RESEARCH PAPER

Integrated Analytical Characterization of Shwaskuthar Rasa: A Herbomineral Pharmaceutical Formulation

Dr. Meghna Vaidya[1*], Dr. Sanjay Kumar[2], Dr. Abhishek Upadhyay[3]
[1*]Professor, Department of Rasa-Shastra & Bhaishajya Kalpana, Mahatma Jyotiba Fule Ayurvedic Medical College & Hospital Harota, Jaipur. Email: drvaidyameghna@gmail.com
[2]Professor, Department of Rasa-Shastra & Bhaishajya Kalpana, National Institute of Ayurveda, Deemed to be University (de novo), Jaipur. Email: drsanjaynia@gmail.com
[3]Assistant Professor, Department of Kayachikitsa, National Institute of Ayurveda, Deemed to be University (de novo), Jaipur. Email: dr.abhishek82@gmail.com
***Corresponding author: Dr. Meghna Vaidya, Professor, Department of Rasa-Shastra & Bhaishajya Kalpana, Mahatma Jyotiba Fule Ayurvedic Medical College & Hospital Harota, Jaipur**
Email: drvaidyameghna@gmail.com
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ABSTRACT

Background
Shwaskuthar Rasa (SKR) is a traditional herbomineral formulation containing processed metallic, mineral, and herbal ingredients. Scientific characterization is essential for its quality evaluation and standardization.

Objective
To establish a comprehensive analytical profile of SKR using integrated physicochemical and instrumental techniques.

Materials and Methods
SKR was prepared according to standardized Ayurvedic pharmaceutical procedures. Physicochemical parameters were evaluated as per Ayurvedic Pharmacopoeia standards. Characterization was performed using PSA, XRD, SEM–EDX, FTIR, HPTLC, and GC–MS.

Results
SKR was obtained as a fine greyish-black powder with low moisture content (7% w/w), high total ash (23.55% w/w), and near-neutral pH (7.97). PSA revealed a polydisperse system with a median particle size (D50) of 17.84 µm. XRD identified HgS as the predominant crystalline phase, present as cinnabar and metacinnabar, along with sulphur and minor arsenic-containing phases. SEM–EDX confirmed heterogeneous particle morphology and the presence of mercury, sulphur, arsenic, carbon, and oxygen. FTIR indicated diverse organic functional groups, while HPTLC and GC–MS demonstrated a complex organic profile comprising multiple chromatographic constituents and tentatively identified fatty acid esters, glyceride derivatives, piperine, and piperidine-related compounds.

Conclusion
SKR is a complex organic–inorganic system comprising crystalline mineral phases and a chemically diverse organic matrix. The generated analytical profile provides reference data for characterization, quality evaluation, and future standardization of herbomineral formulations.

Keywords: Shwaskuthar Rasa; Ayurvedic medicine; Herbomineral formulation; Analytical characterization; Standardization; X-ray diffraction.
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Introduction

Analytical characterization of complex multicomponent drug matrices is challenging due to the coexistence of inorganic phases and chemically diverse organic constituents. Herbo-mineral formulations represent a unique category of such systems, comprising metals, minerals, and plant-derived ingredients processed together to produce structurally and chemically heterogeneous products.[1] Ensuring their identity, quality, consistency, and safety requires comprehensive analytical approaches integrating physicochemical, chromatographic, spectroscopic, and elemental techniques.[2]

Variations in raw materials, manufacturing processes, and potential contamination can significantly affect the quality and physicochemical properties of these formulations.[3] Consequently, reproducible analytical fingerprints and validated instrumental methods are increasingly emphasized for standardization, quality control, and safety assessment of complex formulations containing mineral-derived components.[4,5]

Advanced analytical techniques provide complementary information on different formulation attributes. XRD enables identification of crystalline phases,[6] SEM–EDX provides morphological and elemental information,[7] FTIR reveals functional groups and molecular interactions, chromatographic techniques characterize diverse chemical constituents,[8] and particle size analysis (PSA) evaluates physical characteristics that may influence dissolution and bioavailability.[9] The integration of these methods allows comprehensive characterization of both inorganic and organic fractions within a single analytical framework.[4]

Shwaskuthar Rasa (SKR) is a complex herbo-mineral formulation containing processed metallic, mineral, and herbal constituents. Despite its continued therapeutic use, comprehensive analytical characterization using integrated modern techniques remains limited. Therefore, the present study aimed to evaluate SKR using a multi-technique analytical approach and demonstrate its applicability for the quality assessment of complex herbo-mineral drug matrices.

