Original Research (Experimental Study)

Reduction of Hexaconazole Residue on Apples (*Pyrus malus*) Using *Vishaghna Dravyas*: Comparative Analysis of *Shirish* (*Albizia lebbeck*) and *Haridra* (*Curcuma longa*)

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ABSTRACT

Background: Hexaconazole, a systemic fungicide, is extensively used in apple cultivation to manage fungal diseases. Its residue on fruits poses significant health risks, necessitating effective detoxification methods.

Objective: This study evaluates the efficacy of Ayurvedic detoxifiers *Shirish* (*Albizia lebbeck*) and *Haridra* (*Curcuma longa*) in reducing Hexaconazole residue on apples.

Methods: Apples were treated with *Shirish Kwath, Haridra Kwath*, and their combination for 5 and 15 minutes. Residue levels were quantified using the QuEChERS method followed by Gas Chromatography-Mass Spectrometry (GC-MS).

Results: Both *Shirish* and *Haridra* effectively reduced Hexaconazole residue, with the combination achieving a maximum reduction of 75% after 15 minutes.

Conclusion: Ayurvedic detoxifiers offer a natural and effective method for pesticide residue mitigation, enhancing food safety and supporting sustainable agricultural practices.

Key words: Hexaconazole Residue, Ayurvedic Detoxification, *Shirish* (*Albizia lebbeck*), *Haridra* (*Curcuma longa*), Pesticide Decontamination

1. INTRODUCTION

The extensive use of synthetic pesticides in modern agriculture has significantly enhanced crop productivity and food security. However, the persistence of pesticide residues on consumable produce has emerged as a major public health concern. Among these, Hexaconazole, a triazole fungicide, is extensively used for the management of powdery mildew, scab, and other fungal diseases in fruit crops, particularly in apples. Despite its effectiveness, Hexaconazole is known for its systemic activity, high persistence, and potential bioaccumulation, leading to the presence of its residues in the edible portions of fruits even after harvest [1][2].

Consumption of fruits containing residual pesticides has been associated with a variety of toxicological outcomes**,** including hepatotoxicity, endocrine disruption, reproductive toxicity, and carcinogenicity [3]. Chronic exposure, even at low levels, poses long-term health risks, especially in vulnerable populations such as children and the elderly. This has prompted regulatory bodies and researchers to seek efficient, safe, and practical methods to reduce pesticide residues in food products.

Apples **(***Pyrus malus***),** widely consumed for their nutritional and medicinal benefits, are particularly vulnerable to pesticide contamination due to their waxy cuticle and porous skin, which can trap and retain lipophilic compounds like Hexaconazole [4]. Conventional decontamination methods such as washing with tap water, peeling, or chemical rinses offer only limited efficacy and may also lead to nutrient loss or environmental burden**.** Moreover, consumer preference for minimally processed and naturally preserved foods underscores the need for non-toxic, eco-friendly decontamination alternatives**.**

Ayurveda**,** the traditional Indian system of medicine, offers a time-tested and sustainable approach to detoxification. Classical Ayurvedic texts describe certain herbs known as *Vishaghna Dravyas* - agents with anti-poisonous or detoxifying properties - that have been traditionally used to neutralize toxins from various sources, including food, environment, and venom [5]. Among these, *Shirish* **(***Albizia lebbeck***)** and *Haridra* **(***Curcuma longa***)** are well recognized for their broad-spectrum detoxifying, anti-inflammatory, antioxidant, and antimicrobial actions [6].

Shirish is described in Ayurvedic literature as a potent anti-toxic herb (*Vishaghna*), especially effective in managing external and internal toxins, including those from insect bites and environmental pollutants. Its pharmacological properties have been attributed to the presence of flavonoids, alkaloids, and saponins**,** which are known

to interact with and neutralize various xenobiotic compounds [7].

Haridra, or turmeric, is a staple in Ayurvedic medicine and culinary traditions, known for its vibrant yellow pigment curcumin. Curcumin exhibits metal-chelating, antioxidant, and anti-inflammatory properties that support its potential in mitigating chemical toxicity, including that from pesticides [8]. Recent studies suggest that curcumin may break down organophosphate and triazole pesticide residues by interfering with their oxidative degradation pathways, enhancing their removal from the surface of fruits and vegetables.

The rationale behind using *Shirish* and *Haridra* lies in their synergistic properties, traditional documentation, and growing scientific validation. Yet, despite their promise, limited experimental data exist on their practical application for reducing synthetic pesticide residues on fruits in post-harvest settings. This study attempts to bridge that gap by evaluating the residue-reducing efficacy of *Shirish Kwath*, *Haridra Kwath*, and their combination on Hexaconazole-contaminated apples using modern analytical techniques.

