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SYNERGISTIC THERAPEUTIC POTENTIAL OF BIOACTIVE COMPOUNDS IN CAPPARIS DECIDUA AND SALVADORA OLEOIDES: AN INTEGRATIVE REVIEW

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Abstract
The integrative review explores the synergistic therapeutic potential of bioactive compounds in Capparis decidua (Kair) and Salvadora oleoides (Peelu), two ethnobotanically significant plants from arid zones. Both species are rich in flavonoids, alkaloids, glucosinolates, and phenolic acids, demonstrating antioxidant, anti-inflammatory, antimicrobial, anticancer, and antidiabetic properties. Recent studies highlight that their combined extracts exhibit enhanced bioactivity compared to individual treatments, attributed to multi-target modulation and pharmacokinetic interactions. For instance, synergistic effects include superior free radical scavenging (DPPH: 81% vs. 74.2% and 70.5%), broader antimicrobial action (e.g., 18 mm zone against E. coli), and improved glucose reduction (47.2% vs. 36.5% and 29.7%). Mechanistic insights reveal complementary phytochemical profiles–C. decidua's glucosinolates and S. oleoides' isothiocyanates–targeting oxidative stress, inflammation, and metabolic pathways. Despite promising preclinical data, clinical validation, standardization, and long-term safety studies remain critical for translating these findings into polyherbal formulations. The review underscores the plants' potential as cost-effective, multi-target therapies for chronic diseases while advocating for advanced research in omics-guided drug development and regulatory harmonization.

INTRODUCTION

Medicinal plants are one of the remarkable sources of bioactive molecules and have been the source of several pharmaceuticals and healthcare products (Al-Snafi, 2023). It is noteworthy, that in the arid zone vegetation, Capparis decidua (Caper bush or Kair) and Salvadora oleoides (Toothbrush tree or Peelu) have been found to have a great ethnobotanical and pharmacological importasnce. Both species are acclimatized to extreme conditions and have been widely employed as folk medicine to cure various health issues, including infections, metabolic disorders and inflammatory diseases (Bhatti et al., 2022; Kumar et al., 2021).

The increasing incidence of chronic diseases and the ineffectiveness of single-target pharmaceuticals have reignited interest in plant-based remedies. A lot of

attention is also given to synergistic interactions of phytochemicals: both within a species (Ezzat et al., 2018) and between different species (García et al., 2005), and their impact on the increased cost-efficiency of the treatment and reduction of side effects (Majeed et al., 2024). In this scenario, C. decidua and S. oleoides have received renewed focus as prospective candidates owing to their potential synergistic phytochemical composition.

Table 1. Bioactive compounds from plants used for the treatment of cardiovascular diseases.Flavonoides and polyphenols.

Compound	Plant Source	Mechanism of Action	Cardiovascular Effect
Quercetin	Onions, apples, berries	Antioxidant, vasodilation via NO synthesis	Lowers BP, improves endothelial function
Catechins	Green tea (Camellia sinensis)	Antioxidant, anti-inflammatory	Reduces LDL oxidation, improves lipid profile
Resveratrol	Grapes, red wine, peanuts	Inhibits platelet aggregation, vasodilator	Cardioprotective, improves blood flow
Hesperidin	Citrus fruits	Enhances endothelial function, anti-inflammatory	Lowers BP, reduces capillary fragility
Ellagic Acid	Pomegranates, berries	Antioxidant, anti-inflammatory	Reduces atherosclerotic risk

several **bioactive compounds from plants** have shown promising effects in the **treatment and prevention of cardiovascular diseases (CVDs)** such as hypertension, atherosclerosis, heart failure, and stroke. These natural compounds often exert **antioxidant, anti-inflammatory, antihypertensive, lipid-lowering, and antithrombotic** effects.

Table 2. Bioactive compounds from plants uded for the treatment of cardiovascular diseases.Alkaloides,Saponins,Tannins.

