactive compounds, ethnopharmacology, Fabaceae, medicinal plantsn

Introduction

Olor aliteBolivia, with its diverse geography and climatic variability, encompasses a wide range of ecosystems that foster exceptional plant biodiversity. The country's four major ecological regions – the Chaco, Chiquitania, Andes (inter-Andean valleys), and Amazon – utilized an estimated 3,000 medicinal plant species, which play a fundamental role in traditional healthcare practices. Indigenous communities and local populations have long relied on these plant-based remedies to treat a variety of ailments, demonstrating an intricate knowledge of their therapeutic potential. Among these species, *Myroxylon peruiferum* L.f and *Myroxylon balsamum* (L.) Harms of the Fabaceae family stand out for their extensive ethnomedicinal applications (Cussy et al., 2017).

The genus *Myroxylon* has been widely recognized for its diverse pharmacological properties, including antioxidant, antiseptic, antibacterial, antifungal, and antimalarial activities (Pfützner et al., 2003; Silva-Júnior et al., 2015; Pereira et al., 2019a). Traditionally, extracts and balsams derived from *M. peruiferum* and *M. balsamum* have been utilized for the treatment of various respiratory conditions, such as bronchitis, nasal congestion, and cough. Additionally, these species have been employed in wound healing, antiseptic applications, and the management of mite infestations. Their analgesic and anti-inflammatory properties have also made them valuable in alleviating rheumatic pain and gastrointestinal disorders. The long-standing use of these plants in traditional medicine highlights their potential as alternative therapeutic agents for a broad spectrum of diseases (Vargas Ramirez, 1996; Thomas and Vandebroek, 2006).

Despite significant advancements in modern medicine, infectious and inflammatory diseases continue to pose major global health challenges. Conditions such as malaria and rheumatism remain highly prevalent, particularly in tropical and subtropical regions, necessitating the exploration of novel therapeutic agents. Medicinal plants, including *Cinchona* spp., *Geissospermum* spp., and *Myroxylon* spp., have historically provided bioactive compounds – such as alkaloids, flavonoids, and terpenoids – hat contribute to their pharmacological effects. Given their broad spectrum of biological activities, these species have drawn increasing scientific interest for their potential applications in drug discovery and natural product development (OMS, 2020).

Recognizing the critical role of traditional medicine in global healthcare, the World Health Organization's Traditional Medicine Strategy 2014–2023 advocates for the systematic integration of medicinal plants into conventional health systems (OMS, 2013). This strategy underscores the importance of validating traditional remedies through rigorous scientific research, ensuring their safety, efficacy, and sustainability. While *M. peruiferum* and *M. balsamum* have been extensively used in traditional medicine, a comprehensive understanding of their bioactive compounds, pharmacological mechanisms, and potential therapeutic applications remains limited (Ponce-Valle, 2019).

This review aims to systematically compile and analyze traditional knowledge alongside contemporary scientific findings related to the medicinal properties, phytochemistry, and pharmacological activities of *M. peruiferum* and *M. balsamum*. By bridging the gap between ethnobotanical practices and modern pharmacological research, this study seeks to:

a) highlight the therapeutic potential of these species,
b) elucidate their bioactive compounds and mechanisms of action,
c) encourage further research into their pharmacological applications.

Additionally, this review emphasizes the need for sustainable harvesting, conservation strategies, and potential commercial utilization of these valuable medicinal plants in the pharmaceutical and healthcare industries.

Botanical Description, Distribution and Ecological Characteristics of *Myroxylon peruiferum* and *Myroxylon balsamum*

The genus *Myroxylon*, belonging to the Fabaceae family, comprises two species: *Myroxylon peruiferum* L.f.

and *Myroxylon balsamum* (L.) Harms. These species are widely distributed across the Neotropical region, extending from Mexico in the north to Argentina, southern Brazil, and Paraguay in the south (Sartori et al., 2015). Their natural habitat includes primary and secondary tropical and subtropical forests, which grow under varying ecological conditions. Due to their adaptability, they can be found in diverse forest types, including dry deciduous, semi-deciduous, and humid forests, playing an important ecological role in these ecosystems (Aguilar-Sandí, 2020).

