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**ORIGINAL RESEARCH ARTICLE**

# Pharmaceutical and Analytical Evaluation of *Kajjali*

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**ABSTRACT**

**Background:** *Kajjali* is a classical *Ayurvedic* formulation prepared by the trituration of *Parada* and *Gandhaka* and serves as a fundamental component in various *Rasashastra* formulations.

**Material and methods:** The present study was undertaken to prepare *Kajjali* according to classical guidelines and to evaluate its physiochemical and morphological characteristics using modern analytical techniques.

**Observations and Results:** During preparation, classical parameters such as *Nishchandratva, Rekhapurna, Varitara,* and *Sukshma* were observed, indicating proper formation of *Kajjali*. Physicochemical analysis was carried out to assess the quality and standardization of the prepared sample. Scanning electron microscopy analysis revealed fine and agglomerated particles with relatively uniform distribution, indicating effective trituration and reduction in particle size. The analytical findings correlated well with the classical characteristics of *Kajjali* and supported its proper preparation and standardization. The study highlights the importance of integrating traditional *Ayurvedic* parameters with modern analytical techniques for the evaluation of Herbo-mineral formulations.

## 1. INTRODUCTION

*Rasashastra* is the most important and popular branch of *Ayurveda* developed in the medieval period.[1] *Parada* is a chief material of *Rasashastra*. *Kajjali* is one among such preparations, prepared using *Parada* and *Gandhaka* and is one of the dosage forms of *Parada*.[2] About 80% of the *Rasa Kalpas are* used for *Kharaliya Rasayana,* in which *Kajjali* is the key ingredient. *Kajjali* is also used in the preparation of different dosage forms such as *Parpati, Kupipakwa Rasayana,* and *Pottali Kalpana*. The description of *Kajjali* was given first by *Nagarjuna* in the 8th century.[3] Avoiding the use of elemental mercury and combining it with sulfur after necessary processing is the uniqueness of *Ayurvedic* pharmaceutics, pointing out the advancement of science centuries before.[4]

When purified *Parada* is triturated with the other purified metals and mineral drugs, such as sulfur, without adding any liquid till the mixture becomes fine and black in color, it is called *Kajjali*. *Kajjali* is the basic preparation in all the *Sagandha Rasa Yogas*.[5]

The *Ayurvedic Rasashastra* texts have mentioned various parameters in terms of quality, safety, and efficacy of these metallic preparations.[6]

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### 1.1. Objectives

This study aimed to prepare *Kajjali* according to classical *Ayurvedic* procedures and evaluate its physicochemical, morphological, and elemental characteristics using analytical testing and scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) analysis.

## 2. MATERIALS AND METHODS

### 2.1. *Kajjali* Preparation

It is a type of *Niragni Sagandha Murchana* and *Kharaliya Rasayana*.[7]

### 2.2. Ingredients

- *Shuddha Parada* – 320 g

- *Shuddha Gandhaka* – 320 g.

### 2.3. Procedure

- *Shuddha Parada* and *Shuddha Gandhaka* were taken in a *Khalva Yantra*.
- First, both substances were mixed in equal proportions and were triturated slowly with continuous, uniform grinding.
- During this process, gradual changes were observed in color, texture, and consistency.
- After sufficient trituration, the material transformed into a very fine, smooth, black, and lusterless powder.
- This *Kajjali* was collected using a spoon, weighed and stored in a dry glass container.

### 2.4. Observation (Table 1)

- The mixture starts bright yellow with a coarse, gritty texture, showing clearly visible free mercury globules and a strong metallic shine, indicating minimal amalgamation between mercury and sulphur (in figure 1& 2).
- The colour changed from dark grey to jet black, texture becomes finer and smoother, mercury globules progressively reduce, though slight shine flakes remain (in figure 3).
- Rekhapurnata first appears around 15 hours and is firmly established by 36 hours, alongside extremely fine to microfine texture and a fully homogenous, mercury-free mixture.
- Varitaratva (floating on water) is observed around 42 hours, and lustre continues to fade until Nishchandratva is achieved at 54 hours, signifying fully developed Kajjali (in figure 4).