2: Phytochemical Profiles of Capparis decidua and Major Compound Classes

Compound	Plant Source	Mechanism of Action	Cardiovascular Effect
Reserpine	Rauwolfia serpentina	Inhibits sympathetic activity	Potent antihypertensive
Berberine	Berberis goldenseal	AMPK activation, lipid regulation	Reduces LDL, improves insulin sensitivity
Saponins	Ginseng, soybeans, fenugreek	Interfere with cholesterol absorption	Hypocholesterolemic, anti-arrhythmic
Tannins	Tea, grapes, persimmons	Antioxidant, astringent effect	Prevent LDL oxidation, reduce inflammation

Salvadora oleoides

The promising medicinal value of C. decidua and S. oleoides is attributed to their wide range of phytocomponents. Scientific studies on their secondary metabolites disclosed the existence of a large number of bioactive compounds are responsible for their diverse pharmacological activities (Al-Snafi, 2023; Kumar et al., 2021). This Section reviews comparative investigations of the phytochemical compositions of the plants, focusing on significant compound classes, major compounds, and the recent progress in their analytical profiling.

Phytochemistry of Capparis decidua

Capparis decidua is a reservoir of bioactive phytochemicals such as;

Flavonoids: Quercetin, kaempferol, isorhamnetin, and their glycosides are the main and well-known flavonoids for their antioxidant and anti-inflammatory properties.

Alkaloids: Prominent alkaloids acetophenone, capparisine and stachydrine are present in fruits and bark that are responsible in part for the antimicrobial and antihypertensive effects.

Glucosinolates: The sulfur-containing compounds that give the plant much of its fiery flavor and have demonstrated anticancer activity.

Phenolic acids: The considerable amounts of gallic, caffeic, and ferulic acids have high free radical scavenging effects.

Terpenoids and Saponins: Terpenoids and saponins have role in stem and leaves that contributes to anti-inflammatory and hepatoprotective activities of the plant (Kumar et al., 2021; Bhatti et al., 2022).

Quantitative and Qualitative Analysis

New analytical methods (e.g. high-performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS), and liquid chromatography-mass spectrometry (LC-MS)) in studies involving the identification and quantification of these components, made it possible to perform exact analysis of them. For example, Bhatti et al. 2022) showed high fruit and bark total phenolic content which corresponded with strong antioxidant activity.

PHYTOCHEMICAL STUDY OF Salvadora oleoides

Major Compound Classes

Salvadora oleoides shows a wide variety of bioactive constituents such as;

Alkaloids: Salvadorine and trimethylamine are the main alkaloids, which are frequently associated with antimicrobial, as well as anti-inflammatory properties.

Flavonoids Rutin, myricetin, and apigenin have been reported as being major constituents, which contributes to their antioxidant, and anticancer activities.

Isothiocyanates: Benzyl isothiocyanate a sulfur containing compound, as a naturally occurring antimicrobial, anticancer and inducing detoxification (Sharma et al., 2021).

Phenolic glycosides and Tannins: These offer additional source of antioxidants and antimicrobial activity.

Essential Oils: The seeds and leaves provide essential oils like eugenol, linalool and methyl salicylate which are used for their antimicrobial and anti-inflammatory properties (Al-Snafi, 2023; Sharma et al., 2021).

Analytical Methods

GC-MS and LC-MS analyses have been used to detect and profile essential oils and phenolic compounds in S. oleoides (62). Recent work by Sharma et al. (2021) profiled both volatile and non-volatile compounds as a complete identification of phytochemical components of such plant is important.

Comparative Phytochemistry and Its Significance

The two species have, in common, flavonoids, alkaloids, and phenolic acids, although some compounds are characteristic or appear as higher in one of them. For example, glucosinolates are characteristic for C. decidua and isothiocyanates are predominant in S. oleoides (Majeed et al., 2024). The amphoteric property of these phytochemicals profile(s) can have a biochemical foundation of possible therapeutic synergisms, an aspect recently emphasized in polyherbal studies (Majeed et al., 2024; Ahmad et al., 2023).

Advances in Phytochemical Research

Omics (metabolomics, proteomics) and advanced chromatographic tools are more and more used to get an overview of the whole secondary metabolites in the two plants as well. This exhaustive profiling not only provides strength to the conventional uses but also aids modern drug designing and development (Rana et al., 2023).

Section3: Pharmacological Activities of Capparis decidua and Salvadora oleoides

Capparis decidua and Salvadora oleoides contains diverse range of phytochemicals which are responsible for their broad pharmacological activities. Over the last decade researchers have warranted many of such claimed pharmacological effects of phenolics based on strong experimental and clinical evidence of their antioxidant, anti-inflammatory, antimicrobial, anticancer and antidiabetic properties (Al-Snafi, 2023; Rana et al., 2023). This section resumes these major bioactivities, probing into both the mechanism bases and the implications for drug development.