In Bolivia, *M. peruiferum* and *M. balsamum* are present across all four major ecological regions: the Chaco, Chiquitania (Brazilian-Paraná biogeographic province), Andes (Inter-Andean Valleys), and Amazon. These species are particularly prevalent in semi-deciduous dry forests, where they contribute to forest structure and biodiversity. However, their occurrence is relatively less frequent in humid forests, where environmental factors such as precipitation, soil composition, and competition with other flora may influence their distribution. Understanding the ecological preferences and geographic range of *Myroxylon* species is crucial for conservation efforts, sustainable management, and further research on their pharmacological potential. Figure 1 represents a map-based distribution of these two plants in Bolivia (Jørgensen et al., 2014; Araujo-Murakami et al., 2015).

Myroxylon peruiferum L.f.

M. peruiferum is a large deciduous tree that can reach heights of up to 50 meters, with a trunk diameter ranging from 20 to 70 cm. The bark is rough, greyish-brown, and often marked with distinctive whitish spots. Its leaves are compound, odd-pinnate, with alternate leaflets. The leaflet lamina measures approximately 3.0–4.5 cm in length and 1.5–3.0 cm in width, exhibiting translucent dots and streaks along with retuse to acuminate apices.

The inflorescence consists of racemes bearing papilionaceous flowers. The calyx lacks well-defined lobes, while the standard petal is broadly ovate.

