

Comprehensive Quality Assessment of Siddha Polyherbal Tablet *Kadukkai Maathirai*: HPLC Analysis, Iron Estimation, Heavy Metal Screening, and Microbial Contamination Evaluation

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ABSTRACT

The global use of herbal drugs for liver diseases is on the rise, driven by increasing rates of liver-related ailments. Despite their widespread use, growing concerns have been raised about the safety and quality of herbal formulations. The present study assessed *Kadukkai Maathirai* (KM), a Siddha-based polyherbal preparation, for potential contamination with heavy metals and microbial agents. Samples of KM procured from the SKM Company and then analyzed for microbial contamination and for the presence of heavy metals. The findings depicted that the heavy metals, such as arsenic (As), Cadmium (Cd) and Lead (Pb), were in permissible limits. Moreover, microbial analysis revealed no detectable growth on culture plates, indicating the absence of bacterial and fungal contamination in the KM samples. In addition, when the samples were analysed for Marker compounds, the chebulic acid content in the hydroalcoholic extract was determined to be 1.13% w/w. The current findings of the study support the safety of KM for therapeutic use. The herbal medicine standardization and the integration of present analytical tools with traditional knowledge may enhance therapeutic reliability of the patients using it. Clinical studies are essential to validate KM's efficacy in liver diseases and support its incorporation into evidence-based medical practice.

Keywords: Heavy metal screening, Siddha herbal tablets, HPLC, Quality assessment.

INTRODUCTION

The origin of herbal medicine was recorded in the ancient Chinese and Indian civilization around 2100 BC¹. Polyherbal medicine is a therapeutic approach combining multiple medicinal herbs, has gained significant consideration for their potential in managing various ailments and diseases. These preparations are very affordable, user friendly and perceived as a safer alternate to conventional pharmaceutical therapies^{2,3}. Liver plays key role in balancing metabolic activity and removal of xenobiotics from the body, making it highly prone to damage by various metabolites, metalloids and toxins⁴. Polyherbal formulations have been integral to various traditional medical systems of the globe to address liver disorders due to their synergistic effects and multi-targeted mechanisms⁵⁻⁷.

An Indian study reported 26.7% patients diagnosed with liver disorders used complementary and alternative medicine (CAM) approaches specifically targeting chronic liver conditions. Among the various CAM modalities, Ayurveda was the most utilized followed by Naturopathy and Siddha. Interestingly more than 50% of patients simultaneously use more than one CAM system⁸. The widespread consumption of herbal and polyherbal products by the patient for various ailments in recent years has raised significant concerns pertaining to their safety, quality, and standardization⁹. Heavy metal content in herbal formulations should be minimum as it causes

toxicity when it cumulatively increased in daily diet. The acceptable limits are typically standardized based on product type and the regional or national regulatory standards¹⁰.

The permissible limits of specific heavy metals herbal medicine in India should align with the official standards outlined in the Ayurvedic, Siddha, and Unani (ASU) pharmacopoeias. These regulatory guidelines specify maximum allowable concentrations for specific heavy metals to safeguard the regulatory compliance and consumer safety in herbal raw materials and end-use products intended for human therapeutics¹¹.

In another study, while the overall prevalence of herbal product use in drug-induced hepatic damage cases varied between 2% to 11%, certain regions reported higher usage. For instance, Korea and Singapore observed herbal product usage in 73% and 71% of DILI cases, respectively¹². However, India reported a lower prevalence of 1.3%, which the study attributed to factors like heavy metal contamination in remedies leading to non-hepatic organ involvement overshadowing liver-related issues¹³.

Herbal products are susceptible to microbial contamination at any stage of preparation and storage. The detection of microorganisms beyond permissible limits is often indicative of substandard product quality and inadequate handling practices^{14,15}. Permissible limits for microbial contamination in herbal products vary based on the quality of herb

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and its intended application. WHO recommends specific guidelines for permissible limits of various fungi and bacterial organisms in herbal products. Additionally, it must be free of some pathogenic microbial species¹⁶.

