



Application of Spectroscopic and Chromatographic Methods for Chemical Characterization of an Ayurvedic Herbo-Mineral Preparation: Maha Yograja Guggulu

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Abstract

Rasa Shastra is an exclusive branch of ayurveda that uses processed metals and minerals in various combinations. Though the formulations are time tested, safety and quality concerns are being raised since the past two decades. In view of this, it becomes mandatory to generate quality control profiles of such formulations by following available parameters. Considering this, we attempted to develop standard manufacturing procedures of *Maha Yogaraja Guggulu* and generate preliminary physicochemical profiles using inductively coupled plasma mass spectrometry, X-ray diffraction, and high-performance thin-layer chromatography. The results from high-performance thin-layer chromatography revealed presence of organic constituents from plant material. X-ray diffraction indicated that the prepared drug contained cinnabar (mercury sulfide; *Rasa sindhura*), cassiterite (tin oxide; *Vanga bhasma*), litharge (lead oxide; *Naga bhasma*), and iron dioxide and magnetite (di-iron oxide; *Loha and Mandura bhasma*). The observations of the present study are preliminary and first of its kind that may be considered as baseline data for future studies.

Keywords

bhasma, loha, maha yogaraja guggulu, mandura, naga, rasa sindhura, vanga

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Maha yogaraja guggulu (MYG) is a well-known ayurvedic herbo-mineral formulation known for its *Rasayana* (rejuvenative), *Shothahara* (anti-inflammatory), *Vedanahara* (analgesic) properties. It is in practice mainly for *Vatavyadhi* (specific disorders occurring due to *Vata dosha*), *Kustha* (skin diseases), *Arshas* (hemorrhoids), *Prameha* (diabetes), *Vatarakta* (gout), *Nabhi shula* (pain around umbilicus), *Bhagandara* (fistula-in-ano), *Gulma* (abdominal tumors), *Swasa* (dyspnea), *Kasa* (cough), *Aruchi* (anorexia), *Retasdosha* (seminal abnormalities), and *Rajadosha* (menstrual disorders).^{1,2}

Considering its importance in clinical use, the detailed standard operative procedures for the preparation, standardization, and chemical characterization of this formulation should be well documented with substantial evidences for worldwide acceptance. Hence, this study was conducted with the objectives to evolve standard operative procedures for the preparation as per classical ayurvedic texts and physicochemical profile of *Maha Yogaraja Guggulu*.

Materials and Methods

Pharmaceutical Processing

Maha yogaraja guggulu was prepared as per standard methods mentioned in the Ayurvedic Formulary of India.³ The details about the ingredients used are presented in Table 1. The whole process of preparation was divided into following steps.

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Table 1. Formulation Composition of *Maha Yogaraja Guggulu*^a.

Materials Used	Botanical/English Name	Part/Form Used	Proportion
<i>Shunthi</i>	<i>Zingiber officinale</i> Rose.	Dried rhizome	1 part
<i>Pippali</i>	<i>Piper longum</i> Linn.	Dried fruit	1 part
<i>Chavya</i>	<i>Piper chaba</i> Hunter.	Dried stem	1 part
<i>Pippali mula</i>	<i>Piper longum</i> Linn.	Dried root	1 part
<i>Chitraka</i>	<i>Plumbago zeylanica</i> Linn.	Dried root	1 part
<i>Hingu</i>	<i>Ferula foetida</i> Regel.	Exudates	1 part
<i>Ajamoda</i>	<i>Apium graveolens</i> Linn.	Dried fruit	1 part
<i>Sarshapa</i>	<i>Brasica compestris</i> Linn.	Dried seed	1 part
<i>Shweta jiraka</i>	<i>Cuminum cyminum</i> Linn.	Dried fruit	1 part
<i>Krishna jiraka</i>	<i>Carum carvi</i> Linn.	Dried fruit	1 part
<i>Renuka</i>	<i>Vitex agnus-castus</i> Linn.	Dried seed	1 part
<i>Indrayava</i>	<i>Holarrhena antidysentrica</i> Wall.	Dried seed	1 part
<i>Patha</i>	<i>Cissampelos pareira</i> Linn.	Dried root	1 part
<i>Vidanga</i>	<i>Embelia ribes</i> Burn. f.	Dried fruit	1 part
<i>Gaja pippali</i>	<i>Sciendapsus officinalis</i> Schott	Dried fruit	1 part
<i>Katuki</i>	<i>Picrorhiza kurroa</i> Royle ex Benth.	Dried root/rhizome	1 part
<i>Ativisha</i>	<i>Aconitum heterophyllum</i> Wall ex Royle.	Dried root	1 part
<i>Bharangi</i>	<i>Clerodendrum serratum</i> Moon.	Dried root	1 part
<i>Vacha</i>	<i>Acorus calamus</i> Linn.	Dried rhizome	1 part
<i>Murva</i>	<i>Marsdenia tenacissima</i> Wight and Arn.	Dried root	1 part
<i>Triphala</i>			40 parts
<i>Amalaki</i>	<i>Emblia officinalis</i> Gaertn.	Dried pericarp	
<i>Haritaki</i>	<i>Terminalia chebula</i> Retz.	Dried pericarp	
<i>Bibhitaka</i>	<i>Terminalia bellerica</i> Roxb.	Dried pericarp	
<i>Guggulu</i>	<i>Commiphora wightii</i> (Arn.) Bhandari	Oleo-gum resin	60 parts
<i>Vanga</i>	Tin	<i>Bhasma</i> (incinerated tin)	16 parts (320 g)
<i>Rajata</i>	Silver	<i>Bhasma</i> (incinerated silver)	16 parts
<i>Naga</i>	Lead	<i>Bhasma</i> (incinerated lead)	16 parts
<i>Loha</i>	Iron	<i>Bhasma</i> (incinerated iron)	16 parts
<i>Abhraka</i>	Biotite mica	<i>Bhasma</i> (incinerated mica)	16 parts
<i>Mandura</i>		<i>Bhasma</i> (incinerated sludge iron)	16 parts
<i>Rasa sindoor</i>	Sulfide of mercury (HgS)	A type of <i>kupipakwa rasayana</i> of mercury	16 parts