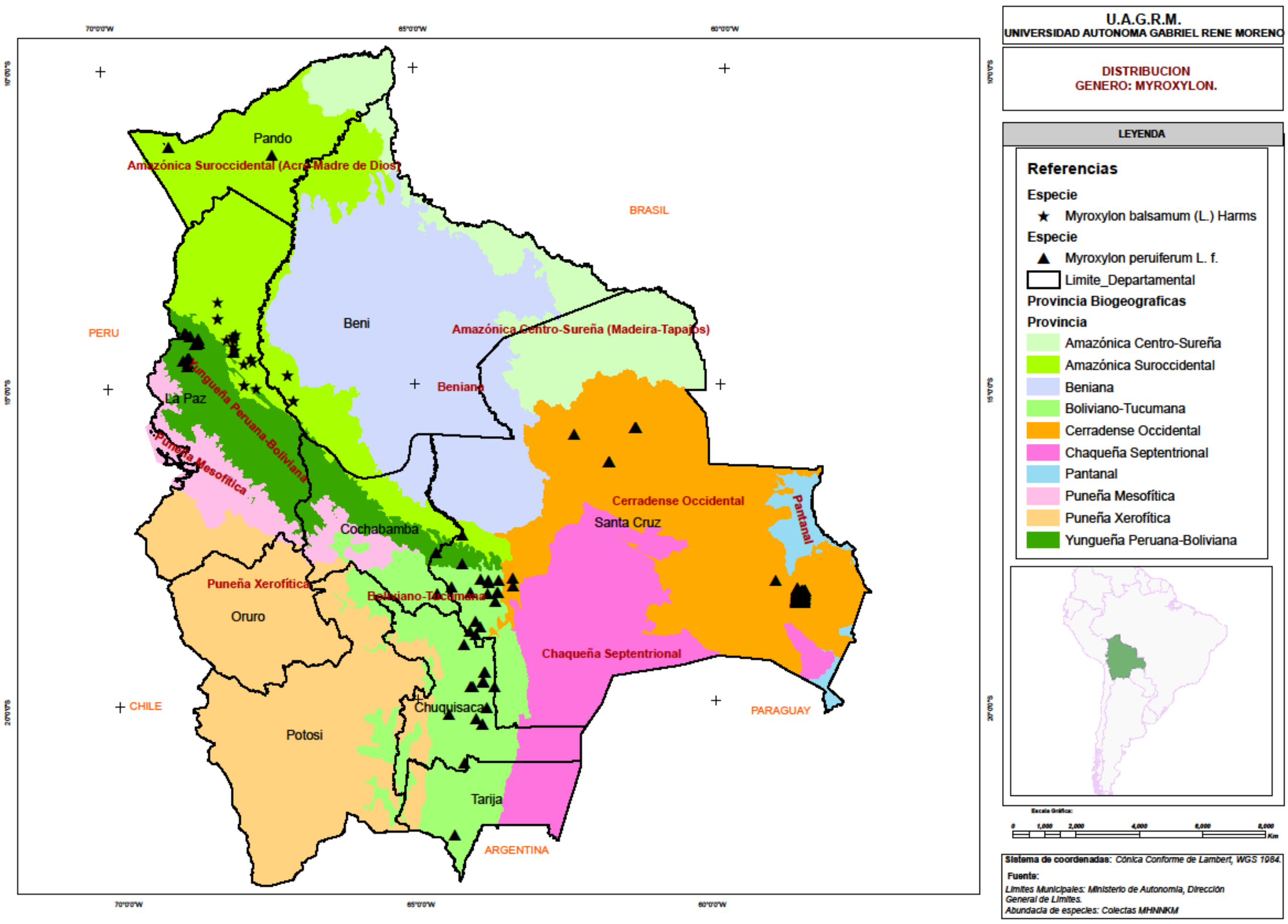

Figure 1 Distribution of *Myroxylon peruiferum* and *Myroxylon balsamum* in Bolivia

The fruit is a samara with a flattened seminiferous chamber in mature specimens, containing one or two kidney-shaped seeds. The seeds are characterized by a rough, resin-impregnated testa. These morphological attributes distinguish *M. peruiferum* from its close relative, *M. balsamum* (Sartori et al., 2015; Aguilar-Sandí, 2019).

Myroxylon balsamum (L.) Harms

M. balsamum is an evergreen tree, typically reaching heights between 30 and 50 meters. It has a straight, upright trunk with an average diameter of approximately 1 meter at breast height. The tree exhibits an ascending branching pattern and develops a rounded crown. Its leaves are compound, odd-pinnate, and range from 8 to 20 cm in length, including the petiole. Each leaf comprises 5 to 10 alternate leaflets.

The species produces axillary racemose inflorescences, measuring 10–20 cm in length, with pubescent zygomorphic white flowers. The calyx is lobed and measures between 6 and 8 mm in length, with petals inserted near the base of the calyx tube. The fruit is an indehiscent samara, housing one to two reniform seeds with a smooth testa. The seeds average 1.6 cm in length and exhibit a characteristic yellowish coloration along with a strong, fragrant aroma. The species possesses a well-developed branched taproot system. Cytogenetically, *M. balsamum* is a diploid species with a chromosome number of $2n = 14$. It thrives at altitudinal ranges between 900 and 2,100 meters above sea level, where annual precipitation levels vary from 1,000 to 1,500 mm, and temperatures range between 20 and 30 °C (Sartori et al., 2015; Aguilar-Sandí, 2020).

Ecological and Conservation Considerations

Both *M. peruiferum* and *M. balsamum* hold significant commercial and medicinal value due to their technological applications and bioactive compounds. However, the lack of sustainable silvicultural strategies for their harvesting and utilization poses a potential threat to their genetic diversity. Unregulated exploitation, combined with habitat loss, may contribute to genetic erosion, endangering the long-term viability of these species. Future conservation efforts should prioritize the development of sustainable management practices to ensure the preservation of these valuable medicinal and industrially important trees (Sartoti et al., 2015).

Ethnobotanical Significance of *Myroxylon peruiferum* and *Myroxylon balsamum*

Traditional Medicinal Uses

The genus *Myroxylon* has played a crucial role in traditional medicine across various indigenous and rural communities in South America, particularly in Bolivia and Peru. Extracts from the bark, resin, fruits, and leaves of *M. peruiferum* and *M. balsamum* have been widely employed in ethnomedicine for the treatment of respiratory, gastrointestinal, dermatological, and musculoskeletal disorders (Aguiar et al., 2022).

In Bolivia, a natural dye extracted from the bark is commonly used in traditional remedies for treating respiratory ailments, including cough, nasal congestion, bronchitis, and other pulmonary conditions. Additionally, it is utilized for gastrointestinal disorders such as stomachaches and digestive ailments (Thomas and Vandebroek, 2006). The resin, which contains bioactive compounds with antiseptic and anti-inflammatory properties, is an essential ingredient in healing balms, wound dressings, and antirheumatic ointments. However, prolonged exposure to the resin has been associated with hypersensitivity reactions, including contact dermatitis and eczema, necessitating cautious application in medicinal preparations (Bourdy et al., 1999; Pfützner et al., 2003).

Commercial and Industrial Applications

Beyond its medicinal applications, *Myroxylon* species hold significant economic value due to their high-quality timber. The wood is particularly prized in Bolivia for its durability, strength, and aesthetic appeal, characterized by a distinctive dark reddish hue. Classified as hard and heavy to very heavy (0.82–0.96 $kg.cm^{-3}$), the wood exhibits high resistance to fungal and insect infestations due to its natural chemical constituents. Furthermore, it is devoid of silica, which enhances its workability in carpentry and construction (Gutierrez, 2002). The wood is commonly utilized in fine furniture, flooring, and artisanal crafts.