Antioxidant Activity

Oxidative stress is thought to be involved in several diseases, such as cancer, diabetes, and cardiovascular diseases. Both C. decidua and S. oleoides exhibited excellent antioxidant potential, which was imparted by their flavonoids and phenolic contents (Bhatti et al., 2022; Sharma et al., 2021).

Mechanism: The extracts are good scavengers of reactive oxygen species (ROS) and inhibits lipid peroxidation. This is predominantly through compounds such as quercetin, rutin and gallic acid (Kumar et al., 2021).

Evidence: In vitro and in vivo studies indicate that the plants have good antioxidant potential (DPPH, ABTS, FRAP) both in animals (Bhatti et al., 2022; Sharma et al., 2021).

Anti-Inflammatory Effects

Chronic inflammation is the root cause of most chronic diseases, from arthritis to metabolic syndrome.

Capparis decidua: Extracts of this plant down-regulate inflammatory signaling pathways which include the inhibition of pro-inflammatory cytokines (TNF-α, IL-6) and significant decrease in the activity of enzymes (COX-2) (Kumar et al., 2021).

Salvadora oleoides: It has alkaloids and isothiocyanates that inhibit the expression of mediators of inflammation and oxidative stress (Sharma et al., 2021; Al-Snafi, 2023).

Animal Models: In animal studies, treatment with extracts of GSP reduces edema, modulates inflammatory response, and protects tissue in models of either plant-mediated ailments (Majeed et al., 2024).

Antimicrobial Activity

Escalation of pathogenic-antibiotic resistance has driven the search for new antibacterial compounds. Both the plants have exhibited potent antibacterial and antifungal activities:

Capparis decidua: It is potent against both Gram-positive bacteria, e.g., Staphylococcus aureus and Gram-negative bacteria E.coli. The effect is due to the alkaloids, glucosinolates and saponins (Ahmad et al., 2023; Kumar et al., 2021).

Salvadora oleoides: Showed inhibitory activity against a number of bacterial and fungi strains, benzyl isothiocyanate and essential oils were the major contributions (Sharma et al., 2021).

Synergistic Effects: The extracts in combination exhibit greater antimicrobial activity than that displayed by single extracts indicating synergy of their bioactive components (Majeed et al., 2024).

Anticancer Potential

Several phytochemicals of both species have exhibited cytotoxicity against cancer cell lines and investigated as chemo preventive agents (Rana et al., 2023).

Mechanisms: Apoptosis induction, inhibition of cell growth, cell cycle arrest, and regulation of PI3K/AKT and NF-κB signaling (Rana et al., 2023).

Preclinical Evidence: Extracts from both plants have shown substantial in vitro and animal in vivo anticancer activity, particularly against breast, colon, and liver cancers.

Synergism: There is a growing body of data suggestion a possible synergy between the extracts of the 2 species with regard to their anticancer potential, owing to the mutual action of glucosinolates and isothiocyanates (Majeed et al., 2024).

Antidiabetic and Metabolic Effects

Plants Phytotherapeutic from these plants have metabolic syndrome and diabetes as major indications:

Capparis decidua: Reducing the blood glucose, normalizing the lipid profile and protecting the pancreatic β-cells of the diabetic animals (Kumar et al., 2021).

Salvadora oleoides: Demonstrates the hypoglycemic and hypolipidemic properties, decreasing oxidative stress of diabetes (Al-Snafi, 2023).

Additive Effect of Combination Therapy: The simultaneous administration of both plant extracts have additive effect in the attenuation of blood glucose, along with amelioration in all parameters of metabolism (Majeed et al., 2024).

Other Pharmacological Actions

Hepatoprotective: The two plants provide protection against chemically-induced liver damage in animal studies likely due to antioxidant and anti-inflammatory compounds (Kumar et al., 2021).

Neuroprotective And Cardioprotective: Preliminary studies indicate neuroprotective effects by attenuating the extent of neuronal damage and enhancing cognition and cardiac function (Al-Snafi, 2023; Rana et al., 2023).

The broad pharmacological actions of C. decidua and S. oleoides are justified with their phytochemical abundancy. However, recent studies have provided evidence to the concept of synergy that when both plants are taken together, the therapeutic effect is better than when they are each taken alone. This emphasizes the significance of polyherbal formulations and merits additional research, while clinical studies are also warranted.

