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# From Decoction to Evidence: Modern Standardization of Ayurvedic Kwatha and Polyherbal Formulations

**Sruthi K.T.K.[1], Pramod Kumar N.[2], J. B. George.[3], Shinoj Mathew.[4]**

**[1] Research and Post Graduate Department of Botany, Mercy College Palakkad, Kerala.**

**[2]*Corresponding Author: Pramod Kumar N., Department of Botany, NSS College, Ottapalam, Palakkad, Kerala, India.**

**[3]Post Graduate and Research Department of Chemistry, St. Berchmans College (Autonomous), Mahatma Gandhi University, Kottayam, Kerala, India.**

**[4]Research and Post Graduate Department of Botany, Mercy College Palakkad, Kerala**

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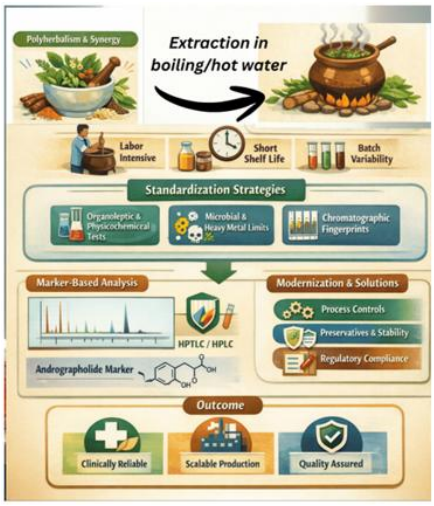
## ABSTRACT

Standardization of Ayurvedic dosage forms have become a central priority for researchers, industry, and regulators because the clinical credibility of traditional medicines depends on reproducible composition, safety, and performance. Among classical dosage forms, Kwatha Kalpana (aqueous decoctions) represents a foundational extraction technology where heat and water mobilize primarily water-soluble phytochemicals from single or multiple herbs. Despite wide therapeutic use in classical practice, kwathas face practical barriers in contemporary care, labor-intensive preparation, short shelf life, batch-to-batch variability, microbial risk, and poor palatability. This review consolidates the historical rationale, formulation principles, preparation variables, and modernization opportunities for kwatha, while emphasizing polyherbalism as a systems-based strategy that can enhance efficacy through pharmacodynamic complementarity, improved bioavailability, and multi-target action. We synthesize current evidence on analytical standardization (organoleptic/physicochemical indices, microbial/heavy-metal limits, and chromatographic fingerprints) and highlight validated platforms such as HPTLC/HPLC marker quantification—including examples where andrographolide served as a robust marker for a classical decoction standardization workflow. We further outline practical, regulator-aligned pathways, process controls, preservative rationalization, and stability-guided formulation redesign to enable clinically relevant, scalable, and quality-assured kwatha products.

**Keywords:** Kwatha (Kashaya), polyherbalism, synergy, standardization, HPTLC, HPLC, GC–MS, LC–MS/MS, quality control.




**Graphical Abstract**

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# INTRODUCTION

Ayurveda represents one of the most comprehensive and enduring medical traditions in human history, with a continuous documented practice spanning over five millennia. Rooted in the philosophical foundations of balance and harmony, Ayurveda conceptualizes health as a dynamic equilibrium among functional principles known as doshas; Vata, Pitta, and Kapha governing physiological and psychological processes, and individual constitution or prakriti, which determines susceptibility to disease and therapeutic responsiveness (Parasuraman et al., 2014). Unlike the reductionist paradigm of modern biomedicine, which frequently targets isolated molecular pathways, Ayurveda adopts a systems oriented therapeutic philosophy, integrating herbs, diet, lifestyle modification, detoxification, and mind–body practices to restore systemic homeostasis.

Central to this medical system is the formulation science that translates theoretical principles into therapeutic reality. Ayurvedic pharmaceutics recognizes multiple dosage forms (kalpanas) tailored to disease stage, patient constitution, and therapeutic objective. Among these, Kwatha Kalpana, the preparation of aqueous herbal decoctions remains one of the most frequently prescribed and clinically relevant forms. Kwathas are designed to extract water soluble phytochemical matrices capable of exerting rapid and potent pharmacological actions, making them particularly suitable for acute and systemic disorders.

However, despite their extensive historical use and recognized therapeutic value, kwathas face substantial challenges in contemporary healthcare. The increasing global interest in herbal and integrative medicine demands pharmaceutical products that demonstrate reproducible quality, safety, stability, and clinical reliability. Classical kwatha preparations, when produced under traditional household or artisanal conditions, often exhibit significant batch to batch variability. Differences in raw material identity, geographical source, harvest season, drying methods, storage conditions, particle size, extraction parameters, and microbial exposure directly influence phytochemical composition and therapeutic performance (Shenoy & Yoganarasimhan, 2009; Bhatt & Deshpande, 2020).

Such variability not only complicates scientific validation but also limits regulatory acceptance and industrial scalability. Modern healthcare systems, insurers, clinicians, and regulators require standardized formulations supported by rigorous quality control and mechanistic understanding. The absence of reproducible quality parameters for many classical decoctions has historically hindered their translation into formal healthcare frameworks, despite widespread public usage.

Parallel to this challenge lies one of Ayurveda's greatest strengths: polyherbalism. Unlike modern singlemolecule pharmacotherapy, Ayurvedic formulations frequently combine multiple herbs to achieve synergistic therapeutic effects. These combinations are designed to act on multiple physiological pathways simultaneously, enhancing efficacy while minimizing adverse effects through balancing and buffering mechanisms intrinsic to classical formulation philosophy (Williamson, 2001; Mukherjee et al., 2018). The concept of synergy in Ayurveda aligns remarkably well with contemporary network pharmacology and systems biology, which recognize complex diseases as emergent properties of interacting biological networks rather than single target dysfunctions.

Yet polyherbal complexity also introduces analytical challenges. A decoction may contain hundreds of chemically diverse constituents, many present in trace amounts but contributing collectively to therapeutic outcome.

Conventional pharmaceutical quality control, traditionally built around single active ingredients, struggles to accommodate such chemical and functional complexity. Therefore, the modernization of kwatha formulations requires not only improved manufacturing control but also advanced analytical strategies capable of capturing the holistic chemical signature of these formulations.

Over the past two decades, significant progress has been made toward this goal. The application of chromatographic and spectrometric technologies; including TLC, HPTLC, HPLC, GC–MS, and LC–MS/MS—has enabled detailed phytochemical fingerprinting, marker compound identification, and batch consistency evaluation for complex herbal formulations (Rajani & Kanaki, 2008; Abraham et al., 2020). These tools allow

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researchers to move beyond subjective organoleptic assessment toward objective, quantitative, and reproducible quality metrics.

