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Scientific validation of Vedic knowledge on 'Rajatam' and the convection current-assisted synthesis of silver nanoparticles

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In the Vedic literature, one can see the mention of silver, 'Rajatam', for diversified day-to-day applications to lead a healthy life. The paper reports the scientific validation of traditional knowledge of synthesising chemical-free, stable metal nanoparticles (NPs), taking silver as an example. Here, silver nanoparticles (SNPs) are synthesised with the assistance of convection current in the water. The prolonged heating of double-distilled water in a silver vessel enables to get a colloidal solution of SNPs. The SNPs produced are characterised by UV-Visible absorption spectroscopy, Field-emission Scanning Electron Microscopy, High-resolution Transmission Electron Microscopy, and Energy Dispersive X-Ray Spectroscopy. Stability of SNPs is revealed through ageing studies with glucose as the surfactant. The method could synthesise stable SNPs of size 30-40 nm. This accounts for the possible reason for taking silver as the material for utensils for cooking food by the ancient Indians, Greek, Romans, Persians and Egyptians.

Keywords: Convection current, Nanoparticles, Rajatam, Scientific validation, Silver

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Today nanotechnology has evolved as an indispensable branch of science and technology that finds applications in Electronics, Physics, Chemistry, Biology, Medicine, and Technology[1,2]. Several top-down and bottom-up methods of synthesising nanoparticles have been developed so far. Laser ablation method, ball milling, chemical vapour deposition, sol-gel method, chemical reduction, radiation assisted methods, electrochemical method, photochemical reduction and green synthesis are some of them[2-5]. Silver nanoparticles (SNPs) have gained significant attraction due to their size and shape-dependent optical, electrical, magnetic, and antimicrobial properties[6-8]. Several SNP applications in biomedical, water treatment, agriculture, and drug delivery are well documented in literature[9-12]. The medicinal value of silver[13] was known to ancient Indians, Greek, Romans, Persians and Egyptians as they used silver utensils for serving food. Since the Vedic period, in Indian medical systems, the metal silver ('Rajatam') was widely used to increase immunity power and general health[14]. The therapeutic potential of silver is described in *Charaka Samhita* – an ancient Indian Ayurvedic book – with the use of 'Rajata Bhasma', 'Rajata Patra', and so on. In *Charaka Samhita*, it is mentioned that if a pregnant lady drinks hot milk regularly in a silver pot, then the baby will have qualities like healthy mind and vigour[15]. The antimicrobial action of silver was well understood in those days and is evident from making surgical instruments and pots in silver[10,11,14]. Silver was widely used as an antimicrobial agent till the discovery of antibiotics by Alexander Fleming.

Among the various preparation techniques reported to synthesise SNPs[5,16,17], all of the physical methods need high-temperature furnaces requiring power consumption of more than several kilowatts, and the chemical methods make use of costly and toxic chemicals. The other methods, like UV-initiated photo reduction, photo induced reduction, electrochemical, and bio-based methods, use a light source or a biological procedure for metal nanoparticles synthesis[7,18-23].This disclosure is related to the scientific validation of traditional method of synthesising chemical-free, stable metal nanoparticles (NPs) taking silver as an example, as it has gained significant attraction due to its size and shape-dependent optical, electrical, magnetic, and antimicrobial properties. The present method of synthesising SNP is significant, as a layman can practice the method without any knowledge in Chemistry or Physics.