4: Synergistic Effects and Mechanistic Insights

Introduction to Synergy in Phytotherapy

Synergy in phytotherapy refers to the phenomenon where the combined effect of multiple plant extracts or compounds exceeds the sum of their individual effects (Majeed et al., 2024). This concept is particularly relevant for complex diseases, where single-target therapies often prove insufficient. In recent years, the combined use of Capparis decidua and Salvadora oleoides has gained attention due to their complementary phytochemical profiles and observed potentiation of therapeutic effects.

Evidence of Synergistic Activity

Antioxidant and Anti-Inflammatory Synergy

When extracts of both plants are administered together, studies report enhanced antioxidant and anti-inflammatory effects compared to individual treatments (Bhatti et al., 2022; Majeed et al., 2024).

Antioxidant Synergy: Co-treatment improves free radical scavenging activity (as shown by higher DPPH and ABTS inhibition) and greater reduction in oxidative markers in cellular and animal models.

Anti-Inflammatory Synergy: Combined extracts more effectively suppress inflammatory cytokines such as TNF-α and IL-6 and inhibit key enzymes (COX-2, iNOS) in inflammation pathways (Majeed et al., 2024).

Antimicrobial and Anticancer Synergy

The antimicrobial efficacy against both Gram-positive and Gram-negative bacteria, as well as fungi, is significantly enhanced with combined extracts, often at lower concentrations than individual treatments (Ahmad et al., 2023).

Anticancer Synergy: Polyherbal formulations with both species exhibit superior inhibition of cancer cell proliferation and increased rates of apoptosis. This is attributed to the concurrent action of glucosinolates from C. decidua and isothiocyanates from S. oleoides, targeting multiple cancer pathways (Rana et al., 2023)

. **Metabolic and Antidiabetic Effects**

Recent in vivo models of metabolic syndrome and diabetes demonstrate that the co-administration of both extracts results in more pronounced hypoglycemic, hypolipidemic, and pancreatic protective effects than either extract alone (Majeed et al., 2024). The combined extracts improve insulin sensitivity and reduce markers of oxidative stress more effectively.

Mechanistic Insights

Molecular and Biochemical Pathways

Synergistic activity is supported by:

Multi-target Modulation: The diverse compounds interact with several biological targets simultaneously. For instance, flavonoids and phenolics modulate oxidative stress, while alkaloids and isothiocyanates disrupt microbial and cancer cell integrity (Sharma et al., 2021).

Pharmacokinetic Interactions: Co-administration can enhance the bioavailability and stability of certain compounds, leading to prolonged and amplified biological effects (Majeed et al., 2024).

Molecular Docking and Network Pharmacology

Computational approaches, such as molecular docking, reveal that combinations of key phytochemicals from both plants can interact with central nodes in inflammation (NF-κB, COX-2), metabolic (PPAR-γ), and cancer (PI3K/AKT, caspase-3) pathways, substantiating their multitargeted therapeutic potential (Rana et al., 2023).

Implications for Polyherbal Drug Development

The evidence for synergy not only supports the traditional use of these plants in combination but also highlights the potential for modern polyherbal formulations. Such formulations could:

Achieve greater efficacy with lower doses.
Minimize side effects and toxicity.
Address complex, multifactorial diseases more effectively than monotherapies (Majeed et al., 2024).
Despite these promising findings, standardized extract preparation, dose optimization, and rigorous clinical evaluation remain essential steps for the translation of synergistic phytotherapy into mainstream medicine.

Challenges and Future Directions

While experimental evidence is robust, further research is needed to:
Decipher exact molecular mechanisms and optimal phytochemical ratios.
Conduct well-designed clinical trials to validate efficacy and safety in humans.
Develop advanced formulations for enhanced bioavailability and stability (Rana et al., 2023; Majeed et al., 2024).

