CHARACTERIZATION OF ZNO NANOPARTICLES PREPARED IN CURCUMA AROMATICA SALISB. ROOT EXTRACT

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ABSTRACT

The root extract of the locally available Curcuma Aromatica Salisb. was used with the ZnO precursors to study the effect of the Curcuma Aromatica Salisb. extract on the growth and optical absorption behaviour of the ZnO nanoparticles. ZnO nanoparticles were synthesized in various concentrations of Curcuma Aromatica Salisb. root extract. X-ray diffraction studies show that the prepared samples consist of nanocrystallites of having sizes in the range between 17 nm to 26 nm. The optical absorption studies reveal that the eco-dyeing on ZnO nanoparticles using Curcuma Aromatica Salisb. root extract has enhanced the optical absorption behaviour of ZnO to the visible region of the spectrum.

Keywords: ZnO nanoparticles; curcuma aromatica salisb; eco-dyeing.

INTRODUCTION

Curcuma aromatica Salisb., the wild turmeric, 'Vanaharidra' in Ayurveda, belongs to the 'ginger family' Zingiberaceae. This wild turmeric is an aromatic medicinal plant and is commonly known as “kasturi manjal” (musk turmeric) in south India. The rhizome of the plant is loaded with alkaloids, flavonoids, curcuminoids, tannins and terpenoids. The medicinal properties of this rhizome are being used in many traditional systems of medicines. The rhizomes have characteristic fragrance. The paste of rhizome is used for facial application to reduce acne and excessive hair growth and also to improve skin tone and complexion by village women in South India [1-3]. The colouring matter in the rhizomes of Curcuma aromatica Salisb. is predominantly curcumin and demethoxycurcumin[4]. Revathi et al., studied the antibacterial activity of the rhizome of Curcuma aromatica Salisb. and reported that the hexane extract of the rhizome of Curcuma aromatica Salisb[5], contains the compounds such as Aromadendrene, a-Vatrenene, Epiglobulol, Germaneron,
Eco-dying or natural colouring of the nanoparticles for enhancing their absorption characteristics is an important field of research for developing electrode materials for Dye Sensitized Solar Cells (DSSCs). In DSSCs, the incident light causes the photoexcitation of the dye molecules which subsequently injects electrons into the conduction band of the semiconducting material. In this work, we have chosen ZnO for the eco-dying and the Curcuma aromatica Salisb. as an eco dye or natural colouring materials. ZnO is chosen because of its wide bandgap (3.37 eV), large exciton binding energy (60 meV), high electron mobility, piezoelectric and pyroelectric properties, biocompatibility, non-toxic nature, very high specific surface area, good chemical and thermal stability[6]. Zinc oxide (ZnO) nanoparticles are promising material due to their unique and multifunctional properties and is used to create photoanodes for Dye-Sensitized Solar Cells (DSSCs).

The main objective of this paper is to discuss the potential use of the Curcuma aromatica Salisb. to sensitize the ZnO nanoparticles and to study their characteristics. There are lots of reports are available on green synthesis of ZnO nanoparticles using plant leaf, root, stem, flower and seed extracts, but no reports available on the synthesis of nanoparticles in Curcuma aromatica Salisb. and of eco-dyeing of nanoparticles. Green synthesis of ZnO nanoparticles and eco-dyeing are different in the process itself. In the case of green synthesis, especially based on plant extracts, the extracts are utilized to reduce and stabilize the nanoparticles. The phytochemicals present in plant extracts have the potential to reduce metal ions in a much shorter time when compared to other reducing agents. The main phytochemicals present in plants are flavanoids, terpenoids, sugars, ketones, aldehydes, carboxylic acids, and amides, which are responsible for bioreduction of nanoparticles [4]. But in the eco-dyeing process, natural dyes are used with the purpose of surface modification to change their optical behavior not to control their particle size. The optical absorption and surface characteristics of eco-dyed ZnO nanoparticles are discussed here.

