Original Article

Biosynthesis, and characterization of Zinc oxide nanoparticles (ZnONPs) obtained from the extract of waste of strawberry

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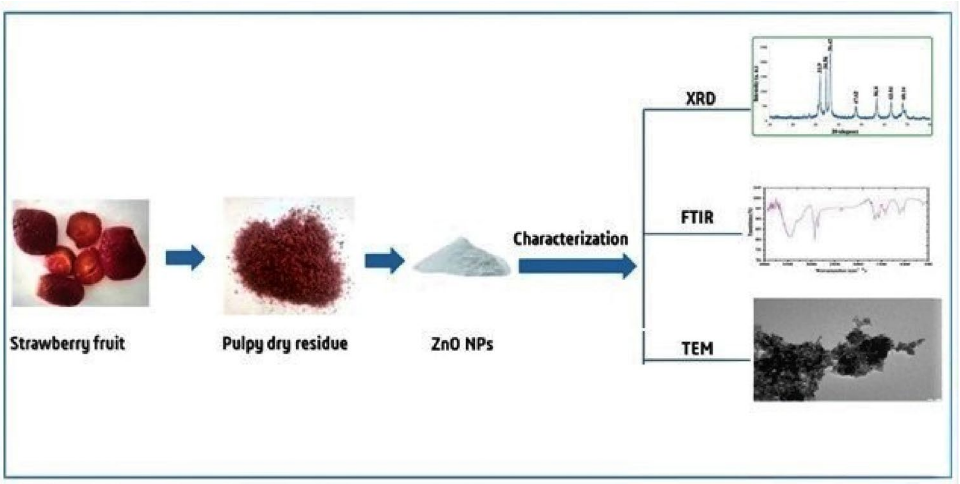
Abstract

Nanotechnology has become a promising approach and gain the appreciable recognition due to have biomedical application. Nanoparticles exhibited unique characteristic and play an effective role in area of science. The synthesis of nanoparticles with desire size and shape is an important field of research in nanotechnology. Herein we synthesized the zinc oxide nanoparticles (ZnO NPs) using zinc acetate as precursor and extract of waste strawberry extract as a reducing agent and stabilizing agent. Further, obtained ZnO NPs characterized by UV–vis, FTIR, EDX, XRD, and TEM analysis. The UV–vis result confirm ZnONPs formation with its surface Plasmon resonance peak (SPR) at 311 nm due to the collective oscillations of electrons in the conduction band in UV–vis spectra. XRD peaks also meet the standard of ZnONPs peaks and indicated that the prepared material consists of particles in nanoscale range. The SEM and TEM analyze the morphology, shape and size in range 50 nm with spherical shape. The FTIR was tested the functional group liable for the synthesis of ZnONPs.

Graphical Abstract



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Keywords Green synthesis · ZnONPs · Waste of strawberry · Antimicrobial activity

1 Introduction

In the previous year's survey revealed that nanotechnology grow as a technology beneficial in the field of science. The nanoparticles (NPs) developed in form of nanoscale materials a very small particles exhibited the size ranging from 1 to 100 nm shown the distinctive properties [1]. The area of nanotechnology specially enclose with biology, physics, chemistry and material sciences and fabricated novel the therapeutic nanosized materials for biomedical, pharmaceutical, electronics, optical, catalytic and medicine applications [2–4]. Recent studies have described in synthesizing green nanoparticles (NPs) using dissimiliar part of plants, a cost-effective, eco-friendly, sustainable and simple [4, 5]. The bottom-up method is applied for the synthesis of biogenic nanoparticles, mainly, in which atoms and compounds act as building blocks and self-assemble to build a final product [6]. Herein we described the green approach for synthesis different metal and metal oxide nanoparticles with their applications a better approach as compared to physical, chemical approach [7–12]. The significance of ZnONPs more interesting as compared to other metal oxide nanoparticles having diverse applications such as optical, piezoelectric, magnetic and gas sensing. Inspite of this characteristic, ZnONPs shown high catalytic efficiency, strong adsorption ability and use quickly in the manufacture of sunscreens [13–15] and also uses as food preservation materials, packaging, coating, biological tagging, optical, catalyst, agriculture and cytotoxic applications [16–20]. Nanomaterials such as organic–inorganic hetero-nano-interfaces (OIHNIs)-based electrodes/platforms that have made a significant role in the development of EC biosensors [21], nanopartiucles based NIR-drive photocatalyst, enhance the emission efficiency and also photocatalytic action [22]. Herein a green synthesize spongy defective zinc oxide nanoparticles (ZnONPs) using first time pomegranate seeds molasses as a green capping fuel/reducing mediator during an aqueous solution combustion process [23]. A biogenic-mediated synthesis of the Cs2O-MgO/MPC nanocomposite for biodesel production from oliver oil [24]. A another case study revealed that sol–gel derived nano-structure zinc oxide film for sexually transmitted disease sensor [25].