Ayurvedic treatments like Liv-52, which is widely used as liver tonic are approved and regulated for clinical use in India¹⁷. In India, Drug Controller General of India (DCGI) undertake quality and import of plant based and alternative medicines. These regulatory body defines the quality control and ensures the Good Manufacturing Practices of herbal products manufacturing and packing in India. Furthermore, it retains the authority to revoke the approval of any herbal product found to exhibit harmful adverse effects. It also adheres to permissible heavy metals limits for herbals following guidelines instituted by WHO¹⁸⁻²⁰.

Numerous studies conducted worldwide have focused on evaluating the contamination levels in herbal products and their ingredients following the regulatory guidelines. The primary focus of these investigations was to identify the occurrence of microbial load and various heavy metals contaminants as these are used in the preparation process of herbal products. These assessments were undertaken to determine whether the contamination levels fall within internationally accepted safety limits²¹⁻²⁴. A study from Tanzania reported that the levels of Magnesium, Mn, iron, and Nickel in certain plants exceeded the permissible levels²⁵. Notably, even when heavy metal levels remain within internationally accepted thresholds, the potential for bioaccumulation in chronic intake may still lead to toxicological effects. This raises significant concerns, as prolonged consumption of such products may pose considerable health risks to patients consuming it^{26,27}.

The aim of the present study was to estimate the quality of *Kadukkai Maathirai* (KM), a Siddha herbal formulation by assessing its microbial load and heavy metal contamination, which is reputed for its hepatoprotective properties, used widely among the Tamil Nadu and Kerala state in India. The outcomes of the current investigation focus on the status of contamination issues in KM within the Indian context and may serve as a basis for raising awareness and prompting regulatory action among relevant authorities.

MATERIALS AND METHODS

Standardization of hydroalcoholic extract of KM using chebulic acid as a marker compound

Procurement of KM

KM was obtained from SKM, a GMP Company (India) Pvt. Limited. This was used for all the experiments in this study.

Preparation of sample

A portion of the hydroalcoholic extract, corresponding to 0.1 mg/mL chebulic acid was taken and added in 40 mL of HPLC-grade hot water and the procedure of sonicator for 10 minutes to aid dissolution. After cooling, the volume was adjusted for 100 mL using HPLC-grade water. Further, it was thoroughly mixed and passed via 0.45 µm filter membrane before analysis.

Preparation of standard

A chebulic acid standard solution was prepared by dissolving 10 mg of chebulic acid in HPLC-grade water and diluting the solution to a final volume of 100 mL to achieve a concentration of 0.1 mg/mL.

Chromatographic conditions

Chromatographic analysis was performed using Phenomenex Luna C18(2). The mobile phase comprised of a gradient system comprising phosphate buffer (pH 2.8) as solvent A, acetonitrile as solvent B, and

then delivered at a rate of flow at 1.5 mL/min. Of about 20 µL injection volume was used, and detection was conducted out at 270 nm using a Ultra Violet detector.

Quantification procedure

A volume of 20 µL from both the sample and standard solutions (each containing 0.1 mg/mL of chebulic acid) was injected to the HPLC. The chebulic acid concentration in KM extract was quantified by assessing the chromatographic retention time and peak area of the test sample to that of the standard²⁸⁻³⁰.

Determination of heavy metals

Heavy metals like arsenic, cadmium, lead, and mercury were estimated in hydro-alcoholic extract of KM by ICP-MS method.

Sample preparation

Accurately weighed 500 mg of KM hydroalcoholic extract was treated with 5 Conc. HNO₃ and digested using Microwave Accelerated Reaction System (MARS). After the digestion process was completed and the vessel was cooled, the digested product was diluted to 400 mL along with pure water.

ICP-MS analysis

Working standard solutions were prepared by dilution tested in ICP-MS instrument. System response was monitored and used to construct a calibration curve. The sample digest was then analyzed under the same instrumental conditions. Arsenic, mercury, cadmium, and lead levels were quantified by comparing the sample signal intensities to those obtained from the calibration standards^{31,32}.

Microbial contamination analysis

To assess microbial contamination, 1 mL of sterile normal saline was placed in a sterile vial and mixed with the hydroalcoholic extract of KM. The mixture was then inoculated onto blood agar to screen for bacterial presence and Sabouraud Dextrose Agar (SDA) to detect fungal contamination. The media for inoculation was incubated at optimum conditions for 48 hours and subsequently examined for any signs of microbial growth³³.