By integrating Ayurvedic detoxification concepts with scientific residue analysis (QuEChERS-GC-MS), this research aims to contribute toward the development of natural, cost-effective, and scalable solutions for enhancing food safety. The findings are expected to support a paradigm shift from purely chemical residue mitigation strategies to holistic, plant-based interventions that align with both traditional knowledge systems and sustainable agricultural practices.

2. MATERIALS AND METHODS

Collection of Samples - Mature apples were sourced from Dharali village, Uttarkashi, Uttarakhand, in September 2023. *Shirish* bark and *Haridra* rhizomes were collected from Rishikul Campus, Haridwar, and authenticated at the Dravyaguna Department (Ref. No. DG/RC/UAU-171) [9].

Preparation of *Kwath* - *Kwath* (decoctions) of *Shirish* and *Haridra* were prepared according to *Sarangadhara Samhita*. Coarse powders of *Shirish* bark and *Haridra* rhizomes were boiled with 16 parts water until reduced to one-fourth of the initial volume. The decoctions were filtered and stored for experimental use [10].

Experimental Groups - Collected apples were divided into two main groups:

- **Control Group (A)**: No *Dhavan* (washing).
- **Experimental Groups**: Treated with the following:
  - Tap Water (Group B)
  - *Shirish Kwath* (Group C)

- *Haridra Kwath* (Group D)
- Combined *Kwath* of *Shirish* and *Haridra* (Group E)

Each experimental group underwent *Dhavan* for 5 and 15 minutes [11].

Residue Analysis - Hexaconazole residues were analyzed using the QuEChERS method, followed by GC-MS. The method included liquid micro-extraction, solid-phase cleanup, and chromatographic analysis [12][13].

3. RESULTS

The initial hexaconazole residue level in control apples was 0.004 mg/kg. The effects of different treatments are summarized below (shown in Table No. 1 & Graph No. 1):

- **Group B (Tap Water)**: Minimal reduction (25%) observed after 15 minutes.
- **Group C (*Shirish Kwath*)**: Significant reduction, with residue levels decreasing by 75% after 15 minutes.
- **Group D (*Haridra Kwath*)**: Similar efficacy as *Shirish*, achieving a 75% reduction after 15 minutes.
- **Group E (Combined *Kwath*)**: Maximum reduction observed, with a 75% decrease achieved in 15 minutes [14].

4. DISCUSSION

The present study demonstrates the significant potential of Ayurvedic Vishaghna *Dravyas* - *Shirish* **(***Albizia lebbeck***)** and *Haridra* **(***Curcuma longa***)** - in reducing residues of Hexaconazole, a systemic fungicide, from the surface of apples (*Pyrus malus*). The data clearly show that both the individual decoctions and their combination outperform standard tap water washing in mitigating pesticide contamination, especially with prolonged exposure.

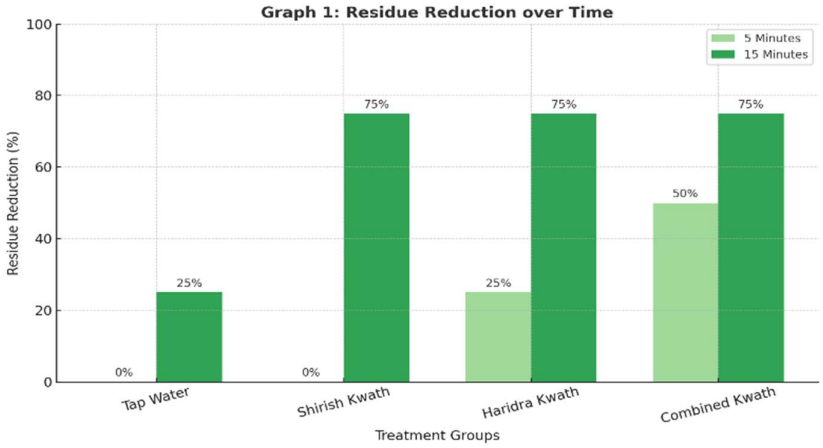
Comparison with Conventional Methods

Washing with plain water, although a widely practiced method among consumers, resulted in only 25% residue reduction even after 15 minutes. This finding aligns with earlier research showing that systemic pesticides like hexaconazole cannot be effectively removed by water alone due to their ability to penetrate the cuticular layers of fruits [15]. In contrast, *Shirish* and *Haridra* decoctions achieved up to a 75% reduction, reflecting a promising enhancement over conventional washing techniques. This suggests that water-soluble or surface-bound pesticide molecules may be better solubilized or degraded in the presence of certain phytochemicals present in these Ayurvedic formulations.