^aSource: The Ayurvedic Formulary of India, Government of India, Part I, 5:6.

Table 2. Details of Media Used, Nature and Number of *Putra*, and Temperature Used for the Preparation of Each *Bhasma*.

Name of <i>Bhasma</i>	Reference	Media Used	Nature of <i>Putra</i>	Number of <i>Putas</i>
<i>Vanga</i>	<i>Ayurved Sara Sangrah</i>	<i>Nimbu rasa</i>	<i>Ardha gaja putra</i>	10
<i>Rajata</i>	<i>Rasa Tarangini, Taranga</i> ¹⁶	<i>Nimbuk swarsa</i>	<i>Urdhav patan yantra</i>	For 6 hours
<i>Naga</i>	<i>Sarangdhar Samhita</i>	<i>Kanjika</i>	<i>Ardha gaja putra</i> and <i>gaja putra</i>	60 (where last 10 <i>putas</i> are <i>gaja putra</i>)
<i>Abhraka</i>	<i>Rasa Tarangini, Taranga</i> ¹⁰	<i>Arka ksheera</i>	<i>Gaja putra</i>	<i>Arka Ksheera</i> —7 <i>putas</i>
		<i>Nyagrodha mula kwatha</i>		<i>Nyagrodha mula kwatha</i> —3 <i>putas</i>
		<i>Kadali rasa</i>		<i>Kadali rasa</i> —7 <i>putas</i>
<i>Mandura</i>	<i>Rasa Tarangini, Taranga</i> ²⁰	<i>Triphala kashaya</i>	<i>Sadharana putra</i>	30
<i>Lauha</i>	<i>Rasa Tarangini, Taranga</i> ¹⁶	<i>Triphala kashaya</i>	<i>Gaja putra</i>	60

Processing of Guggulu. One part (1700 g) of *Guggulu* was made into small pieces carefully by removing physical impurities like stone, glass, and so on, bundled into a *Pottali*, suspended in a vessel containing *Triphala kashaya* (3400 mL), and boiled on moderate flame maintaining the temperature at around 80°C. On complete dissolution of *Guggulu* in the liquid, the contents were filtered through mesh No. 60 (to remove possible insoluble impurities, if any) and the filtrate was again heated till the liquid converts into a semisolid mass. This semisolid mass was shifted into steel trays and dried in a tray drier at 50°C. The dried mass was taken out from the tray and used in the preparation of *maha yogaraja guggulu*.⁴

Preparation of Bhasmas (*Vanga/Rajata/Naga/Lauha/Abhraka/Mandura/Rasa Sindhura*)

Preparation of vanga bhasma. *Vanga* was melted and poured 3 times each in *Tila taila*, *takra*, *kanjika*, *gomutra*, and decoction of the seeds of *kulattha* (*Dolichus biflorus* L.).⁵ It was further processed for *vishesha sodhana*, where molten *vanga* was poured in the leaf juice of *Nirgundi* (*Vitex negundo* Linn.) and powder of *haridra* (*Curcuma longa* Linn.) consecutively 3 times.⁶

Vanga collected at this stage was again molten in an iron pan, added with powder of *ashvattha* (bark of *Ficus religiosa* Linn.)