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Materials and Methods

For SNPs' synthesis, double-distilled water (200 mL) is taken in a thick-walled pure silver pot of inner volume 250 mL. Water is slowly heated to boiling temperature. When water starts boiling the flame is reduced so that the turbulence on the water surface is a minimum. Due to gradual heating and maintaining water at 100°C, water molecules gradually evaporate. The room, where the experiment is carried out, is closed, and the setup is secured from the blow of wind by using cardboards. The heating process is continued till the water in the pot reduces to 10 to 15 mL. Again the water in the pot is made up to 200 mL and the heating process is repeated. The entire process is repeated five times to get a colloidal solution of silver. To synthesise stable SNPs, a small amount of glucose (2 g) is added to the double-distilled water (200 mL) in the silver pot before heating. SNPs' formation in the liquid medium is confirmed through the surface plasmon resonance peak in the UV-Visible absorption spectrum recorded using Jasco V-550 UV–Visible spectrophotometer. When the morphology of the particles is understood from Nova Nano Field-emission (FE) Scanning Electron Microscopic (SEM) and JEOL JEM- 2100 High-resolution (HR) Transmission Electron Microscopic (TEM) analyses, the structure purity is revealed through the X-ray powder diffraction (XRD- Bruker D8 Advanced Diffractometer of $\lambda = 1.5406$ Å) pattern of the silver pot used and the Energy Dispersive X-Ray Spectroscopy (EDS) of the SNPs formed.

Results and Discussion

For the synthesis of SNPs, double-distilled water is taken in a thick-walled pure silver pot and gradually heated to 100°C. The heating accelerates the convection current in the liquid medium, resulting in the rapid collision of water molecules with the walls of the silver pot. The thermal energy gained by the silver atoms of the pot, together with the mechanical energy, result in the slow release of SNPs into the liquid medium. The number of silver nanoparticles (SNPs) liberated depends on the effective surface area of the pot's inner surface, which depends on the surface smoothness. Hence, identical pots of different surface roughness will have different collision cross-section in the molecular movement due to convection current. As a result of continued heating, the water in the pot reduces to 10 mL. To increase the amount of SNPs in the liquid medium, the water in the pot is made up to 200 mL and the heating process is repeated. The entire process is repeated five times to get a colloidal solution of SNPs.

The structure purity of the pot used is understood from the XRD pattern displayed in Figure 1. The sharp peaks (corresponding to the planes) obtained at 38° (111), 44° (200), 64°, (220) and 77° (311) indicate the crystalline nature of silver that matches well with the peaks for pure silver given in the ICCD No: 00-004-0783. The presence of SNPs can be ensured from the UV-Visible spectrum. The UV-Visible spectrum of the sample synthesised is given in Figure 2, which shows a hump at 270 nm and a peak at 518 nm. From the literature, it can be seen that the peak corresponds to the presence of SNPs of size in the range 80 nm – 90 nm[24]. The presence of the hump around 270 nm is due to a quadrupole resonance which has a different electron oscillation pattern than the primary dipole resonance. The peak wavelength and the peak width are the spectral fingerprints for a plasmonic nanoparticle with a specific size and shape.

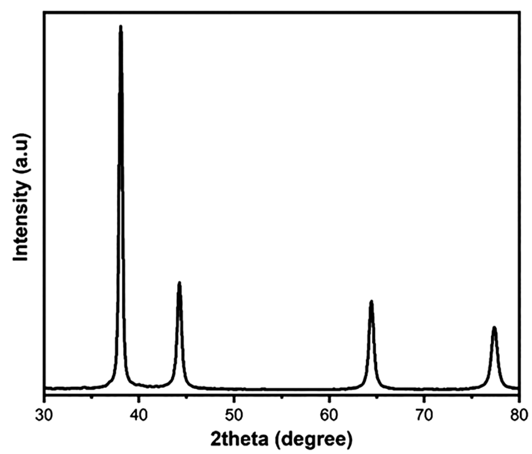

Fig. 1 — XRD pattern of the silver pot.

