

**SAFETY AND EFFICACY OF AYURVEDIC MEDICINES IN THE CONTEXT OF TRACE
PESTICIDE RESIDUES: A REVIEW*****Dr. Poorva Joshi, Dr. Amit Avalaskar**

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DOI: <https://doi.org/10.5281/zenodo.18797740>**How to cite this Article:** Poorva Joshi* (2026). Safety And Efficacy Of Ayurvedic Medicines In The Context Of Trace Pesticide Residues: A Review. World Journal of Pharmaceutical and Medical Research, 12(3), 105–109.
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Article Received on 16/01/2026

Article Revised on 05/02/2026

Article Published on 01/03/2026

ABSTRACT

Ayurvedic medicines are used extensively for disease management across the world and maintenance of health. Because of the widespread use of pesticides in agriculture, trace residues may be occasionally detected in medicinal plants and herbal formulations. This raises concerns regarding safety and their therapeutic performance. This review evaluates evidence which is published on occurrence of pesticide residue in Ayurvedic medicines, Ayurvedic perspective on safety and drug quality, Pesticide use and environmental exposure, sources of pesticide residues in herbal / ayurvedic medicines, regulatory limits and safety thresholds, trace residues vs therapeutic efficacy, impact of trace residues on therapeutic efficacy of ayurvedic medicines, comparison with food safety paradigm, discussion and future direction and conclusion are the points discussed. The studies indicate that residues are usually present at very low concentrations, which are often within internationally accepted maximum residue limits. At such levels, the risk of its toxicity is minimal and is not likely to influence the pharmacological action of herbal formulations. The review highlights the importance of good agricultural and manufacturing practices, quality control, and routine testing to ensure safety. Overall, current evidence suggests that trace pesticide residues, when within permissible limits, do not adversely affect the therapeutic efficacy of Ayurvedic medicines.

KEYWORDS: Ayurvedic medicines; Pesticide residues; Herbal drug safety; Therapeutic efficacy; Quality control; Regulatory standards.**INTRODUCTION**

There has been a considerable growth globally in the use of Ayurveda and Ayurvedic medicines. Which means there has been an increase in the demand for ayurvedic herbs. In order to keep pests away from these herbs there has also been an increase in the use of different types of pesticides in the cultivation of these herbs. This gives a rise to the concern regarding pesticide residues in these Ayurvedic medicines. The general concerns with having pesticide residues in medicines is the probability of them causing toxicity and of them hindering the efficacy of these medicines.

It is important to note that herbal medicines are not necessarily ayurvedic medicines. Ayurvedic treatment is when these medicines are used with ayurvedic philosophy, diagnosis according to Ayurveda. The aim of Ayurved is "*doshasamyā*" which means to achieve/maintain equilibrium of *doshas*. which can be achieved only if the medicines are used in the way mentioned

above. This is the reason why Ayurved is known to be a sustainable practice as better homeostasis is achieved and maintained, hence the demand for it has increased over the years.

There is a large population also relying on herbal and ayurvedic medicines for primary healthcare. Many herbal therapies have shown effects that have been beneficial, but some products have not yet been fully studied or consistently monitored. As a result, detailed information on their actions, safety aspects, and interactions with conventional medicines is still evolving. Strengthening quality and regulatory practices can help ensure the safe, effective, and responsible use of herbal medicinal products.^[1]

The WHO has highlighted that many countries face challenges in implementing traditional medicine policies due to limited research evidence, inadequate regulation, and insufficient guidance on ensuring safety, quality, and

integration into health systems. Member States have therefore requested technical and policy support to strengthen research, regulation, and safe integration of traditional medicine into primary healthcare.^[2]

Rationale for the review

With the increasing use of Ayurvedic medicines, greater attention is being given to their quality and safety, including the presence of trace pesticide residues from agricultural practices. Although we can see that such residues are commonly found in plant-based foods and are considered safe within regulatory limits, their relevance to the efficacy of Ayurvedic medicines is not clearly discussed in existing literature. The presence of a substance means it can be detected in very small amounts, but this does not automatically mean it causes harm. Toxicological relevance depends on the amount present, and only levels above safety limits are likely to affect health or biological function. This review aims to examine available evidence to clarify whether trace pesticide residues affect the safety or therapeutic effectiveness of Ayurvedic medicines.