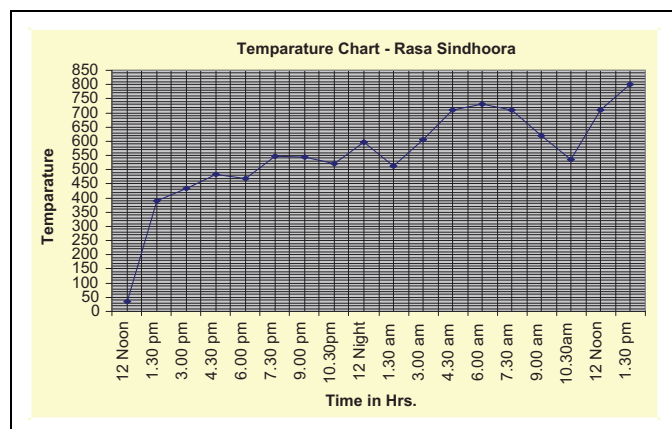


Figure 1. The temperature pattern for the preparation of *rasa sindhoora*.

Table 3. Preliminary Physicochemical Profile of *Maha Yogaraja Guggulu*.

Parameter Tested	Observations
<i>Organoleptic characters</i>	
Color	Blackish
Taste	Acrid
Odor	Pleasant
Appearance	Tablet
<i>Physicochemical</i>	
Identification	Yields the reaction characteristics of silver, mercury, lead, tin, and iron
Loss on drying, % w/w	2.0-5.0
Total ash, % w/w	43.0-46.0
Acid-insoluble ash, % w/w	12.0-14.50
Water-soluble extractive, % w/w	11.0-14.0
Alcohol (90%) soluble extractive, % w/w	8.0-10.0
Resin content, % w/w	12.50-14.0
pH of aqueous extract	5.0-6.0
Organic and volatile matter, % w/w	55.50-57.50
Specific gravity	0.9980-0.9990
Particle size distribution	
10%	2.15-2.76 μm
50%	11.01-20.35 μm
90%	54.11-81.65 μm
<i>Assay of elements</i>	
Silver (% w/w)	1.5-2.0
Iron (% w/w)	4.0-5.0
Sulfur (% w/w)	2.0-2.5
Silica (% w/w)	0.5-2.0
Calcium (% w/w)	2.5-3.0
Copper (% w/w)	0.1-0.5
Boron (% w/w)	0.01-0.30
Manganese (% w/w)	0.05-0.07
Magnesium (% w/w)	0.50 -1.50
Chromium (% w/w)	0.03-0.05
Aluminum (% w/w)	0.50 -1.0
Mercury (% w/w)	1.0 -1.5

(continued)

Table 3. (continued)

Parameter Tested	Observations
Lead (% w/w)	2.0-2.5
Arsenic (% w/w)	0.3-0.4
Cadmium (% w/w)	0.1-0.2
Tin (ppm)	350-750
<i>Residual pesticide ($\mu\text{g}/\text{kg}$)</i>	
Alpha and beta HCH	Not detected
Gamma HCH	Not detected
Delta HCH	Not detected
DDT and metabolites	Not detected
D.T.	18-20 minutes
Hardness	2.5 kg/cm^2
Friability	0.30-0.60%
Average weight	125-127 mg/tablet
<i>Microbial contamination</i>	
Total aerobic count	20 000-40 000
Coliform	Not detected
<i>Escherichia coli</i>	Not detected
<i>Salmonella sp.</i>	Not detected
<i>Staphylococcus aureus</i>	Not detected
Yeasts	Not detected
Molds	70-100
<i>Pseudomonas aeruginosa</i>	Absent
High-performance thin-layer chromatography	Incorporated

and *chinchavak* (bark of *Tamarindus indica* Linn.) in small quantities, and stirred continuously with *lohadarvi* (iron spatula). This process was continued till reduction of *vanga* to powder (*jaritavanga*).⁷ Furthermore, equal quantity of orpiment powder was added to this *jaritavanga* and levigated with lemon juice; small *chakrikas* (flat cakes) were prepared, dried, placed in *sarava samputa*, and subjected to *gajaputa*. From the second *puta* onwards, one fourth part of the orpiment powder was added to *vanga*. The process of *puta* was repeated 10 times to obtain *vangabhasma*.