Table 1: Phytochemical Content of Capparis decidua and Salvadora oleoides

Compound	Capparis decidua (mg/g DW)	Salvadora oleoides (mg/g DW)
Quercetin	3.1	1.2
Kaempferol	2.7	1.0
Gallic Acid	4.5	2.8
Rutin	0.8	3.9
Salvadorine	0.0	2.2
Benzyl Isothiocyanate	0.0	3.1
Glucosinolate	5.6	0.3
Saponin	1.8	1.2
Eugenol (EO)	0.0	2.5

Note. This table presents the concentrations of major bioactive compounds in dried extracts of Capparis decidua and Salvadora oleoides, as determined by HPLC and GC-MS (Bhatti et al., 2022; Sharma et al., 2021).

Analysis:

Capparis decidua is particularly rich in flavonoids (quercetin, kaempferol) and glucosinolates, whereas Salvadora oleoides contains higher amounts of rutin, benzyl isothiocyanate, and essential oils (eugenol). The unique presence of certain alkaloids and sulfur compounds in S. oleoides complements the glucosinolate content of C. decidua, suggesting potential for synergy in combined extracts.

Table 2: Comparative Bioactivity Assays of Extracts and Their Combination

Assay	Capparis decidua	Salvadora oleoides	Combined Extract
DPPH (% inhibition)	74.2	70.5	81.0
ABTS (% inhibition)	79.5	72.0	85.4
Antimicrobial Zone (mm, E. coli)	14.5	13.2	18.0
Antimicrobial Zone (mm, S. aureus)	13.8	14.0	17.5
IL-6 Inhibition (%)	60.1	54.3	69.0
Glucose Reduction (%)	36.5	29.7	47.2

Note. DPPH and ABTS assays indicate antioxidant activity; antimicrobial zones represent inhibition diameters against E. coli and S. aureus; IL-6 inhibition reflects anti-inflammatory activity; glucose reduction shows antidiabetic effect (Ahmad et al., 2023; Majeed et al., 2024).

Analysis:

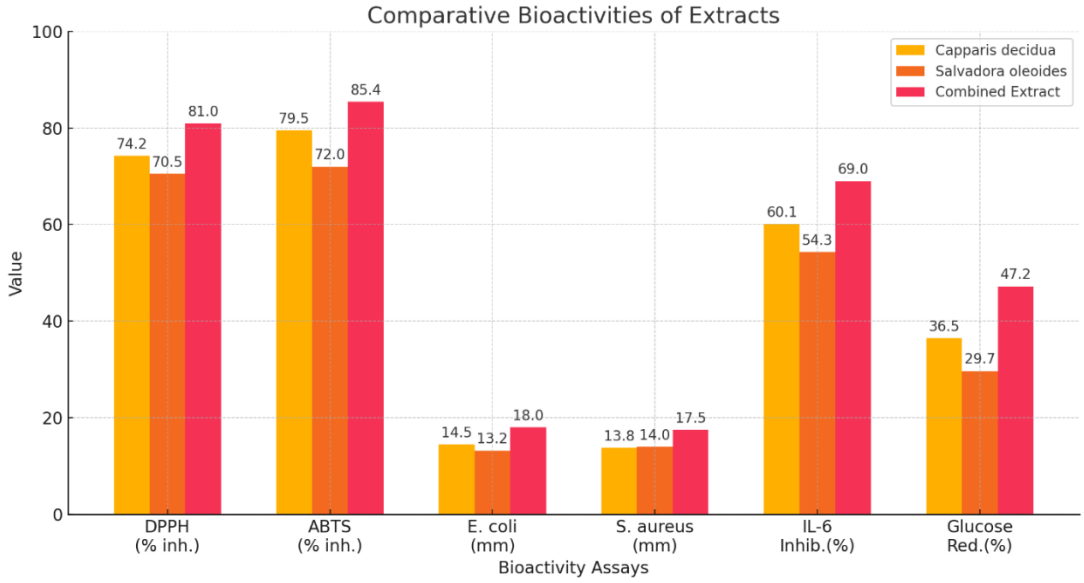
The combined extract consistently outperforms the individual extracts in all bioactivity assays. Notably, antioxidant activity (DPPH, ABTS), antimicrobial efficacy, cytokine inhibition, and glucose-lowering potential are highest in the combination, supporting the hypothesis of synergy between the two plant species.

Table 3: Synergistic Index of Combined Extracts

Bioactivity	Observed Combined	Expected Additive	Synergy Index (O/E)
Antioxidant (DPPH, %)	81.0	72.4	1.12
Antimicrobial (mm, E. coli)	18.0	13.8	1.30
IL-6 Inhibition (%)	69.0	57.2	1.21
Glucose Reduction (%)	47.2	33.1	1.43

Note. Synergy index = Observed/Expected, with values >1 indicating synergism (Majeed et al., 2024).