In parallel, regulatory frameworks such as those promoted by the World Health Organization (WHO) and national bodies like AYUSH in India increasingly emphasize the necessity of standardization, stability testing, safety evaluation, and pharmacovigilance for traditional medicines. This regulatory evolution creates both pressure and opportunity: pressure to upgrade classical formulations to modern pharmaceutical standards, and opportunity to position standardized Ayurvedic products within evidence based integrative healthcare.

Within this evolving landscape, Kwatha Kalpana occupies a critical junction between tradition and modernity. It embodies the core principles of Ayurvedic therapeutics—individualized treatment, polyherbal synergy, and holistic action—while also presenting clear challenges of stability, palatability, shelf life, and batch reproducibility. Addressing these challenges requires reframing kwatha not merely as a traditional preparation but as a process defined pharmaceutical product whose quality is inseparable from its method of manufacture.

This review therefore seeks to bridge classical Ayurvedic knowledge with contemporary pharmaceutical science. By synthesizing evidence on polyherbal synergy, process optimization, analytical standardization, and regulatory integration, we propose a coherent roadmap for transforming kwatha from a traditionally supported remedy into a clinically credible, industrially scalable, and scientifically validated therapeutic platform.

The subsequent sections examine the mechanistic foundations of polyherbal synergy, the pharmaceutical science of kwatha preparation, modern approaches to quality control and analytical characterization, and future pathways for modernization and regulatory integration.

## 2. Polyherbal formulation, principles of Ayurveda and methods of preparation of decoctions

Beyond the conventional techniques like tongue analysis and pulse reading ayurveda uses AI in improved diseases diagnosis and can create individualised treatment regimens. For the upgradation of traditional medicinal system, AI can be ethically incorporated, conserving the holistic principles and fundamental knowledge.(Veerakannan, 2025). Ayurvedic treatment may be very fruitful when applied with proper analysis and care, and thereby overcome the problems met with surgery. Even in severe condition of cholelithiasis (gallstone), very markable changes in the visible symptoms observed and imaging tests showed stone's shrinkage which may thought to require surgical removal.(Sreeni & Haris, 2024). Ayurvedic therapies like Rookshana, Snigda sweda, Pizhichil, and Brihmana, along with herbal formulations like Adarisahacharadi Kashayam, Suntibaladi choornam and Vyoshadi gugguku can enhance the quality of life and successfully reduce sciatic nerve pathological symptoms.(Soman & Marikutty, 2024).

The Ayurvedic formulation "Amruthotharam Kashayam," which is made from Tinospora cordifolia, Terminalia chebula, and Zingiber officinale and was made using both traditional and contemporary methods, revealed both preparation techniques have positive pharmacological effects and notable antioxidant activity using in-vitro antioxidant assays and in-vivo investigations on Wistar rats while changing the preparation procedure affects efficacy, both approaches yield formulations that are beneficial against the symptoms of metabolic disorders.(Dhane et al., 2023). The therapeutic potency and pharmacological selectivity of kwatha can also be enhanced by appropriately standardising the characteristics including vessel selection temperature regulation, raw drug particle size, water content and heating time.(K. Sharma et al., 2023)(Maddesiya et al., 2024). Even in the chronic conditions of migraine, treatment including the intake of Pathyashadangam Kashaya and Kumkumadi Ghrita Nasya and also some internal herbal remedies can significantly reduce head-ache intensity, duration and other related symptoms. Vata and Kapha, which are thought to play a major role in the pathophysiology of migraine. Ayurvedic treatments, can be used in managing such conditions since Ayurveda have tridosha shamaka qualities.(Jain et al., 2023).

The legitimacy and acceptance of the age-old systems to the larger medical community involving a range of stakeholders, practitioners, scholars and governmental organisations, when this system incorporates into contemporary health care following thorough scientific research. The studies can help understand the working of Ayurvedic treatments and make it easier to use them to treat global health issues including aging, lifestyle

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disorders, and pandemics, and can also prove the effectiveness, safety and uniformity of ayurvedic treatments. By combining evidence-based research with conventional knowledge holds promise for advancing comprehensive, and guaranteeing Ayurveda's ongoing applicability and advantages to individualized treatments.(M. K. Sharma et al., 2023).

The contemporary developments including delivery techniques based on nanotechnology can improve Kwatha formulations' stability and bioavailability, The quality and efficacy of Kwatha in clinical applications can be greatly enhanced by combining modern procedures with suitable pharmacological and analytical parameters.(N. Bhatt et al., n.d.). Kabasura decoction has anti-inflammatory hepatoprotective analgesic and antibacterial properties. Numerous ingredients have antiviral properties, especially when it comes to influenza viruses and the human respiratory syncytial virus. Kabasura decoction is recommended as a possible treatment for COVID-19, helping to reduce symptoms and potentially averting the disease's consequences.(Sujeethasai, 2020).

Polyherbalism, utilizing combinations of multiple herbs, achieves better therapeutic effects and reduces toxicity compared to single herb treatments. According to the World Health Organization, a sizable percentage of the world's population still uses traditional medicines.(Parasuraman et al., 2014b). The therapeutic efficacy will be improved when mixing many herbs together. The potential of polyherbal formulation has been well appreciated when the preparations used after thorough clinical tests for scientific validation and public awareness campaigns regarding their application.(Dattatray Shrikar & Ashpak, 2020). The complex preparation methods and limited shelf life advocates for the incorporation of modern techniques to increase its usability and marketability. It is much significant to standardise ayurvedic polyherbal formulation for improving the efficacy. (N. S. Bhatt & Deshpande, 2020).

When the quality of commercially manufactured kwatha compared with that of handmade decoction, significant differences can be assessed like pH, TDS, preservatives like sodium benzoate level and microbial load. Clinical efficacy has to be improved for the formulation by standardising them.(Radha et al., 2014). Herbal medicines being prepared with the ingredients that are prone to perish easily, the safety and efficacy can be raised by the addition of preservatives. The method of preparation of kwatha nowadays employ more preservatives than the commonly advised limit.(Reddy, 2018). The medicinal effectiveness of kwatha can be improved by optimizing the particle size of their ingredients, when larger particles used greater the amount of active components extracted.(Baghel & Chaudhary, 2018).

Gojihwadi Kwatha (GK), a traditional Ayurvedic herbal formulation have the potential to prevent cancer. The GK sample’s chloroform extracts showed highest inhibition zone revealing the strong antibacterial activity, hence can be suggested that this kwatha is a natural anticancer agent which may be due to its potential to inhibit tumor.(Prakash Jondhale et al., n.d.).