Preparation of rajatabhasma. *Rajataptras* were heated to red hot and immersed consecutively in *tilaitaila*, *takra*, *kanjika*, *gomutra*, and decoction of the seeds of *kulattha*. The whole process was repeated 3 times. *Rajataptra* thus obtained was further processed to *visheshasodhana* by processing in *agastyaswarasa* (leaf juice of *Sesbania grandiflora*) 3 times.⁸ In the next step, this was added with *suddhahingula* (processed cinnabar in lemon juice), ground well, and heated in *urdhva patana yantra* for 6 hours. On cooling, the apparatus was opened to collect *rajatabhasma* from the lower vessel.⁹

Preparation of nagabhasma. Molten *naga* was poured consecutively in *tilaitaila*, *takra*, *kanji*, *gomutra*, and decoction of the seeds of *kulattha* 3 times each in all the liquids. This was further collected in an iron pan and heated. On melting, powders of *chinchavak* and *asvatthavak* were sprinkled in small quantities and stirred with *lohadarvi* (iron spatula). This process was continued till the molten *naga* is reduced to powder form (*jaritanaga*). Furthermore, equal quantity of *manahsila* was added to *jaritanaga* and levigated with *kanji*; small *chakrikas* were prepared, dried, and placed in *sarava samputa* and *ardhagajaputa* is given. This process was repeated 60 times to obtain *nagabhasma* of desired quality.¹⁰

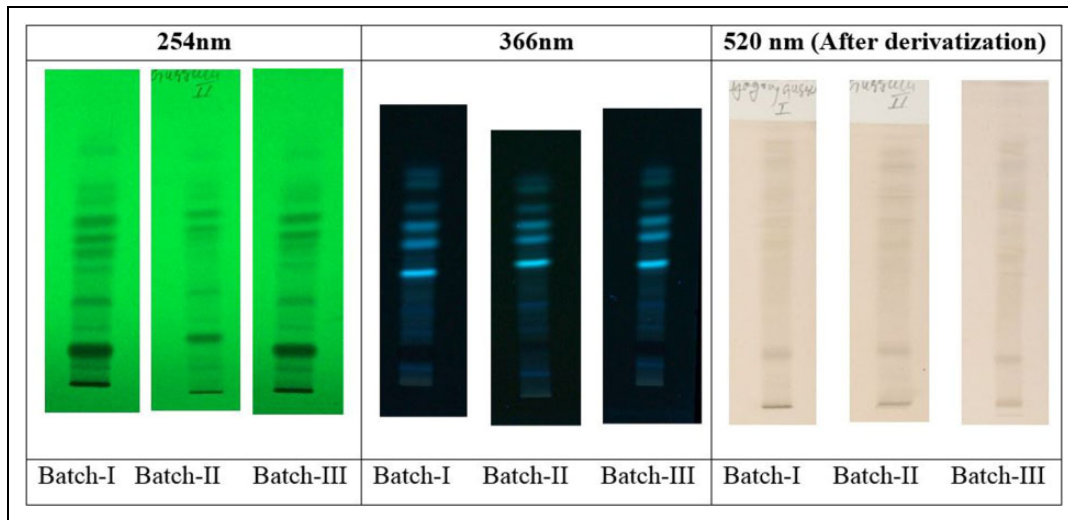


Figure 2. High-performance thin-layer chromatography profiles of *maha yogaraja guggulu*.

Preparation of abhraka bhasma. *Abhraka* was heated to red hot and immersed in decoction of *Triphala* (3 myrobalans) 7 times.¹¹ The *shodhita abhraka* was bundled in a jute bag (into *pottali* form) with one fourth quantity of paddy and immersed in *kanji*¹² for 3 days. Thereafter, the *pottali* was rubbed thoroughly and squeezed in the liquid itself so that only fine *abhraka* particles can escape through the holes of the bag. The bag was removed from the *kanji* and the contents were allowed to settle down. The supernatant liquid layers were separated carefully to collect fine particles of *abhraka* that had settled down in the container. These particles (*dhanyabhraka*) were dried and stored for further use.¹³

Dhanyabhraka was levigated with required quantity of *arka ksheera* (latex of *Calotropis procera* (Ait) R.Br.) for a day; *chakrikas* were prepared and dried in the sun. These *chakrikas* were placed in a *sharava samputa*, the junctions were sealed properly, and subjected to *gaja puta*.¹⁴ The material thus obtained at the end of this *puta* was processed in similar way 6 more times. At the end of the seventh *puta*, the contents were levigated with *nyagrodha mula kwatha* (decoction of *Ficus bengalensis* roots), dried, and *gaja puta* was given. The process was repeated 3 times followed by levigation with *Rambha rasa* (juice of rhizome of *Musa paradisiaca*) and 7 *gaja putas* were given. Finally, this was grounded in *nyagrodha mula kwatha* and 3 *gaja putas* were given. After completion of these *putas*, the finished product *abhraka bhasma* was obtained.¹⁵

Preparation of mandura bhasma. *Shuddha mandura*¹⁶ was levigated in *triphala kvatha* and *chakrikas* were prepared and dried that are placed in *sharava samputa* and subjected to heat in *sadharan puta*. The process was repeated 30 times to obtain red-colored *mandura bhasma*.¹⁷