**METHODS**

Curcuma aromatica Salisb. powder were obtained from local ayurvedic shop and the extracts were obtained in deionized water. Different concentrations of the Curcuma aromatica Salisb. extracts were prepared in 10 ml of deionized water. Then the extract was filtered to remove the residues and impurities and the filtrate is used for further experiments. Zinc acetate dihydrate (Zn(CH₃COO)₂·2H₂O) and sodium hydroxide (NaOH) of 99.95% purity were purchased from Sigma-Aldrich Chemicals and used without further purification.

20 ml of 0.75 M zinc acetate dihydrate was prepared in de-ionized water then 10ml of the prepared Curcuma aromatica Salisb. solution of different concentrations were added slowly to the 0.75 M zinc acetate dihydrate solution under magnetic stirring. The mixture was stirred for 10 minutes by keeping the hotplate at 70°C. while stirring, 20 ml of 1M NaOH solution added dropwise to the mixture of zinc acetate dihydrate and tannin using a burette. A precipitate of ZnO was obtained and the sodium acetate formed during the reaction process is soluble in water, that can be removed by repeated washing. The supernatant is removed using a syringe and the precipitate was washed many times by continuing the syringe method. After, repeated washing, the obtained precipitate was dried and the resultant powder was collected for analysis.

X-ray diffraction (XRD) analysis of the powder samples were done at wavelength 0.1546 nm, running at 40 kV and 30 mA in X-ray diffractometer (Bruker D8 Advance). X-ray
diffractograms of zinc oxide nanoparticles were recorded in the region from 10° to 80° at a scan speed of 2° per minute. For UV spectroscopic analysis, prepared powder of ZnO nanoparticles were dispersed in distilled water (1 mg/ mL) and scanned in Agilent Cary 5000 UV–vis spectrometer at 25°C in the range of 250–900nm. Fourier Transform Infrared (FTIR) analysis of the ZnO were done by mixing ZnO nanoparticles and potassium bromide to form a salt plate. Spectra between 4000 and 400 cm⁻¹ were recorded using a Thermo Nicolet Avtar 370 spectrometer.

RESULTS AND DISCUSSION

*Curcuma aromatica Salisb.* solution of various concentrations (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 mg per 10 ml of deionized water) were used to enhance the absorption characteristics of the ZnO nanoparticles. *Curcuma aromatica Salisb.* solution consists of many number of organic compounds [5]. The extracts confirmed the presence of phenolic (−OH) groups [7] and the FTIR spectrum of the solution is shown in Figure 1. The analysis was performed in a frequency range of 4000–400 cm⁻¹ at room temperature. The observed peaks and corresponding vibrations are tabulated in the Table 1. The O–H stretch band around 3400 cm⁻¹ is associated with the moisture. From the intensity of the absorption, it is inferred that the 0.8T sample has little higher moisture than other samples. The spectrum presented a band at around 890 cm⁻¹ and around 424 cm⁻¹ signals the characteristic bond of Zn – O, which confirms the presence of zinc oxide in the sample.

![Figure 1. FTIR Spectra of the as synthesized and *Curcuma aromatica Salisb.*dyed ZnO nanoparticles.](image)

| S1   | 0.2T | 0.4T | 0.6T | 0.8T | 1T   | 1.2T | Vibrations                   |
|------|------|------|------|------|------|------|----------------------------|
| 3439 | 3413 | 3418 | 3433 | 3433 | 3421 | 3416 | O–H stretching vibration   |
|      | -    | -    | 2922 | 2924 | 2926 | 2928 | C–H stretching vibration   |
| 1633 | 1634 | 1636 | 1633 | 1632 | 1636 | 1336 | C=O stretching vibration   |
| 1386 | 1393 | 1393 | 1391 | 1389 | 1384 | 1388 | CH₃ sym. bending           |
|      | -    | -    | 1150 | 1149 | 1120 | 1151 | C–O–C stretching vibration |
| 869  | 892  | 896  | 890  | 893  | 898  | 907  | ZnO                        |
| 424  | 478  | 403  | 433  | 433  | 437  | 428  | ZnO stretching[8]          |