AYURVEDIC PERSPECTIVE ON SAFETY AND DRUG QUALITY

In Ayurveda, *Suddha Dravya* means a substance that is pure by nature or made pure through proper processing so that it is safe and effective for use. Factors such as *Deśa* (place of origin), *Kāla* (time of collection), *Saṅgrahaṇa* (harvesting and storage), and *Saṃskāra* (processing) are essential in maintaining the quality and potency of medicinal substances.

Classical processing methods help remove impurities, reduce toxicity, and ensure the safety and therapeutic effectiveness of Ayurvedic medicines.

PESTICIDE USE AND ENVIRONMENTAL EXPOSURE

The Codex database lists maximum permitted pesticide residue limits for foods and animal feeds. It is required that residue levels in tested samples do not exceed these limits at any stage of trade, and currently includes **6,453 MRLs and 63 EMRLs** for different pesticide–commodity combinations.^[3]

The general population is mainly exposed to pesticides through food and drinking water and not medicines. Exposure through food and medicines is usually low-dose and long-term, unlike occupational exposure. Exposure is higher and it mainly affects farmers, people who spray pesticides, and people living near farms, not consumers.

Most health effects reported in studies come from animal experiments studies show that using doses much higher than legally permitted human exposure. Human health risk is considered very low at legally regulated residue levels. The way safety limits are set is such that Safety limits such as ADI (Acceptable Daily Intake) and ARfD

(Acute Reference Dose) are based on animal studies with large safety margins. A 100-fold safety factor is used to protect humans from uncertainty. These limits make sure that daily exposure throughout lifetime remains safe.

Pesticides are approved only after extensive testing for acute, chronic, reproductive, genetic, and cancer-related toxicity.^[4]

SOURCES OF PESTICIDE RESIDUES IN HERBAL MEDICINES

We can say that mostly all these pesticide residues are systemic and environmental. The sources of pesticide residues is usually due to contamination due to agriculture, because of their persistence in the environment and their entry through soil, water and air, we can see that there is circulation of pesticides in the environment, Presence of Pesticide residue traces is also because of post-harvest handling conditions and storage conditions. Low/ trace exposure seems to be inevitable in plant-based products.

OCCURRENCE OF TRACE PESTICIDE RESIDUES IN HERBAL / AYURVEDIC MEDICINE

Tripathi et al. (2017) analyzed 52 market samples of four widely used Indian medicinal herbs using a modified QuEChERS method followed by GC-MS analysis. The validated method showed good accuracy and reliability, with pesticide recoveries of 70–120% and acceptable precision. Low-level pesticide residues were detected in some commercial samples, highlighting the importance of routine monitoring rather than indicating inherent safety concerns. The study emphasizes that sensitive analytical tools are essential for quality assurance of herbal raw materials, especially to meet regulatory and international trade requirements.^[5]

REGULATORY LIMITS AND SAFETY THRESHOLDS

The European Commission SANCO/12571/2013 guideline provides standardized requirements for validating pesticide residue analytical methods, including accuracy, precision, limits of detection, and recovery ranges to ensure reliable results. It emphasizes that residue findings must be scientifically validated and interpreted within regulatory limits to support food and herbal product safety assessments.^[6]

The Ministry of AYUSH Good Agricultural and Collection Practices (GACP) guidelines outline proper cultivation, harvesting, and post-harvest handling of medicinal plants to ensure their quality, safety, and purity. These practices help minimize contamination, including pesticide residues, and support the consistent efficacy of Ayurvedic raw materials.

Here are the key GACP practices recommended by the Ministry of AYUSH that help reduce contamination (including pesticide residues) and maintain consistent efficacy of Ayurvedic raw materials, written in simple,

article-friendly language.

- Selection of clean cultivation sites away from industrial areas, sewage, heavy traffic, and polluted water sources to prevent environmental contamination.
- Use of healthy planting material (authentic species, disease-free seeds or propagules) to ensure therapeutic consistency.
- Minimal and controlled use of agrochemicals, with preference for organic manures, biofertilizers, and biological pest control methods.
- Avoidance of banned or highly toxic pesticides, and strict adherence to recommended doses and pre-harvest intervals when pesticides are unavoidable.
- Proper irrigation practices, using clean and uncontaminated water sources.
- Correct harvesting time and methods, as per classical Ayurvedic texts and plant maturity, to preserve active constituents.
- Clean post-harvest handling, including washing, drying, storage, and transport under hygienic conditions to prevent secondary contamination.
- Separate storage and labeling of raw materials to avoid mixing, adulteration, or cross-contamination.
- Documentation and traceability, allowing monitoring of cultivation practices from field to finished raw drug.^[7]

