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Medicinal Benefits and Bioactive Compounds of Artemisia Species: A Critical Comparative Literature Review

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Index Terms

Artemisia, Bioactive Compounds, Medicinal Plants, Phytochemistry, Pharmacological Activities.

Abstract

This study provides a critical comparative analysis of recent scientific literature on Artemisia species, with particular emphasis on their medicinal compounds and biologically active constituents. The study aimed to examine the phytochemical diversity of Artemisia and evaluate its reported pharmacological activities based on peer-reviewed studies published between 2020 and 2025. The analysis revealed that Artemisia species are rich in secondary metabolites, including essential oils, terpenoids, flavonoids, phenolic acids, coumarins, sesquiterpene lactones, and artemisinin-related compounds. These constituents are strongly associated with antioxidant, antimicrobial, anti-inflammatory, antiparasitic, enzyme-inhibitory, cytotoxic, and potential antidiabetic activities. The reviewed studies generally support the medicinal importance of Artemisia; however, the degree of biological activity varies considerably according to plant species, geographical origin, plant organ, harvesting stage, extraction method, solvent type, and experimental design. The findings also indicate that most available evidence remains based on in vitro and computational approaches, while in vivo, toxicological, pharmacokinetic, and clinical studies remain limited. Therefore, although Artemisia represents a promising natural source of bioactive compounds, its therapeutic application requires further standardization, compound isolation, mechanism-based validation, toxicity assessment, and clinically relevant investigation. Overall, the study concludes that Artemisia should be regarded as a chemically diverse medicinal genus with significant pharmacological potential, but its use in pharmaceutical or therapeutic applications must be supported by rigorous scientific validation.

الفوائد الطبية والمركبات النشطة حيويًا لأنواع الشيح (Artemisia): مراجعة أدبية نقدية مقارنة

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الكلمات المفتاحية

الشيح، المركبات النشطة حيويًا، النباتات الطبية، الكيمياء النباتية، الأنشطة الدوائية.

الملخص

تقدم هذه الدراسة تحليلًا نقديًا مقارنًا للأدبيات العلمية الحديثة حول أنواع الشيح، مع التركيز على مركباتها الطبية ومكوناتها النشطة حيويًا. هدفت الدراسة إلى فحص التنوع الكيميائي النباتي لنبات الشيح وتقييم أنشطته الدوائية المبلغ عنها استنادًا إلى دراسات محكمة منشورة بين عامي 2020 و2025. أظهر التحليل أن أنواع الشيح غنية بالمستقلبات الثانوية، بما في ذلك الزيوت الأساسية، والتربينويدات، والفلافونويدات، والأحماض الفينولية، والكومارينات، واللاكتونات السيسكويتربينية، والمركبات المرتبطة بالأرتيميسينين. وترتبط هذه المكونات بأنشطة مضادة للأكسدة والميكروبات والالتهاب والطفيليات، إضافة إلى نشاط مثبط للإنزيمات وسمي خلوي واحتمال نشاط مضاد للسكري. كما بينت النتائج أن معظم الأدلة المتاحة تعتمد على دراسات in vitro ومقاربات حاسوبية، بينما لا تزال الدراسات in vivo والسمية والحرائك الدوائية والسريرية محدودة. لذلك، يمثل الشيح مصدرًا طبيعيًا واعدًا للمركبات النشطة حيويًا، غير أن تطبيقه العلاجي يحتاج إلى توحيد قياسي، وعزل للمركبات، وتحقق قائم على الآليات، وتقييم للسمية، ودراسات سريرية ذات صلة.

1. INTRODUCTION

Plants of the genus Artemisia, belonging to the family Asteraceae, are among the most widely studied medicinal plants because of their diverse bioactive compounds and broad therapeutic applications. The genus includes more than 500 species, comprising herbaceous and semi-shrub forms that grow mainly in temperate and semi-arid regions (Bora & Sharma, 2011; Nigam et al., 2019). Traditionally, Artemisia species have been used for the treatment of malaria, digestive disorders, fever, inflammation, microbial infections, and some parasitic diseases, reflecting their wide medicinal relevance across different cultures.