Table 1. FTIR bands and corresponding vibrations of eco-dyed ZnO using *Curcuma aromatica Salisb.*
Figure 2. UV-visible absorption spectrogram of the *Curcuma aromatica Salis b.* liquid sample

![Absorption spectrogram](image)

Figure 3. UV-visible absorption spectra of the pristine ZnO and the ZnO nanoparticles prepared in *Curcuma aromatica Salis b.*

The UV-visible absorption spectra of the prepared liquid sample of the concentration 0.2T was obtained as given in the Figure 2. It is observed that the *Curcuma aromatica Salis b.* has absorption peak around 270 nm and absorption edge around 340 nm. Neerja et al. reported UV absorption peaks at around 240, 420 nm for curcumin 251 and 423 for demethoxycurcumin\(^4\). The observed spectrum of our *Curcuma aromatica Salis b.* solution shows that the samples have absorption in the visible region and the solution were seen as yellowish in color. This absorption in the visible region helps us to sensitize ZnO nanoparticles to expand ZnO spectrum to visible region. Also, the broadening of the
absorption spectra is desirable for harvesting the solar spectra in visible region that leads to a higher photocurrent from the dye sensitized solar cell. Then the absorption spectra of the prepared ZnO nanoparticles powder were studied and the spectra is shown in the Figure 3. The absorption edge observed at 400 nm (3.1 eV) for the pristine ZnO white powder. But, the absorption spectra of the ZnO prepared in the various concentrations of the tamarind tannin extended to visible region (650 nm) with the same absorption peak seen in the spectrum of the Curcuma aromatica Salisb. solution alone. The absorption edge due to the ZnO in the eco-dyed sample has not moved remarkably from the position of the pristine sample, it means that the size of the ZnO has not much changed when they are prepared in the presence of Curcuma aromatica Salisb.

The band gap of the prepared powder material has been determined by the modified tauc plot method proposed by Ragib Ahsan et al [9].

For preparing Tauc plot for nanoscale powders, Ragib Ahsan et al [9] assumed that

$$\frac{\Delta I}{I_o} = \alpha \Delta x$$

From this equation they derived as

$$\frac{I_o}{I_T} = 1 + \alpha \Delta x$$

$$\alpha \Delta x = 10^A - 1$$

$$\alpha \propto 10^A - 1$$

Where A is the absorbance, \(\alpha\) is the absorption coefficients, \(I_o\) and \(I_T\) are the incident photon intensity and transmitted photon intensity respectively.

Using the equation (4), the absorption coefficients (\(\alpha\)) calculated from absorbance spectrum using the modified equation [9]. Here the importance is given only to the linear part of the Tauc plot and approximated the value of absorption coefficients by considering absorption coefficient is proportional to the absorbance [9]. This value of \(\alpha\) is substituted in the tauc plot equation (5) [10].

$$(\alpha h\nu)^{\frac{1}{n}} = A(h\nu - E_g)$$

Where \(h\) is plank’s constant, \(\nu\) is the photon frequency, \(\alpha\) is the absorption coefficient, \(E_g\) is the band gap and A is proportionality constant. The value of the exponent denotes the nature of the electronic transition, such as \(n=1/2\) for direct allowed transition, \(n=3/2\) for direct forbidden transition, \(n=2\) for indirect allowed transition, \(n=3\) for indirect forbidden transition. Generally the allowed transitions dominate the basic absorption process, either \(n=1/2\) or \(n=2\), for direct and indirect transitions respectively. By plotting and by finding the best fit of the \((\alpha h\nu)^{\frac{1}{n}} vs h\nu\) using \(n=1/2\) and \(n=2\) gives the correct transition type. Band gap is found from the intersecting point of the curve in the energy axis. Here it is assumed that the optical absorption strength depends on the difference between the photon energy and the band gap.