The survey of literature revealed that several papers have published in the synthesis of zinc oxide nanoparticles ZnONPs and other metals from strawberry and other fruits peel [26–34]. Herein, we explained the biogenic synthesis of ZnO NPs from extract strawberry fruit, ecofriendly and less hazardous chemical produced, the formation of ZnO NPs confirmed by spectral evidences like UV–vis, FTIR, XRD, EDX, SEM and TEM.

2 Material and methods

Zinc acetate AR and other chemicals and solvents used in this work were purchased from Merck India Ltd. and were used without any purification. To confirm the formation of ZnONPs, UV–vis spectroscopy was conducted using a Shimadzu spectrophotometer (UV–vis 1800, Japan). Fourier transform infrared (FT-IR) spectroscopy was obtained in the range of 4000–400 cm-1 with an FT-IR spectrophotometer (Perkin Elmer Spectrum 2000 FT-IR) using KBr pellets. X-ray diffraction (XRD, Panalytical, X' pert PRO-MPD, The Netherlands) was performed using CuKα radiation (λ = 0.15405 nm). The size and morphology of the ZnONPs were analyzed by SEM (NOVA nano FE-SEM 450 FEI) and TEM (TECNAI-G-20).

2.1 Preparation of extract of waste of strawberry

A fresh strawberry was procured from near JNU shop Jaipur, India, cleaned, washed, dried and ground into the powder 200 gm. The powder were refluxed for 45 min in deionized water in a round-bottom flask and cooled at room temperature (RT). The resultant solution was filtered through Whatman filter paper to obtain a purified crude extract. The filtrate was then stored in a cool environment for further requirements.

2.2 Green synthesis of zinc oxide nanoparticles

In a 250 mL conical flask, 15 ml of strawberry extract were heated at 50 °C for 10 min then 85 ml of 1 mM zinc acetate solution was added dropwise with continuous stirring for 6 h. The reaction mixture turned yellowish and a cream-colored precipitate of zinc hydroxide was formed. The reaction mixture was allowed to stand for 30 min to complete the reduction to zinc hydroxide and then centrifuged at 10,000 rpm for 10 min. The residue was vacuum dried at 40–50 °C and preserved for further investigation. The reduction of Zn^{2+} to Zn^{o} was confirmed by change in colourof the solution from light yellow to cream. The UV–visible spectroscopy (Shimadzu, USA) showed a peak in the range of 311 favour the formation of ZnONPs [32].

3 Result and discussion

The spectral studies favour the formation of ZnONPs from the strawberry waste extract. The bioactive moieties in strawberry extract act as bioreducing, stabilizing and capping agent and enhance the potential of biogenic ZnONPs. Table 1 compares ZnO NPs obtained through the participation of various plant parts, as well as their various applications and morphological nature.

3.1 TEM analysis

The surface morphology and size of the as-prepared NPs were interpreted using TEM analysis, as shown in Fig. 1. The TEM investigation gave the authenticity of the size and shape of synthesized ZnO NPs. The TEM image (Fig. 1) asserts that the ZnO NPs are on nanoscale and importantly come in the size range 50 nm or spherical. The data are distinguishable that synthesized colloidal ZnO NPs were well disseminate, homogeneous, predominantly spherical in shape and well crystalline as shown in Fig. 5 Hence the agglomeration of the ZnO NPs not comes in notice due to the encapsulation of the ZnO NPs with pumpkin seeds extract. The bioactive constituents observed due to the presence of the alkaloids, flavonoids, polyphenols etc. naturally found in the pumpkin respectively.