One of the most significant compounds isolated from Artemisia annua is artemisinin, a sesquiterpene lactone that represents a cornerstone in modern antimalarial therapy (Sharifi-Rad et al., 2022). However, the medicinal value of Artemisia is not limited to artemisinin alone. Various species synthesize a wide range of primary and secondary metabolites, including terpenes, flavonoids, phenolic acids, coumarins, sesquiterpene lactones, and essential oils, which have been associated with antioxidant, antimicrobial, anti-inflammatory, anticancer, antidiabetic, and enzyme-inhibitory activities (Bisht et al., 2021; Diab et al., 2025).

Flavonoids such as chrysosplenol D, casticin, and artemetin are important antioxidant constituents in Artemisia, contributing to the reduction of oxidative damage and enhancement of cellular protection. Phenolic compounds also play a major role in neutralizing free radicals and protecting biological molecules, including DNA, from oxidative stress (Nigam et al., 2019; Sharifi-Rad et al., 2022). In addition, essential oils of Artemisia species commonly contain volatile compounds such as camphor, cineole, thujone, borneol, and davanone, which have demonstrated antimicrobial and anti-inflammatory effects in laboratory studies (Aati et al., 2020; Khan et al., 2022).

Despite the promising pharmacological potential of Artemisia, the chemical composition of these plants varies considerably according to species, geographical origin, plant part, harvesting season, and extraction method. This variability may influence therapeutic efficacy and raises important questions regarding safe dosage, active compounds, toxicity, and standardization. Therefore, there is a need for a critical comparative review that connects the phytochemical composition of Artemisia species with their medicinal benefits and evaluates the extent to which traditional uses are supported by modern scientific evidence.

2. RESEARCH PROBLEM

Despite the widespread traditional and modern use of Artemisia species in medicinal applications, there remains a lack of comprehensive scientific understanding of the relationship between their bioactive compounds and precise therapeutic effects. Although many studies have reported antioxidant, antimicrobial, anti-inflammatory, anticancer, antiparasitic, and antimalarial activities, much of the evidence remains based on crude extracts, essential oils, in vitro assays, and computational models. Furthermore, geographical and ecological variation in chemical composition may affect biological activity, making it difficult to determine safe dosages, standardized extracts, and the most active compounds.

3. RESEARCH QUESTIONS

1. What are the major bioactive compounds identified in different Artemisia species?
2. How do these compounds contribute to medicinal properties such as antioxidant, antimicrobial, anti-inflammatory, antimalarial, and anticancer activities?
3. How does geographical variation influence the chemical composition and therapeutic potential of Artemisia species?
4. Which medicinal applications of Artemisia are scientifically supported, and which remain mainly traditional or insufficiently validated?

4. RESEARCH OBJECTIVES

The main objective of this study is to critically analyze the medicinal benefits and bioactive compounds of Artemisia species. The specific objectives are:

1. To identify and classify the major bioactive compounds in Artemisia species, including terpenes, flavonoids, phenolic acids, coumarins, essential oils, and artemisinin-related compounds.
2. To analyze the medicinal benefits of these compounds, with emphasis on antioxidant, antimicrobial, anti-inflammatory, antimalarial, cytotoxic, and antidiabetic activities.
3. To examine the impact of geographical variation, plant part, extraction method, and analytical technique on chemical composition and biological activity.
4. To compare traditional medicinal applications with modern scientific findings in order to assess the validity of reported therapeutic uses.
5. To identify major research gaps related to compound isolation, mechanism of action, toxicity, bioavailability, and clinical relevance.

5. SIGNIFICANCE OF THE STUDY

This study is significant because it provides a critical and organized synthesis of scientific literature on Artemisia species and their medicinally important compounds. It contributes to the understanding of how phytochemical composition is related to biological activity and therapeutic potential. The study may also support future research concerned with natural product

development, standardized herbal extracts, complementary medicine, and pharmaceutical applications.

In addition, the study highlights the importance of safety and toxicity assessment. Although Artemisia species are widely used in traditional medicine, natural origin does not necessarily guarantee safety. Some compounds, such as thujone, may produce toxic effects at high doses or with prolonged use. Therefore, evaluating the pharmacological potential of Artemisia requires a balanced approach that considers both therapeutic activity and safety limitations.