2. Materials and Methods

2.1. Materials and reagents

All raw materials used in the preparation of SKR were procured from a Good Manufacturing Practice certified pharmacy at the National Institute of Ayurveda, Jaipur, India. Herbal ingredients were authenticated at the Raw Materials Herbarium and Museum, CSIR-National Institute of Science Communication and Policy Research, New Delhi (authentication no. NIScPR/RHMD/Consult/2023/4416-17-1,2,3,4).

All reagents and solvents used for analytical studies were of analytical grade unless otherwise specified.

2.2. Preparation of Shwaskuthar Rasa

SKR was prepared following standardized Ayurvedic pharmaceutico-technical procedures. All ingredients were subjected to prescribed purification procedures before incorporation into the formulation. (Table 1) Mercury was obtained through the sublimation of cinnabar, whereas sulphur, realgar, borax, and aconite underwent traditional processing methods involving trituration, thermal treatment, and liquid-assisted purification. Kajjali (black sulphide of mercury) was prepared by triturating purified mercury and sulphur in equal proportions until a homogeneous, lustreless black powder was obtained. The purified ingredients were then combined with Kajjali and processed according to classical manufacturing protocols to obtain the final formulation.

Table 1: Ingredients used in pharmaceutical processing of Shwaskuthar Rasa

S. No	Name of Ingredient	English/Latin name	Part Used	Quantity
	Shudha Parada (extracted from cinnabar)	Processed Mercury	-	1 Part
	Shudha Gandhaka	Processed Sulphur	-	1 Part
	Shudha Visha	*Aconitum chasmanthum*	Root	1 Part
	Shudha Tankana	Processed Borax	-	1 Part
	Shudha Manahshila	Processed Realgar	-	1 Part
	Maricha	*Piper nigrum L.*	Fruit	9 Parts
	Shunthi	*Zingiber officinale Rosc.*	Rhizome	1 Part
	Pippali	*Piper longum L.*	Fruit	1 Part

2.3. Physicochemical characterization

Physicochemical parameters including loss on drying, total ash, acid-insoluble ash, pH (10% aqueous solution), water-soluble extractive, and alcohol-soluble extractive values were determined according to protocols described in the Ayurvedic Pharmacopoeia of India.

2.4. Instrumental Analysis

Particle size distribution was determined using a laser diffraction particle size analyzer (Sympatec HELOS-BF, Germany). Measurements were performed over a detection range of 0.1–875 µm. D10, D50, D90, surface mean diameter (SMD), and volume mean diameter (VMD) were recorded.

Powder X-ray diffraction (XRD) patterns were obtained using a Bruker D8 Advance diffractometer with Cu Kα radiation ($\lambda = 1.5406$ Å) over a 2θ range of 10°–80°. Crystalline phases were identified by comparison with the ICDD and RRUFF databases.

Surface morphology and elemental composition were examined using a Nova Nano SEM 450 scanning electron microscope equipped with an EDX detector. Images were acquired at accelerating voltages of 20–30 kV and magnifications ranging from 350x to 5000x. Elemental composition was determined semi-quantitatively from EDX spectra.

FTIR spectra were recorded in the range of 4000–400 cm^{-1} using the KBr pellet method, and functional groups were assigned by comparison with standard reference spectra.

For HPTLC analysis, SKR (500 mg) was extracted with methanol (10 mL), filtered, and applied onto silica gel plates using a CAMAG system (Switzerland). The mobile phase consisted of toluene:ethyl acetate:formic acid:methanol (3:4:0.8:0.7, v/v/v/v), and densitometric scanning was performed at 254, 320, and 366 nm.

GC–MS analysis was carried out using a Shimadzu GCMS-QP2010 system. The methanolic extract of

SKR was analyzed, and compounds were identified by comparison with standard spectral libraries.

2.5. Analytical Reliability and Data Acquisition

Instrumental analyses were conducted at established research facilities using calibrated instruments and standardized operating procedures. Data were generated using validated instrument-specific methodologies under controlled analytical conditions.

3. Results

3.1. Organoleptic and physicochemical characteristics

SKR was obtained as a fine, homogeneous greyish-black powder with a characteristic pungent odour and taste. Loss on drying, total ash, and acid-insoluble ash values were 7.00%, 23.55%, and 13.20% (w/w), respectively. The pH of a 10% aqueous solution was 7.97, indicating a near-neutral to slightly alkaline nature. The water-soluble and alcohol-soluble extractive values were 35.36% and 17.64% (w/w), respectively.

3.2. Particle size distribution

Particle size analysis demonstrated a monomodal particle size distribution with a broad size range, indicating a polydisperse particulate system. The formulation consisted predominantly of micron-sized particles, with a median particle size (D50) of 17.84 µm. Detailed particle size distribution parameters are presented in Table 2, while the distribution profile is shown in Figure 1.