Phytochemical screening

Phytochemical screening of hydroalcoholic extract of KM was assessed qualitatively for glycosides, alkaloids, flavonoids, carbohydrates, proteins, steroids, proteins, saponins and phenols^{34,35}.

RESULTS

Quantification of chebulic acid

The content of chebulic acid in the hydroalcoholic extract of KM was quantified as 1.13% w/w, as determined by HPLC analysis. The chromatographic profiles for the chebulic acid standard and the KM extract sample are presented in Figure 1 and Figure 2, respectively.

Heavy metal analysis

The levels of all analyzed heavy metals complied with established safety thresholds as specified by ASU Pharmacopoeia analysed by ICP-MS method and then results are tabulated in Table 1.

Microbial contamination analysis

The incubated petri plate and test tube were observed for microbial growth after 48 hours (Figure 3), and no visible growth was seen, indicating the absence of microbial growth in KM.

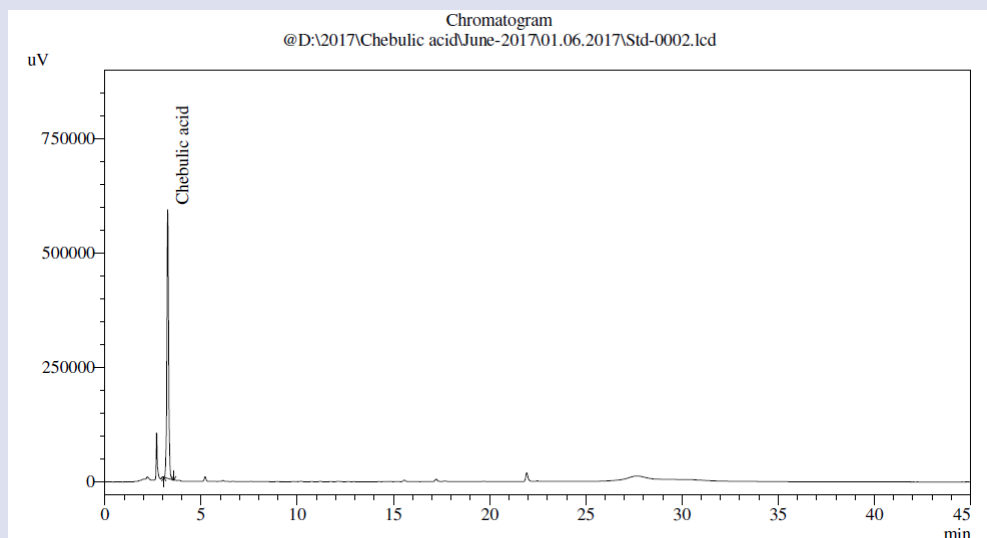


Figure 1. HPLC chromatogram of chebulic acid reference standard

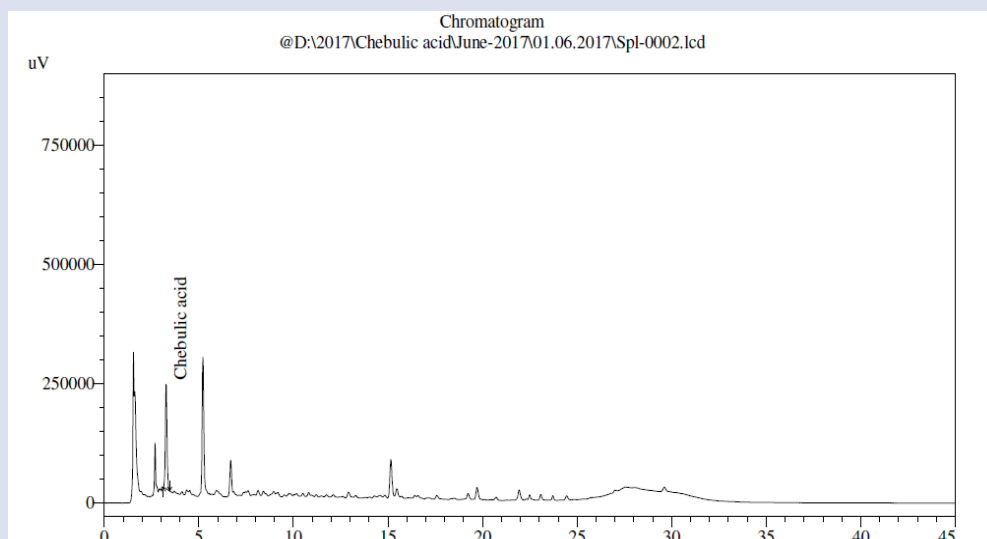


Figure 2. HPLC chromatogram of KM hydroalcoholic extract showing the chebulic acid peak