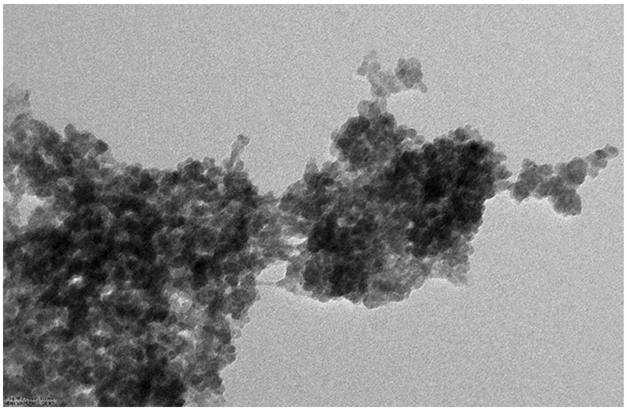


Fig. 1 TEM of ZnO NPs from strawberry extract

3.2 SEM and EDX Analysis

The SEM results revealed that the morphology and sized of biosynthesized ZnO NPs obtained as irregular in shape, well dispersed, uniform in size and well crystalline in nature. The elemental compositions of Zn ONPs were

Table 1 Environmentally friendly ZnO NP synthesis using various plant extracts, as well as their characterization techniques, shapes, sizes, and applications

S.N	Plants Name	Plants parts	Techniques for characterization	Shape/morpholog	Size ZnO NPs	Applications	Reference
1	*Kalopanax septemlobus*	Bark	UV, FRTIR, XRD,EDX, TEM	Flower	500 nm	Photocatalytic activity	[35]
2	*Zizyphus jujube*	fruit	UV, FTIR, XRD, SEM, TEM	Spherical	29 nm	Photocatalytic activity	[36]
3	*Codonopsislanceolata*	Root	UV, FTIR, XRD, EDX, TEM	Flower	500 nm	Photocatalytic activity	[37]
4	*Cydonia oblonga*	Seeds	FESEM, EDX, FTIR, XRD, UV	–	25 nm	Photocatalytic activity	[38]
5	*Musa acuminate*	Peel	UV, FTIR, XRD, SEM	Triangular	30–80 nm	Photocatalytic activity	[39]
6	*Berberis aristata*	leaf	XRD, EDX, SEM, FTIR, UV	Needle	20–40 nm	Antoxidant and antibacterial activity	[40]
7	*Catharanthus roseus*	Leaf	UV, FTIR, XRD, DLS, EDX,TEM	Hexagonal	62–94 nm	Antibacterial activity	[41]
8	*Veronica multifida*	Leaf	XRD, SEM, TEM, FTIR, UV	hexagonal	11.5 nm	Antimicrobial activity	[42]
9	*Eclipta alba*	leaves	TEM, XRD,UV	sphrical	5, 100, 110, 112 nm	Antimicrobial activity	[43]
10	Onion	peel	FTIR, DLS, FESEM	spherical	20–80 nm	Phototoxicity	[44]
11	*Aegle marmelos*	leaves	UV–vis, FTIR, XRD,SEM,TEM	Quasi-sphrical	18 + 2 nm	Agriculture and food pathogens	[45]
12	Solanum nigrum	leaf	UV–vis DRS, FTIR, XPS,XRD,TG–DTA, FE-SEM, TEM	Hexagonal	20–30 nm	Antibacterial activity	[46]
13	Strawberry	Waste	UV–Vis, FTIR, XRD, SEM, EDX, TEM	Shpherical	50 nm		Present work