Ayurveda is an age-old holistic approach, which aims to keep the three doshas pitta, kapha, and vata in a balanced condition, which may decide an individual’s constitution. In addition to herbal medicines, yoga, medication and detoxification techniques, the therapeutic approach also includes other treatments for promoting health and preventing diseases and to bring body and mind back into harmony.(Lata, n.d.). It is crucial to uphold the core ideas of ayurveda such as tridosha theories to meet the individual demands of contemporary world. Modern medicines sometimes are uniform and have a reductionist approach while ayurvedic treatments have inherent individuality that each patient’s unique humoral disturbances are being treated. It is much difficult to validate scientifically, and identify the active pharmacologic compounds which can ignore the system’s holistic philosophy.(S. Kumar et al., 2014).

Understanding individual body make up and environmental factors, the approach of balancing the body’s energies or doshas through detoxification process, dietary changes, herbal medicines and lifestyle adjustments places a high priority on preventive and individualised therapy.(L. Mishra et al., 2001). Scientific knowledge in the contemporary areas like Cell Biology, Genetics, Biochemistry and Molecular Biology can be used to comprehend and validate ayurvedic formulations and principles inorder to move beyond traditional experience based approach. Experimental validation and biological characterization of notions such as prakriti, doshas, and other classical ideas strengthens the link between traditional knowledge and contemporary science, by highlighting attempts by the Indian scientific community to investigate Ayurvedic principles using research

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models like Drosophila, which can change Ayurveda into a more impartial, evidence-based, and integrative healthcare system.(Lakhotia, 2019a). Ayurvedic product quality control may be improved, evidence-based procedures can be produced, and a comprehensive, integrated healthcare system that builds on the advantages of both contemporary and traditional medicine can be promoted. To prove Ayurvedic's legitimacy and applicability in modern healthcare, the study calls for more cooperation between Ayurvedic practitioners and scientists, and a re-evaluation of Ayurvedic principles in light of present scientific understanding.(Lakhotia, 2019b).

The epistemologically sensitive research approaches can honour patient-centred tenets of Ayurveda, including the idea of individual constitution, can bring about customized therapies. It promotes strategic documentation, quality control, and cooperative research initiatives to produce reliable scientific proof, facilitating the more seamless integration of Ayurveda into contemporary healthcare. In order to improve the efficacy, safety, and validity of Ayurvedic methods, conventional knowledge systems are to be incorporated with modern methods and personalised, medications and cutting-edge projects like personalized medicine.(Patwardhan, 2014). Identification, characterization, and evaluation of the biological activities of natural products derived from higher plants have been greatly improved by the advancement in the analytical methods like Mass Spectrometry, NMR and Chromatography. Combining ethnopharmacology, traditional medicine, and biotechnology has been essential in converting traditional knowledge into medications with scientific backing, encouraging global cooperation, and advancing standardization initiatives. As a result of the breakthroughs in phytochemistry and pharmacognosy, significant therapeutic molecules have been found like artemisinin which has anti malarial and anti cancer activities.(Phillipson, 2007).

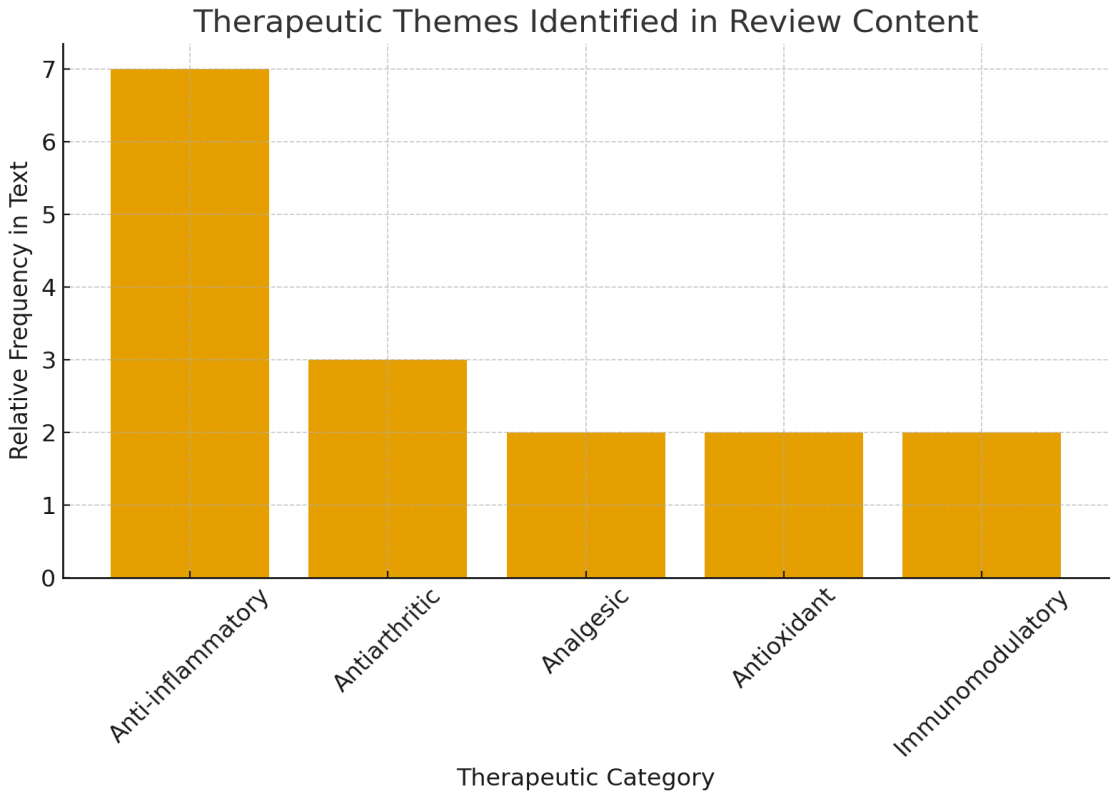


Fig. 2.1 showing graphical representation of the therapeutic activities identified in the review content.

### 3. Phytochemical analysis of Kwatha

Standardisation improve safety and efficacy and can forecast how well a formulation would perform for a particular ailment due to the diversity in therapeutic outcomes.(M. M. Kumar et al., 2025). Guduchyadi kashayam are contained to be very rich in phenolic compounds when examined using Liquid Chromatography Tandem Mass Spectrometry. Because of the high phytochemical concentration especially phenolic compounds are responsible for the therapeutic efficacy of the formulation like, anti-inflammatory, anti-oxidant, anti-ageing, and anti-proliferative action.(S. S. Sruthi & Anand, 2024). Prasarinyadi Kashayam contain 19 phytochemicals

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includes secondary metabolites with anti-inflammatory, immunostimulant, and antioxidant qualities which are alkaloids, flavonoids, terpenoids, and phenolic compounds revealed in the ESI-QTOF-MS analysis.(Girija et al., 2024). The concentration of sodium benzoate was found to be very high in all three commercial brands of Sahacharadi kwatha, also numerous phytochemical have been detected, but there is an urgent need for standardization and effective quality control procedures to improve customer safety and trust in Ayurvedic commodities.(Gopal & Ittiachen, 2024).