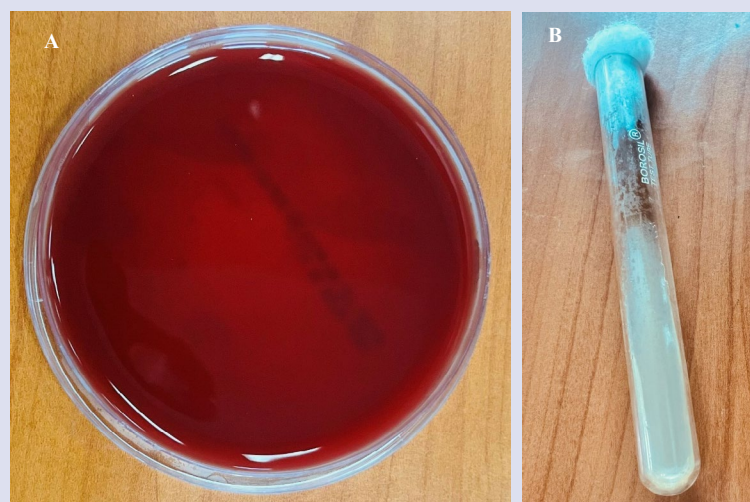


Figure 3. A) Absence of bacterial growth in KM after 48 hours of incubation in Blood agar; B) Absence of fungal growth in KM after 48 hours of incubation in Sabouraud dextrose agar

Table 1. Heavy metal analysis in KM by ICP-MS

S. No	Heavy metals	Heavy metals in KM (ppm)	ASU Permissible limits (ppm)
1	Arsenic	0.645	≤3.0 ppm
2	Cadmium	0.062	≤0.3 ppm
4	Lead	1.355	≤10.0 ppm

Table 2. Phytochemical screening of KM

Sl. No	Phytochemicals	Screening method	Results
1	Carbohydrates	Molisch's test	+
		Fehling's test	
2	Proteins	Ninhydrin test	+
3	Saponins	Frothing test	+
		Ferric chloride test	+
4	Phenols	Lead acetate test	
5	Flavonoid	Shinoda's test	+
6	Steroid	Liebermann–Burchard's test	+
		Salkowski test	+
7	Alkaloids	Mayer's test	
		Dragendroff's test	-
8	Glycosides	Borntrager's test	
		Legal's test	

+ means presence of the phytochemical, - means absence of the phytochemical

Phytochemical screening

The phytochemical screening of KM has been evaluated and the results are presented in Table 2.

DISCUSSION

The global reliance on herbal drugs for treating liver diseases highlights the significance of traditional medicine in modern healthcare³⁶. As liver-related ailments rise, herbal formulations such as KM are gaining attention due to their historical use in Siddha medicine. It was also proved by many pharmacological assessments^{37,38}. However, concerns regarding contamination and standardization emphasize the need for rigorous safety assessments.

This study conducted a throughout assessment of KM for heavy metal and microbial contamination, which are critical parameters influencing the safety limits of plant-based drugs and its formulations. The detection of arsenic, cadmium, mercury and lead within permissible limits set the safety criteria for herbal formulations for human consumption. The existence of heavy metals in plant based medicinal products continues to be a subject of global concern and regulatory scrutiny, as excessive levels can pose significant health risks, including hepatotoxicity and nephrotoxicity^{39,40}. KM's adherence to regulatory safety limits strengthens its prospects as a reliable and safe therapeutic option.

Microbial contamination is another pivotal concern in herbal drug safety, given that bacterial and fungal contaminants can lead to severe infections, particularly in immunocompromised individuals^{41,42}. The absence of microbial growth in KM samples demonstrates stringent quality control practices and suggests that the production process effectively eliminates microbial contamination.