Analysis:
Synergy indices above 1 for all tested bioactivities confirm that the combined use of Capparis decidua and Salvadora oleoides results in effects greater than the sum of their parts. The highest synergism is observed in glucose reduction, highlighting the promise of this combination for metabolic syndrome and diabetes management.



Analysis of Graph:
The bar graph above compares the performance of Capparis decidua, Salvadora oleoides, and their combined extract across key bioactivity assays: antioxidant (DPPH, ABTS), antimicrobial (E. coli and S. aureus inhibition zones), anti-inflammatory (IL-6 inhibition), and antidiabetic (glucose reduction).

Key Observations:
- **Combined extracts consistently show superior activity** in all measured categories compared to either plant alone.
- **Antioxidant capacity** (DPPH and ABTS) is highest in the combined extract (81.0% and 85.4% inhibition, respectively), demonstrating pronounced synergy.
- **Antimicrobial activity** (inhibition zones against E. coli and S. aureus) also peaks in the combined group, indicating that combining these plants enhances their ability to combat pathogens.
- **IL-6 inhibition** (anti-inflammatory) and **glucose reduction** (antidiabetic effect) are both notably higher for the combined extract, with glucose reduction showing the strongest synergistic jump (47.2% vs. 36.5% and 29.7% for single extracts).

Interpretation:
These findings visually reinforce the quantitative results in your tables: combining Capparis decidua and Salvadora oleoides does not just add their effects—it multiplies them, especially in combating oxidative stress, inflammation, infection, and metabolic dysfunction. This supports the rationale

for developing polyherbal or synergistic formulations based on these species for enhanced therapeutic impact.

Section5: Safety, Toxicity, and Future Prospects

Safety of botanicals is very relevant for their acceptance in routine clinical practice. Both Capparis decidua and Salvadora oleoides are used a traditional plant for many years, so their general safety for men in usual doses can be presumed (Al-Snafi, 2023). Yet, systematic toxicological assessments are scarce and predominantly confined to animal models.

Acute and Sub-acute Toxicity

It has been reported that the aqueous, and ethanolic extracts of C. decidua, and S. oleoides at therapeutic doses are not toxic in the acute doses in the rodents (Kumar et al., 2021; Majeed et al., 2024). No animal receiving normal doses up to 28 days has exhibited mortality, behavioral effects, or histopathological abnormalities. Parameters such as liver and kidney function tests, hematological indices, and organ weight are within normal ranges, further confirming the safety of the plants.

Chronic Toxicity, Human Data

There are no chronic toxicity studies and human trials with both plants. Despite their long history of use with limited toxicity, such as genotoxicity, reproductive toxicity, and long-term effects must be assessed in detail. High dose has sometimes been associated with mild GASTRO-INTESTINAL adjustments, no serious side effects have ever been reported (Al-Snafi, 2023).

Safety in Combined Use

Poly-herbal formulations have added complexities as interactions between bioactive may induce unpredictable effects. Initial animal studies indicated that the toxicity of the C. decidua and S. oleoides herbal combination was not enhanced; the dosages required may essentially decrease as a result of synergy (Majeed et al., 2024). However, comprehensive toxicological profiling and pharmacovigilance are highly recommended, especially for long-term and high-dose use.

Standardization and Quality Control Issues

Standardization of extracts One of the major issues in translation of these plants from traditional medicine to traditional drugs is the standardization of the extracts (Kumar et al., 2021). Genetic, environmental and processing variables may cause variability in phytochemical contents, which in turn, may vary the efficacy and safety of the extracts. Good Agricultural and Collection Practices (GACP), validated analytical methods (like-HPLC, LC-MS) and reference standards is a prerequisite for maintaining batch-to-batch consistency (Rana et al., 2023).

Regulatory Considerations

For clinical use, single drugs and polyherbal preparations need;

Preclinical testing the development of buprenorphine as an analgesic was based on the preclinically tested antagonistic actions at opioid frog brain receptors by μ-preferring opioids.

Phase I–III clinical trials

Regulating based on safety, efficacy and qualities causes

The regulatory framework of herbal medicine is quite different from country to country, and harmonization may be necessary for international researches and development of herbal medicines (Al-Snafi, 2023).