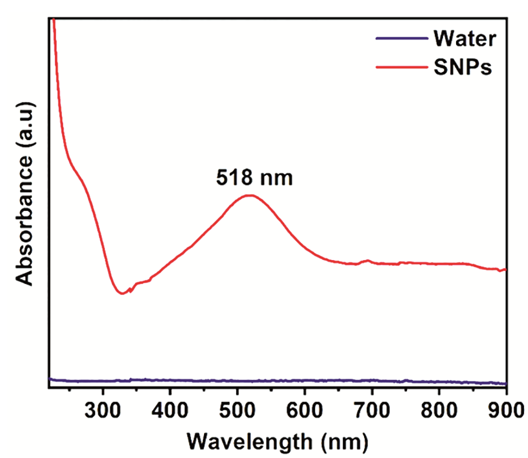

Fig. 2 — UV-Visible absorption spectrum of water and silver nanoparticles

The FESEM image of the SNPs synthesised, shown in Figure 3a, exhibits a flower-like morphology of size about 100 nm. This is in good agreement with Fig. 2 and the literature report of the peak value in the UV-Visible absorption spectrum and the particle size. The FESEM image of the sample recorded after 24 h shows agglomeration as shown in Fig. 3b, revealing that the SNPs formed are not stable. The EDS shown in Figure 4 confirms the purity of the SNPs formed, revealing that the SNPs retain the purity of the target, the XRD of which is shown in Fig. 1. The Silicon (Si) appears in EDS as the sample is drop-cast in a silica wafer.

A small amount of glucose is also added as a surfactant to the double-distilled water in the silver pot before heating for getting stable SNPs. Following the synthesis procedure detailed above, 10 mL of the colloidal solution of SNPs is prepared. The UV-Visible spectrum of water with glucose and the colloidal solution of SNPs formed after one-time heating and reducing to 10 mL are shown in Figure 5a. The spectrum shows peaks at 290 nm, 360 nm, and 450 nm, suggesting SNPs of different sizes. When the entire process is repeated five times, the colloidal solution exhibited a prominent peak at 432 nm in the UV-Visible spectrum, as shown in Fig. 5b, indicating the presence of SNPs of size 30 to 40 nm. The FESEM image of the stable SNPs, shown in Figure 6, reveals the

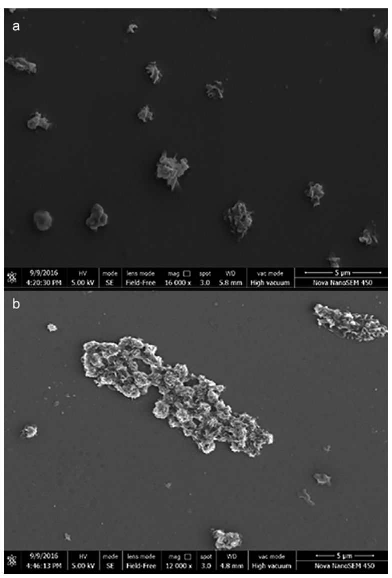

Fig. 3 — FESEM image of the silver nanoparticles with flower-like morphology (a) as-prepared sample (b) after 24 h ageing

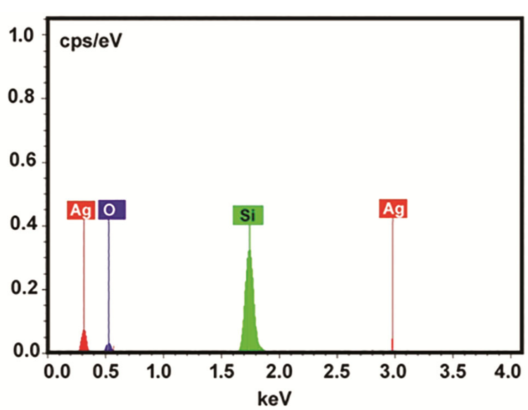

Fig. 4 — EDS of the silver nanoparticles

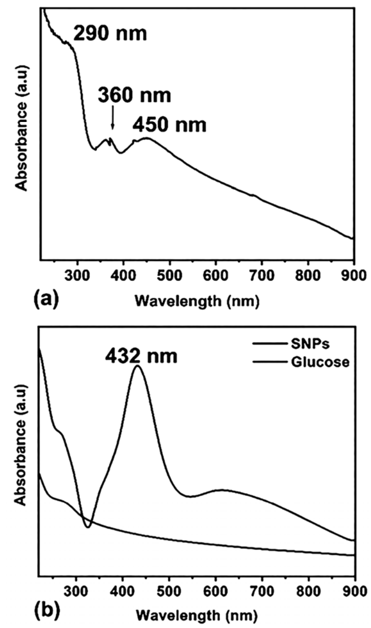

Fig. 5 — UV-Visible spectrum of SNPs in water containing glucose after (a) 1-time heating and (b) 5-time heating.