Additionally, HPLC quantification of chebulic acid was performed and it was 1.13% w/w in the hydroalcoholic extract of KM. Chebulic acid, a bioactive component derived from *Terminalia chebula*, is known for hepatoprotective, oxidative stress reduction, and inflammation control⁴³. The presence of chebulic acid strengthens KM's pharmacological relevance and suggests that its therapeutic efficacy aligns with traditional claims.

Despite these positive findings, constant research efforts are necessary to evaluate ongoing safety, genotoxicity, bioavailability, and

pharmacokinetics. Standardization of herbal formulations remains a challenge, and integrating modern analytical techniques with traditional knowledge could enhance reproducibility and therapeutic consistency. Clinical trials assessing KM's efficacy in liver disorders would provide more definitive evidence of its medicinal benefit⁴⁴.

CONCLUSION

This investigation emphasizes the pivotal role of implementing stringent quality control measures of herbal formulations and phytopharmaceutical development. The compliance of KM with established safety standards indicates its promising application in the treatment of hepatic disorders. The safety assessments, additional pharmacological investigations, good manufacturing practice, and toxicity studies are necessary to validate the therapeutic potential and support its integration into medical practice.

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REFERENCES

- Schuppan D, Jia JD, Brinkhaus B, Hahn EG. Herbal products for liver diseases: A therapeutic challenge for the new millennium. *Hepatology*. 1999;30(4):1099-1104. doi:10.1002/hep.510300437
- Singh S, Javed Naquvi K, Singh A, Wadood Siddiqui A. Hepatoprotective activity of polyherbal extract against CCl₄ induced liver damage in rats. *South East Eur J Public Health*. 1829-1842. doi:10.70135/seejph.vi.4423
- Ammari AA, Alhimaidi AR, Amran RA, Rady A, Aljawdah H, Al-Mekhlafi F. Evaluating the hepatoprotective effects of polyherbal extracts a comprehensive study on liver function and health in rats. *Arq Bras Med Vet Zootec*. 2025;77(4). doi:10.1590/1678-4162-13390
- Li S, Tan HY, Wang N, et al. The role of oxidative stress and antioxidants in liver diseases. *Int J Mol Sci*. 2015;16(11):26087-26124. doi:10.3390/ijms161125942