### 2.5. Precautions

- Use a clean, dry and contamination-free *Khalva Yantra* (mortar and pestle).
- Regularly scrape the material from the sides and bottom of the mortar for uniform mixing.
- Trituration was carried out carefully at a uniform speed to prevent spillage and ensure proper mixing.
- Purified sulfur was finely powdered and then added to the purified mercury.

## 3. RESULTS

The prepared *Kajjali* was subjected to physicochemical and instrumental characterization. Physicochemical analysis was carried out at Central Laboratory Patanjali Food and Herbal Park Pvt. Ltd., Haridwar, Uttarakhand, India, using standard analytical procedures. Advanced instrumental analyses, including SEM, SEM-EDS, and X-ray fluorescence (XRF), were performed at the Department of Metallurgical and Materials Engineering, Indian Institute of Technology (IIT) Roorkee, Uttarakhand, India, using standard analytical protocols and calibrated instruments.

### 3.1. Classical Parameters

Mention in table 2.

### 3.2. Results (Table 3)

The trituration process was carried out with an initial weight of 640 g, which reduced to a final weight of 636 g after 60 hours, resulting in a total loss of 4 g. This corresponds to a minimal loss percentage of just 0.6%.

#### *3.2.1. Organoleptic parameters (Table 4)*

The sample tested positive for *Nischandrata*, confirming complete loss of metallic shine, and showed the presence of *Rekhapurnta*, meaning it could spread into fine, unbroken lines when applied (In figure 6).

*Varitara* (the ability to float on water) and *Unama* were both present, further validating the fineness and homogeneity of the mixture (in figure 5).

The Rasa (taste) was tasteless, the Sparsha (touch) confirmed a fine powder consistency, and the Gandha (smell) was odorless.

#### *3.2.2. Physiochemical parameters (Table 5)*

The physicochemical evaluation of Kajjali revealed a pH of 7.16 for a 1% aqueous solution, indicating that the sample is essentially neutral in nature. The loss on drying at 105°C was found to be very low at 0.11% w/w, suggesting minimal moisture content and good stability of the prepared formulation.

#### *3.2.3. XRF*

*3.2.3.1. XRF value of the element in Kajjali*

The elemental analysis (Given in table 6) of Kajjali revealed that sulfur (S) and mercury (Hg) are the two predominant constituents, accounting for 51.36% and 47.35% by mass. This near-equal proportion of sulfur and mercury confirms the successful formation of mercury sulfide (HgS).

#### *3.2.4. SEM*

SEM-based particle size analysis using histogram and Gaussian distribution curve fitting revealed a mean particle size of 9.5 nm for Kajjali. The nanoscale particle size may indicate effective size reduction during mardana (in figure 7).

#### *3.2.5. SEM-EDS*

The SEM-EDS analysis may confirm the predominance of mercury and sulfur in Kajjali, which may indicate the successful formation of a Hg-S complex. The higher atomic percentage of sulfur may suggest effective binding and possible detoxification of mercury (in figure 8).

#### *3.2.6. EDS*

Mention and dipicted in figure 9.

## 4. DISCUSSION

During the preparation process, *Kajjali* exhibited the classical characteristics of *Varitara, Sukshma, Nishchandratva*, and *Rekhapurnata*. The final product was obtained as a fine, smooth, lusterless black jet powder, which may indicate proper trituration and uniform mixing of mercury and Sulfur. *Nishchandratva* may suggest the complete disappearance of metallic luster due to the proper conversion and uniform amalgamation of mercury with sulfur. *Rekhapurnata* may indicate extremely fineness of the prepared *Kajjali*. *Varitara* may suggest the lightness and fineness of the prepared *Kajjali*. The floating property on the water surface may be attributed to reduced particle size, increased surface area, and proper trituration of finely processed particles. *Sukshma* may indicate the attainment of a very fine particle size and smooth texture due to effective trituration. The absence of any perceptible sound during chewing may suggest the fine nature of the particles. These classical characteristics may reflect uniform particle distribution, increased surface area, and proper processing of the prepared *Kajjali*. The physicochemical parameters may show acceptable values, with

a near-neutral pH (7.16), low moisture content (0.11% w/w), and appropriate ash values, which may suggest good stability, purity, and quality of the formulation.