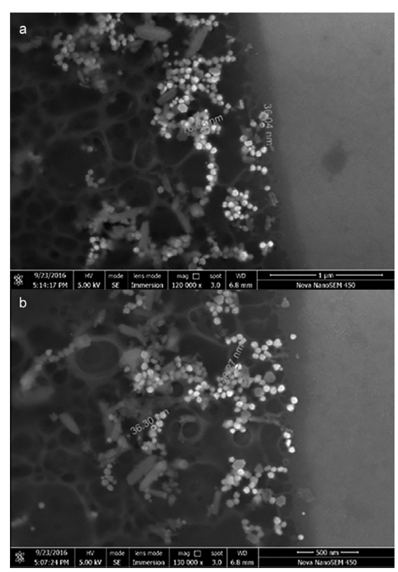

Fig. 6 — FESEM images of the spherical and hexagonal shaped silver nanoparticles in water with glucose

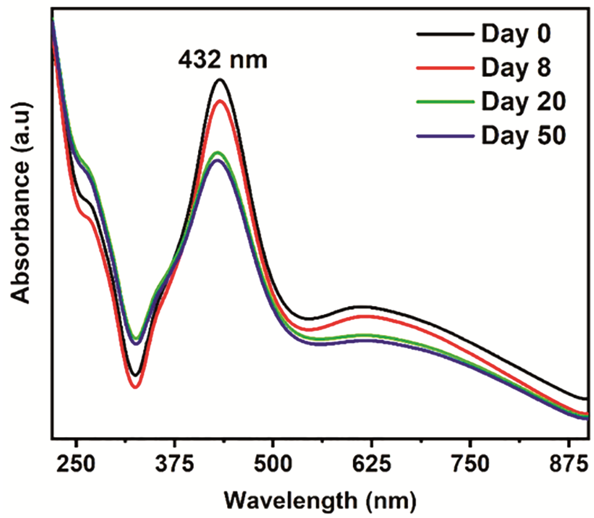

Fig. 7 — UV-Visible spectrum of silver nanoparticles in water containing glucose – Ageing study

morphology of particles to be spherical and hexagonal of size ranging from 40 to 50 nm. The stability of the nanoparticles formed in the glucose medium is understood from the UV-Visible absorption spectrum recorded on the first, eighth, twentieth, and fiftieth day after synthesis and is shown in Figure 7. The ageing studies show excellent stability to SNPs even after 50 days.

Thus, we could successfully establish that this technique can synthesise SNPs through the thermal-induced convection current in water. The continuous heating of water molecules on the hot metal surface and the collision of water molecules with the metal surface walls leads to the generation of SNPs. The number of particles in water gradually increases as we repeat the process. When double-distilled water alone is taken in the silver pot, several repetitions are needed to get SNPs. The addition of glucose helps in holding the NPs in water without agglomeration, which may be due to the attachment of SNPs with the ring structure of glucose. The HR-TEM image, the Selected Area Electron Diffraction (SAED) pattern, and the particle size distribution are shown in Figure 8. The SAED pattern confirms the formation of SNPs with lattice spacing 0.23 nm corresponding to the (111) plane of the face centred cubic structure of silver (JCPDS No.: 00-004-0783). However, from the HR-TEM image of the SNPs given below, we can see volume occupancy of about 25% in a film of volume 300x300x100 nm^3 and with average particle size 40 nm as confirmed by the UV-Visible spectrum with a prominent peak at 432 nm.

