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"*BHAVANA* (WET TRITURATION) AS MECHANOCHEMISTRY: A REVIEW OF ITS EFFECTS ON PARTICLE SIZE, PHYTOCHEMICAL TRANSFER AND BIOACTIVITY"

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ABSTRACT

Background: *Bhavana* is the repeated wet grinding of a powder with a liquid medium until dryness. It is used in almost every branch of Ayurvedic pharmaceutics, from herbal *churna* and *vati* to *kajjali* and *bhasma* preparation. Classical texts attribute to it the transfer of the liquid's properties to the drug and an increase in potency. **Objective:** To review the experimental evidence on what *bhavana* does physically and chemically, and to interpret it using the concepts of mechanochemistry. **Methods:** A critical narrative review of classical rules for *bhavana*, experimental studies comparing preparations with different numbers or types of *bhavana*, and relevant literature on mechanochemistry. **Results:** Classical texts prescribe from one to a thousand *bhavanas*, using 39 different liquid media, with seven days as the default duration. In *Gandhaka Rasayana*, 88 *bhavanas* gave a D90 particle size of 26.9 µm, compared with 40.8 µm after 11 *bhavanas* and 93.7 µm without *bhavana*, together with higher water- and methanol-soluble extractives and a more uniform surface. In *kajjali*, longer trituration narrowed particle size from 185–661 nm at 22 hours to 100–171 nm at 120 hours and reduced free mercury, consistent with a mechanochemical reaction between mercury and sulphur. *Bhavana* also influenced pharmacognostical parameters of *Amalaki* and *Haritaki* preparations. **Conclusion:** *Bhavana* is a combined process of comminution, impregnation and mechanochemical reaction. Defined energy input, number of cycles and instrumental end-points would allow it to be standardised and scaled up.

KEYWORDS: *Bhavana*; Trituration; Mechanochemistry; Particle size; *Kajjali*; *Gandhaka Rasayana*; Ayurvedic pharmaceutics

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INTRODUCTION

Few processes are as characteristic of Ayurvedic pharmaceutics as *bhavana*. A powdered drug is moistened with a specified liquid, usually a juice, decoction or other fluid, and ground in a mortar until it dries, and the cycle is repeated a prescribed number of times. *Bhavana* appears in the preparation of herbal powders and pills, in the purification and incineration of metals and minerals, and in the making of *kajjali* and compound *rasa* preparations[1,2]. Classical authorities state that the process transfers the properties of the liquid to the drug and increases potency even when the dose is small.

Modern science offers a framework to understand such claims. Mechanochemistry is the study of chemical and physicochemical changes induced by mechanical energy, such as grinding and milling. Grinding can reduce particle size, create defects and fresh surfaces, mix components intimately, and drive chemical reactions without solvent or with minimal liquid[3,4]. This review examines how far the experimental evidence on *bhavana* fits this framework.

METHODS OF THE REVIEW

This is a critical narrative review. Literature was identified through PubMed, PubMed Central, DOAJ, Crossref-indexed records and journal archives using the terms *bhavana*, *bhavana samskara*, trituration, levigation, wet grinding, *kajjali* and particle size. Reviews of classical rules and experimental studies comparing preparations with and without *bhavana*, or with different numbers or media of *bhavana*, were included. Literature on mechanochemistry was used for interpretation.

CLASSICAL RULES

Classical rules for *bhavana* concern the quantity of liquid, the duration and the number of cycles. The liquid should be enough to wet the powder thoroughly, typically equal to its quantity or sufficient to submerge it, with adjustment for weather; when a decoction is specified, it is prepared fresh and added so that the material stays wet throughout the day. If no duration is stated, *bhavana* continues for seven days[5]. The number of *bhavanas* prescribed ranges from one to a thousand, and a compilation of classical sources identified 39 liquid media, 15 of plant origin, 21 of animal origin and 3 of mineral origin[6]. *Bhavana* is generally advised in sunlight, although some preparations, such as *pishti*, specify night[6].

The stated purposes of *bhavana* are to bring fine particles into contact with the liquid, to transfer the properties of the liquid to the drug, to convert minerals into intermediate forms, and to reduce particle size[5]. These purposes correspond closely to the physical and chemical effects of wet milling.