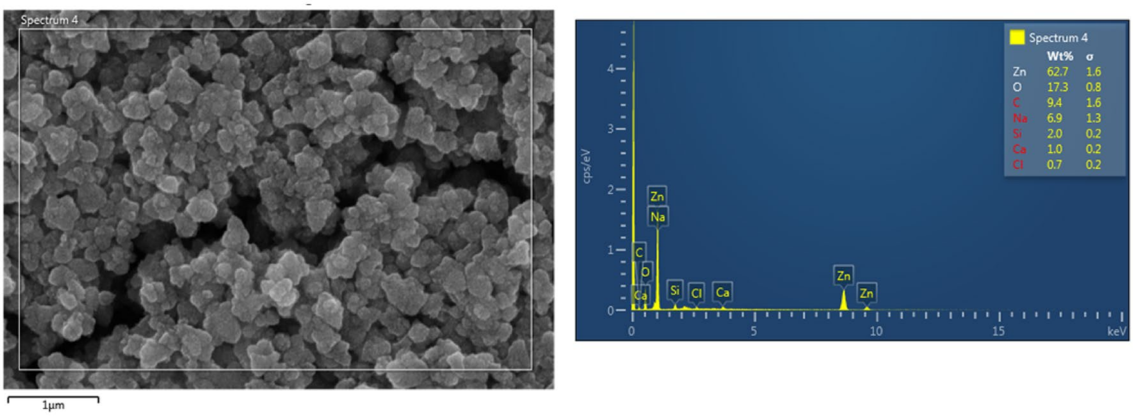


Fig. 2 FESEM of ZnO NPs from waste of strawberry fruit

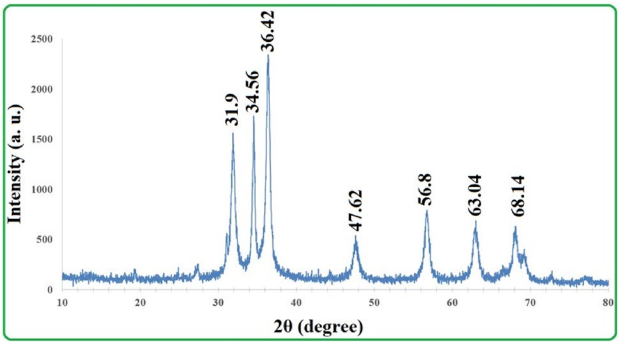


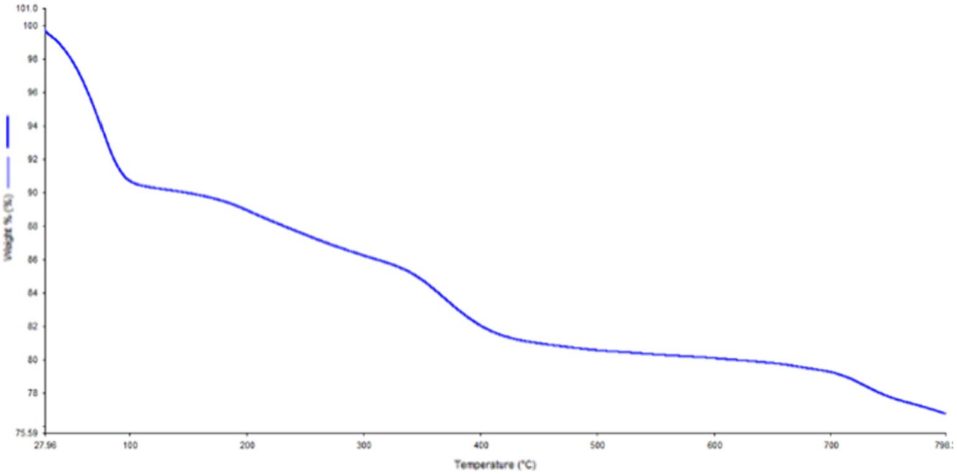
Fig. 3 XRD pattern of biosynthesized of ZnO NPs

determined using EDX analysis, as shown in the Fig. 2. The presence of zinc at 1 and 8.7 keV, which is typical for the absorption of metallic ZnO nanocrystallites due to surface plasmon resonance, was confirmed by the EDX spectrum. Along with the peaks for Zn and O, weak signals from the elements Na, Si, Ca, and Cl were also detected. The extract's X-ray emission is most likely the cause of these weaker signals. The composition of each element contained in the as-prepared material is shown in Fig. 4, which yields strong to weak signals of 62.7% for zinc at 1.0, 8.7, and 9.2 eV and 17.3% for oxygen at 0.5 eV (Fig. 2), which is consistent with previous work on the synthesis of ZnO NPs.