The GCMS profile of Amrutotharanam Kashayam, revealed to include imported biomolecules with cytotoxic effects on cancer cells which have notable antioxidant activity when compared to common compounds like ascorbic acid. Molecular docking and dynamics simulations also showed that these chemicals might inhibit target proteins linked to viral infections and cancer.(Raman et al., 2023). Using HPTLC it has been comparatively found that significant differences are there between the ingredient plants and the finished formation. The detailed chemical finger printing and spectrophotometric assays estimated major classes of compounds like total phenolics and flavonoids. Specific bioactive molecules have accumulated by the interaction of phytoconstituents in the raw drugs both synergistically and antagonistically during the preparation of Kashayam.(C. Sulaiman et al., 2023). A variety of invitro analysis such as ABTS, DPPH, FRAP, ORAC and BCB were met to identify the key phytochemicals like alkaloids, flavanoids, terpeniods, Saponins and glycosides present in TC-16, a novel polyherbal formulation. Result showed, TC-16 has high antioxidant qualities and potential health benefits which might be due to the synergistic effects of herbal constituents and which is mostly caused by hydrogen atom transfer processes.(Yap et al., 2023). By following WHO recommendations, a thorough analysis carried out for Patolakaturohinyadi Ghanavati, a polyherbal Ayurvedic formulation derrived from the traditional Patolakaturohinyadi Kashaya inorder to assess the Ghanavati form for improved palatability and transportability. The formulation had favorable properties, including a microbiological count of 38 CFU/mL, a moisture content of 6.268%, a hardness of 6.0 kg/cm, and a disintegration time of 25 minutes. The Ghanavati confirmed having much therapeutic effectiveness for long term condition such as for liver diseases and kushta.(Rohini & Prashanth, 2023).

The therapeutic efficacy of four medicinal plants Xylopia aethiopica, Euphorbia heterophylla, Vernonia amygdalina, and Greenwayodendron suaveolens was found to be due to the presence of rich phytochemicals, micro and macronutrients like Calcium, Magnesium, Iron, and Manganese.(Oshomoh et al., 2022). Using various spectroscopic techniques including HPTLC, FTIR, and tandem mass spectrometry, Amruthotharam Kashayam exhibited distinct chemical profile compared to its individual components.(C. T. Sulaiman et al., 2021). The safety efficacy and quality of herbal medicines can be enhanced by implementing phytochemical standardisation, procedures like fingerprint profiling and marker compound measurement. The shift in modern pharmacology from single drug therapies to polyherbal approaches implies that mixed herbal extracts can produce better medicinal effects.(Neethu et al., 2021). TLC, phytoconstituent, physicochemical, and organoleptic evaluations done to compare freshly prepared Dasamoola kwatha and commercially available ready to use formulations. Market sample had a high level of unreported sugar, which may be dangerous, particularly for diabetic individuals. potential adulterants or unlisted substances that could compromise safety and efficacy, to Ayurvedic formulations.(Mehta et al., 2021). Dhanwantaram Kashayam (DK), a polyherbal Ayurvedic infusion used for postpartum healing and rejuvenation, were examined for its antioxidant qualities using a variety of tests such as ferric reducing antioxidant power (FRAP) and free radical scavenging activities against DPPH, ABTS, phosphomolybdenum, hydrogen peroxide, hydroxyl radical, and nitric oxide. DK showed strong antioxidant and radical scavenging properties with low IC50 values.(Renganathan & Pillai, 2021). The single-drug phytotherapy has recently given way to polyherbal formulations because of their improved therapeutic efficacy and fewer adverse effects. Marker based fingerprint profiling and bioactive chemical quantification can be used for the quality control assurance in such herbal preparations.(Kurian et al., 2021). Vyaghryadi Kashayam (VK), exhibit efficacy against SARS-CoV-2 and can be used in the treatment of Covid-19, stressing the value of conventional formulation as a source of possible antiviral drugs.(Nandakumar et al., 2021).

Pathyashadangam kwath, a traditional Ayurvedic polyherbal composition used to treat conditions like cluster headaches and upper respiratory infections, has seven important ingredients. The quality and purity of this kwath has assessed by using techniques like HPLC and HPTLC and revealed andrographolide is an appropriate marker for kwath standandardisation. The crucial characteristic parameters and chromatographic profiles can be used as

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reference for quality control and assurance in future preparation of Pathyashadangam kwatha.(Abraham, Samuel, et al., 2020). Burning Mouth Syndrome (BMS), a disorder marked by a burning or tingling feeling in the mouth that is frequently linked to dryness and changed taste, which are due to the abnormalities in mouth secretion and lubrication, is examined in this study. Bhunimbadi Kwath can be orally taken for increased lubrication and lessen burning feelings. Ayurvedic treatments are effective in controlling dosha imbalance and local symptoms of burning mouth syndrome.(Deshmukh et al., 2020). Multi-herb approach, which can provide synergistic therapeutic effects, lower required doses, and lessen potential side effects. Sophisticated LC-MS techniques are useful in characterizing complicated herbal mixes and validate the formulation's therapeutic efficacy.(Girija et al., 2024)(CT et al., 2020).

Two varieties of Sharibadi decoctions used in Ayurveda Sharibadi decoction A contained both the Indian and local Sri Lankan varieties of Hemidesmus indicus, while Sharibadi decoction B only contained the Indian variety in double quantity were assessed. The secondary metabolites, including flavonoids, phenols, alkaloids, tannins, terpenoids, saponins, and phytosteroids, were identical in both decoctions. But Sharibadi decoction A contained more flavonoids, tannins, and phenolic substances. The two have different thin layer chromatographic profiles at UV 254 nm.(Kulathunga et al., 2019).

The GCMS analysis of Sahacharadi Kashayam revealed the presence of major chemicals like Heptanediamide, Eugenol, and Lupeol, which are meant for the therapeutic efficiency of the Kashayam.(P. P. Kumar et al., 2018).

The novel polyherbal formulation made up of aqueous extracts of four different plant Commiphora mukul, Madhuca indica, Picrorhiza kurroa, and Syzygium cumini contained high amount bioactive substances like phenols and flavonoids.(Iqbal & Gurumurthy, 2016). The commercially available Ayurvedic formulation Balaguloochyadi kashayam was found to be safe for use and have standardised it after thorough physicochemical and microbiological tests.(Khan et al., 2016).