Preparation of lauha bhasma. *Lauha* was heated to red hot and immersed 3 times each consecutively in *tila taila*, *takra*, *kanji*, *gomutra*, and decoction of the seeds of *kulattha*. This was further processed in equal quantities of *triphala kashaya* and *gomutra*.¹⁸ *Lauha churna* thus obtained was further processed through *bhanupaka* (processed in sun rays), followed by *sthalipaka* (heated with decoction of *triphala* in stainless steel vessel).^{19,20} This was further levigated with *triphala kwatha*, *Chakrikas* were prepared, dried, and placed in *sharava samputa*, and subjected to *gaja puta*. The same procedure was repeated 60

times to get *lauha bhasma* of desired quality.²¹ The details of media used, nature, and number of *putas* and temperature used in the preparation of each *bhasma* are mentioned in Table 2.

Preparation of rasa sindhura. Preparation of *rasa sindhura* involves preparation of *kajjali*, *bhavana* (levigation) with *vatankura jala* (decoction of leaf buds of *Ficus bengalensis* Linn.), and processing in *valuka yantra*.²²⁻²⁴ *Kajjali* was prepared by triturating equal quantities of *hingulottha parada* (mercury obtained from cinnabar) and *shuddha gandhaka* (processed sulfur) in a *khalva yantra* (mortar pestle), till the formation of a black-colored, soft, lusterless fine powder like collyrium. This was further levigated with *vatankura jala* and then dried. This was filled in a strong amber-colored *kachakupi* (glass bottle) in *valuka yantra* (heating device) and subjected to heat by increasing the temperature gradually. Mild heat was applied for the first 6 hours, followed by moderate heat. The temperature pattern for the preparation of *rasa sindhura* is shown in Figure 1.

When the bottom of the bottle appears red, the mouth of the bottle was blocked with cork and sealed with mud mixed with lime and jaggery smeared cloth. This was followed by application of strong heat for the next 6 hours. Thereafter, the *valuka yantra* was allowed to cool down on its own (Figure 1). The bottle was then removed from the *valuka yantra* and the mud-smeared cloth was scrapped with a knife; the bottle was broken down carefully to collect crystallized *rasa sindhura* from the neck of the bottle.

Preparation of Finished Product. *Shuddha guggulu* (1.2 kg) was dissolved in 3 L of water to prepare a thick paste, to which fine powders of other components were added in end runner followed by levigation for 3 days. At the end of this process, the material was removed from the end runner, shifted to clean stainless steel trays, and dried at 50°C.

The dried material was converted into granules by passing through No. 40 sieve and shifted to the tablet section. Two percent of talcum powder was added as excipient to the granules and were compressed into tablets of 125 mg in a rotary tablet machine.

Physicochemical Analysis

Physicochemical analysis, that is, description, estimation of loss on drying, ash content, acid insoluble ash, water/alcohol soluble