Additionally, the bark and wood yield a natural dye, which has been traditionally employed in textile dyeing practices (Fuentes, 1993; Osorio-Cuellar, 2011). These industrial and medicinal applications underscore the significant economic potential of *Myroxylon* species, making them valuable not only for their therapeutic properties but also for sustainable commercial utilization.

Ethnobotanical Use in Bolivia

The species *M. peruiferum* and *M. balsamum* are widely distributed across Bolivia, where they are recognized under various vernacular names. In different indigenous languages, they are referred to as quina, quina quina, quina colorada, bálsamo (Apoleño), aquí madi (Tacana), cascaria (Tsimané), and chanachana (Yuracaré) (Thomas and Vandebroek, 2006; Araujo-Murakami et al., 2020).

- Yuracaré community: utilizes these species to treat anemia, "wind sickness," dizziness, and general weakness (Thomas and Vandebroek, 2006).
- Tacana people: the name "quina quina" originates from its traditional use as a malaria remedy (Bourdy et al., 1999).
- Uchupiamonas (Quechua-Tacana): employ the plant as a natural insect repellent (Paniaqua-Zambrana et al., 2017).
- Chimanes (Tsimané people): use preparations from *Myroxylon* species to manage diarrhea, cough, and common colds (Nates et al., 2001).
- Quechuas of Cochabamba's dry valleys: recognize its efficacy in treating toothache, earache, and as a hair-strengthening agent (Arrázola et al., 2002).

Ethnobotanical Use in Peru and the Amazon

In Peru, *Myroxylon* species are traditionally used to treat a wide range of ailments, including respiratory, neurological, infectious, and inflammatory conditions:

- Respiratory diseases: asthma, bronchitis, cough, lung infections, nasal congestion, and tuberculosis (Schultes and Raffauf, 1990; Bussmann and Sharon, 2015).
- Neurological disorders: nervous system imbalances, epilepsy, dizziness, and headaches (Bussmann and Sharon, 2015).
- Infectious diseases: malaria, venereal diseases, and fever management (Duke and Wain, 1981; Duke and Vasquez, 1994).
- Dermatological applications: treatment of wounds, abscesses, ulcers, scabies, and skin inflammation (Duke and Vasquez, 1994; Lorenzi and Matos, 2002).
- Musculoskeletal disorders: rheumatism, sprains, joint pain, and stiffness (Duke and Wain, 1981).

Additionally, extracts from *Myroxylon* species are widely incorporated into personal care and cosmetic products. The resin, fruits, and leaves are used in the formulation of anti-dandruff treatments, hair conditioners, deodorants, soaps, creams, and lotions.

Phytochemical Diversity and Biological Activities of *Myroxylon peruiferum* and *Myroxylon balsamum*

Phytochemistry of *Myroxylon* Species

The genus *Myroxylon* is characterized by a complex and diverse chemical composition, which includes essential oils, flavonoids, phenolic compounds, alkaloids, terpenoids, and steroids. These bioactive constituents are primarily responsible for the wide range of pharmacological properties exhibited by *M. peruiferum* and *M. balsamum*. The leaves of these species contain significant amounts of essential oils, with nerolidol being the predominant sesquiterpene, alongside various flavonoids and phenolic substances (Popova et al., 2002; Zitterl-Eglseer et al., 2012; Pereira et al., 2019a).

The major active phytochemicals extracted from *Myroxylon* species include phenolic compounds such as benzyl alcohol, benzoic acid, cinnamic acid, and vanillin, flavonoids and chalcones such as cabreuvin, coumarin, chalcone isoliquiritigenin, isoflavones, terpenoids such as (*E*)-Nerolidol, benzyl benzoate, benzyl cinnamate, pentacyclic triterpenes, cabreuvin and *E*-nerolidol (Aguiar et al., 2022).

Specifically, *M. peruiferum* is reported to contain isoflavones, nerolidol, vanillin, and flavonoids as key bioactive constituents (Maranduba et al., 1979; Ohsaki et al., 1999; Pereira et al., 2019). In contrast, *M. balsamum* is particularly rich in pentacyclic triterpenes, which contribute to its medicinal properties (Mathias et al., 2000).