The antibacterial and antioxidant properties of Kushtakhnani kwatha, a polyherbal formulation traditionally been used to treat skin problems, has assessed by extracting phytochemicals using various solvents and tested invitro against common skin pathogens.(Jalaj et al., 2016). The GCMS profile revealed numerous bioactive substances in Kulathadi Kashayam that has long been used to treat amenorrhea.(Phillips et al., 2015). In the comparative assay of commercially available and freshly prepared Cirivilvadi Kashaya, the result showed that the preservatives and prolonged cooking times may change the physicochemical characteristics and possibly the clinical efficacy of the formulations.(Mahapatra et al., 2015).

Another Polyherbal Formulation made up of Centella asiatica, Bacopa monnieri, and Hippophae rhamnoides, have high antioxidant and free radical scavenging activities.(Singh et al., 2012). Kutajarista, an Ayurvedic formulation have antibacterial activity, which can be used to treat gastrointestinal problems like dysentery and diarrhoea.(Shenoy KR & Yoganarasimhan, 2009). The phytochemicals in the herbal medications differ depending on plant species, processing technique, and storage conditions.(Rajani & Kanaki, 2008).

**Table 3.1. Phytochemical analysis of Kwatha**

| **Formulations** | **Analytical Techniques Used** | **Key Phytochemicals / Markers Identified** | **Pharmacological Significance** | **Reference** |
|---|---|---|---|---|
| Pathyashadangam Kwatha | HPLC, HPTLC | Andrographolide | Established andrographolide as a suitable marker; chromatographic fingerprints useful for quality control and standardization | Abraham et al., 2020 |

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|---|---|---|---|---|
| General Polyherbal Standardization | Fingerprinting, Marker quantification | Multiple bioactive compounds | Phytochemical standardization improves safety, efficacy, and consistency of herbal medicines | Neethu et al., 2021 |
| Amruthotharam Kashayam | HPTLC, FTIR, Tandem MS | Distinct formulation-specific metabolites | Chemical profile differed from individual ingredients, indicating formulation-induced phytochemical changes | C. T. Sulaiman et al., 2021 |
| Kushtakhnani Kwatha | Solvent extraction, In-vitro antibacterial & antioxidant assays | Alkaloids, flavonoids, terpenoids | Effective against P. aeruginosa, S. aureus, S. pyogenes; validates traditional dermatological use | Jalaj et al., 2016 |
| Amrutotharanam Kashayam | GC–MS, Molecular docking & dynamics | Antioxidant and cytotoxic biomolecules | Compounds showed higher antioxidant activity than ascorbic acid and potential antiviral and anticancer activity | Raman et al., 2023 |
| Sahacharadi Kashayam | GC–MS | Eugenol, Lupeol, Heptanediamide | Identified bioactive compounds contributing to therapeutic efficacy | P. P. Kumar et al., 2018 |
| Kashayam Preparation Process | HPTLC, Spectrophotometric assays | Phenolics, Flavonoids | Phytochemical interactions during decoction lead to synergistic or antagonistic compound accumulation | C. Sulaiman et al., 2023 |
| TC-16 Polyherbal Formulation | DPPH, ABTS, FRAP, ORAC, BCB | Alkaloids, flavonoids, terpenoids, saponins | Strong antioxidant activity via hydrogen atom transfer; synergistic effects highlighted | Yap et al., 2023 |
| Polyherbal formulation (C. mukul, M. indica, P. kurroa, S. cumini) | DPPH assay | Phenols, Flavonoids | High free-radical scavenging capacity; effective against oxidative stress | Iqbal & Gurumurthy, 2016 |
| Polyherbal hepatoprotective formulation | Antioxidant assays | Polyphenols | Exhibited antioxidant and hepatoprotective potential | Singh et al., 2012 |

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|---|---|---|---|---|
| Medicinal plant blend | Phytochemical & mineral analysis | Alkaloids, phenolics, Ca, Mg, Fe | Therapeutic efficacy linked to phytochemicals and micronutrients | Oshomoh et al., 2022 |
| Balaguloochyadi Kashayam | Physicochemical, Microbiological tests, HPTLC | Ephedrine | Confirmed safety and standardization through marker quantification | Khan et al., 2016 |
| Commercial Sahacharadi Kwatha | Preservative analysis | Sodium benzoate | Excess preservative levels raise safety concerns; need for strict quality control | Gopal & Ittiachen, 2024 |
| Dasamoola Kwatha (Fresh vs Marketed) | TLC, Physicochemical tests | Sugars, phytoconstituents | Market samples contained unreported sugars; potential risk for diabetic patients | Mehta et al., 2021 |
| Dhanwantaram Kashayam | DPPH, ABTS, FRAP, Radical scavenging assays | Antioxidant metabolites | Strong antioxidant and free-radical scavenging activity with low $IC_{50}$ values | Renganathan & Pillai, 2021 |
| Kulathadi Kashayam | GC–MS | Benzoic acid, fatty acids, alkanes | Bioactive compounds support its use in amenorrhea | Phillips et al., 2015 |
| Kutajarista | Antibacterial assays | Active phytoconstituents | Laboratory-prepared formulation showed superior antibacterial activity | Shenoy & Yoganarasimhan, 2009 |
| Bhunimbadi Kwatha | Clinical evaluation | Lubricating phytochemicals | Reduced burning sensation and dryness in Burning Mouth Syndrome | Deshmukh et al., 2020 |
| Sharibadi Decoction (A vs B) | TLC, Phytochemical analysis | Flavonoids, tannins, phenols | Decoction with mixed plant varieties showed higher phytochemical content | Kulathunga et al., 2019 |
| Cirivilvadi Kashaya | Comparative physicochemical study | Altered phytochemical profile | Preservatives and prolonged cooking affected formulation quality | Mahapatra et al., 2015 |
| Patolakaturohinyadi Ghanavati | WHO-guided quality assessment | Multiple bioactives | Improved palatability, stability, and therapeutic potential | Rohini & Prashanth, 2023 |