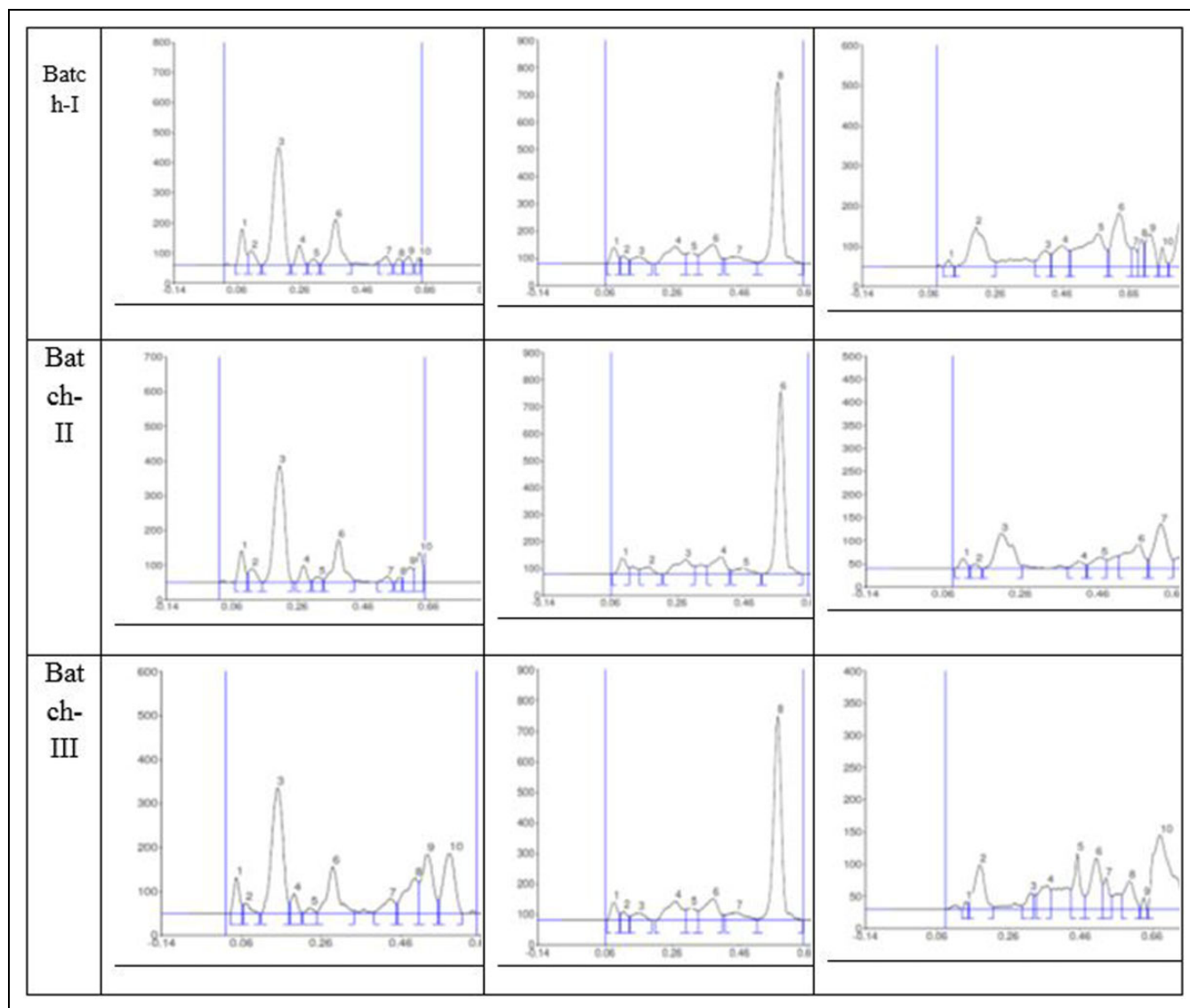


Figure 3. High-performance thin-layer chromatography fingerprints of *maha yogaraja guggulu*.

extractive, pH, and so on; qualitative/quantitative elemental testing; residual pesticide; microbiological examination; and tablet parameters, that is, hardness, friability, average weight, dissolution time, and so on, were carried out by following standard methods as per Ayurvedic Pharmacopoeia of India²⁵⁻²⁷ guidelines. The quantitative estimation of heavy metals, that is, Pb, Cd, As, Hg, and Sn was carried out by atomic absorption spectrometer (Perkin Elmer Analyst 400), and the other elements that is, Ca, Mg, Cu, B, Mn, Al, Cr, Fe, and Ag were analyzed on ICP-AES (THERMO ELECTRON Corporation's model IRIS INTREPRID II XDL). However, sulfur and silica were quantified by using conventional methods.²⁷

High-Performance Thin-Layer Chromatography Method

Sample preparation. Two grams of powders each of the 3 batches of *maha yogaraja guggulu* were soaked overnight separately in 20 mL of methanol. The solutions were continuously stirred for 6 hours and kept for the next 18 hours and then the samples were filtered, dried, and made into 10% solution.

High-performance thin-layer chromatography was performed on thin-layer chromatography plates pre-coated with 0.25 μm thin layers of silica gel 60 F₂₅₄ (E. Merck). Ten microliters of methanolic solution of formulation (3 batches) were applied on the plates as bands 8.0 mm wide by use of a Linomat-V applicator (CAMAG, Switzerland) fitted with a 100 μL syringe (Hamilton, Switzerland). The application positions X and Y were both 10 mm, to avoid edge effects. Linear ascending development to a distance of 80 mm with toluene–ethyl acetate–formic acid 10:3:1 (v/v) as mobile phase was performed in a twin-trough glass chamber previously saturated with vapors of the mobile phase for 20 minutes. The plates were dried in air and visualized under 254 nm and 366 nm for ultraviolet detection and taken the fingerprints as evident. The same thin-layer chromatography plate was also derivatized with anisaldehyde-sulfuric acid reagent and visualized in white light.