Additionally, hexane fractions derived from *Myroxylon* species contain a significant proportion of flavonoids, including cabreuvin and chalcone isoliquiritigenin, which are well-documented for their pharmacological potential (Simas et al., 2004).

Pharmacological Properties and Biological Activities

The bioactive compounds present in *Myroxylon peruiferum* and *Myroxylon balsamum* have been extensively studied for their antimicrobial, antioxidant, antiparasitic, anticancer, and dermatological properties, with their pharmacological effects primarily attributed to flavonoids, alkaloids, terpenoids, and essential oils (Rocha et al., 2007). Several studies have confirmed the potent antibacterial and antifungal activities of *Myroxylon* species, with isoflavones, essential oils, and cabreurin playing key roles in inhibiting pathogenic bacteria and fungi (Pereira et al., 2019). Specifically, the isoflavan and essential oil extracts of *M. peruiferum* have demonstrated significant antimicrobial effects against Gram-positive bacteria and filamentous fungi (Pereira et al., 2019), while its hydroalcoholic bark extract exhibits potent activity against *Escherichia coli*, *Enterobacter aerogenes*, *Klebsiella pneumoniae*, *Providencia* spp., *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Salmonella typhimurium* (Gonçalves et al., 2005; Gonçalves, 2007; Matos-Neto, 2013; Pereira et al., 2018). Additionally, hexane and chloroform fractions from *M. peruiferum* bark show high efficacy against *S. aureus*, one of the most common bacterial pathogens (Pereira et al., 2019a), and the isoliquiritigenin chalcone isolated from this species has potent activity against *S. aureus*, *S. epidermidis*, and *S. haemolyticus* (Machado et al., 2005). Ethanol extracts from *M. balsamum* have also been successfully incorporated into antimicrobial soaps targeting *S. aureus* (Requeno Ardón and Madrid Guzmán, 2012). Beyond bacterial and fungal infections, *Myroxylon* species exhibit notable antiparasitic and antimalarial properties, with essential oil extracts from *M. peruiferum* fruits (100 μg.mL^{-1}) demonstrating strong activity against *Leishmania amazonensis*, the causative agent of cutaneous leishmaniasis (Muñoz et al., 2000, 2000a, 200b; Andrade et al., 2016). Moreover, *M. peruiferum* extracts have shown antifungal efficacy against *Chalara paradoxa* and *Fusarium guttiforme*, two major fungal pathogens affecting crops and human health (Lee and Lee, 2010; Sales et al., 2016). The sesquiterpene *E*-nerolidol, found in the bark of *M. peruiferum*, also displays high larvicidal activity against *Aedes aegypti*, the vector of dengue and Zika viruses, with significant effects observed at concentrations of 17 ppm and 0.9 ppm (Chantraine et al., 1998; Simas et al., 2004). The antioxidant potential of *Myroxylon* essential oils is remarkable, with over 90% inhibition of the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) at concentrations of 100 mg.mL^{-1}, 25 mg.mL^{-1}, and 5 mg.mL^{-1}, suggesting promising applications in pharmaceutical and nutraceutical formulations targeting oxidative stress-related diseases. In addition to their antimicrobial and antioxidant properties, *Myroxylon* species also demonstrate significant anticancer potential, with dichloromethane and ethanol extracts of *M. peruiferum* exhibiting cytostatic and cytocidal effects against various cancer cell lines, including melanoma, breast carcinoma, resistant breast carcinoma, large cell carcinoma, leukemia, ovarian, prostate, colorectal, and renal cell adenocarcinomas (Jankowsky, 2005). Furthermore, the monoterpene ascaridol, found in *Myroxylon* extracts, has been reported to exert antineoplastic effects against ovarian, lung, brain, cervical, and glioma cancer cells, while also demonstrating antiviral activity against picornavirus, adenovirus, cytomegalovirus, herpes, and influenza viruses (De Souza Alwes et al., 2019). The dermatological and anti-inflammatory properties of *Myroxylon* species are largely attributed to benzoic and cinnamic acid derivatives, particularly benzyl benzoate and benzyl cinnamate, which have been successfully applied in the treatment of allergic and irritant contact dermatitis, as well as photosensitivity reactions in animals, such as dogs, without causing irritation or allergic responses (Popova et al., 2002; Zitterl-Eglseer et al., 2012). Collectively, these findings highlight the significant pharmacological potential of *M. peruiferum* and *M. balsamum*, supporting their use in antimicrobial, antiparasitic, antioxidant, anticancer, antiviral, and dermatological applications. Table 1 emphasizes the major bioactive compounds and potential biological activities of both studied plants.