ZnO has a direct allowed transition [6] and drawn the Tauc plot by substituting \(n=1/2\). At low energies the photon energy absorption approached to zero and at higher energies the absorption process saturate and the curve again deviate from linear, which is the characteristic of the Tauc Plot. At the near of the band gap the the absorption gets stronger.
and shows a region of linearity in the plot. This linear regions used to extrapolate to the x-axis intercept to find the band gap value.

The Tauc plots of the prepared powder samples are given in the Figure 4 and the band gaps found from the plots are given in the Table 2. It is observed that the band gap has not shown much changes with the concentration of the Curcuma aromatica Salisb. solution. This implies that the Curcuma aromatica Salisb. has not any remarkable effect on controlling the particle size of the ZnO nanoparticles when ZnO nanoparticles prepared by this method.

![Tauc plot](image)

**Figure 4.** Tauc plots of the prepared ZnO powder samples

**Table 3.** Band gap and Urbach energy of the eco-dyed ZnO

| Sample | Band Gap (eV) | Slope from ln(α) vs \( h\nu \) curve | Intercept | Urbach energy |
|--------|---------------|--------------------------------------|-----------|---------------|
| S1     | 3.33          | 10.10142                             | -31.63335 | 0.0989        |
| 0.2T   | 3.28          | 10.15605                             | -31.4826  | 0.0984        |
| 0.4T   | 3.28          | 10.23398                             | -31.60108 | 0.0977        |
| 0.6T   | 3.25          | 10.37584                             | -31.99108 | 0.0963        |
| 0.8T   | 3.26          | 10.55659                             | -32.58798 | 0.0947        |
| 1.0T   | 3.28          | 10.14698                             | -31.35804 | 0.0985        |
| 1.2T   | 3.29          | 10.02314                             | -31.07025 | 0.0997        |

The UV-visible absorption spectra also gives an information about the Urbach tails related to the width of the localized states available in the optical band gap of the ZnO nanoparticles. The band structure in the semiconductor may be damaged due to the disorder in the crystals or may be due to the addition of other extra atoms. Therefore the Urbach energy found below the absorption band edge gives us an idea about the amount of the damage happened to the crystal. For highly imperfect crystal, Urbach energy is large. The generation of absorption edge at the band gap energy is due to the exciton phonon interaction or may be due to the electron phonon interaction. The defects in crystals also absorb light but does not contribute to free electrons instead it recombined or trapped there. This is the curve in the tauc plot after the absorption edge. Urbach energy is the energy that gives the spectral dependence of the absorption coefficients that are examined at photon energies, which are less than the band gap of the material. That is, the formation of localized states with energies at the boundaries of the energy gap which is one of the effects of the structural disorder on the
electronic structure of the material. These defect states trap the excited electrons and prevent the movement of electron to the conduction band when the samples are irradiated with light of a particular wavelength. This absorption tail is called the Urbach tail and is associated with the Urbach energy. The equation for calculating the Urbach energy is

$$\alpha = \alpha_o + e^{\frac{hv}{E_u}}$$  \hspace{1cm} (6)

Where $\alpha$ is the absorption coefficient, $E_u$ is the Urbach Energy. The Urbach energy is calculated by plotting $\ln(\alpha)$ vs $hv$. Figure 5 shows the Urbach energy plots for all the samples. The slope and intercept of the linear region found by using linear quick fit gadget tool in the Origin Software. The reciprocal of the slope of the linear fit, gives the Urbach energy values and the $E_u$ values are tabulated in Table 3 with band gap energies. There is not seen any trend of changing the disorders as varying the tamarind seed coat tannin concentrations.

**Figure 5.** Urbach energy curve for ZnO samples prepared in *C. aromatica Salisb.*
Figure 6. XRD spectra of the prepared ZnO powder samples prepared in *Curcuma aromatica Salisb*.