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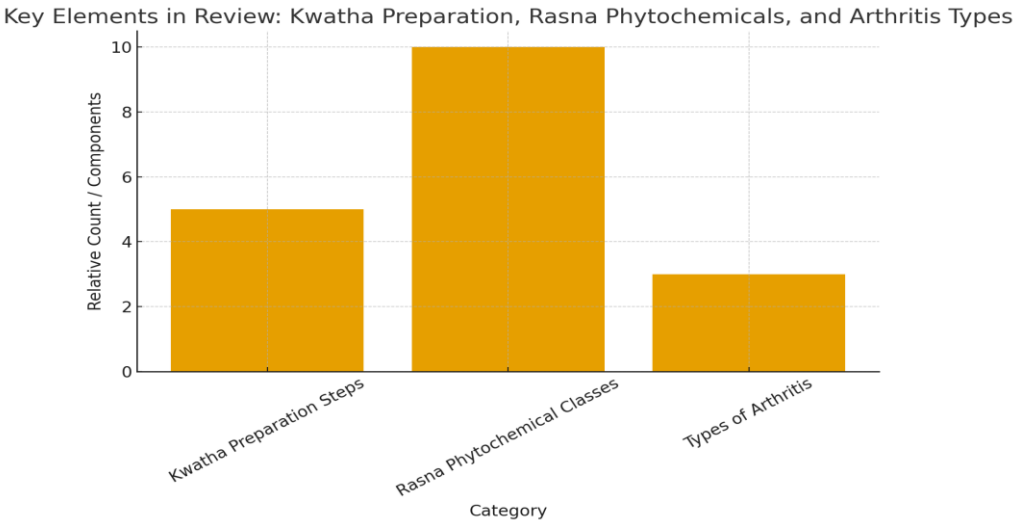
| Guduchyadi Kashayam | LC–MS/MS | Phenolic compounds | High phenolic content linked to antioxidant, anti-inflammatory, and anti-ageing effects | S. S. Sruthi & Anand, 2024 |
| Prasarinyadi Kashayam | ESI-QTOF-MS | Alkaloids, flavonoids, phenolics | Identified 19 bioactive phytochemicals with immunomodulatory effects | Girija et al., 2024 |
| Vyaghryadi Kashayam | In-vitro antiviral assays | Multiple secondary metabolites | Demonstrated activity against SARS-CoV-2 | Nandakumar et al., 2021 |
| General Herbal Standardization | TLC, HPTLC, HPLC, LC-MS/MS | Marker compounds | Ensures batch consistency, authenticity, and therapeutic reliability | Rajani & Kanaki, 2008; M. M. Kumar et al., 2025 |




## 4. Synergistic interactions of herbal medicines in Ayurvedic Formulations

Synergistic interactions are not consistent across antioxidant pathways, interaction effects between the components showed antagonistic effects on ferric reducing antioxidant capacity but additive effects on DPPH radical scavenging. In a polyherbal formulation made by adding five ingredients namely Andrographis paniculata, Tinospora crispa, Curcuma longa, Curcuma comosa, and Phyllanthus niruri. The ratios of constituents in the polyherbal formulations are to be optimised and can be treated to cure disorders linked to oxidative stress such as diabetes mellitus.(Hartanti & Hamad, 2023). Optimizing the ratios of constituents in polyherbal formulations are crucial to boost antioxidant efficacy for possible therapeutic uses especially for the treatment for disorders linked to oxidative stress. Synergistic interactions are not consistent across antioxidant pathways, interaction effects between the components in polyherbal formulations can show antagonistic effects too.(Hartanti & Hamad, 2023). TC-16, a novel polyherbal formulation, as strong antioxidant activity and found to contain the key phytochemicals like alkaloids, flavonoids, terpenoids, saponins, and glycosides. The interactions in this formulations have antagonistic, synergistic or additive effects on antioxidant activity. The complexity of herb interactions in polyherbal formulations and potential health benefits of TC-16 can be optimized by more researches.(Yap et al., 2023).

Notable differences between the phytochemical profiles of the final formulation and its individual plant ingredients were found in the Gugguluthikthakam Kashayam (GTK) using HPTLC and detailed fingerprinting and spectrophotometric assays. During the formulation's manufacture, phytoconstituents interacted both

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antagonistically and synergistically, resulting in chemical changes and the accumulation of bioactive molecules that are specific to GTK.(C. Sulaiman et al., 2023). The interaction effects on antioxidant activity of four herbal extracts lemongrass, curry leaves, ginger, and turmeric were examined inorder to formulate these herbals in a favourable and effective proportion. A 1:1 combination of turmeric and ginger showed a strong synergistic effect in DPPH but an antagonistic effect in FRAP. A mixture of lemongrass and curry leaves showed the best antioxidant activity, surpassing others in both assays. 53.7% lemongrass, 43.4% curry leaves, 2.9% ginger, and no turmeric make up the ideal formulation.(Rahim et al., 2020).

The finished formulation exhibits a distinct chemical profile compared to its individual components that can be revealed by tandem mass spectrometry, FTIR, and HPTLC.(C. T. Sulaiman et al., 2021). Diabetes is a chronic metabolic disease that is becoming more and more common and is defined by elevated blood glucose levels. Even though there are synthetic antidiabetic medications, their usage is restricted because of their negative side effects. Common in Ayurvedic medicine, polyherbal formulations take use of the synergistic interactions amongst herbal ingredients to promote therapeutic efficacy and decrease side effects through combined pharmacodynamic and pharmacokinetic actions and improved bioavailability. These compositions' strong antidiabetic and antioxidant properties are supported by a number of research, including in vitro and in vivo models.(Pande & Chandel, n.d.).

Ridayarishta, a traditional Ayurvedic liquid formulation standardized by fluorescence-based assays, for important phytochemicals such arjunolic acid, berberine, piperine, and found having negligible inhibitory effects on important cytochrome P450 enzymes.(Pandit et al., 2017). There are also possibilities of drug interactions while using ayurvedic and allopathic medications at the same time.

Ayurvedic formulations including a variety of herbal drugs can interact with prescription medication by altering humoral responses, metabolism and absorption frequency through pharmacodynamic effects. Safety and potential positive synergistic effects can be maximized which includes thorough drug history, suitable timing, and sales regulation.(Dhanya & Shukla, 2017).

The therapeutic efficacy can be improved when combining multiple herbs together in ayurvedic formulations.(Mukherjee et al., 2018). Even if synergistic interaction may provides better therapeutic outcomes, caution may be taken in the area of antimicrobials, anticancer medicines and hypoglycemics, since multiherbal formulations also have the chance for negative effects too. It is crucial to comprehend these interactions in order to maximize therapeutic advantages and prevent harm.(Kapoor & Singla, 2015).

Herbal extracts have better therapeutic benefits than the sum of their constituent parts. The whole plant extracts are often be more potent than separate active substances and have lessened side effects. The analysis of each components separately can be found very difficult to evaluate synergy of herbal medicines.(Williamson, 2001).

**5. Antiarthritic property of Kwatha**

BDK (Bhadradarvadi Kashayam) possesses potent anti-inflammatory properties, which may provide a valuable therapeutic approach for managing autoimmune disorders, particularly rheumatoid arthritis, through the modulation of immune response mechanisms and inflammatory pathways responsible for chronic inflammation.(Ali & Sundararajan, 2024).