5. Pandey B, Baral R, Kaundinnayana A, Panta S. Promising hepatoprotective agents from the natural sources: a study of scientific evidence. *Egypt Liver J.* 2023;13(1). doi:10.1186/s43066-023-00248-w
6. Ray S, Taraphdar AK, Gupta M. Hepatoprotective activity of Amalakyadi Gana, A polyherbal ayurvedic formulation in paracetamol-induced hepatotoxicity in mice. *J Phytopharmacol.* 2022;11(4):255-259. doi:10.31254/phyto.2022.11405
7. Fu K, Wang C, Ma C, Zhou H, Li Y. The potential application of Chinese medicine in liver diseases: A new opportunity. *Front Pharmacol.* 2021;12. doi:10.3389/fphar.2021.771459
8. Philips CA, Paramaguru R, Augustine P, et al. A single-center experience on outcomes of complementary and alternative medicine use among patients with cirrhosis. *Hepatol Commun.* 2019;3(7):1001-1012. doi:10.1002/hep4.1355
9. Ekor M. The growing use of herbal medicines: Issues relating to adverse reactions and challenges in monitoring safety. *Front Pharmacol.* 2013;4. doi:10.3389/fphar.2013.00177
10. WHO guidelines for assessing quality of herbal medicines with reference to contaminants and residues. World Health Organization; 2007.
11. Guidelines series-I general guidelines for drug development of ayurvedic formulations central council for research in ayurvedic sciences. Ministry of AYUSH, Government of India; 2018.
12. Nunes DR da CMA, Monteiro CS de J, Dos Santos JL. Herb-induced liver injury- A challenging diagnosis. *Healthcare (Basel).* 2022;10(2). 278. doi:10.3390/healthcare10020278
13. Devarbhavi H. Drug-induced liver injury unique to India. *Clin Liver Dis.* (3):108-110. doi:10.1002/cld.1120
14. Opuni KFM, Kretschy JP, Agyabeng K, et al. Contamination of herbal medicinal products in low-and-middle-income countries: A systematic review. *Heliyon.* 2023;9(9). doi:10.1016/j.heliyon.2023.e19370
15. de Sousa Lima CM, Fujishima MAT, de Paula Lima B, Mastroianni PC, de Sousa FFO, da Silva JO. Microbial contamination in herbal medicines: a serious health hazard to elderly consumers. *BMC Complement Med Ther.* 2020;20(1):17. doi:10.1186/s12906-019-2723-1
16. Quality control methods for medicinal plant materials. World Health Organization; 1998.
17. Shivnitwar SK, Gilada I, Rajkondawar A V, et al. Safety and effectiveness of Liv.52 DS in patients with varied hepatic disorders: An open-label, multi-centre, Phase IV study. *Cureus.* 2024; 16(5). doi:10.7759/cureus.60898
18. Mititelu M, Neacșu SM, Busnatu Ștefan S, et al. Assessing heavy metal contamination in food: Implications for human health and environmental safety. *Toxics.* 2025;13(5). doi:10.3390/toxics13050333
19. Sahane MB, Basarkar GD. A review of herbal regulations and approval process in India and Europe. *Int J Drug Regul Aff.* 2023;11(4):25-33. doi:10.22270/ijdra.v11i4.629
20. Guidance document on common submission format for import and registration of bulk drugs and finished formulations in India. Central Drugs Standard Control Organization (Import & Registration Division), India. Document No. IMP/REG/200711.
21. Street RA. Heavy metals in medicinal plant products - An African perspective. *S Afr J Bot.* 2012;82:67-74. doi:10.1016/j.sajb.2012.07.013
22. Alharbi SF, Althbah AI, Mohammed AH, et al. Microbial and heavy metal contamination in herbal medicine: A prospective study in the central region of Saudi Arabia. *BMC Complement Med Ther.* 2024;24(1). doi:10.1186/s12906-023-04307-y
23. Islam N, Zamir R, Faruque MdO. Health risk assessment of metals in antidiabetic herbal preparations: A safety screening. *Evid Based Complement Alternat Med.* 2024;2024:1-12. doi:10.1155/2024/6507185
24. Kulhari A, Sheorayan A, Bajar S, Sarkar S, Chaudhury A, Kalia RK. Investigation of heavy metals in frequently utilized medicinal plants collected from environmentally diverse locations of northwestern India. *Springer Plus.* 2013;2:676. https://doi.org/10.1186/2193-1801-2-676
25. Nkuba LL, Mohammed NK. Heavy metals and essential elements in selected medicinal plants commonly used for medicine in Tanzania". *Chemical Science International Journal.* 2017;9(2):1-11. doi.org/10.9734/CSJI/2017/31963.
26. Angon PB, Islam MS, KC S, et al. Sources, effects and present perspectives of heavy metals contamination: Soil, plants and human food chain. *Heliyon.* 2024;10(7). doi:10.1016/j.heliyon.2024.e28357
27. Akhbarizadeh R, Dobaradaran S, Spitz J, et al. Metal(lloid)s in herbal medicines and their infusions: Levels, transfer rate, and potential risks to human health. *Hyg Environ Health Adv.* 2023;5. doi:10.1016/j.heha.2022.100042
28. Munawar TM, Surya Prakash D V., Vangalapati M. Development of response surface methodology for optimization of parameters and quantitative analysis of chebulinic acid from composition of medicinal herbs by HPLC. *Saudi J Biol Sci.* 2019;26(7):1809-1814. doi:10.1016/j.sjbs.2018.02.013
29. Pompimon W, Wattananon S, Udomputtimekakul P, et al. HPLC Determination of the gallic Acid and chebulinic acid contents of *Phyllanthus emblica* Linn., *Terminalia bellirica* Roxb., *Terminalia chebula* Retz. and triphala products from Chae Son district, Lampang, Thailand. *Am J Food Sci Technol.* 2020;8(3):87-98. doi:10.12691/ajfst-8-3-2
30. Dhanani T, Shah S, Kumar S. A validated high-performance liquid chromatography method for determination of tannin-related marker constituents gallic acid, corilagin, chebulagic acid, ellagic acid and chebulinic acid in four terminalia species from India. *J Chromatogr Sci.* 2015;53(4):625-632. doi:10.1093/chromsci/bmu096
31. Kamat SS, Suryawanshi RP. Quantitative analysis of toxic elements by ICP-MS in herbal tablets. *J Acad Ind Res.* 2015;3:445.
32. Filipiak-Szok A, Kurzawa M, Szlyk E. Determination of toxic metals by ICP-MS in Asiatic and European medicinal plants and dietary supplements. *J Trace Elem Med Biol.* 2015;30:54-58. doi:10.1016/j.jtemb.2014.10.008
33. Mahmudul Islam AFM, Khalik MF, Uddin N, et al. Evaluation of microbiological and physicochemical profile of some herbal preparations manufactured by pharmaceutical and herbal manufacturers in Bangladesh. *J Pharm Investig.* 2015;45(2):223-235. doi:10.1007/s40005-014-0168-6
34. Bakir Çilesizoglu N, Yalçin E, Çavuşoğlu K, Sipahi Kuloğlu S. Qualitative and quantitative phytochemical screening of *Nerium oleander* L. extracts associated with toxicity profile. *Sci Rep.* 2022;12(1). doi:10.1038/s41598-022-26087-0
35. Dubale S, Kebebe D, Zeynudin A, Abdissa N, Suleman S. Phytochemical screening and antimicrobial activity evaluation of selected medicinal plants in Ethiopia. *J Exp Pharmacol.* 2023;15:51-62. doi:10.2147/JEP.S379805
36. Balkrishna A, Sharma N, Srivastava D, Kukreti A, Srivastava S, Arya V. Exploring the safety, efficacy, and bioactivity of herbal medicines: Bridging traditional wisdom and modern science in healthcare. *Future Integrative Medicine.* 2024;3(1):35-49. doi:10.14218/fim.2023.00086
37. Shetty M, Shenoy S, Amuthan A, et al. Kadukkai maathirai (Indian herbal drug) prevents hepatocellular cancer progression by enhancing GSTM1 expression and modulating β catenin transcription: in-silico and in-vivo study. *F1000 Res.* 2024;13:639. doi:10.12688/f1000research.145961.1