6. KEY TERMS

Artemisia: A medicinal plant genus within the family Asteraceae that includes several species with pharmacological and economic importance.

Bioactive compounds: Natural compounds found in plants that produce biological effects in living organisms.

Terpenes: Plant-derived compounds commonly found in essential oils and associated with antimicrobial, anti-inflammatory, and anticancer activities.

Flavonoids: Polyphenolic compounds with antioxidant, anti-inflammatory, and protective biological effects.

Phenolic acids: Plant secondary metabolites known for antioxidant and anti-inflammatory properties.

Coumarins: Natural compounds associated with anti-inflammatory, antioxidant, and potential pharmacological activities.

Artemisinin: A sesquiterpene lactone isolated from Artemisia annua, widely used in antimalarial therapy.

7. LITERATURE REVIEW

The genus Artemisia represents one of the medicinally important plant genera due to the richness and diversity of its secondary metabolites, including essential oils, terpenoids, flavonoids, phenolic acids, coumarins, sesquiterpene lactones, and artemisinin. Between 2020 and 2025, scientific interest in Artemisia increased considerably, not only because of its traditional therapeutic uses, but also because it is viewed as a promising biological source for the discovery of antioxidant, antimicrobial, anti-inflammatory, anticancer, antiparasitic, and potentially antiviral compounds.

7.1 Essential Oils and Antimicrobial Activity

Aati et al. (2020) investigated the chemical composition and antimicrobial activity of essential oils extracted from Artemisia absinthium, Artemisia scoparia, and Artemisia sieberi grown in Saudi Arabia. Using GC-MS and GC-FID analyses, the study revealed that these essential oils were rich in volatile compounds such as camphor, cineole, and thujone, which are commonly associated with antibacterial and antifungal activity. The comparative value of this study lies in its examination of more than one species within the same geographical environment. However, its main limitation is that the findings remained within the scope of in vitro assays.

Batiha et al. (2020) presented an extensive review of the bioactive compounds, pharmacological activities, and pharmacokinetics of Artemisia absinthium. The review highlighted active compounds such as thujone, artabsin, flavonoids, and phenolic compounds, which may explain antimicrobial, anti-inflammatory, antiparasitic, antioxidant, and other biological effects. Nevertheless, the review relied on methodologically heterogeneous studies, which indicates the need for standardized experimental investigations.

7.2 Phenolic Composition and Antioxidant Activity

Mohammed et al. (2021) focused on the phenolic composition, antioxidant capacity, and antibacterial activity of Artemisia herba-alba. The study demonstrated that white wormwood extracts contain phenolic and flavonoid compounds with antioxidant and antibacterial potential. Its strength lies in attempting to relate biological activity to chromatographically separated phenolic fractions. However, further cellular and animal-model studies are needed to confirm biological efficacy.

Chebbac et al. (2021, 2022, 2023) examined essential oils from different Artemisia species, including A. negrei, A. aragonensis, and A. annua. These studies confirmed antioxidant and antimicrobial activities, particularly against drug-resistant microorganisms. Their value lies in focusing on antimicrobial resistance, but their limitation is that the use of whole essential oils makes it difficult to determine which individual compounds or synergistic combinations are responsible for the observed effects.

Ed-Dra et al. (2021) investigated the effectiveness of essential oil from the aerial parts of Artemisia herba-alba against multidrug-resistant bacteria isolated from food and hospitalized patients. The study is important because it used clinically and environmentally relevant isolates. However, moving from in vitro efficacy to practical medical or food-related applications requires further evaluation of toxicity, stability, antibiotic interactions, and possible effects on human cells.

Ali et al. (2021) studied antioxidant and antibacterial activities, as well as cytotoxic effects on a liver cancer cell line, of extracts from Artemisia absinthium and Citrus paradisi. The findings indicated that wormwood extract exhibited biological activity and reduced cancer cell viability. However, because another plant species was included in the experimental design, it is difficult to isolate the independent contribution of Artemisia absinthium in some findings.

