RESEARCH PAPER

Scientific Dimensions of Siddha Alchemy: Chemical Characterization and Biomedical Applications

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Abstract

The Siddha alchemy, popularly referred to as Rasavatham, is an important traditional branch of Siddha pharmaceutical knowledge related to processing and transforming metals, minerals and other inorganic substances into medicines. Traditional procedures such as purification (Suddhi), grinding, trituration and calcination are used in the preparation of different mineral and metallic formulations. These practices are mentioned in classical siddha literature but the chemical and physicochemical changes involved in these practices have yet to be scientifically researched. Traditionally prepared formulations have been explored by techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR) and inductively coupled plasma spectroscopy, which have provided valuable opportunities to examine these formulations in recent developments in analytical chemistry and materials science. These methods are useful for the understanding of elemental composition, crystalline structure, particle morphology and chemical interactions. This review highlights the traditional basis of Siddha alchemy, its possible chemical interpretations, modern techniques for the characterisation and potential biomedical research applications. Special emphasis is placed on nanoscience, pharmacological evaluation, toxicological assessment and quality standardisation. The traditional knowledge of Siddha with modern scientific approach could give a better basis to understand the preparations and give scientific research. Therapeutic claims however must be backed by a reproducible experimental finding and a thorough evaluation of safety.

Keywords: Siddha medicine; Rasavatham; Siddha alchemy; chemical characterisation; nanoscience; metallopharmaceuticals; biomedical applications; toxicological evaluation.

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1. Introduction

Siddha medicine is one of the traditional Indian system of medicine and has an abundant pharmaceutical heritage that has been developed through the efforts of the Siddhars. Its medicinal preparations contain substances derived from the plant, animal and mineral. Of these, alchemy has a particularly special significance, due to its focus on the processing and transformation of metals and minerals into certain pharmaceutical preparations.

The traditional understanding of Rasavatham is related to the changes in the material by certain processes. The use of metals, minerals and other inorganic materials along with special purification and processing techniques is described in the classical Siddha texts. Preparations like Parpam, Chendooram, Chunnam and Karuppu are important categories of the Siddha mineral and metallic medicines [1,2].

Siddha alchemy has an interdisciplinary charm in this modern era from the science point of view involving inorganic chemistry, pharmaceutical technology, materials science and nanotechnology. These preparations can be analysed using modern methods to determine their chemical composition, structure and particle properties.

But the processing which has been used is not necessarily proof of detoxification or of the efficacy of the therapy. In order to be scientifically validated, the chemical constituents of the product should be identified, the possible toxic effects should be evaluated and the biological activity should be demonstrated by suitable experimental studies. Advanced analytical techniques have been tried and tested in recent investigations of Siddha metallopharmaceuticals, and it

has been shown that these sophisticated techniques can be used to understand these preparations [3,4].

2. Traditional Foundations of Siddha Alchemy

Siddha alchemy is traditionally associated with the pharmaceutical and alchemical knowledge of the Siddhars. Rasavatham involves the processing and transformation of metals, minerals and other substances through specialised procedures described in Siddha literature.

Several categories of mineral and metallic preparations are recognised in Siddha pharmaceutical practice:

Parpam: Traditionally prepared calcined formulations.

Chendooram: Specially processed preparations, often characterised by red or other distinctive colours.

Chunnam: Preparations obtained through specific processing of mineral substances.

Karuppu: Traditionally prepared black-coloured formulations.

Mezhugu: Wax-like or semi-solid pharmaceutical preparations.

These preparations differ in their ingredients, processing methods and final physicochemical characteristics. Their traditional classification provides a useful foundation for understanding the diversity of Siddha mineral-based medicines [1,2].

Traditional procedures include Suddhi (purification), Araippu (grinding), Pudam (thermal processing) and repeated trituration with specified liquid media. From a scientific perspective, such procedures may influence particle size, chemical composition, crystalline phases and surface properties.

The extent of these changes depends on the raw materials and the conditions under which they are processed. Therefore, the chemical transformations associated with each traditional procedure need to be established through appropriate laboratory investigations rather than assumed from the method of preparation alone.

3. Chemical Principles of Siddha Alchemical Processing

3.1 Purification and chemical transformation

Suddhi is an important preliminary process in making several Siddha mineral and metallic formulations. Some of the traditional purification processes could be washing, soaking, grinding, heating and treatment with particular herbal or other biological contents.

These may affect the chemical and physical properties of the raw materials. It could be removal of some impurities, surface properties or changes in the oxidation state of inorganic components, or change in interactions between inorganic and organic components.

Malarvizhi et al. for instance, studied the processing and characterisation of the Siddha metallopharmaceutical formulation Sivanar Amirtham. They have compared the raw materials, processed ingredients and formulation by employing various modern analytical techniques. The results proved that the traditional processing method can be systematically explored by physicochemical characterization [3].

However, don't equate the purification with full detoxification. The toxicity reduction shall be proven by means of chemical analyses and appropriate biological safety studies.