Table 2: Particle size distribution parameters of Shwaskuthar Rasa

S. No.	Results	Particle size
1	X10	2.89 µm
2	X16	4.32 µm
3	X50	17.84 µm
4	X84	55.59 µm
5	X90	73.95 µm
6	X99	232.89 µm
7	SMD	8.48 µm
8	VMD	31.92 µm

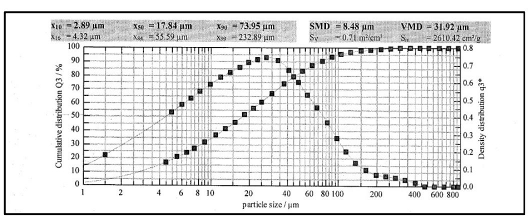


Figure 1: Particle size distribution curve of Shwaskuthar Rasa showing a monomodal distribution with a median particle size (X_{50}) of 17.84 µm.

3.3 X-ray diffraction analysis

The XRD pattern of SKR exhibited multiple sharp and well-defined diffraction peaks, indicating the crystalline nature of the formulation. Phase identification revealed mercury sulphide (HgS) as the predominant crystalline component, present in both hexagonal and cubic forms, along with orthorhombic sulphur. Minor phases corresponding to arsenic sulphide (As_2S_2) and trace elemental arsenic were also detected. The identified crystalline phases and diffraction parameters are presented in Table 3, while the corresponding diffractogram is shown in Figure 2.

Table 3. Major crystalline phases identified in Shwaskuthar Rasa by X-ray diffraction analysis

2θ (°)	d-spacing (Å)	Relative Intensity (I/I_0, %)	(hkl) Plane	Identified Phase
26.499	3.36092	100.0	(101)	HgS (Hexagonal/Cinnabar)
43.854	2.06280	31.4	(220)	HgS (Cubic/Metacinnabar)
51.900	1.76033	25.2	(312)	HgS (Cubic/Metacinnabar)
23.184	3.83344	21.7	(111)	Sulphur (S)
15.507	5.70958	19.6	(022)	Sulphur (Orthorhombic)
30.623	2.91704	17.6	(200)	HgS (Cubic/Metacinnabar)
31.241	2.86076	17.2	(012)	HgS
29.991	2.97709	9.7	(112)	HgS
27.834	3.20272	8.9	(040)	Sulphur (Orthorhombic)
22.778	3.90090	8.8	(131)	Sulphur (Orthorhombic)
25.437	3.49882	6.1	(026)	Sulphur (S)
70.170	1.34013	5.6	(331)	HgS (Cubic/Metacinnabar)
59.260	1.55000	1.0	(−244)	As_2S_2 (Realgar phase)
67.450	1.38000	0.7	(220)	Elemental Arsenic (As)

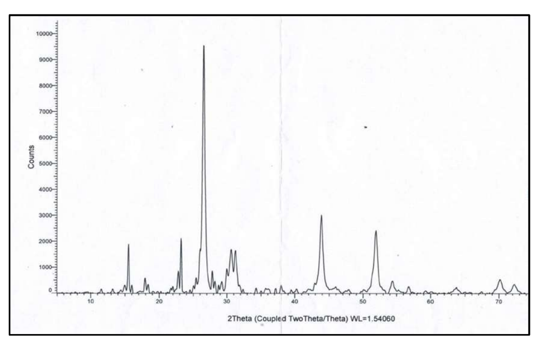
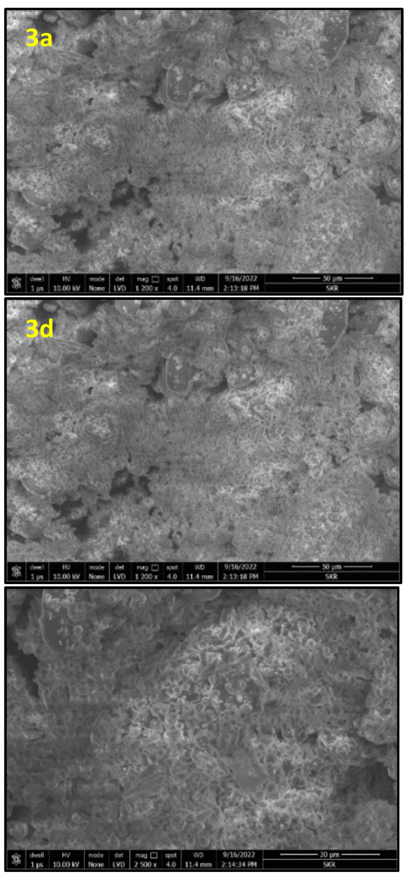


Figure 2: X-ray diffraction pattern of Shwaskuthar Rasa indicating the crystalline nature of the formulation and the presence of characteristic mineral phases.