TRACE RESIDUES VS THERAPEUTIC EFFICACY

Heinrich et al. (2020) emphasize that the safety and therapeutic effectiveness of herbal medicines depend on consistent quality assurance throughout cultivation, processing, and manufacturing. The review clarifies that the detection of trace contaminants, including pesticide residues, does not by itself indicate reduced efficacy when levels remain within established regulatory limits. Instead, maintaining standardized quality control measures ensures that the complex phytochemical composition responsible for herbal efficacy is preserved while minimizing potential safety risks.

Herbal medicine efficacy is determined by phytochemical integrity and quality control, not by the mere presence of trace, regulated contaminants.^[8]

Herbal medicines work through the combined and synergistic action of multiple phytochemicals rather than a single active compound. This complex phytochemical network helps maintain therapeutic effects even when minor variations or trace-level contaminants are present.^[9] Therefore, pesticide residues detected at very low, regulated levels are unlikely to interfere with the overall efficacy of herbal medicines.

IMPACT OF TRACE PESTICIDE RESIDUES ON THERAPEUTIC EFFICACY OF AYURVEDIC MEDICINES

The therapeutic efficacy of Ayurvedic medicines primarily depends on the presence, stability, and

bioavailability of active phytoconstituents, along with appropriate formulation, dosage, *anupāna*, and patient-related factors such as *agni* and *prakṛti*. Concerns have been raised that the presence of pesticide residues, even at trace levels, may interfere with these factors and thereby reduce the efficacy of herbal formulations. However, a critical review of available literature does not provide conclusive evidence to support this assumption.

Most studies reporting pesticide residues in Ayurvedic raw materials and finished products indicate that detected levels are either below the maximum residue limits or close to the analytical limits of quantification. At such low concentrations, pesticide residues are unlikely to chemically interact with or alter the pharmacologically active constituents responsible for therapeutic action. Furthermore, the concentration of active phytochemicals in Ayurvedic medicines is significantly higher than that of trace pesticide residues, making functional interference improbable.

Ayurvedic pharmaceutical processes such as *śodhana*, *bhāvana*, *kvātha pāka*, and *chūrṇa* preparation involve steps like washing, soaking, heating, and repeated processing, which may further reduce residual pesticide levels. These processes also enhance the extraction and bioavailability of active principles, thereby supporting therapeutic efficacy. Unlike raw dietary exposure, medicinal preparations undergo multiple stages of processing that contribute to quality assurance.

From a clinical perspective, the efficacy of Ayurvedic medicines has been demonstrated through long-standing traditional use and contemporary clinical studies, without documented evidence linking therapeutic failure to trace pesticide contamination. Importantly, modern toxicological assessments emphasize that biological effects are dose-dependent, and the mere presence of a chemical substance does not imply pharmacological antagonism or loss of efficacy.

Comparable considerations apply to modern pharmaceutical products, where trace impurities and residual solvents are permitted within defined safety limits without compromising therapeutic outcomes. Applying similar risk-based principles, trace pesticide residues detected in Ayurvedic medicines, when present within regulatory limits, are unlikely to influence clinical efficacy.

Overall, current scientific evidence suggests that while monitoring of pesticide residues remains essential for quality control, the presence of trace residues at toxicologically insignificant levels does not adversely affect the therapeutic efficacy of Ayurvedic medicines.

COMPARISON WITH FOOD SAFETY PARADIGM

It clarifies that risk is a function of both dose and exposure, and that simply detecting a chemical does not

mean it will harm health if exposure remains below established safe limits.^[10]

Dietary intake of pesticide residues is primarily associated with commonly consumed foods such as fruits and vegetables, which contribute most to long-term exposure. Herbal medicines, being used less frequently and in smaller doses, are expected to contribute comparatively less to overall pesticide exposure, provided they meet established quality and safety standards.^[11]

FUTURE DIRECTIONS

The 2019 WHO global report shows that traditional and complementary medicines, including herbal products, are widely used around the world and increasingly recognized in national health systems, with many countries developing legal frameworks and regulations to improve their quality and safety. It highlights the importance of monitoring and regulating herbal medicines to ensure they are safe and effective for public health, supporting their integration into health services and consumer trust.