SEM-based particle size analysis using histogram and Gaussian distribution curve fitting revealed a mean particle size of 9.5 nm for *Kajjali*. The nanoscale particle size may indicate effective size reduction during *mardana.* The fine particle size may increase the surface area and may contribute to improved physicochemical properties and therapeutic potential of the formulation. The Gaussian distribution pattern may also suggest a relatively uniform particle size distribution and homogeneity of *Kajjali.*

The SEM-EDS analysis may confirm the predominance of mercury and sulfur in *Kajjali*, which may indicate the successful formation of a Hg-S complex. The higher atomic percentage of sulfur may suggest effective binding and possible detoxification of mercury. The negligible oxygen content may indicate minimal oxidation during the preparation process. Slight elemental variations observed among different spectra may reflect microscopic heterogeneity; however, the overall elemental composition may suggest a relatively stable and homogeneous *Kajjali* matrix.

## 5. CONCLUSION

The prepared *Kajjali* exhibited the classical characteristics of *Nishchandratva, Rekhapurnata, Varitara*, and *Sukshma*, indicating proper trituration and successful preparation according to classical standards. Physicochemical analysis suggested the quality, purity, and uniformity of the formulation. SEM analysis revealed fine and uniformly distributed particles with smooth morphology, indicating effective particle size reduction during trituration. SEM-EDS analysis demonstrated the predominance of mercury and sulfur with relatively uniform elemental distribution, supporting the successful formation of *Kajjali*. Overall, the analytical findings showed good correlation with the classical parameters and provided scientific support for the proper preparation and standardization of *Kajjali*.

## 6. ACKNOWLEDGMENTS

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## 7. AUTHORS' CONTRIBUTIONS

All authors give equal contribution in making of this manuscript.

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Nil.

## 9. ETHICAL STATEMENT

Ethical approval was not required for this study as it is a case report.

## 10. CONFLICT OF INTERESTS

The authors declare no conflicts of interest regarding the publication of this paper.

## 11. DATA AVAILABILITY STATEMENT

The data analyzed in this review were obtained from publicly available sources, including peer-reviewed articles, observational studies, and surveys accessible through databases.

## 12. DISCLAIMER/VIEW AND OPINIONS

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## 13. AI-USE DECLARATION

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**Table 1:** Observation: *Kajjali Nirmana*

| Hours | Color | Texture | Observation |
|---|---|---|---|
| After 5 min. | Bright yellow with silvery streaks | Coarse, gritty | Free mercury globules clearly visible |
| After 10 min. | Yellowish grey | Slightly less coarse | Mercury breaks into smaller globules |
| After 30 min. | Greyish yellow | Moderately fine | Initial mixing begins; lobules reduce |
| After 1 h | Grey | Smoother | Mercury dispersing, shine still present |
| After 2 h | Dark grey | Fine | Better amalgamation, less luster |
| After 3 h | Dark grey | Finer | Mercury globules almost absent |
| After 4 h | Blackish grey | Smooth | Metallic shine decreasing |
| After 6 h | Black | Very smooth | Uniform mixing, no visible Hg |
| After 8 h | Deep black | fine | Homogeneous mass farming |
| After 10 h | Intense black | Very fine | Lusterless appearance starts |
| After 12 h | Jet black | Silky smooth | Classical *Kajjali* features begin |
| After 15 h | Jet black | Extremely fine | No globules, near *Rekhapurna* |
| After 18 h | Deep black | Very fine | *Rekhapurnata* present |
| After 24 h | Stable black | Ultra-fine | Homogenous mixture |
| After 30 h | Black | Extremely fine | Completely homogenous |
| After 36 h | Black | Microfine | Clearly passes *Rekhapurna* |
| After 42 h | Black | Very fine | May start showing *Varitaratva* |
| After 48 h | Deep black | Ultra fine | Classical *Kajjali* is almost complete |
| After 54 h | Stable deep black | Silky | Fully developed *Kajjali* |
| After 60 h | Deep black | Extremely fine | Ideal *Kajjali* (all tests positive) |