3.4. Surface morphology and elemental composition (SEM–EDX)

SEM analysis revealed predominantly irregular to spherical particles with agglomerated clusters and heterogeneous surface morphology. Representative micrographs obtained at different magnifications are shown in Figure 3(a-e).

EDX analysis confirmed the multi-elemental composition of SKR, with carbon, oxygen, mercury, sulphur, and arsenic as the major detected elements. The quantitative elemental composition and corresponding spectrum are presented in Table 4 and Figure 4, respectively.



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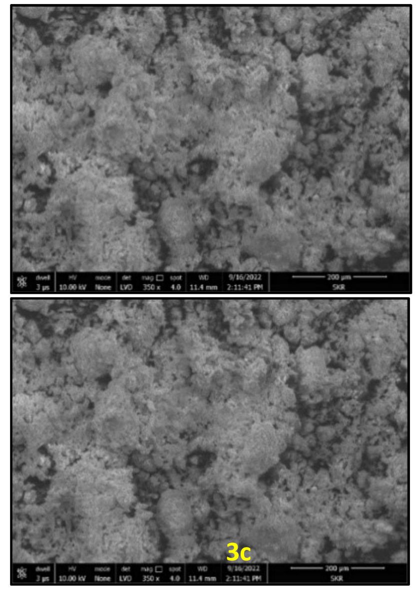

Figure 3(a-e): SEM micrographs of SKR at different magnifications showing irregular to spherical particles with agglomerated clusters and heterogeneous surface morphology.

Table 4: Elemental composition of Shwaskuthar Rasa by EDX

Element	Weight %	Atomic %	Net Int.	Error %	Kratio	Z	R	A	F
C K	31.80	51.82	188.11	10.75	0.09	1.14	0.91	0.26	1
O K	30.97	37.90	300.42	9.85	0.06	1.10	0.93	0.19	1
Na K	1.69	1.44	42.83	11.88	0.01	1.00	0.96	0.37	1
Si K	0.16	0.11	9.48	36.47	0.00	1.00	0.98	0.67	1.01
S K	5.40	3.30	302.59	3.77	0.04	0.98	1.00	0.82	1
Cl K	0.34	0.19	15.61	19.30	0.00	0.94	1.00	0.88	1
K K	2.09	1.05	85.48	8.12	0.02	0.93	1.02	0.83	1

Ca K	0.59	0.29	21.20	20.98	0.00	0.95	1.02	0.87	1
Hg L	19.15	1.87	42.77	28.43	0.11	0.57	1.12	1.04	1
As K	7.81	2.04	31.10	16.35	0.06	0.76	1.05	1.00	1.02

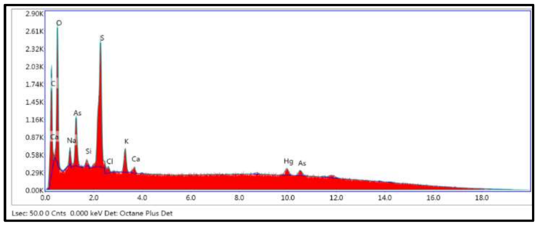

Figure 4: EDX spectrum of Shwaskuthar Rasa showing the elemental constituents detected in the formulation.

3.5. FTIR analysis

FTIR analysis revealed multiple absorption bands corresponding to diverse organic functional groups present in the formulation. Prominent bands observed around 3421 and 2928 cm^{-1} were indicative of hydroxyl and aliphatic C–H stretching vibrations, respectively. Additional absorptions in the regions around 2377, 2285, and 1639 cm^{-1}, together with several bands in the fingerprint region (1500–500 cm^{-1}), suggested the presence of oxygenated, nitrogen-containing, and other organic functionalities associated with the herbal constituents of the formulation. Detailed peak assignments are presented in Table 5, and the corresponding FTIR spectrum is shown in Figure 5.