XRD spectrum shown in Figure 6 has prominent peaks corresponding to the diffraction peaks at $2\theta = 31^\circ, 34^\circ, 36^\circ, 47^\circ, 56^\circ, 62^\circ, 65^\circ, 72^\circ$ and $76^\circ$ were indexed with the diffraction planes (100), (002), (101), (102), (110), (103), (200), (112), (004) and (202) which well correlates with the JCPDS card no. 36–1451. The XRD pattern shows that the prepared ZnO has hexagonal wurtzite structure (with $a = b = 3.25$ Å, $c = 5.20$ Å) belonging to the C46v space group (P63mc). The broadening of peak in the XRD pattern clearly implies that small nanocrystals are present in the samples. There is no evidence of bulk form of the materials or any impurity. In the XRD pattern, the (101) diffraction peak is much stronger than other peaks. This indicates that the formed ZnO nanocrystals have a preferential crystallographic (101) orientation. The average crystallite size of prepared sample was calculated by the Debye-Scherrer’s formula $^{[11]}$ i.e.,

$$D = \frac{0.9 \lambda}{\beta \cos \theta} \quad (7)$$
where, $D$ is the particle size, $\lambda$ the wavelength of x-rays ($\lambda = 1.5406$ Å for Cu Ka), $\theta$ the Bragg angle and $\beta$ is the full width at half maxima (FWHM). Average particle size ($D$) of synthesized ZnO nanoparticles were found to be 17 nm using this equation (7).

The induced micro strain in the crystal due to the crystal imperfection and distortion was calculated using the equation \[^{[12]}\]

$$\epsilon = \frac{\beta}{4 \tan \theta}$$ \hspace{2cm} (8)

The strain and particle size can also be found from the Williamson-Hall Plot. Williamson-Hall Plot were drawn using the equation

$$\beta \cos \theta = \frac{k \lambda}{D} + 4 \epsilon \sin \theta$$ \hspace{2cm} (9)

Table 4. Geometric parameters of the ZnO nanoparticles of sample S1

| 2θ (degree) | Interplanar distance, d (Å m) | Standard JCPDS, d (Å m) | hkl | Crystallite Size, D (nm) | Micro strain, $\epsilon$ |
|-------------|-----------------------------|------------------------|-----|-------------------------|-------------------------|
| 31.43       | 2.84396                     | 2.8143                 | 100 | 16.9                    | 0.007583                |
| 34.091      | 2.62785                     | 2.6033                 | 002 | 21.5                    | 0.005507                |
| 35.921      | 2.49802                     | 2.4759                 | 101 | 17.6                    | 0.006394                |
| 47.19       | 1.92444                     | 1.9111                 | 102 | 17.7                    | 0.004905                |
| 56.225      | 1.63475                     | 1.6247                 | 110 | 17.8                    | 0.004414                |
| 62.488      | 1.48511                     | 1.4771                 | 103 | 18.7                    | 0.003567                |
| 65.992      | 1.41449                     | 1.4071                 | 109 | 13.4                    | 0.004762                |
| 67.554      | 1.38552                     | 1.3781                 | 112 | 12.9                    | 0.004822                |
| 72.158      | 1.30803                     | 1.3017                 | 004 | 20.2                    | 0.002918                |
| 76.516      | 1.24402                     | 1.2380                 | 202 | 17.5                    | 0.003192                |
| **Average** |                            |                        |     | **17.4**                | **0.004779**             |

**Figure 7.** Williamson – Hall plot pristine ZnO sample (S1)

The plots were made by taking $4 \sin \theta$ along x-axis and $\beta \cos \theta$ along y-axis for all the ZnO samples as shown in Figures 8, 9 and 10. From the linear fit, the crystallite size was
estimated from the y intercept and the strain $\varepsilon$ from the slope of the fit $^{[12]}$. Geometric parameters of the prepared ZnO nanoparticles are tabulated for the samples S1, Tm0.2 and Tm1.0 are given in the Table 4, 5 and 6. Table 7 shows the values obtained from Scherrers formula and from the Williamson-Hall plot. When comparing the tabulated values, it is seen that the size of the crystallites have increased little from 17 nm to 26 nm in the case of Tm0.2 sample and to 21 nm in the case of Tm1.0 sample. But, this increase is not evident from the optical absorption analysis. TEM and HRTEM images of the sample S1 and 1.0T are shown in Figure 10 and 11 respectively. The figures shows that the sizes of the prepared particles are below 50 nm. The interplanar spacing measured as 0.22 nm corresponds to the (101) plane.