Bisht et al. (2021) provided a comprehensive review of the phytochemistry and pharmacological activity of the genus Artemisia. The review showed that the genus contains a wide range of bioactive compounds, including terpenoids, flavonoids, saponins, carotenoids, and polysaccharides. Its value lies in providing broad theoretical background, although its general scope limits detailed discussion of each individual species.

Khan et al. (2022) examined essential oils extracted from the leaves of Artemisia scoparia and Artemisia absinthium in terms of chemical profile, antioxidant activity, antimicrobial activity, and cholinesterase

inhibitory effects. This study expanded the research focus from antimicrobial activity to neuropharmacological potential. However, in vitro enzyme inhibition alone is insufficient to infer clinical effectiveness against neurological disorders.

Mohammed (2022) investigated the phytochemical composition, antioxidant potential, and cytotoxicity of Artemisia absinthium growing in the central region of Saudi Arabia. The study reported phenolic and flavonoid compounds, antioxidant activity, and cytotoxic effects against selected cancer cells. Critically, crude extracts may contain both beneficial and potentially harmful compounds, which requires compound isolation and dose-response evaluation.

Mohammed et al. (2022) explored phytochemical composition and antimicrobial activities of several Artemisia species and attempted rapid isolation of artemisinin from Artemisia annua. The study combined phytochemical analysis, antimicrobial testing, and isolation of a well-known pharmaceutical compound. However, the relatively low yield of artemisinin raises questions about extraction efficiency and industrial feasibility.

Ouedrhiri et al. (2022) studied the antibacterial effect of an optimized mixture of essential oils from Myrtus communis, Artemisia herba-alba, and Thymus serpyllum. The findings suggested that combining essential oils may enhance antibacterial activity. However, the effect of Artemisia alone is difficult to isolate within the mixture.

7.3 Phytochemical Profiling and Metabolomic Studies

Salih et al. (2023) identified and quantified bioactive compounds in Artemisia judaica, Artemisia monosperma, and Artemisia sieberi grown in Saudi Arabia. Using GC-MS, UV-Vis, and HPLC techniques, the study detected compounds such as gallic acid, tannic acid, quercetin, and artemisinin. This study is significant because it combined qualitative identification with quantitative estimation, although it focused more on chemical characterization than direct biological testing.

Liu et al. (2023) conducted metabolomic analysis and evaluated antibacterial and antioxidant activities of three Artemisia species from Tibet. The study found that these plants contain flavonoids, phenolic acids, coumarins, and artemisinins. Its comparative metabolomic approach is valuable, but stronger causal links are needed between specific compounds and observed biological activities.

7.4 Applied Pharmacological and Bioprospecting Studies

Chakraborty et al. (2023) investigated essential oil and extract of Artemisia vulgaris produced from meta-topolin-induced micropropagated plants, with activity against urinary tract infection pathogens. The study adds an applied dimension by proposing sustainable and controlled production. However, consistent pharmaceutical quality standards remain necessary.

Jha et al. (2023) evaluated the physicochemical properties and biological potential of essential oil from Artemisia pallens, including antimicrobial, antitubercular, antimalarial, anticancer, antibiofilm, and antioxidant activities. Its broad testing scope is valuable, although each biological activity requires independent mechanistic validation.

7.5 Recent Reviews and Comparative Evidence

Negri et al. (2024) examined the chemical diversity and potential bioactivity of five Artemisia species, including A. absinthium, A. annua, and A. vulgaris. The study confirmed that Artemisia represents a rich reservoir of compounds that extend beyond artemisinin. However, translating bioprospecting findings into drug development requires compound isolation and preclinical testing.

El Ouardi et al. (2024) investigated essential oils from Artemisia herba-alba and Artemisia huguetii in Morocco using in vitro evaluation and computational modeling. The study demonstrated geographical variation in chemical composition and biological activity. However, computational modeling remains supportive and should be confirmed experimentally.

Alsaleh et al. (2024) evaluated Artemisia absinthium root extract and its antidiabetic, antibacterial, anticancer, and antioxidant activities, supported by ADMET prediction and molecular docking. The study is important because it focused on the root, a less frequently studied plant part. However, the wide range of biological activities requires fractionation and clarification of structure-activity relationships.