**Table 2:** Classical parameters of *Kajjali*

| S. No. | Test | Observation | Significance |
|---|---|---|---|
| 1. | *Nishchandratva* | No free mercury visible | Indicates complete amalgamation |
| 2. | *Rekhapurna* | Enters finger lines | Microfine particle size |
| 3. | *Varitara* | Floats on water | Lightness and fineness |
| 4. | *Sukshma* | Very fine texture | Enhances bioavailability |
| 5. | *Mrdutva* | Soft to touch | Uniform mixing |
| 6. | *Kajjalabha* | Black, collyrium-like appearance | Characteristic feature |

**Table 3:** Result of *Kajjali Nirmana*

| Initial weight (g) | Final weight (g) | Loss (g) | Loss (%) | Duration |
|---|---|---|---|---|
| 640 | 636 | 4 | 0.6 | 60 rs |

**Table 4:** Organoleptic parameters of *Kajjali*

| Parameters | *Kajjali* |
|---|---|
| *Roop* (*color*) | Soft, Black |
| *Nischandrica* | Positive |
| *Rekhapurna* | Present |
| *Varitara* | Present |
| *Unama* | Present |
| *Rasa* (Taste) | Tasteless |
| *Sparsha* (Touch) | Fine powder |
| *Gandha* (Smell) | Odorless |

**Table 5:** Physiochemical parameters of *Kajjali*

| S. No. | Parameters | Units | *Kajjali* |
|---|---|---|---|
| 1. | pH (1% aqueous solution) | - | 7.16 |
| 2. | Loss on drying at 105°C | %w/w | 0.11 |
| 3. | Total ash | %w/w | 4.07 |
| 4. | Sulfated ash | %w/w | 4.02 |
| 5. | Acid-insoluble ash | %w/w | 2.1 |
| 6. | Water-soluble ash | %w/w | 3.2 |
| 7. | Alcohol soluble extractive value | %w/w | 2.52 |

**Table 6:** Value of element in *Kajjali*

| Compound | Unit (%) | *Kajjali* |
|---|---|---|
| S | Mass | 51.3611 |
| Cl | Mass | 0.1294 |
| K | Mass | 0.3327 |
| V | Mass | 0.2601 |
| Mn | Mass | 0.4704 |
| Fe | Mass | 0.0384 |
| Co | Mass | 0.0628 |
| Hg | Mass | 47.3451 |

| *Kajjali* | Mercury (Hg) | | Sulfur (S) | | Oxygen (O) | |
|---|---|---|---|---|---|---|
| | Weight (%) | Atomic (%) | Weight (%) | Atomic (%) | Weight (%) | Atomic (%) |
| Spectrum 8 | 70.50 | 25.5 | 26.07 | 59.0 | 3.42 | 15.5 |
| Spectrum 9 | 83.06 | 43.9 | 16.94 | 56.1 | - | - |
| Spectrum 10 | 70.90 | 28.0 | 29.10 | 72.0 | - | - |