X-Ray Diffraction Study. Powder X-ray diffraction analysis was carried out using Rigaku Ultima-IV X-ray diffractometer with CuK α radiation

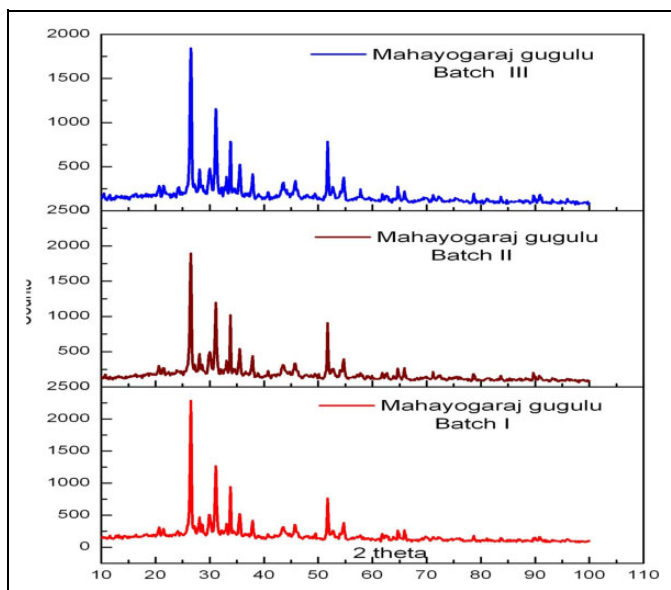


Figure 4. X-ray diffraction pattern of maha yogaraja guggulu.

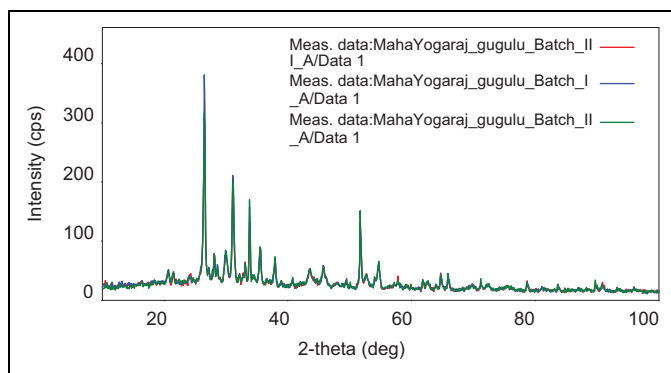


Figure 5. Overlay of X-ray diffraction pattern of maha yogaraja guggulu.

($\lambda = 1.54 \text{ \AA}$) operating at 40 kV and 30 mA. The pattern was recorded for angle (2θ) ranging from 10° to 100° at a scanning rate of $1^\circ/\text{second}$ and scan step of 0.1° . X-ray diffraction pattern of maha yogaraja guggulu (3 batches) is shown in the spectra. Sample identification was done by matching d-spacing with the standard database.

Results and Discussion

Organoleptic observations show that maha yogaraja guggulu is in the form of a brownish-colored tablet having characteristic pleasant odor and slightly acrid in taste. The qualitative analysis shows positivity for the presence of mercury, silver, sulfur, calcium, copper, iron, and lead. Chemical analysis revealed 2.39% of lead, 1.31% of mercury, 2.25% of sulfur, 4.36% of iron, 1.63% of silver, 2.73% of calcium, 1.08% of magnesium, and 1.18% of silica along with other trace elements like aluminum, manganese, arsenic, copper, tin, boron, chromium, and cadmium, which were found in $<1.0\%$ range. Moisture content 3.62% was found when determining loss on drying at 105°C .

Table 4. d-Spacing and 2-Theta ($^\circ$) Values of X-Ray Diffraction Analysis.