Diab et al. (2025) provided a recent review of phytochemistry, biological activities, and uses of Artemisia species. The review emphasized that flavonoids, terpenoids, essential oils, and phenolic acids are associated with antimicrobial, antioxidant, anti-inflammatory, and anticancer activities. However, comprehensive reviews cannot replace local experimental studies connecting plant species, habitat, extraction method, chemical composition, and biological efficacy.

7.6 General Critical Analysis of Previous Studies

The reviewed studies reveal that recent research on Artemisia has shifted from merely describing traditional uses toward more precise chemical analyses using GC-MS, HPLC, metabolomics, and computational modeling. Essential oils and phenolic extracts are the most frequently investigated forms, while the compounds most often associated with biological activity include camphor, thujone, 1,8-cineole, davanone, borneol, quercetin, gallic acid, phenolic acids, and flavonoids.

However, most studies remain either in vitro or computational and have not progressed sufficiently to in vivo models or clinical trials that could confirm therapeutic efficacy in humans. In addition, differences in plant species, geographical origin, harvesting stage, extraction method, solvent type, and analytical approach lead to substantial variation in chemical composition and biological outcomes. Therefore, findings from one Artemisia species cannot be generalized to all species.

8. RESEARCH GAP

Despite the increasing number of recent studies on Artemisia species and their bioactive constituents, several important research gaps remain evident. Most available studies have focused mainly on chemical profiling, antioxidant activity, and antimicrobial potential of essential oils or crude extracts. Although these studies provide valuable preliminary evidence, many of them remain limited to in vitro assays and do not sufficiently progress toward in vivo validation, clinical evaluation, or comprehensive toxicological assessment.

Another major gap concerns the lack of standardization in extraction methods, plant parts used, geographical origin, harvesting season, and analytical procedures. The reviewed studies show that the phytochemical composition of Artemisia varies significantly according to species, habitat, and extraction technique. This variability makes it difficult to compare findings across studies or establish reliable pharmacological standards.

In addition, most studies have investigated crude extracts or whole essential oils rather than isolating and testing individual bioactive compounds. While compounds such as thujone, camphor, 1,8-cineole, davanone, quercetin, gallic acid, phenolic acids, flavonoids, and artemisinin have been repeatedly reported, the precise contribution of each compound to the observed biological effects remains unclear. This creates a methodological gap because the biological activity of crude extracts may result from synergistic interactions, antagonistic effects, or unidentified minor constituents.

Furthermore, although antimicrobial and antioxidant activities are widely investigated, fewer studies have deeply explored the molecular mechanisms underlying the pharmacological effects of Artemisia compounds. The mechanisms related to antibacterial action, anti-inflammatory pathways, anticancer effects, enzyme inhibition, cellular toxicity, and bioavailability remain insufficiently clarified. Therefore, further research is needed to clarify the relationship between the phytochemical composition of Artemisia and its medicinal effects, particularly through compound isolation, mechanistic evaluation, and studies on locally grown species.

9. METHODOLOGY

This study adopted a critical comparative literature review approach to examine previous scientific studies related to Artemisia species, their medicinal compounds, and bioactive constituents. The review focused mainly on peer-reviewed articles published between 2020 and 2025, while foundational references were used where necessary to support background information. A total of 28 references were included and evaluated, with emphasis on studies available through Google Scholar and indexed in reputable scientific databases such as Scopus, PubMed, ScienceDirect, SpringerLink, MDPI, Frontiers, and other peer-reviewed platforms.

The search process was conducted using combinations of relevant keywords, including “Artemisia,” “wormwood,” “Artemisia herba-alba,” “Artemisia absinthium,” “Artemisia annua,” “bioactive compounds,” “phytochemical composition,” “essential oils,” “antioxidant activity,” “antimicrobial activity,” “medicinal plants,” and “pharmacological properties.” Studies were included if they were directly related to Artemisia, written in English, published in peer-reviewed journals, and contained clear methodological details and a valid DOI. Studies were excluded if they were unrelated to Artemisia, lacked sufficient methodological clarity, lacked DOI information, or did not provide relevant phytochemical or pharmacological findings.