3.2 Thermal processing and calcination

Another significant aspect of Siddha Pharmaceutical preparation is thermal processing. Several heatings and calcinations can cause a change in the physical and chemical characteristics of metals and minerals. These processes can act on the crystal structure and phase composition, on the oxidation and reduction reactions, on the formation of metal oxides/sulphides, on the particle morphology and aggregation and on the thermal stability and chemical reactivity, depending on temperature, duration and atmospheric conditions. These changes are especially important in the study of mercury, sulphur, arsenic, iron, copper and other inorganic ingredients formulated. Elemental and spectroscopic methods can give complementary information, and XRD and thermal analysis may be useful for identifying phase changes [3].

3.3 Role of herbal processing media

Some Siddha preparations require repeated grinding and trituration with herbal juices, decoction or other media mentioned. This may involve addition of organic compounds that react with inorganic components.

Interactions that could occur involve adsorption on the surface, complex formation and dispersion of particles. The information from FTIR and XPS can be used to determine functional groups and chemical states, but the results need to be correlated with other analytical results.

Such interactions pose an interesting subject for further study of chemical behaviour of Siddha herbo-mineral preparations.

4. Modern Analytical Approaches to Chemical Characterisation

The modern analytical chemistry supplies a scientific apparatus to the analysis of Siddha alchemical preparations with respect to their composition, structure and physical property. Complementary techniques are also significant in their use as no single analytical technique can give a complete understanding of a complex formulation.

The information from each analytical approach is different. XRD is used to identify crystalline phases, while SEM and TEM can give information on particle morphology and size. Vibrational bands are associated with functional groups and may be identified by FTIR; quantitative elemental analysis can be done using ICP-MS and ICP-OES.

It is important to recall the difference between elemental detection and chemical speciation. For instance, the presence of mercury in a preparation does not indicate that it is present as elemental mercury or as mercuric sulphide or as some other mercury compound. There is a significant variation in their chemical reactivity and biological activity.

In the above study, XRD and FTIR were used to study the chemical properties of Vaalai Rasa Mezhugu, a Siddha herbo-mineral formulation. The investigators identified several functional groups from FTIR analysis, and reported the presence of crystalline phases of sylvite and zinc sulphide.

These studies point to the importance of instrumental methods for elucidation of the composition of traditional preparations. Reproducibility should be established by further studies using traceable methods, reference materials and independent manufacturing batches.

5. Siddha Alchemy and Nanoscience

Nanoscience has opened-up new vistas for the study of the structural and biological characteristics of inorganic materials. Nanomaterials are typically considered to possess sizes of about 1-100 nm, though the size range may vary depending on the nanomaterial and the measurement condition.

Nanoparticles can be found in some traditionally prepared Siddha medicines. Nanosized particles, however, do not necessarily indicate a preparation to be an engineered nanomedicine. They should be studied separately with regards to their composition, structure, stability and biological behaviour.

5.1 Physicochemical properties of nanoscale materials

Particle size and size distribution, surface area and surface charge, shape and morphology, crystalline structure, chemical composition and surface chemistry, solubility, dissolution and aggregation are examples of biological behaviours that can be influenced by the material. Such properties could affect the protein-protein interactions, protein-cell membrane and other biological interactions. Hence, it is pertinent to consider the nanoscale characterisation, while exploring the biological activities of Siddha mineral formulations.

5.2 Evidence from Siddha formulations

Kannan et al. studied the chemical, elemental, morphological and toxicological properties of Kasthuri Karuppu. They used XRD, FTIR, XPS, ICP-OES and other analytical techniques for their study. The investigators presented the size of the particles between 10 and 80 nm and showed that the biological effects obtained were dependent upon concentration and exposure time [5].

It is worth noting, though, that longer exposure to this mixture was also reported to have a negative cellular effect. This observation further emphasizes the importance of considering toxicity in addition to the particle properties and potential biomedical applications.

The results of the study should be viewed as evidence obtained from experiments with the formulation and not generalized to other Siddha mineral formulations.

6. Potential Biomedical Applications

The systematic Pharmacological and Toxicological studies can be carried out for biomedical relevance of the Siddha alchemical preparations. Currently there are a number of proposed applications that need experimental validation before therapeutic statements can be made.

6.1 Antimicrobial activity

Some of the selected Siddha formulations can be explored for their antimicrobial effect (bacterial and fungal). Standard microbiological methods can be used to determine minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC) and effects on microbial biofilms. Appropriate positive and negative controls, standardised test organisms and parallel cytotoxicity studies should form part of such investigations.

6.2 Antioxidant and anti-inflammatory research

Oxidative stress and inflammation play a role in many chronic disease processes. The antioxidant and anti-inflammatory effect of selected Siddha preparations may be studied by the well established experimental techniques. The DPPH, ABTS and FRAP assays can give preliminary data on the chemical antioxidants activity. But these assays are not enough to determine antioxidant activity in vivo. Further studies could examine the cellular pathways related to inflammatory mediators like TNF- α, IL-6 and IL-1 β.