Table 5: FTIR peaks and functional group assignment in Shwaskuthar Rasa

S. No.	Peak Position (cm^{-1})	Reference peak position	Group assigned	Class
1.	3421.89	3200-3550	O-H stretching	Alcohol
2.	2928.04	2500-3300 3700-3200 2800-3000 2840-3000	O-H O-H N-H C-H	Broad O–H and aliphatic C–H stretching vibrations
3.	2377.1	2349	O=C=O	Carbon dioxide
4.	2285.28	2250-2275	N=C=O	Isocyanate
5.	1639.19	1638-1648 1580-1650 1680	C=C N-H C=O	Alkene Amine 2^{O} and 3^{O} Amides
6.	1443.77	1465,1450	C-H	Alkane
7.	1252.31	1250-1310 1200-1275	C-O C-O	Aromatic ester Alkyl aryl ether
8.	1151.38	1000-1400 1020-1250 1124-1205	C-F C-N C-O	Flouro compound Amine 3^{O} Alcohol
9.	1078.37	1000-1400 1020-1250 1050-1085	C-F C-N C-O	Flouro compound Amine 1^{O} Alcohol
10	1024.95	1020-1250	C-N	Amine
11	760.96	760-780 730-770	C-H C-H	1,2,3 Trisubstituted Monosubstituted
12	576.42	550-850 515-690 500-600	C-Cl C-Br C-I	Halo Compounds

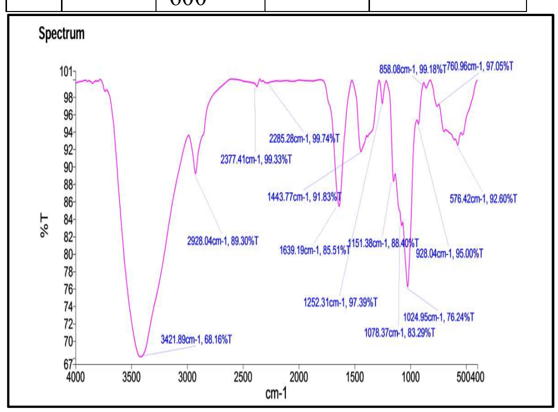

Figure 5: FTIR spectrum of Shwaskuthar Rasa showing characteristic absorption bands corresponding to the organic constituents present in the formulation.

3.6. HPTLC fingerprinting

HPTLC analysis of SKR revealed multiple well-resolved chromatographic peaks, indicating the presence of several constituents with varying chromatographic mobility. The densitometric profile showed consistent peak patterns across the analyzed tracks, with a few peaks exhibiting comparatively higher abundance. Detailed peak data are presented in Table 6, and the corresponding densitograms are shown in Figure 6(a-c).

Table 6: Prominent HPTLC peaks of Shwaskuthar Rasa in six tracks

Peak Number	Rf Value	Track 1 (AU)	Track 2 (AU)	Track 3 (AU)	Track 4 (AU)	Track 5 (AU)	Track 6 (AU)	Average (AU)
1	0.33	12.9	28.1	36.9	50.0	63.7	49.4	40.17
2	0.46	11.3	23.3	-	28.1	33.5	27.9	24.82
3	0.60	507.8	630.1	685.9	727.2	755.8	761.3	678.02
4	0.72	162.9	253.4	320.0	380.4	432.9	462.7	335.38
5	0.94	76.4	69.0	76.0	72.0	83.9	-	75.46
6	1.01	568.0	697.7	728.8	765.8	781.8	789.4	636.58

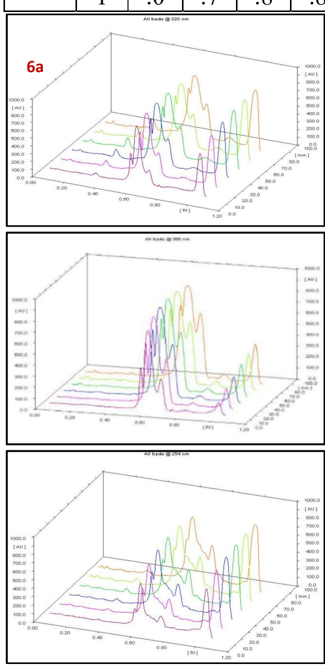

Figure 6(a-c): Three-dimensional HPTLC densitograms of SKR recorded at 320, 366, and 254 nm, showing multiple chromatographic peaks corresponding to the constituents present in the formulation.

3.7. GC–MS analysis

GC–MS analysis of SKR tentatively identified multiple organic compounds based on retention time and mass spectral matching. The major constituents detected included 9-octadecenoic acid derivatives, ethyl linoleate, glycerol esters, and piperidine derivatives.

Among the tentatively identified compounds, 9-octadecenoic acid, 1,2,3-propanetriyl ester (30.76%) and piperidine derivatives (45.43%) were the most predominant constituents based on peak area percentage. The complete list of identified compounds along with retention times and peak areas is presented in Table 7 and Figure 7.