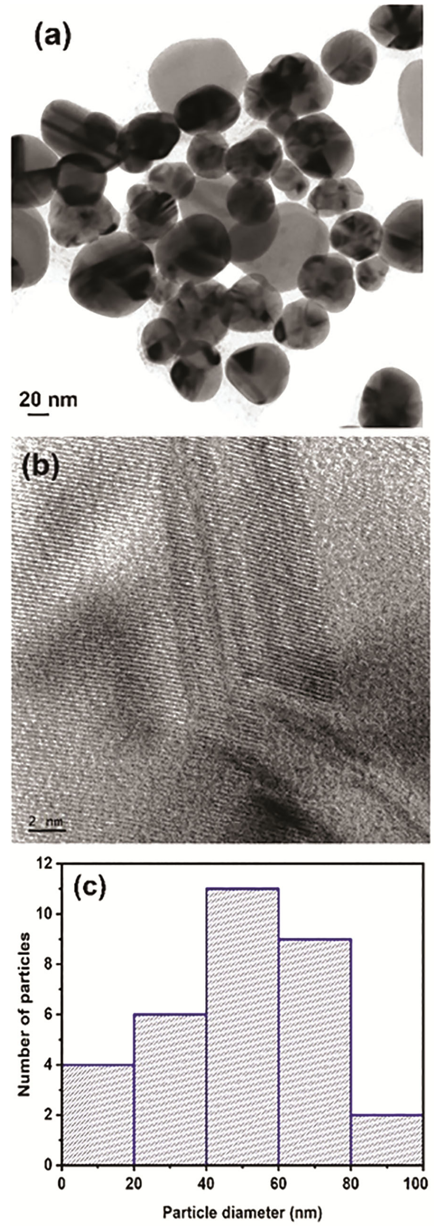

Fig. 8 — (a) The HR-TEM image (b) SAED pattern, and (c) particle size distribution of silver nanoparticles

Conclusion

The present work attempts to provide a scientific validation to the traditional knowledge of using silver utensils for cooking food by our ancestors. Here, SNPs are synthesised by prolonged heating of double-distilled water in a silver pot. The thermal energy obtained by heating, together with the mechanical energy due to the rapid collision of water molecules with walls of the pot, results in SNPs' release into the liquid medium. The purity of the SNPs depends on the purity of the pot used. When the pot's structure purity is evident from the XRD pattern with crystalline peaks of pure silver, the colloidal SNP solution's EDS indicates silver alone. SNPs' presence is confirmed from the UV-Visible absorption spectrum with a hump at 270 nm and prominent peak at 521 nm, indicating particles of size between 80-90 nm, which is also apparent from the FESEM image showing flower-like SNPs having the same size. The colloidal solution's stability is enhanced by using a small amount of glucose as a surfactant during the synthesis process. One time heating of the water in the silver pot with glucose generates SNPs of different sizes, understood from the peaks 290 nm, 360 nm, and 450 nm in the UV-Vis spectrum. Uniform sized spherical and hexagonal SNPs of size range 30 to 40 nm are obtained after heating five times, which is evident from the FESEM image and the appearance of sharp SPR peak at 434 nm. The HRTEM image, SAED pattern, and particle distribution histogram analyses further confirm SNPs' formation in the colloidal solution. The ageing studies give conclusive evidence of greater stability of SNPs even after 50 days. Thus, synthesising stabilised SNPs is simple, least expensive and free of toxic chemicals than other conventional methods. Hence, even common people can use these SNP samples for water treatment, agriculture, antimicrobial, and therapeutic applications as practised by our ancestors. It is the lower concentration of the SNP that makes it suitable as an antimicrobial and bactericide agent. The study also gives a scientific base to traditional practice. The higher level of SNPs in food can adversely affect human health which does not happen in the present method of synthesis.

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Conflict of Interest

The author declare no potential conflicts of interests.

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