3.3 X-ray diffraction analysis

Figure 3 depicts the XRD pattern of ZnO nanoparticles. The XRD pattern of ZnO NPs was recorded in the range 10θ–80θ, as shown in Fig. 3, which demonstrates that nanoparticles are semi-crystalline based on the peaks that appear in the XRD pattern. The X-Ray diffraction pattern in the present study suggests 2θ values at 31.9˚, 34.56˚, 36.42˚, 47.62˚, 56.8˚, 63.04˚ and 68.14˚, which could be indexed as the zinc oxide wurtzite structure (JCPDS Data Card No: 36–1451).The experimental results were validated with previously reported diffraction patterns of ZnO nanoparticles in the literature [24, 29].

Fig. 4 TGA analysis of ZnONps from waste of strawberry



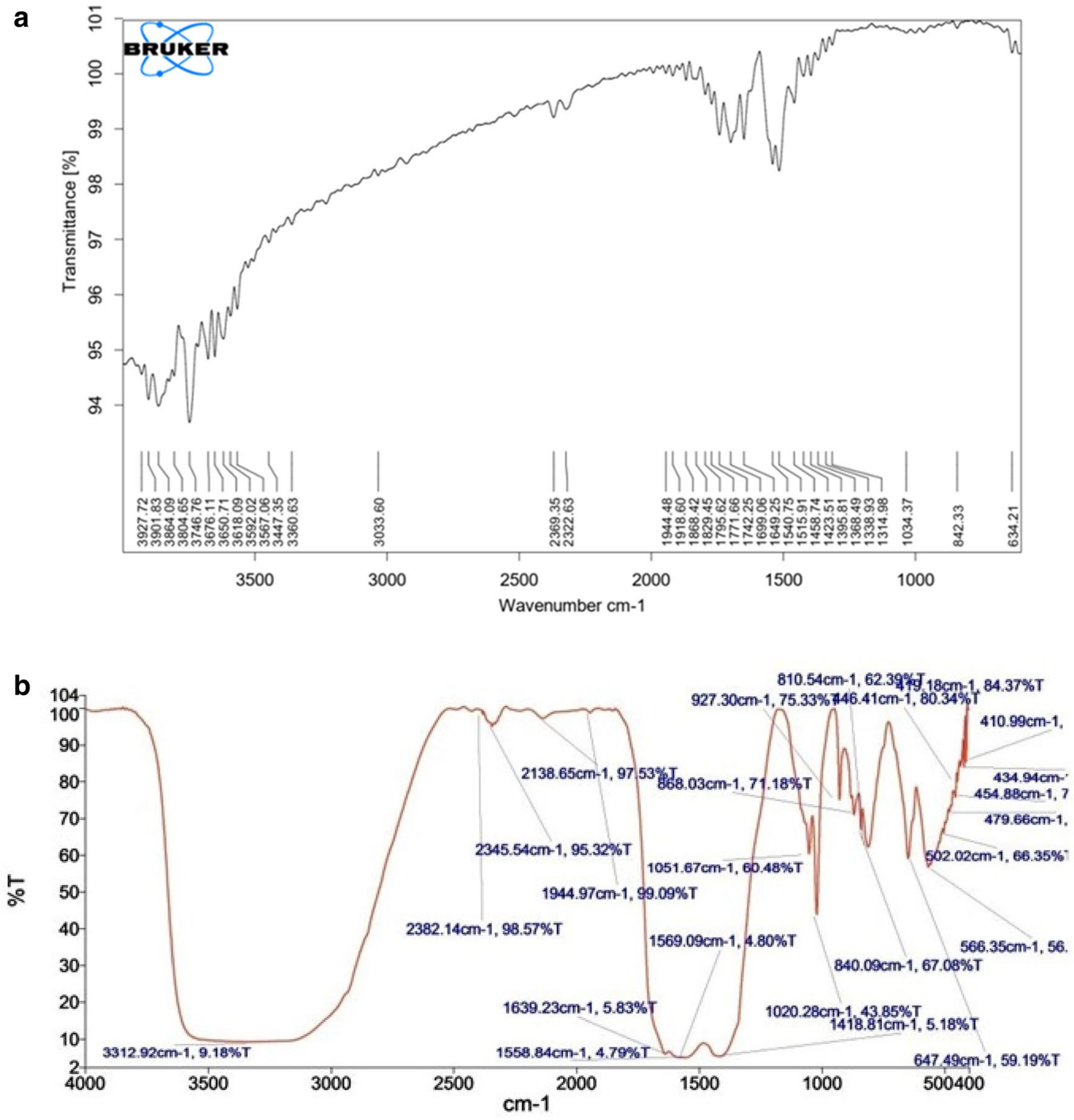
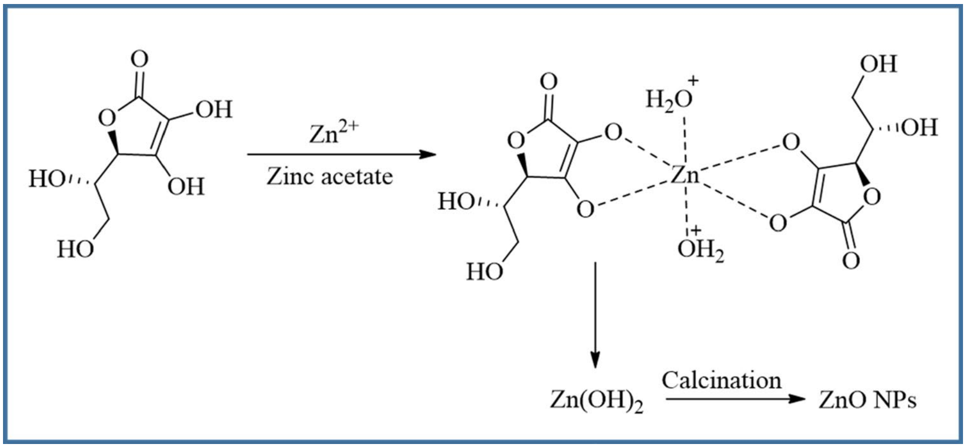