Table 7: Compounds identified by GC-MS in Shwaskuthar Rasa

Peak #	R. Time	Area	Area %	Name
1	34.544	347288	1.01	OCTATHIOCANE
2	35.496	337529	0.98	9-Octadecenoic acid, methyl ester, (E)-
3	36.274	1910295	5.54	cis-9-Hexadecenal
4	38.865	1186893	3.44	HEXADECANOIC ACID, 2-HYDROXY-1,
5	39.854	207934	0.60	9-OCTADECENAMIDE
6	40.747	203684	0.59	9,12-OCTADECADIENOIC ACID (Z,Z)-, 2
7	40.837	379900	1.10	Oleoyl chloride
8	41.449	5638539	16.34	ETHYL (9Z,12Z)-9,12-OCTADECADIENOic acid
9	41.532	10613642	30.76	9-Octadecenoic acid, 1,2,3-propanetriyl ester
10	41.639	2310420	6.70	Tricyclo[20.8.0.0(7,16)] triacontane, 1(22),7(
11	41.901	1625515	4.71	Glycidol stearate
12	42.144	275984	0.80	Bicyclo[10.1.0]tridec-1-ene
13	42.789	451586	1.31	ETHYL (9Z,12Z)-9,12-OCTADECADIENO
14	43.645	1087997	3.15	Ehtyl piperonylcyanoacetate
15	43.906	379174	1.10	Piperine
16	44.634	208642	0.60	Glycidol stearate
17	45.150	448977	1.30	1,3-Benzenedicarboxylic acid, bis(2-ethylhex

18	45.269	1339461	3.88	PIPERIDINE, 1-[5-(1,3-BENZODIOXOL-5
19	45.434	5244867	45.434	PIPERIDINE, 1-[5-(1,3-BENZODIOXOL-5
20	45.560	306251	0.89	2-Decalone, c&t
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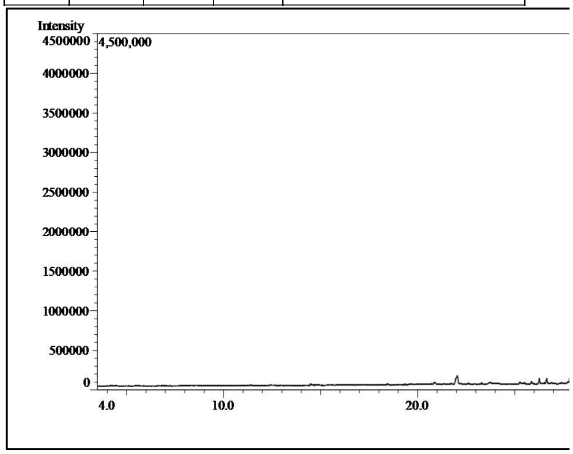

Figure 7: GC–MS chromatogram of Shwaskuthar Rasa showing the chromatographic profile of organic constituents detected in the formulation.

4. Discussion

The present study employed an integrated analytical approach to characterize the physicochemical and compositional features of Shwaskuthar Rasa (SKR), a herbomineral formulation containing both mineral and herbal constituents. The combined application of physicochemical testing, particle size analysis, X-ray diffraction, SEM–EDX, FTIR, HPTLC, and GC–MS enabled the characterization of its physical attributes, crystalline phases, elemental composition, and organic chemical profile, providing a comprehensive analytical framework for its evaluation.

4.1. Physicochemical Characteristics

The physicochemical parameters indicate that SKR possesses characteristics typical of a mineral-rich pharmaceutical preparation. The low moisture content may contribute to improved storage stability by reducing susceptibility to microbial growth and physicochemical degradation. The relatively high total ash and acid-insoluble ash values are consistent with the substantial mineral component of the formulation and reflect the incorporation of processed inorganic ingredients.[10] In addition, the near-neutral pH suggests physicochemical compatibility of the formulation and may influence its behaviour under gastrointestinal conditions, where pH-dependent solubility can affect the release of formulation constituents.[11]

4.2. Particle Size Distribution and Implications

Particle size analysis demonstrated a broad and polydisperse distribution of predominantly micron-sized particles. Such heterogeneous distributions are common in finely powdered pharmaceutical formulations prepared through repeated grinding and trituration processes. The observed difference between surface mean diameter and volume mean diameter suggests that smaller particles contribute substantially to the available surface area of the formulation.

Particle size is an important determinant of surface interactions and dissolution behaviour in solid dosage systems.[12] Although dissolution studies were not performed in the present investigation, the coexistence of finer and coarser particle fractions may potentially influence dispersion characteristics and interaction with dissolution media. Similar behaviour has been reported in polydisperse pharmaceutical systems, where finer particles contribute to initial dissolution owing to their higher surface area, while larger particles dissolve more slowly and may prolong particle persistence within the system.[13]

4.3. Crystallographic Characterization

XRD analysis confirmed that SKR is a predominantly crystalline formulation composed mainly of mercury sulphide (HgS) phases together with sulphur and minor arsenic-containing phases. The occurrence of HgS in both hexagonal (cinnabar) and cubic (metacinnabar) forms suggests phase transformation and stabilization during pharmaceutical processing.[14] The sharp diffraction peaks observed in the diffractogram indicate a relatively high degree of crystallinity and structural organization within the mineral fraction.[15]

The predominance of sulphide phases is particularly noteworthy, as cinnabar and metacinnabar represent thermodynamically stable forms of mercury sulphide characterized by low aqueous solubility and lower bioavailability compared with elemental mercury or soluble mercury salts.[16] The coexistence of these crystalline phases therefore contributes to the structural stability and physicochemical characteristics of the formulation.