The selected studies were analyzed according to predefined comparative criteria, including the Artemisia species investigated, plant part used, extraction method, analytical techniques, identified bioactive compounds, biological activities, and major findings. Particular emphasis was placed on comparing phytochemical profiles and medicinal activities across species and geographical origins. The analysis also critically evaluated methodological strengths and limitations, especially regarding the use of crude extracts, essential oils, in vitro assays, computational models, toxicity evaluation, and mechanistic validation.

10. RESULTS

The findings of the current critical comparative study indicate that Artemisia species represent a chemically diverse genus with considerable medicinal potential, mainly due to the abundance of phenolic acids, flavonoids, sesquiterpene lactones, coumarins, monoterpenes, and oxygenated essential-oil constituents. This finding is consistent with the general conclusions reported by Bisht et al. (2021), Sharifi-Rad et al. (2022), Negri et al. (2024), and Diab et al. (2025), who emphasized the pharmacological value of Artemisia as a source of diverse secondary metabolites. Across the reviewed literature, the strongest agreement was observed in relation to antioxidant, antimicrobial, anti-inflammatory, enzyme-inhibitory, and antiparasitic potential.

phenolic acids, flavonoids, sesquiterpene lactones, coumarins, monoterpenes, and oxygenated essential-oil constituents. Across the reviewed literature, the strongest agreement was observed in relation to the antioxidant, antimicrobial, anti-inflammatory, enzyme-inhibitory, and antiparasitic potential of Artemisia extracts and essential oils.

The current study further found that phenolic compounds, particularly chlorogenic acid, dicaffeoylquinic acid derivatives, caffeoylquinic acids, rutin, luteolin, quercetin derivatives, and other flavonoids, are among the most consistently reported contributors to the antioxidant capacity of Artemisia species. This agrees with the findings of Mohammed et al. (2021), Trifan et al. (2022), Liu et al. (2023), and Țicolea et al. (2024). However, antioxidant activity

differs substantially according to species, plant organ, extraction solvent, geographical origin, and growth stage.

Regarding antimicrobial activity, the current study found broad support for the antibacterial and antifungal potential of Artemisia essential oils and extracts, particularly against Gram-positive bacteria, selected Gram-negative bacteria, fungal pathogens, and mycobacterial strains. This is supported by Aati et al. (2020), Chebbac et al. (2021, 2022, 2023), Ed-Dra et al. (2021), Khan et al. (2022), Singh et al. (2023), and Nikitin et al. (2023). Nevertheless, antimicrobial efficacy is not uniform across the genus and should be interpreted in relation to chemotype, extraction method, tested microorganism, and assay conditions.

The anti-inflammatory potential of Artemisia species was also supported by recent studies, especially those showing effects on oxidative stress and inflammatory pathways. However, compared with in vitro antioxidant and antimicrobial evidence, the number of in vivo and mechanistic studies remains relatively limited.

Another major result is that safety and toxicity remain central limitations in the medicinal application of Artemisia. Although several studies confirmed promising bioactivities, compounds such as thujone may be associated with toxic effects at high doses or prolonged exposure. Therefore, Artemisia species are pharmacologically promising, but their therapeutic application requires standardization of extract composition, dosage, route of administration, and toxicity evaluation.

11. DISCUSSION

The findings of this critical comparative study confirm that the medicinal importance of the genus Artemisia is mainly associated with its rich and variable profile of bioactive secondary metabolites, particularly essential oils, terpenoids, flavonoids, phenolic acids, coumarins, sesquiterpene lactones, and artemisinin-related compounds. This interpretation is supported by previous studies, which consistently reported that different Artemisia species possess antioxidant, antimicrobial, anti-inflammatory, antiparasitic, enzyme-inhibitory, and cytotoxic activities.

One of the major points of agreement between the current study and previous research concerns antioxidant potential. The present findings indicate that phenolic acids and flavonoids are among the most important contributors to antioxidant activity. This agrees with studies reporting phenolic compounds in Artemisia herba-alba and other species. Nevertheless, many studies report correlations between total phenolic or flavonoid content and antioxidant assays without proving direct causality between individual compounds and specific mechanisms of action.