Table 5. Geometric parameters of the ZnO nanoparticles of sample Tm0.2

| 20 (degree) | Interplanar distance, d (Å m) | Standard JCPDS, d (Å m) | hkl | Crystallite Size, D (nm) | Micro strain, $\varepsilon$ |
|-------------|-----------------------------|-------------------------|-----|-------------------------|---------------------------|
| 31.576      | 2.83111                     | 2.8143                  | 100 | 22.5                    | 0.005663                  |
| 34.227      | 2.61756                     | 2.6033                  | 002 | 29.1                    | 0.004053                  |
| 36.062      | 2.48859                     | 2.4759                  | 101 | 22.6                    | 0.004946                  |
| 47.331      | 1.91903                     | 1.9111                  | 102 | 19.2                    | 0.00449                   |
| 56.375      | 1.63083                     | 1.6247                  | 110 | 20.2                    | 0.003623                  |
| 62.618      | 1.48255                     | 1.4771                  | 103 | 19.5                    | 0.003414                  |
| 66.129      | 1.41189                     | 1.4071                  | 200 | 88.9                    | 0.000715                  |
| 67.685      | 1.38316                     | 1.3781                  | 112 | 15.7                    | 0.003965                  |
| 68.814      | 1.3632                      | 1.3017                  | 004 | 15.5                    | 0.00395                   |
| 72.276      | 1.30619                     | 1.2380                  | 202 | 24.1                    | 0.002439                  |
| 76.67       | 1.2419                      | 2.8143                  | 100 | 18.2                    | 0.003073                  |
| **Average** |                            |                         |     | **26.9**                | **0.003667**              |

Figure 8. Williamson – Hall plot pristine ZnO sample (0.2T)
Table 6. Geometric parameters of the ZnO nanoparticles of sample 1.0T

| 2θ (degree) | Interplanar distance, d (Å) | Standard JCPDS, d (Å) | hkl | Crystallite Size, D (nm) | Micro strain, ε |
|-------------|-----------------------------|-----------------------|-----|-------------------------|----------------|
| 31.726      | 2.81842                     | 2.8143                | 100 | 24.6                    | 0.005159       |
| 34.376      | 2.60686                     | 2.6033                | 002 | 27.3                    | 0.004288       |
| 36.211      | 2.47857                     | 2.4759                | 101 | 23.8                    | 0.004684       |
| 47.48       | 1.91337                     | 1.9111                | 102 | 18.2                    | 0.004742       |
| 56.527      | 1.62682                     | 1.6247                | 110 | 22.4                    | 0.003262       |
| 62.765      | 1.47917                     | 1.4771                | 103 | 19.5                    | 0.003419       |
| 66.285      | 1.40893                     | 1.4071                | 200 | 16.5                    | 0.003839       |
| 67.839      | 1.3804                      | 1.3781                | 112 | 13.4                    | 0.004633       |
| 68.969      | 1.36052                     | 1.3017                | 004 | 17.8                    | 0.003434       |
| 72.432      | 1.30375                     | 1.2380                | 202 | 17.4                    | 0.003364       |
| 76.832      | 1.23969                     | 2.8143                | 100 | 17.4                    | 0.003196       |

Average: 21.8 0.004402

Figure 9. Williamson – Hall plot pristine ZnO sample (Tm1.0)