4.4. Morphology and Elemental Composition

SEM analysis demonstrated a heterogeneous particulate system comprising agglomerated particles with irregular surface features. Such morphological characteristics are commonly observed in particulate formulations subjected to repeated trituration and processing.[17] Surface irregularities and particle aggregation may influence dispersion behaviour and interactions within the particulate matrix. In addition, porous and irregular particle surfaces have been reported to facilitate liquid penetration and increase the effective surface area available for solvent interaction, which may influence mass-transfer processes and dissolution behaviour in particulate formulations.[18] The observed morphology therefore reflects structural features that may contribute to the physicochemical behaviour of the formulation.

EDX analysis corroborated the mineral composition identified by XRD through the detection of mercury, sulphur, and arsenic, while the presence of carbon and oxygen reflected the contribution of herbal constituents. Minor elemental components further illustrate the compositional complexity of the formulation and the coexistence of organic and inorganic fractions within a single system.

4.5. Functional Group Analysis

FTIR spectroscopy revealed the presence of multiple organic functional groups associated with the herbal component of the formulation. The detection of hydroxyl-, nitrogen-, and oxygen-containing functionalities indicates the presence of chemically diverse organic constituents.[19]

The simultaneous detection of organic functional groups by FTIR and mineral phases by XRD and EDX supports the existence of an organic–inorganic composite system. Such systems are known to exhibit complex physicochemical interactions that may influence the stability, dispersion characteristics, and overall behaviour of the formulation.[20]

4.6. Chromatographic and Spectrometric Profiling

HPTLC fingerprinting demonstrated the presence of multiple chromatographically resolved constituents, reflecting the chemical complexity of the formulation. The characteristic fingerprint profile may serve as a useful analytical tool for identity assessment and future quality-control applications.[21]

GC–MS analysis further revealed a diverse organic composition comprising fatty acid esters, glyceride derivatives, alkaloidal constituents, and other minor organic compounds. The predominance of fatty acid esters and glyceride derivatives reflects the chemically diverse organic fraction of the formulation. The detection of piperine- and piperidine-related compounds is consistent with the herbal ingredients incorporated into the formulation and further supports its chemically heterogeneous nature.[22]

Together, the chromatographic and spectrometric findings demonstrate the complexity of the organic fraction and provide complementary information to the mineral characterization obtained through XRD, SEM–EDX, and FTIR analyses.

Conclusion

The present study establishes a comprehensive analytical profile of Shwaskuthar Rasa, demonstrating its complex herbomineral nature through the coexistence of crystalline mineral phases and a chemically diverse organic matrix. The findings provide reference data for the characterization and quality evaluation of SKR while enriching the scientific evidence base for traditionally processed herbomineral formulations. Future studies on batch-to-batch consistency, elemental bioaccessibility, and safety assessment may further strengthen its scientific evidence base.

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Declaration of Interest statement

The authors have no competing interests.

Authors contribution

Conceptualization: M. Vaidya, S. Kumar; Data Curation & Analysis: M. Vaidya; Writing – Original Draft: M. Vaidya; Writing – Review & Editing: M. Vaidya, A. Upadhyay; Supervision: S. Kumar

References

1. Jagtap CY, Mishra AK, Nariya M, Shukla VJ, Prajapati PK. Product development and characterization of the Ayurvedic herbo-mineral-metallic compound-Hridayarnava Rasa. Journal of Ayurveda and Integrative Medicine. 2024 May 1;15(3):100886.
2. Srikanth N, Singh A, Ota S, Sreedhar B, Dhiman KS. Chemical characterization of an Ayurvedic herbo-mineral preparation-Mahalaxmivilas Rasa. Journal of Ayurveda and integrative medicine. 2019 Oct 1;10(4):262-8.
3. Balekundri A, Mannur V. Quality control of the traditional herbs and herbal products: a review. Future Journal of Pharmaceutical Sciences. 2020 Oct 5;6(1):67.
4. Liang YZ, Xie P, Chan K. Quality control of herbal medicines. Journal of chromatography B. 2004 Dec 5;812(1-2):53-70.
5. World Health Organization. Quality control methods for medicinal plant materials. World Health Organization; 1998.
6. Ali A, Chiang YW, Santos RM. X-ray diffraction techniques for mineral characterization: A review for engineers of the fundamentals, applications, and research directions. Minerals. 2022 Feb 6;12(2):205.
7. Srivastava A, Jain VK, Srivastava A. SEM-EDX analysis of various sizes aerosols in Delhi India. Environmental Monitoring and Assessment. 2009 Mar;150(1):405-16.