Fig. 5 a FTIR of extract of waste of strawberry, b FTIR of ZnONPs

Fig. 6 A possible mechanism for the formation of NPs is depicted, along with the involvement of an expected biomolecule (ascorbic acid) (other biomolecules may be participated)



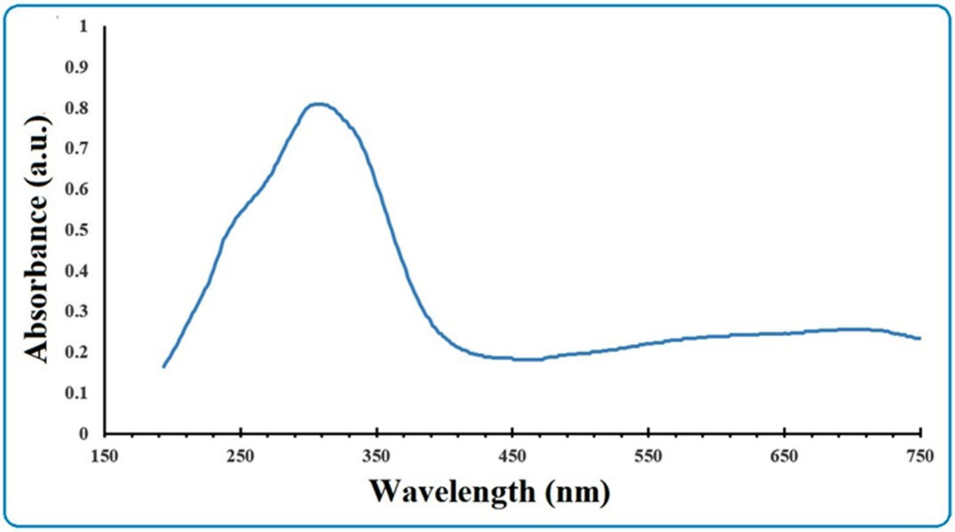


Fig. 7 UV–vis spectra of ZnONPs from waste of strawberry

3.4 TGA analysis

The TGA spectrum of ZnO-NPs shows that the sample decomposes quickly as temperature rises. Thermal gravimetric analysis (TGA) described the thermal stability of the biosynthesis of ZnONPs mentions in TGA thermogram as shown in Fig. 4. The sample was completely lost from 27 to 700 °C due to the various volatile components present in the extract capping nanoparticles, as shown in Fig. 4. Any moisture in the sample was evaporated until it reached 100 oC, and as the temperature rises, the various components of the simple evaporate slowly and continuously. Data above 400 degrees Celsius revealed thermal stability and insignificant weight loss for the bulk sample. This can be attributed to the thermal degrading of residual phenolic and flavonoid biomolecules involved in the biosynthetic pathway. As a result, subsequent incremental temperature increases did not result in significant loss, indicating high thermal stability.

3.5 Fourier transform infrared spectroscopy study

FT-IR analysis on zinc acetate was act as to explore and identify the functional group associated on the surface of the ZnONPs. FT-IR spectroscopy perform and involvement of probable fruit waste biocompound responsible for the reduction of $Zn^{2+}$to Zn^0 ions and capping as well as stabilization of bioreduced ZnONPs manufacturing using the extract. Hence on the basis of mechanism the formation of ZnO NPs utilizing the waste fruit extract associated to the flavonoids/phenolic molecules reacting with Zn^{2+} ions through the donor–acceptor. Figure 2 shows the FT-IR spectrum of the ZnONPs synthesized using extract of waste of strawberry where the spectrum manifests prominent transmittance located at peak identified at 3312 cm-1 due to the presence of bioactive compound containing –OH along with ZnO NPs. Further peak observed at 2345, 1629, 1559 and 1418 cm^{-1} attributed to C-H and C = C fused C = O stretching vibration of alkane and ketones. The prominent peak about 566 cm^{-1} FTIR spectrum of ZnO NPs matching to metal–oxygen (M–O) favor for confirmation of nanoparticles. Hence the spectral evidences of the extract support in identification of phytochemicals as phenol, terpenes and flavonoids play an active role in the reduction of metal ions to metal. The FTIR spectra of the biosynthesized ZnO NPs (sharp and intense band at 566 cm^{-1} showing the presence the formation of Zn–O vibrations (Fig. 5a, b).

Based on ongoing studies [33] and the IR spectra of extracts and nanoparticles, tentative mechanisms can be sketched to study the involvement of biomolecules in nanoparticle production, as shown below (Fig. 6).

3.6 UV–Vis spectroscopy

UV–vis absorption spectroscopy analysis was carried out to confirm the formation of ZnONPs using aqueous extract of waste of strawberry. The green synthesis of ZnONPs and its stability were confirmed by UV–vis spectroscopy. It was noticed that the creamy brown color was observed due to the formation of stable ZnONPs. Hence the UV–vis spectra of synthesized ZnONPs is shown in Fig. 7 and developed a optical absorption at ~ 311 nm which is the characteristic band of ZnONPs owing to the surface plasma resonance (SPR) of zinc.

4 Conclusions

ZnONPs were synthesized in this study using strawberry waste extract as a reducing and stabilizing agent. The extract of strawberries was found to be an effective reducing agent in controlling particle size. Spectral evidence from techniques such as UV–vis, FTIR, XRD, SEM, and TEM supports the structure, size, and crystallinity of Zn nanoparticles, indicating that ZnONPs could be a promising option for a variety of applications.

Author contributions AUK collected and analyzed the samples. AUK, BS, NH, MR, NMand AY carried out experimental analyses. AUK and NM reviewed and edited the article. All authors read and approved the manuscript.

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Data availability This manuscript has no associated data.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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