**Figure 1:** Equal parts of *Parada* and *Gandhaka* added in *Khalwa Yantra*

**Figure 4:** Final jet-black *Kajjali*

**Figure 2:** After 30 mins of *Mardana*

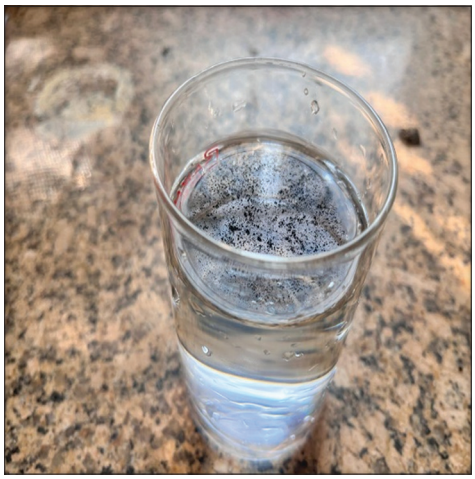

**Figure 5:** *Varitara*

**Figure 3:** *Kajjali* after 12 hours

**Figure 6:** *Rekhapurnata*

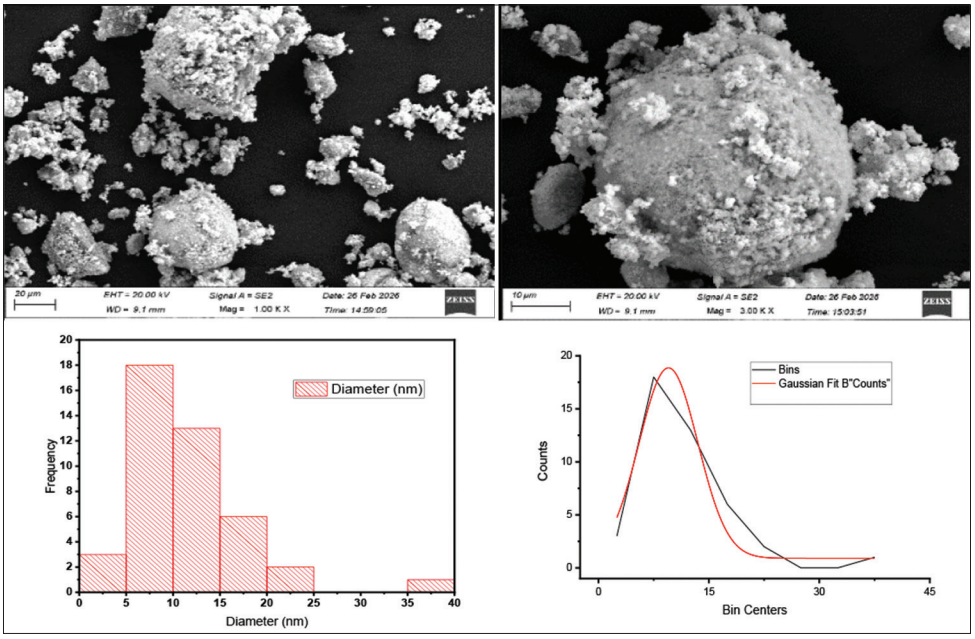


**Figure 7:** *Kajjali* image from SEM scan

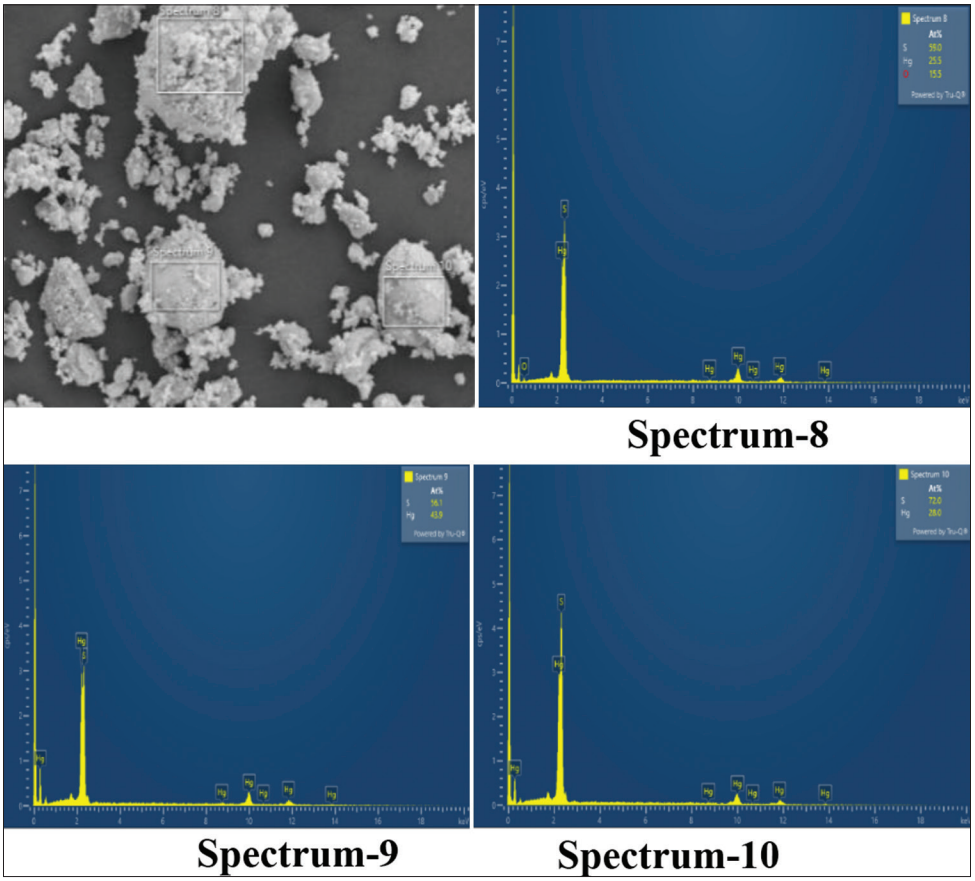


**Figure 8:** SEM-EDS spectrum of *Kajjali*

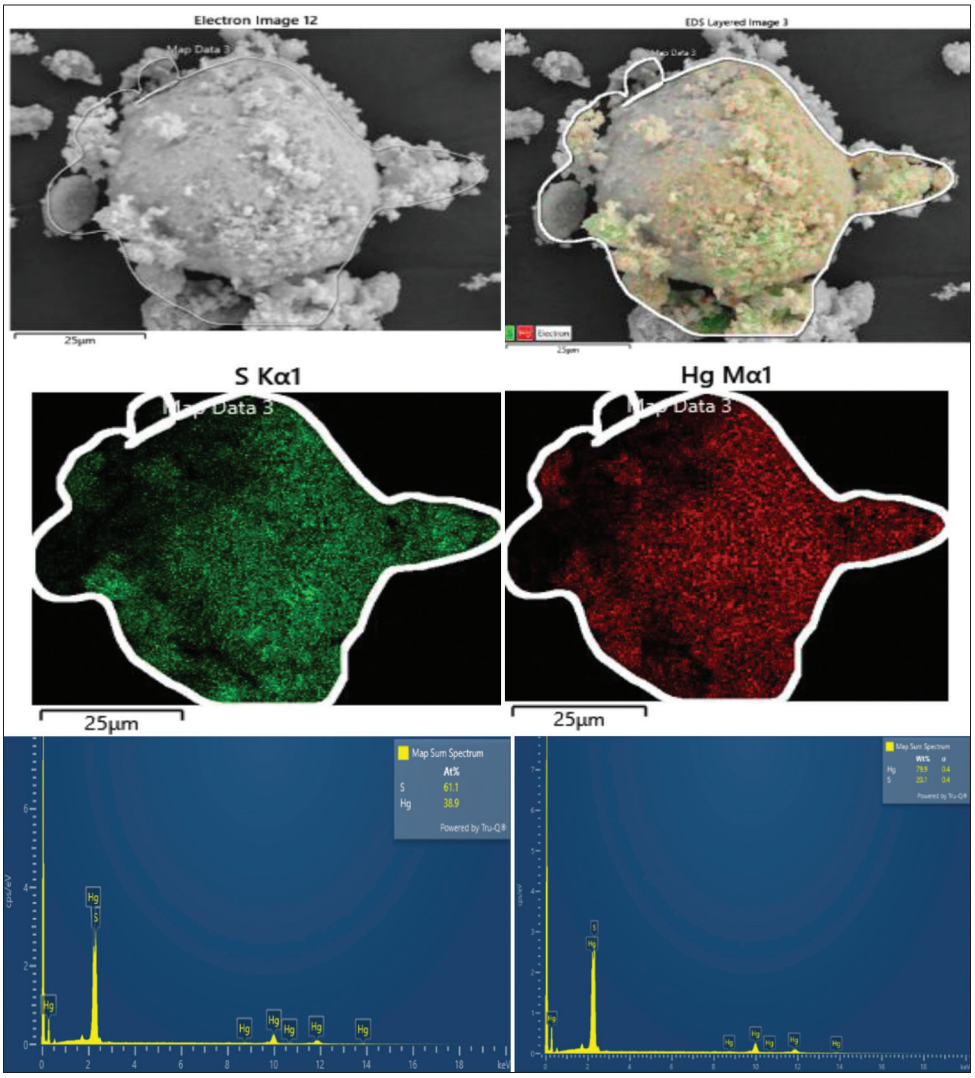


**Figure 9:** Elemental mapping data