2 theta	d (Å)	Size (Å)	Chemical Formula	Phase Data Name	cps
21.5	4.1	214.2	Sn	Tin (1,1,0)	12.7
26.5	3.4	381.0	HgS, SnO ₂	Cinnabar (1,0,1), cassiterite, syn (1,1,0)	271.0
28.0	3.2	106.0	HgS	Cinnabar (0,0,3)	17.2
28.7	3.1	217.2	PbO	Litharge (1,0,1)	16.1
29.9	3.0	191.0	Fe ₃ O ₄	Iron di-iron (III) oxide, magnetite HP, syn (2,2,0)	35.0
31.1	2.9	268.0	HgS	Cinnabar (1,0,2)	123.0
34.0	2.6	220.1	SnO ₂	Cassiterite, syn (1,0,1)	122.3
35.4	2.5	336.0	Fe ₃ O ₄ , PbO	Iron di-iron (III) oxide, magnetite HP, syn (3,1,1), litharge (0,0,2)	47.0
37.9	2.4	297.0	HgS, SnO ₂	Cinnabar (1,0,3), cassiterite, syn (2,0,0)	27.0
43.4	2.1	117.0	HgS, Fe ₃ O ₄ , Sn	Cinnabar (1,1,0), iron di- iron (III) oxide, magnetite HP, syn (4,0,0), tin (2,2,0)	17.8
45.7	2.0	228.0	HgS, PbO	Cinnabar (1,0,4), litharge (2,0,0)	21.5
49.5	1.8	231.7	Sn	Tin (3,1,0)	12.9
51.7	1.8	593.0	HgS, SnO ₂	Cinnabar (2,0,1), cassiterite, syn (2,1,1)	95.0
52.8	1.7	235.0	HgS	Cinnabar (1,1,3)	17.4
54.7	1.7	224.0	HgS, SnO ₂ , PbO	Cinnabar (2,0,2), cassiterite, syn (2,2,0), litharge (2,1,1)	26.0
61.8	1.5	245.3	SnO ₂	Cassiterite, syn (3,1,0)	14.3
62.5	1.5	246.2	Fe ₃ O ₄ , SnO ₂ , Sn	Iron di-iron (III) oxide, magnetite HP, syn (4,4,0), cassiterite, syn (2,2,1), tin (1,1,2)	6.8
64.8	1.4	249.2	HgS, SnO ₂	Cinnabar (2,0,4), cassiterite, syn (1,1,2)	22.8
66.0	1.4	914.0	Fe ₃ O ₄ , SnO ₂	Iron di-iron (III) oxide, magnetite HP, syn (5,3,1), cassiterite, syn (3,0,1)	32.0
69.7	1.3	29.0	HgS, SnO ₂ , Sn	Cinnabar (2,1,0), cassiterite, syn (3,1,1), tin (2,0,2)	3.0
71.2	1.3	258.9	Fe ₃ O ₄ , SnO ₂	Iron di-iron (III) oxide, magnetite HP, syn (6,2,0), cassiterite, syn (2,0,2)	4.9
78.7	1.2	272.2	SnO ₂	Cassiterite, syn (3,2,1)	12.7
83.7	1.2	282.6	SnO ₂ , PbO	Cassiterite, syn (2,2,2), litharge (1,1,4)	7.7
89.8	1.1	297.0	Fe ₃ O ₄ , SnO ₂	Iron di-iron (III) oxide, magnetite HP, syn (7,3,1), cassiterite, syn (3,1,2)	5.9
90.9	1.1	212.0	HgS, SnO ₂ , PbO	Cinnabar (2,0,7), cassiterite, syn (4,1,1), litharge (3,2,1)	6.0

Total ash content (44.38%) is ash left after burning of organic and volatile matter (56.29%). As shown in the observations, water soluble (12.03%) and alcohol soluble (9.06%) matter were also present in this formulation. The drug also tested for residual pesticides and microbial contamination, which was found to be within permissible limits (Table 3). The results from high-performance thin-layer chromatography, as shown in Figures 2 and 3, revealed presences of organic constituents from plant material.

The X-ray diffraction patterns of the 3 batches, as shown in Figures 4 and 5 and Table 4, are nearly identical, showing clear crystalline phases of the inorganic constituents. The X-ray diffraction results have indicated that all the samples contained cinnabar (mercury sulfide added as *rasa sindhura*), cassiterite (tin oxide, *vanga bhasma*), litharge (lead oxide; *naga bhasma*), and iron dioxide and magnetite (di-iron oxide; *loha* and *mandura bhasma*). Some clear but weak signature of elemental tin is also seen. No signature of *rajat bhasma* could be identified in these spectra, indicating that the method used for its preparation did not yield any crystalline products or the signature is buried under the strong lines of other constituents. The X-ray diffraction lines at 21.5° and 49.5° could show the presence of elemental tin. The crystalline form of *abhrak bhasma* does not appear to be present. It can be seen that 3 X-ray diffraction patterns on the samples are qualitatively same in the relative intensities of the peaks, and the X-ray diffraction results indicate that the inorganic contents have remained intact over time.

Conclusion

This study reveals that *yogaraja guggulu* prepared following the classical guidelines seems to be very effective in converting the macro elements into therapeutically effective medicines in micro form. Well-prepared herbo-mineral drugs offer many advantages over plant medicines due to their longer shelf-life, lesser doses, easy storing facilities, better palatability, and so on. The inferences and the standards laid down in this study certainly can be utilized as baseline data of standardization and quality assurance of this herbo-mineral formulation. It will be helpful in laying down further pharmacopoeia standards of *maha yogaraja guggulu*.

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Author Contributions

Arjun Singh: Data generation, data interpretation, and drafted the chemical characterization part of the article.

Sarada Ota: Coordination of the project and drafted the ayurvedic part and standard operative procedures for the preparation of the formulation in the article.

Narayan Srikanth: Monitored the project work and revised the article critically.

Galib: Generated the data related to the standard operative procedures for the preparation of the formulation.

Sreedhar Bojja: Generated and analyzed the data related to chemical characterization.

Kartar Singh Dhiman: Supervision and final approval of the article for publication.

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Ethical Approval

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