Table 7. Crystallite size and microstrains of the samples S1, Ta0.2 and Ta1.2

| Sample Name | Average Crystallite Size using Scherrer Formula (nm) | Average crystallite size from W-H plot | Micro strain from eqn. | Micro strain from W-H plot |
|-------------|------------------------------------------------------|---------------------------------------|------------------------|---------------------------|
| S1          | 17.4                                                 | 18.9                                  | 0.0047                 | 0.00080                   |
| 0.2T        | 26.9                                                 | 25.8                                  | 0.0036                 | 0.00085                   |
| 1.0T        | 21.8                                                 | 44.3                                  | 0.0024                 | 0.00440                   |
CONCLUSIONS

The extracts of Curcuma aromatica Salisb. was obtained in deionized water for eco-dying ZnO nanoparticles and their FTIR and absorption were studied. The particle size of the prepared ZnO particles were calculated as approximately 17 nm and the particle sizes were seen increased when they prepared in Curcuma aromatica Salisb. extract by the proposed method. The UV-visible absorption spectroscopic results shows that the optical behaviour is enhanced and the eco-dyed ZnO can absorb a wide spectrum of light from 400 nm to 650 nm. Curcuma aromatica Salisb. extract can be successfully employed as a natural dye to sensitize ZnO nanoparticles without changing their size much.

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REFERENCES

1. Maheshwari, P., & Sher-Gil, U. S. 1965. *Dictionary of economic plants in India*. Indian Council of Agricultural Research.

2. Banfield, A. F. 1951. *The Wealth of India: A Dictionary of Indian Raw Materials and Industrial Products; Raw Materials, Vol. II, and Industrial Products, Part II*, covering letter ‘C.’ B. N. Sastri, Ed. New Delhi, India: Council of Scientific & Industrial Research, 1950, 1951.,” Science (80-.).

3. Sikha, A., Harini, A., & HegdePrakash, L. 2015. Pharmacological activities of wild turmeric (Curcuma aromatica Salisb): a review. *Journal of Pharmacognosy and Phytochemistry*, 3, 01-04.

4. Pant, N., Misra, H., & Jain, D. 2013. Phytochemical investigation of ethyl acetate extract from Curcuma aromatica salisb. rhizomes. *Arabian Journal of Chemistry*, 6 (3), 279-283.

5. Revathi, S., & Malathy, N. S. (2013). Antibacterial Activity of Rhizome of Curcuma aromatica and Partial Purification of Active Compounds. *Indian journal of pharmaceutical sciences*, 75 (6), 732–735.

6. Janotti, A., & Van de Walle, C. G. 2009. Fundamentals of zinc oxide as a semiconductor. *Reports on Progress in Physics*, 72 (2), 126501.

7. Coates, J. 2006. Interpretation of infrared spectra, a practical approach. *Encyclopedia of Analytical Chemistry*.

8. Handore, K., Bhavsar, S., Horne, A., Chhattise, P., Mohite, K., Ambekar, J., Pande, N., & Chabukswar, V. 2014. Novel green route of synthesis of zno nanoparticles by using natural biodegradable polymer and its application as a catalyst for oxidation of aldehydes. *Journal of Macromolecular Science, Part A*, 51 (12), 941-947.

9. Ahsan, R., Khan, M. Z., & Basith, M. A. 2017. Determination of optical band gap of powder-form nanomaterials with improved accuracy. *Journal of Nanophotonics*, 11 (4), 1.

10. Viezbicke, B. D., Patel, S., Davis, B. E., & Birnie, D. P. 2015. Evaluation of the TAUC method for optical absorption edge determination: Zno Thin films as a model system. *Physica Status Solidi (b)*, 252 (8), 1700–1710.

11. Cullity, B. D. 1978. *Elements of x-ray diffraction*. Reading, MA: Addison-Wesley Publishing Company, Inc.

12. Pant, N., Misra, H., & Jain, D. C. 2013. Phytochemical investigation of ethyl acetate extract from Curcuma aromatica salisb. rhizomes. *Arabian Journal of Chemistry*, 6 (3), 279–283.