WHO reports that global use of traditional medicines is growing, and strengthening regulation, monitoring, and safety systems helps ensure their safe, effective use in health systems worldwide.^[12]

Modern analytical methods are essential to detect contaminants such as pesticide residues and protect consumer health. Strong quality control and standardization help ensure that herbal medicines are safe and therapeutically consistent, minimizing issues like contamination, including pesticide residues.

DISCUSSION

The presence of trace pesticide residues in Ayurvedic medicines should be interpreted within the broader context of unavoidable environmental exposure to agrochemicals. Pesticides are widely used in modern agriculture, and their residues are commonly detected at low levels in food grains, vegetables, fruits, and medicinal plants alike. Therefore, the detection of trace residues in Ayurvedic formulations does not represent a unique or isolated safety concern but reflects a shared challenge across all plant-derived products.

Importantly, regulatory agencies such as the World Health Organization (WHO), Food and Agriculture Organization (FAO), and the European Commission have established maximum residue limits (MRLs) based on rigorous toxicological risk assessment. Residue levels reported in most analytical studies on Ayurvedic raw materials and finished products are generally found to be below these prescribed safety thresholds or even below the limit of quantification. At such low concentrations, pesticide residues are unlikely to pose toxicological risk or interfere with biological activity.

From a pharmacological perspective, the therapeutic efficacy of Ayurvedic medicines is derived from the complex synergy of multiple phytoconstituents rather than the action of a single isolated compound. Modern phytochemical and systems-biology research has demonstrated that herbal formulations show their effects through multi-target, multi-pathway mechanisms. The presence of trace-level contaminants, far below pharmacologically active concentrations, is therefore unlikely to disrupt these synergistic interactions or negate therapeutic outcomes.

This understanding is consistent with food safety paradigms, where the presence of regulated trace pesticide residues does not render food ineffective or unsafe for consumption. Similarly, Ayurvedic medicines prepared from plant materials containing residues within permissible limits should not be assumed to have compromised efficacy. In fact, centuries of empirical clinical use of Ayurvedic formulations, often prepared from plants cultivated under diverse environmental conditions, support the continued therapeutic relevance of these medicines.

Classical Ayurvedic principles further emphasize the importance of processing methods such as *Shodhana*, *Bhavana*, *Samskara*, and formulation strategies that enhance bioavailability and safety. These pharmaceutical processes may further reduce or neutralize potential contaminants while preserving or enhancing therapeutic potency. Additionally, adherence to Good Agricultural and Collection Practices (GACP) and Good Manufacturing Practices (GMP), as advocated by the Ministry of AYUSH, plays a crucial role in minimizing contamination risks.

Nevertheless, the presence of trace pesticide residues underscores the need for continuous monitoring, standardized analytical methods, and quality control frameworks. Rather than undermining Ayurveda, such regulatory and scientific vigilance strengthens its global credibility and acceptance. Emphasizing evidence-based safety assessment alongside traditional knowledge can bridge the gap between classical Ayurveda and contemporary regulatory science.

Overall, the available evidence suggests that trace pesticide residues, when present within established safety limits, do not adversely affect the therapeutic efficacy of Ayurvedic medicines. Future research should focus on correlating residue levels with pharmacological outcomes and clinical efficacy to further reinforce this conclusion. Integrating modern analytical tools with Ayurvedic pharmaceuticals will ensure both the safety and sustained effectiveness of traditional herbal medicines in the modern era.

CONCLUSION

The growing global use of Ayurvedic medicines has increased the need to ensure the quality and safety of

medicinal herbs, including careful attention to pesticide residues arising from modern agricultural practices. Available evidence shows that trace pesticide residues detected in Ayurvedic raw materials and formulations are generally within established regulatory limits and are unlikely to cause toxicity or interfere with therapeutic efficacy. Ayurvedic efficacy primarily depends on the integrity of active phytoconstituents, synergistic interactions, and classical processing methods, which may further reduce residue levels and support safety. Therefore, while routine monitoring and strict adherence to Good Agricultural and Manufacturing Practices remain essential, current scientific data suggest that trace pesticide residues within permissible limits do not compromise the safety or effectiveness of Ayurvedic medicines.

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