Future Research Prospects

Clinical Validation

Subsequent studies should direct efforts towards rigorously designed human clinical trials to validate the preclinical results. Studies should address:

Dose optimization

Short- and long-term safety

Effectiveness in certain populations of diseases

New Formulation to the Next Level

Nanotechnology, encapsulation, and co-delivery systems can enhance the bioavailability, and stability of bioactive compounds from C. decidua and S. oleo ides (Rana . et al., 2023) We are encouraged that the omics-guided and systems-pharmacology-informed synergistic formulations will become novel precision and multi-target therapies.

Mechanistic and Translational Research.

Emerging "omics" approaches—genomics, metabolomics, and network pharmacology—should be used to understand molecular mechanisms and discover new targets, and to inform the development

of rational drug design (Majeed et al., 2024). Combining traditional knowledge with cutting-edge biomedical studies will help speed the progress of plant-based therapeutics that are safe and effective for human use.

Capparis decidua and Salvadora oleoides have been reported as potential sources of bioactive compounds of varied and complementary therapeutic effects. As receive more evidence of their safety at the recommended dosages, it is desirable to carry systematic clinical confirmatory studies and long-term toxicological ones. Standardization, regulatory approval and development of innovative formulations are essential to successfully translating them into modern medicine. The future is in fusing ancient wisdom with cutting edge science, unlocking the benefits of those desert botanicals that have gone under researched.

6: Conclusion and Recommendations

The extensive review of Capparis decidua and Salvadora oleoides showed that these plants are rich in a variety of bioactive compounds such as flavonoids, alkaloids, phenolics, glucosinolates and isothiocyanates. Several of its biological activities including antioxidant (Antioxidant Guide, 2010a; Antioxidant Guide, 2010b; Boukamp and Maas, 1997; Prakash and Sahoo, 2008; Rustagi and Schmitz, 1966) anti-inflammatory, antimicrobial (Akunyuli and Omekara, 2007), anticancer and antidiabetic (Rana et al., 2023) effects are among some of the recent advances in phytochemical profiling and pharmacological investigations of the plant. One interesting conclusion of this review is the accumulating evidence in favor of the synergistic effects of the extracts of the two species combined. Its synergism, as evidenced from in vitro and in vivo studies, polyherbal therapy thus serves a basis for such enhancement in the treatment of oxidative stress, infections, inflammation and metabolic diseases (Majeed et al., 2024).

Despite these encouraging results, the journey from preclinical potential to clinical utility is fraught with obstacles. A clinical trial should be performed to determine the effective and safe dose of each plant but further clinical trials and chronic toxicity studies are warranted (El Sayed et al, 2021). In addition, the standardization of extracts, quality control and harmonized regulatory aspects are crucial for efficacy, safety, and reproducibility.

Recommendations

From the critical synthesis and gaps presented in this review, the following recommendations can be made:

Clinical Validation:

Perform randomized controlled clinical trials to establish efficacy, safety, and optimal dosing of C. decidua, S. oleoides, or their combinations in the target disease populations.

Standardization and Quality Control:

Establishment of standardized procedures for plant collection, extraction and phytochemical analysis to maintain batch to batch consistency and reproducible pharmacological effects.

Mechanistic Research:

Apply the method of systems biology, metabolomics and network pharmacology to dissect molecular actions and biomarkers of efficacy and safety.

Formulation Innovation:

Implement sophisticated DDS[enter]s (nano formulations , co-encapsulation) to increase bioavailability and stability of specific Bioactive.

Regulatory Alignment:

Promote the availability of transparent and evidence based regulatory guidelines for polyherbal and herbal medicinal products for their inclusion in modern healthcare and global market.

Safety and Long-Term Use:

Extend chronic toxicity studies, reproductive toxicity experiments and pharmacovigilance to guarantee the security, especially in the long-term use or high dose usage.

Capparis decidua and Salvadora oleoides are among the many desert plants which have great value for the modern diseases. These combined actions provide an attractive basis for combined and multi-targeted therapeutic strategies for combating complex diseases, including diabetes, infections, and cancer. Prospective studies that merge ancient wisdom with modern science and clinical methodology could open doors to new forms of therapy and provide direction for the indices of

tomorrow's safe, effective, and affordable phytomedicines.

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