38. Shetty M, Shenoy S, Kumar N, et al. Kadukkai maathirai (Siddha herbal formulation) reverses liver pathology associated with metabolic dysfunction in high fat diet-induced fatty liver disease – a preclinical study. *Res J Pharm Technol*. 2023;16(12):6032-6038. doi:10.52711/0974-360X.2023.00979
39. Yang CM, Chien MY, Chao PC, Huang CM, Chen CH. Investigation of toxic heavy metals content and estimation of potential health risks in Chinese herbal medicine. *J Hazard Mater*. 2021;412. doi:10.1016/j.jhazmat.2021.125142
40. Mikulski MA, Wichman MD, Simmons DL, Pham AN, Clotney V, Fuortes LJ. Toxic metals in ayurvedic preparations from a public health lead poisoning cluster investigation. *Int J Occup Environ Health*. 2017;23(3):187-192. doi:10.1080/10773525.2018.1447880
41. Ahiabor WK, Darkwah S, Donkor ES. Microbial contamination of herbal medicines in Africa, 2000-2024: A systematic review. *Environ Health Insights*. 2024;18. doi:10.1177/11786302241293345
42. Tyski S, Burza M, Laudy AE. Microbiological contamination of medicinal products -Is it a significant problem? *Pharmaceuticals*. 2025;18(7):946. doi:10.3390/ph18070946
43. Wang C, Zhang H, Wang X, et al. Comprehensive review on fruit of *Terminalia chebula*: traditional uses, phytochemistry, pharmacology, toxicity, and pharmacokinetics. *Molecules*. 2024;29(23). doi:10.3390/molecules2923554
44. Parveen A, Parveen B, Parveen R, Ahmad S. Challenges and guidelines for clinical trial of herbal drugs. In: *J Pharm Bioall Sci*. Vol 7. Wolters Kluwer Medknow Publications; 2015:329-333. doi:10.4103/0975-7406.168035

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