Table 1: Percentage Reduction of Hexaconazole Residue

Treatment Group	5 Minutes (%)	15 Minutes (%)
Tap Water	0	25
Shirish Kwath	0	75
Haridra Kwath	25	75
Combined *Kwath (Sh. and Hr.)*	50	75

Graph 1: Residue Reduction over Time



(Graph illustrating the percentage reduction across treatment groups at 5 and 15 minutes)

Probable Mechanism of Detoxification

The observed residue reduction may be attributed to the bioactive phyto-constituents of the test substances. *Shirish* is rich in flavonoids, tannins, alkaloids, and saponins**,** which are known to exhibit surfactant-like, chelating and antioxidant properties**.** These constituents could facilitate the disruption of pesticide binding on fruit surfaces, enhance solubilization, and potentially initiate hydrolytic or oxidative breakdown of pesticide molecules [16] [17].

Haridra's active compound, curcumin**,** has been extensively studied for its lipophilic, antioxidant, and xenobiotic-binding capacities. Curcumin's molecular structure allows it to interact with and destabilize chemical compounds, potentially enhancing the degradation of complex pesticides like Hexaconazole [18][19]. Additionally, turmeric's natural

antimicrobial and preservative qualities could add value by extending post-wash shelf life and preventing microbial spoilage.

The combination of *Shirish* and *Haridra Kwath* showed the most consistent and rapid reduction at both 5 and 15 minutes, possibly due to synergistic effects of their phytochemical constituents. The interaction of polyphenols, flavonoids, and saponins across both herbs may enhance penetration into the fruit's cuticular layers and improve residue dissociation.

Integration with Ayurvedic Principles

From an Ayurvedic standpoint, this study embodies the application of *Dravyaguna* principles in contemporary food safety challenges. *Shirish* is traditionally classified under *Vishaghna Mahakashaya* in the *Charaka Samhita*, with documented efficacy in neutralizing *Visha* (toxins of internal and external origin). *Haridra* is known for its *Shothahara* (anti-inflammatory), *Krimighna* (antimicrobial), and *Vishaghna* properties, making it highly suitable for detoxification and purification processes.

The concept of *Shodhana* in Ayurveda, particularly *Drava Shodhana* (liquid-based purification), parallels the idea of *Dhavan* (washing) applied in this study. Thus, the use of these *Kwathas* aligns with both *Ayurvedic* pharmacodynamics and modern detoxification strategies.

Implications for Public Health and Food *Safety* - The increasing public demand for pesticide-free and naturally preserved food calls for innovations that are both scientifically sound and culturally acceptable. Herbal decoctions offer an eco-friendly, biodegradable, and non-toxic alternative to synthetic decontaminants and do not alter the nutritional or organoleptic quality of the fruits [20].

Furthermore, the use of herbs that are readily available, cost-effective, and culturally acceptable enhances the feasibility of household or farm-level implementation. The results from this study may inform post-harvest practices**,** community health programs, and even institutional food services focused on safer food preparation.

Limitations of the Study

While the study shows promising outcomes, certain limitations must be acknowledged:

- The mechanistic pathways of pesticide degradation were not biochemically elucidated. Further studies involving chemical analysis of breakdown products would provide greater insight.

- The organoleptic impact and shelf-life analysis post-treatment were not evaluated. These aspects are essential for consumer acceptance and market viability.
- The study was limited to Hexaconazole; hence, generalizing the efficacy of *Shirish* and *Haridra* against other classes of pesticides (e.g., organophosphates, carbamates) requires further experimentation.
- Environmental conditions such as temperature, water hardness and pH—factors that could influence decoction efficacy—were not varied or standardized.

Future Directions

To fully harness the potential of Ayurvedic detoxification in agriculture and food safety, future research should focus on:

- Large-scale trials involving various fruit and vegetable crops with different surface characteristics.
- Standardization and optimization of decoction preparation and treatment protocols for practical scalability.
- Comparative studies with chemical washing agents and commercial detoxification products to validate cost-effectiveness and efficacy.
- Interdisciplinary collaboration between Ayurveda, analytical chemistry, and agricultural sciences to formulate integrated post-harvest technologies.

5. CONCLUSION

The study highlights the potential of Ayurvedic detoxifiers *Shirish* and *Haridra* in mitigating Hexaconazole residues on apples. Their efficacy, simplicity and alignment with traditional practices make them viable alternatives for enhancing food safety. Future investigations should explore broader applications and scalability to reinforce their role in sustainable agriculture [21].

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