The molecular effects of anti arthritic effects of three classical ayurvedic polyherbal formulations Balaguluchiadi Kashayam (BgK), Punarnavadi Kashayam (PuK), and Gugguluthiktam Kashayam (GuK) has been assessed. The histopathological analysis, cytokine profiling, and gene expression assessments confirmed the molecular effects which leads to the significant reduction in the proinflammatory mediators such as TNF-α, IL-1β, COX-2, and iNOS, and promotes the expression of the anti-inflammatory cytokine IL-10. For inflammatory joint condition, and for managing rheumatoid arthritis these formulations are utmost effective.(Aswathy et al., 2021).

Sahacharadi Kashayam have anti-arthritic potential, all the ingredients in this decoction are therapeutically effective in the treatment of vata related disorders. Further study needed to diminish the inflammatory recurrence, longer treatment periods and greater doses.(P. P. Kumar et al., 2020).

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The polyherbal formulation consisting of the dried fruits of Emblica officinalis and the seed coat and kernel of Terminalia chebula and Terminalia bellirica indicates promising antiarthritic capabilities and may contribute to better health outcomes which protects against arthritis related inflammation and considerably reduce paw edema.(Chimagave et al., 2020).

A combination of herbal formulations may provide a more effective treatment strategy, targeting multiple pathological processes associated with arthritis.(Subramoniam et al., 2013). Punarnavasava (PNR) have significant antinociceptive action via CNS regulations and very much effective in inflammation reaction. PNR may be pharmacologically used to treat illness such as arthritis, lumbago and sciatica.(Samad et al., 2013).

Manjishtadi kashayam (MK), Rasna erandadi kashayam (REK), Sahacharadhi kashayam (SK), Maharasnadi kashayam (MRK), and Dhanwantharam kashayam (DK) can be used to treat vata and vatarakta diseaases, because these formulations possess high phenolic content and anti-oxidant activities.(C. V Sruthi & Sindhu, 2012).

Standardized criteria, including grip strength, joint counts, and inflammatory indicators, along with improved functional ability, the results showed notable improvements in a number of measures, including decreased joint swelling, discomfort, and inflammation. Notwithstanding the lack of a control group, traditional Ayurvedic therapy is found to be safe and successful in controlling RA symptoms.(Krishna, 2011).

**6. Antioxidant and anti inflammatory activity**

Dhanwantaram Kashayam (DK), a polyherbal Ayurvedic infusion contain a significant amount of flavonoids, phenolic content, which has been revealed by a variety of tests such as ferric reducing antioxidant power (FRAP) and free radical scavenging activities against DPPH, ABTS, phosphomolybdenum, hydrogen peroxide, hydroxyl radical, and nitric oxide. It demonstrates strong antioxidant and and radical scavenging properties with low IC50 values. DK can be used for postpartum healing and rejuvenation.(Renganathan & Pillai, 2021).

Balaguluchyadi Kashayam (BK), a traditional polyherbal Ayurvedic concoction used to treat chronic inflammatory disorders, inhibits important pro inflammatory enzymes including cyclooxygenase-2, 5-, 12-, and 15-lipoxygenases (LOXs), and 15-prostaglandins which mediates inflammation. BK also reduces the cellular origins of inflammation by efficiently preventing monocytes from differentiating into macrophages. BK functions at several stages of the inflammatory pathway, most likely as a result of the synergistic action of its bioactive phytoconstituents.(Rahitha Devi et al., 2020). Pathyashadangam Kashayam, a traditional Ayurvedic composition used to treat a variety of conditions such as migraines, diabetes, neurodegenerative illnesses, and problems with the eyes, ears, and teeth, shows high antioxidant activity. Among the ingredients Phyllanthus emblica, Terminalia chebula, and Terminalia bellirica revealed to possess strongest radical scavenging power which indicate their significant contribution to the effectiveness of the formulation. Phenol and flavonoid levels and antioxidant activity have a positive association, and these substances play a significant role in Pathyashadangam Kashayam's therapeutic advantages and support its long-standing use in the treatment of illnesses linked to oxidative stress.(Abraham, Mathew, et al., 2020).

Polyherbal formulations with improved antioxidant activity can be developed for food and supplement industries by checking the highest phenolic contents and also for combinatorial assays for positive synergistic interactions.(Rahim et al., 2019). The modified dosage forms of Tamalakyadi decoction (TD), a traditional treatment for allergic rhinitis, and its modified dosage forms, such as freeze-dried (FDF-TD) and spray-dried (SDF-TD), were examined and the former exhibits high antioxidant activity and is a good substitute for traditional decoction.(Dahanayake et al., 2019). Using preclinical trials with excision and incision wound models to assess healing activity and agar diffusion and broth dilution methods for antimicrobial assessment, a polyherbal formulation made of methanolic extract of Argemone Mexicana, Datura stramonium and Plumbago zeylanica improves collagen synthesis, decreased healing time and increased wound contraction.(Dev et al., 2019). The GCMS profile of Drakshadi Kashayam Ayurvedic medicine that has traditionally been used to treat illnesses like anemia (Panduroga) and jaundice revealed numerous important biomolecules like carbonic acid, bisphenol, and histamine which supports its usage as a livertonic.(Narayanan et al., 2019).

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Varanadi Kashayam, assessed quantitatively by quantitative PCR and ELISA and found to reduce monocyte differenciation in macrophages and also can downregulate the expression of several key surface markers and cytokines associated with inflammation. Since the formulation found to be effective in suppressing the production of proinflammatory cytokines especially TNF-α and IL-1β, it may be useful in ayurvedic medication for controlling chronic inflammatory diseases and related disorders.(Chinchu et al., 2018). Patolamuladi Kashayam examined by thorough phytochemical and chromatographic techniques inorder to assess the effect of preservatives on the stability of freshly made kashaya without preservatives and also the sample that had been kept for six months all compared.(Kar et al., 2018).

The antioxidant potential of Sukumara Kashayam, an Ayurvedic concoction that has long been used to alleviate constipation and menstrual pain, has revealed by assays like DPPH, FRAP, and Hydrogen Peroxide Scavenging Activity.(Nirupa et al., 2017).

Another formulation made by combining the aqueous extracts of four different plants: Commiphora mukul, Madhuca indica, Picrorhiza kurroa, and Syzygium cumini showed strong antioxidant activity and the free radical scavenging capabilities.(Iqbal & Gurumurthy, 2016). Dasamula is traditionally used to treat pain and inflammation which indicates a high concentration of beneficial components such as alkaloids, tannins, and flavonoids.(Vadivel, 2016).

The blooms, roots, and leaves of metabolites like saponins, tannins, flavonoids, alkaloids, glycosides Barleria prionitis can be used to treat conditions like pain, fever, cough, and jaundice.(Talukdar et al., 2015).