EXPERIMENTAL EVIDENCE

Table 1. Experimental studies on the effects of *bhavana* and prolonged trituration

Preparation	Comparison	Main findings
Gandhaka Rasayana	88 *bhavanas* with *Chaturjata kwatha* or *arka*; 11 *bhavanas*; no *bhavana* (dry extract mixed with sulphur)	D90 26.9 µm (88, *kwatha*), 41.5 µm (88, *arka*), 40.8 µm (11) and 93.7 µm (none); water-soluble extractive 76–80% vs 58–74%; methanol-soluble extractive 39–41% vs 23–34%; more uniform surface on XPS with 88 *bhavanas*
Kajjali	Sampling at 4–120 h of trituration	SEM size 185–661 nm (22 h), 158–601 nm (94 h), 100–171 nm (120 h); free mercury decreased with time
Kajjali	About 78 h hand trituration	About 90% of particles 60–200 nm; metacinnabar formed; EDX 88.8% Hg, 11.2% S
Kajjali, 1:1 and 1:6	Different sulphur ratios	HgS with free sulphur; SEM average 39 and 61 nm; no free mercury by XRD
Amalaki Rasayana	With *bhavana* vs *Amalaki* powder	*Bhavana* influenced pharmacognostical parameters
Haritaki churna	With and without *bhavana*	*Bhavana samskara* assessed by phyto-pharmacognostical evaluation

1. Particle size reduction

The clearest evidence comes from *Gandhaka Rasayana*, made by triturating purified sulphur with herbal media. Preparations given 88 *bhavanas* with *Chaturjata* decoction had a D90 of 26.9 µm, compared with 40.8 µm after 11 *bhavanas* and 93.7 µm for a sample made by mixing a dry extract into sulphur without *bhavana*[7]. In *kajjali*, particle size narrowed steadily with trituration time[8]. These results show that particle size decreases with the number of cycles or the duration of grinding, as expected from comminution.

2. Transfer of constituents from the medium

Bhavana also changes the composition and solubility profile of the product. In *Gandhaka Rasayana*, water- and methanol-soluble extractives were highest after 88 *bhavanas* with decoction, and lower after fewer cycles or with a distillate (*arka*) as the medium[7]. This indicates that repeated wetting and drying deposits soluble constituents of the medium onto the particle surfaces, and that the choice of medium matters. X-ray photoelectron spectroscopy showed a more uniform surface after 88 *bhavanas*, consistent with a coating of organic material. In herbal preparations such as *Amalaki Rasayana* and *Haritaki churna*, *bhavana* altered pharmacognostical parameters[11,12].

3. Mechanochemical reaction

In *kajjali*, trituration is not only mixing but a chemical reaction. Mercury and sulphur react under mechanical activation to form black cubic mercuric sulphide, and free mercury declines as trituration continues[8,9]. The sulphur ratio governs the proportion of unreacted sulphur[10]. This is a textbook example of a mechanochemical solid–liquid reaction[3,4]. In *bhasma* preparation, *bhavana* with herbal media before each *puta* mixes organic material intimately with the mineral; the carbon and other elements introduced may influence the reactions that occur on heating, as suggested by the changes in trace elements seen during processing of lead[13] and the conversion of chalcopyrite to oxide and sulphide phases[14].

A MECHANOCHEMICAL MODEL OF BHAVANA

The evidence supports a model in which *bhavana* acts through four overlapping mechanisms:

- **Comminution.** Grinding breaks particles and reduces size, increasing surface area. The extent depends on the energy delivered and the number of cycles.
- **Impregnation and coating.** The liquid wets the particles; as it evaporates, its dissolved constituents are deposited on the new surfaces. Repetition builds up the coating.
- **Mechanochemical activation and reaction.** Grinding creates fresh surfaces, defects and local heating, which can accelerate reactions such as the formation of mercuric sulphide.
- **Homogenisation.** Prolonged grinding distributes minor components, including potent ingredients, uniformly through the mass, which is essential for dose accuracy in small-dose preparations.

Wet grinding also limits the temperature rise and agglomeration that occur in dry milling, which may protect heat-sensitive constituents. Exposure to sunlight, as classically advised, adds a photochemical dimension that has not been studied.

IMPLICATIONS FOR STANDARDISATION AND SCALE-UP

The traditional end-point of *bhavana*, a fixed number of cycles or days, does not define the energy delivered. Hand trituration varies with the operator, mortar and batch size, and mechanised triturators deliver energy at different rates. Standardisation therefore needs:

- **Process parameters:** batch size, liquid-to-solid ratio, rotation speed or strokes per minute, duration per cycle, number of cycles and drying conditions.
- **Instrumental end-points:** particle size distribution, extractive values or marker compounds transferred from the medium, and for *kajjali*, free mercury and phase composition.
- **Equivalence testing:** when mechanised equipment replaces hand trituration, products should be compared on these end-points.

RESEARCH GAPS

The main gaps are: measurement of the energy input of hand and mechanised trituration; marker-based studies of how constituents of the medium transfer to the product; studies of the effect of *bhavana* on dissolution and bioavailability; investigation of photochemical effects during sun-drying; and pharmacological studies that test whether more *bhavanas* translate into greater activity.

CONCLUSION

Experimental evidence shows that *bhavana* reduces particle size, deposits constituents of the liquid medium onto the drug, and drives mechanochemical reactions such as the formation of mercuric sulphide in *kajjali*. These effects correspond to well-understood

mechanisms of wet milling and mechanochemistry. Defining *bhavana* in terms of energy input and instrumental end-points, rather than only the number of cycles, would allow this classical process to be standardised, scaled up and linked to biological activity.

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