8. Singh SK, Jha SK, Chaudhary A, Yadava RD, Rai SB. Quality control of herbal medicines by using spectroscopic techniques and multivariate statistical analysis. Pharmaceutical Biology. 2010 Feb 1;48(2):134-41.
9. Mosharraf M, Nyström C. The effect of particle size and shape on the surface specific dissolution rate of microsized practically insoluble drugs. International journal of pharmaceutics. 1995 Aug 1;122(1-2):35-47.
10. Gatfane RY, Ware RA, Denge KS. Pharmaceutical Analysis of a Herbo-mineral Formulation-Pippalyadi Agad from Yogaratnakar. Research Journal of Pharmacy and Technology. 2024 May 1;17(5):1927-32.
11. Dressman JB, Reppas C. In vitro–in vivo correlations for lipophilic, poorly water-soluble drugs. European journal of pharmaceutical sciences. 2000 Oct 1;11:S73-80.
12. Hörter D, Dressman JB. Influence of physicochemical properties on dissolution of drugs in the gastrointestinal tract. Advanced drug delivery reviews. 2001 Mar 1;46(1-3):75-87.
13. Horkovics-Kovats S. Dissolution and coarsening of polydisperse, polymorph drug particles liberated from a disintegrating finished dosage form: Theoretical considerations. European journal of pharmaceutical sciences: official journal of the European Federation for Pharmaceutical Sciences. 2016 Aug 25;91:265-77.
14. Gliozzo E. Pigments—Mercury-based red (cinnabar-vermilion) and white (calomel) and their degradation products. Archaeological and Anthropological Sciences. 2021;13:210.
15. Trivedi MK, Sethi KK, Panda P, Jana S. A comprehensive physicochemical, thermal, and spectroscopic characterization of zinc (II) chloride using X-ray diffraction, particle size distribution, differential scanning calorimetry, thermogravimetric analysis/differential thermogravimetric analysis, ultraviolet-visible, and Fourier transform-infrared spectroscopy. Int J Pharm Investig. 2017 Jan-Mar;7(1):33-40. doi: 10.4103/jphi.JPHI_2_17. PMID: 28405577; PMCID: PMC5370347.
16. Wu Q, Liu J, Li X, Li B, Luo H, Huang Y. The toxicological studies of cinnabar and realgar in traditional Chinese medicines. J Ethnopharmacol. 2013;146(1):1–13.
17. Maghsoodi M. Role of solvents in improvement of dissolution rate of drugs: crystal habit and crystal agglomeration. Advanced pharmaceutical bulletin. 2015 Mar 5;5(1):13.
18. Jange CG, Wassgren CR, Ambrose K. The significance of tablet internal structure on disintegration and dissolution of immediate-release formulas: a review. Powders. 2023 Feb 17;2(1):99-123.
19. Dike CS, Emejulu AA, Chukwudoruo CS, Akpaki MA, Nsofor WN, Edom CV. GC-MS and FTIR analyses of bioactive compounds present in ethanol leaf extract of Sida acuta from Imo State, Nigeria. GSC Biological and Pharmaceutical Sciences. 2023;25(02):394-404.
20. Kyriakoudi A, Spanidi E, Mourtzinos I, Gardikis K. Innovative delivery systems loaded with plant bioactive ingredients: Formulation approaches and applications. Plants. 2021 Jun 18;10(6):1238.
21. Lubis LD, Siregar MF, Nasution IP, Syahrizal D, Siregar KB, Eyanoer PC, Adenin I, Rusda M, Amin MM. Phytochemical Screening, Thin Layer Chromatography and Fourier Transform Infra-Red Spectroscopy Analysis of Eleutherine Bulbous (Mill.) Urb Bulb Extract. Pharmacognosy Journal. 2024 Jan 1;16(1).
22. Mitra S, Anand U, Jha NK, Shekhawat MS, Saha SC, Nongdam P, Rengasamy KR, Proćków J, Dey A. Anticancer applications and pharmacological properties of piperidine and piperine: a comprehensive review on molecular mechanisms and therapeutic perspectives. Frontiers in Pharmacology. 2022 Jan 7;12:772418.