The current study also supports the antimicrobial potential of Artemisia essential oils and extracts. Several studies confirm this finding, particularly those focusing on volatile constituents such as camphor, thujone, 1,8-cineole, borneol, davanone, sabinene, and eucalyptol. However, most antimicrobial evidence remains in vitro, and therefore activity observed through inhibition zones or MIC values cannot be directly translated into clinical use without toxicity testing, pharmacokinetic evaluation, and validation in infection models.

The anti-inflammatory and cytotoxic findings also require cautious interpretation. Although several studies indicate that Artemisia compounds may influence oxidative stress, inflammatory signaling, enzyme activity, and cancer cell viability, crude extracts may contain compounds with nonspecific toxicity. Therefore, future research should isolate active compounds, evaluate selectivity against normal and diseased cells, and clarify dose-response relationships before proposing therapeutic applications.

The study also highlights an important methodological issue: biological activity is strongly affected by extraction and analytical techniques. Essential oil studies frequently identify camphor, thujone, borneol, 1,8-cineole, and davanone, whereas phenolic studies commonly report chlorogenic acid, caffeoylquinic acid derivatives, rutin, quercetin, and gallic acid. This difference does not necessarily represent contradiction; rather, it reflects methodological selectivity.

Overall, the discussion confirms that previous literature largely supports the medicinal potential of Artemisia. Agreement is strongest regarding antioxidant and antimicrobial activities, followed by anti-inflammatory, enzyme-inhibitory, cytotoxic, antiparasitic, and antidiabetic potential. However, disagreement and variability appear in the degree of activity, dominant chemical constituents, biological mechanisms, and safety profile. These differences are most likely explained by species diversity, environmental conditions, plant part used, extraction method, chemical composition, and experimental design.

12. CONCLUSION

This study concludes that Artemisia species represent a chemically diverse medicinal genus with significant pharmacological potential. The reviewed literature confirms that Artemisia plants contain important bioactive compounds, including essential oils, terpenoids, flavonoids, phenolic acids, coumarins, sesquiterpene lactones, and artemisinin-related constituents. These compounds are associated with antioxidant, antimicrobial, anti-inflammatory, antiparasitic, antimalarial, cytotoxic, enzyme-inhibitory, and potential antidiabetic activities.

However, the study also confirms that the therapeutic potential of Artemisia cannot be generalized without considering species variation, geographical origin, plant part, harvesting stage, extraction method, and biological testing model. Most available evidence remains preliminary, relying mainly on in vitro assays and computational predictions. Therefore, transforming Artemisia from a promising medicinal plant into a reliable pharmaceutical or therapeutic resource requires rigorous standardization, compound-level investigation,

mechanistic validation, toxicity assessment, and clinically relevant research.

13. RECOMMENDATIONS

Based on the findings of this critical comparative study, several recommendations can be proposed. First, future studies should focus on the standardization of extraction methods, analytical techniques, and biological assays, since the reviewed literature showed considerable variation in results due to differences in plant species, geographical origin, plant organ, harvesting stage, and solvent type.

Second, further research should move beyond crude extract evaluation and focus on isolation, purification, and structural identification of individual bioactive compounds responsible for antioxidant, antimicrobial, anti-inflammatory, cytotoxic, antiparasitic, and enzyme-inhibitory activities.

Third, more mechanistic studies are recommended to explain how Artemisia compounds exert their biological activities at the cellular and molecular levels.

In particular, future research should investigate pathways related to oxidative stress, inflammation, microbial membrane disruption, enzyme inhibition, apoptosis, and immune modulation.

Fifth, future studies should include more in vivo and preclinical models, since most available evidence remains based on in vitro or computational approaches. Animal-model studies and well-designed clinical trials are needed to determine whether laboratory findings can be translated into safe and effective therapeutic outcomes in humans.

Sixth, locally relevant Artemisia species should receive more research attention, especially species growing in specific ecological and geographical environments. Since chemical composition is strongly influenced by climate, soil, altitude, season, and habitat, regional studies may help identify chemotypes with high medicinal value.

Finally, interdisciplinary research is recommended by combining phytochemistry, pharmacology, microbiology, toxicology, computational biology, and pharmaceutical formulation.

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