Conclusions and Future Perspectives

Scientific studies substantiate the traditional medicinal use of *Myroxylon balsamum* and *Myroxylon peruiferum*, demonstrating their rich phytochemical diversity and biological activities. Extracts from various plant parts, including leaves, fruits, bark, and wood, prepared using ethanol, methanol, hydroalcoholic solutions, essential oils, and ethyl acetates, serve as a fundamental basis for pharmacological applications. Their bioactive compounds, including flavonoids, terpenoids, and phenolics, exhibit antibacterial, antifungal, antiparasitic, antioxidant, anticancer, and dermatological properties, reinforcing their pharmacological relevance. However, despite their widespread traditional use, scientific validation through rigorous phytochemical and pharmacological investigations remains crucial to confirm their therapeutic efficacy and safety.

The increasing commercial demand for *M. balsamum* and *M. peruiferum* for medicinal and timber purposes raises concerns regarding overexploitation and genetic erosion. Sustainable harvesting and conservation strategies must be developed to ensure the long-term availability of these valuable species. Integrating ethnobotanical knowledge with advanced analytical techniques will enhance the understanding of their medicinal potential and facilitate their incorporation into modern healthcare and pharmaceutical industries.

Table 1 Bioactive phytochemicals, biological activities and traditional use of *M. peruiferum* and *M. balsamum* from Bolivia

Scientific name	Common or local name	Parts used	Traditional preparations	Major chemical constituents	Biological activities	References
***Myroxylon balsamum* (L.) Harms**	quina-quina, quina, quina colorada, bálsamo	bark, wood	infusions, essential oil	benzyl benzoate, benzyl cinnamate, cinnamyl cinnamate, cabreurin, pentacyclic triterpenes, hexane fraction of flavonoids, cabreuvin and sesquiterpene ***E***-Nerolidol	anti-feedant activity, antioxidant, cytoprotective, antispasmodic and antibacterial activities	De Groot, 2019 Aguiar et al., 2022 Jurowski, 2023
***Myroxylon peruiferum* L. f.**	quina-quina, quina, quina colorada, bálsamo	leaves, fruits, bark and wood	ethanolic extract, methanolic extract, essential oil, hydroalcoholic extract, Isoflavin (7-hydroxy-4′, 6-dimethoxy-isoflavin), and ethyl acetate extract	isoflavonoids, coumarin, cabreurin, cabreuvin, coumarin, isoliquiritigenin, chalcone and alcohols such as benzyl alcohol, benzoic acid, vanillin, cinnamic acid, Enerolidol, benzyl benzoate, and benzyl cinnamate	antimicrobial, antimalarial, antioxidant activities and cytotoxicity activity	Muñoz et al., 2000b Silva-Júnior et al., 2015 Andrade et al., 2016 Pereira, 2018

Future research should focus on the isolation and structural elucidation of novel bioactive compounds using advanced chromatographic and spectroscopic techniques to identify and characterize the bioactive constituents responsible for pharmacological activities. Furthermore, mechanistic and pharmacological studies should investigate the molecular mechanisms underlying the bioactivity of *Myroxylon* species using *in vitro* and *in vivo* models to elucidate their therapeutic potential. Pathway analysis and cellular assays will be essential in determining their mode of action.

Additionally, preclinical and clinical validation through controlled trials is necessary to assess the efficacy, pharmacokinetics, and safety profiles of these extracts, particularly in antimicrobial, anticancer, and anti-inflammatory applications. Sustainable resource management and conservation efforts should also be prioritized to prevent genetic depletion and ensure the long-term availability of these species for medicinal use. In situ and ex situ conservation strategies, combined with community-based initiatives, will be critical in achieving this goal. Finally, the formulation and development of novel drugs using extract optimization techniques, including nanotechnology and biotechnology approaches, could enhance bioavailability and therapeutic efficacy. By integrating traditional knowledge with state-of-the-art phytochemical, pharmacological, and conservation strategies, *M. balsamum* and *M. peruiferum* hold significant promise as valuable sources of new therapeutic agents in modern medicine.

Conflicts of Interest

The authors declare no conflict of interest.

Ethical Statement

This article doesn't contain any studies that would require an ethical statement.

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