Dashanga Yoga demonstrates to be effective in both anti-inflammatory and analgesic characteristics, necessitating further examination of its active ingredients and mechanisms of action.(Ruknuddin et al., 2013).

The antioxidant activity of a syrup prepared out of Centella asiatica, Bacopa monnieri, and Hippophae rhamnoides was evaluated and showed as the created mixture have high antioxidant capacity.(Singh et al., 2012).

Reverse pharmacology technique can be used to reveal novel anti inflammatory compounds from ayurvedic medicines, which can connect ancient knowledge with current scientific validation.(B. Aggarwal et al., 2011). Triglize, a commercialized polyherbal preparation, appear to have anti oxidant and diuretic qualities and can be used in controlling hypertension and heart diseases.(Parasuraman et al., 2010).

Elakanadi Kashayam, used to treat chronic respiratory conditions, has strong anti-inflammatory, antioxidant, and anti-cancer properties.(Rao & Pazhanimuthu, n.d.). The methanolic extracts of Phyllanthus emblica, Moringa oleifera, and Citrus limon has been assessed phytochemically to reveal the antioxidant activity of a polyherbal formulation and found to have substantial synergistic antioxidant effects.(Ramasamy et al., n.d.).

**Table 6.1. Antioxidant and Anti-inflammatory Activities of Ayurvedic and Polyherbal Formulations**

| **Formulation/Plant** | **Assays Used** | **Key Bioactive Constituents/ Mechanisms** | **Therapeutic Significance** | **Reference** |
|---|---|---|---|---|
| Polyherbal antioxidant formulations | Phenolic estimation, combinatorial assays | Phenolics, flavonoids | High phenolic content and positive synergistic interactions enhance antioxidant potential for food and supplement applications | Rahim et al., 2019 |
| Varanadi Kashayam | qPCR, ELISA | Cytokine modulation (TNF-α, IL-1β) | Suppressed pro-inflammatory cytokines and inhibited monocyte–macrophage differentiation; | Chinchu et al., 2018 |

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| | | | useful for chronic inflammatory disorders | |
| Triglize (commercial polyherbal) | Antioxidant & diuretic assays | Multiple aqueous herbal extracts | Exhibited antioxidant and diuretic properties; beneficial in hypertension and cardiovascular disorders | Parasuraman et al., 2010 |
| Barleria prionitis | Phytochemical screening | Saponins, flavonoids, alkaloids, tannins | Demonstrated antioxidant, anti-inflammatory, hepatoprotective and gastroprotective activities | Talukdar et al., 2015 |
| Tamalakyadi Decoction (TD) & modified forms | DPPH and antioxidant assays | Polyphenols | Freeze-dried form showed superior antioxidant activity and serves as an effective alternative to traditional decoction | Dahanayake et al., 2019 |
| Dasamula | Membrane stabilization assay | Alkaloids, tannins, flavonoids | Strong anti-inflammatory activity; A. marmelos showed highest RBC membrane stabilization | Vadivel, 2016 |
| Patolamuladi Kashayam | Phytochemical & physicochemical analysis | Alkaloids, flavonoids, tannins | Maintained chemical stability and phytochemical integrity for six months, even with preservatives | Kar et al., 2018 |
| Drakshadi Kashayam | GC–MS | Carbonic acid, bisphenol, histamine | Identified hepatoprotective biomolecules supporting its use as a liver tonic | Narayanan et al., 2019 |
| Dashanga Yoga | Anti-inflammatory & analgesic assays | Multiple phytoconstituents | Demonstrated anti-inflammatory and analgesic effects; requires mechanistic studies | Ruknuddin et al., 2013 |
| Polyherbal wound-healing formulation | Wound models, antimicrobial assays | Methanolic extracts | Enhanced collagen synthesis, reduced healing time, and lowered inflammation | Dev et al., 2019 |
| P. emblica, M. oleifera, C. limon | DPPH assay | Synergistic polyphenols | Polyherbal extract showed stronger antioxidant activity than individual extracts | Ramasamy et al., n.d. |
| Polyherbal antioxidant blend | DPPH assay | Phenols, flavonoids | Strong free radical scavenging and oxidative stress reduction | Iqbal & Gurumurthy, 2016 |

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|---|---|---|---|---|
| Hepatoprotective syrup | Antioxidant assays | Polyphenols | High antioxidant activity useful against oxidative liver damage | Singh et al., 2012 |
| Dhanwantaram Kashayam | DPPH, ABTS, FRAP, NO scavenging | Flavonoids, phenolics | Strong antioxidant and radical scavenging activity; beneficial for postpartum rejuvenation | Renganathan & Pillai, 2021 |
| Balaguluchyadi Kashayam | Enzyme inhibition assays | COX-2, LOXs inhibition | Suppressed inflammatory enzymes and macrophage differentiation; acts at multiple inflammatory stages | Rahitha Devi et al., 2020 |
| Sukumara Kashayam | DPPH, FRAP, $H_2O_2$ assays | Antioxidant phytochemicals | High antioxidant potential supporting use in menstrual and gastrointestinal disorders | Nirupa et al., 2017 |
| Elakanadi Kashayam | FRAP, ABTS, membrane stabilization | Synergistic phytochemicals | Strong antioxidant, anti-inflammatory, and anticancer properties | Rao & Pazhanimuthu, n.d. |
| Pathyashadangam Kashayam | DPPH, phenol & flavonoid estimation | Phenolics, flavonoids | High antioxidant activity correlated with phenolic content; effective against oxidative stress-related diseases | Abraham, Mathew, et al., 2020 |

## CONCLUSION

The importance of Kwatha Kalpana as a traditional Ayurvedic dose form based on the concepts of polyherbalism and synergism is highlighted in this review. Kwathas' high concentration of water-soluble bioactive chemicals gives them significant therapeutic promise; nevertheless, issues including difficult preparation, short shelf life, inconsistent quality, and poor palatability prevent them from being widely used in contemporary healthcare.

The reviewed research clearly demonstrate that thorough standardization is required to assure the safety, efficacy, and uniformity of kwatha formulations. Modern analytical techniques such as TLC, HPTLC, HPLC, GC-MS, and LC-MS/MS are critical in phytochemical fingerprinting, marker compound identification, and quality control of complicated polyherbal decoctions. The optimization of preparation parameters—such as raw material selection, particle size, extraction conditions, and regulated preservative use—has a direct impact on phytochemical content and therapeutic performance.

Importantly, combining traditional Ayurvedic knowledge with modern pharmaceutical and analytical developments provides a viable avenue to improving the clinical usefulness of kwathas while maintaining their holistic core. The standardized and scientifically proven kwatha formulations have a high potential for use as safe, effective, and holistic therapeutic choices, allowing them to be integrated into modern integrative healthcare systems.

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