6.3 Cytotoxicity and anticancer research

Selected mineral-based formulations can be studied on cell culture models to assess their effects on cell viability, cell proliferation and apoptosis. Cellular responses can be studied using techniques like MTT assays, flow cytometry and measurement of the activity of caspases. The differential efficacy in inhibiting cancer cells versus non-cancer cells is especially significant. The preparation which damages both normal and cancer cells cannot be called as a selective anticancer agent unless there is any further evidence.

6.4 Pharmaceutical and drug-delivery research

Physical and chemical properties of some inorganic materials might offer avenues for formulation stability studies, controlled-release systems and drug-material interaction studies. Applications of this type, however, do need biocompatibility, reproducibility, chemical stability and proper safety. Currently, these are considered as research directions and not as drugs of Siddha alchemy.

7. Toxicological Evaluation and Quality Standardisation

When conducting any Siddha mineral and metallic preparations research, one of the most crucial factors to consider is safety. Care needs to be taken in the evaluation of potentially toxic elements such as mercury, arsenic, and lead.

The biological activity of these elements is influenced by the chemical state, concentration, mode and duration of exposure. No single method of purification or calcination can ensure safety of a preparation.

Mukhopadhyay et al. did a systematic scoping review on the toxicity of heavy metals in Indian traditional medical systems. They found 220 reported cases of metals like lead, mercury and arsenic. They identified the significance of the correct manufacturing

techniques, quality control and monitoring patient safety [6].

7.1 Essential toxicological investigations

Elemental analysis of Siddha mineral preparations should be done for mercury, arsenic, lead, cadmium or other relevant elements; chemical speciation, in vitro cytotoxicity, repeated-dose toxicity testing, genotoxicity, bioaccessibility and bioavailability, and pharmacokinetic studies should be undertaken as appropriate.

7.2 Quality control and standardisation

The composition of Siddha formulations may vary depending on different raw material, geographical sources, processing conditions and manufacturing procedures. Hence, the need of standardisation for consistency and reproducibility.

Raw material qualification, SOP, batch to batch comparison, elemental analysis, impurity profiling, microbial testing and stability assessment are some of the quality control activities that should be considered.

The official pharmacopoeia and formulary standards published by the Pharmacopoeia Commission Indian Medicine and Homoeopathy give an important support for the quality assurance of Siddha pharmaceutical preparations [7].

8. Research Gaps and Future Perspectives

Although there is an increasing interest in the scientific study of Siddha alchemy, there are some aspects that need further investigation.

First, the chemical characterisation should be extended to multiple batches of the same formulation. This would help to determine if the observed physicochemical properties are reproducible.

Second, more study needs to be done on speciation of chemicals. The concentration of the total element does not give enough information to understand the potential biological effects of a metallic preparation.

Thirdly, nanoscience research should be conducted with methods to characterize the particles for which there is a validation. The occurrence of nanoscale particles cannot be equated with superior therapeutic activity and/or safety.

Fourth, Pharmacological studies need to be taken beyond initial in vitro observations. There is a need for well-designed preclinical investigations and suitable regulated clinical studies prior to establishing therapeutic claims.

Last but not the least, there should be an interdisciplinary cooperation between Siddha doctors, pharmacologists, chemists, toxicologists and materials scientists. This kind of partnership can help to reconcile the traditional knowledge with current scientific studies.

9. Conclusion

Siddha alchemy or Rasavatham is an important facet of traditional Siddha pharmaceutical knowledge and provides opportunities for modern scientific research. The physicochemical changes of the metals and minerals can be studied by the application of traditional methods like purification, grinding, trituration and thermal processing.

These preparations have been investigated in more detail using modern analytical techniques such as XRD, SEM, TEM, FTIR, EDX, ICP-MS and XPS. Further studies on Siddha formulations have also highlighted the importance of materials science and nanoscience in the knowledge of their properties.

But the presence of chemical constituents or nanoscale particles isn't enough to be accepted as scientific evidence. There is a need to be able to replicate the manufacturing, perform chemical speciation, a complete toxicological assessment and validate the compound in the appropriate quality standards.

A combination of traditional knowledge of siddha alchemy with modern analytical chemistry and biomedical sciences could provide useful opportunities for future research. It is important such efforts continue to be informed by scientific evidence, methodological transparency and patient safety.

Table 1. Major analytical techniques used in the characterisation of Siddha mineral and metallic preparations

Analytical technique	Major application
X-ray diffraction (XRD)	Identification of crystalline phases and mineral compounds
Scanning electron microscopy (SEM)	Examination of surface morphology and particle distribution
Transmission electron microscopy (TEM)	Investigation of nanoscale structures
Fourier-transform infrared spectroscopy (FTIR)	Identification of functional groups and possible chemical interactions
Energy-dispersive X-ray spectroscopy (EDX/EDS)	Elemental composition and distribution
ICP-MS	Sensitive quantitative elemental analysis
ICP-OES	Quantification of selected elements
X-ray photoelectron spectroscopy (XPS)	Investigation of surface composition and chemical states
Thermogravimetric analysis (TGA)	Evaluation of thermal stability and mass changes

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