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$AlCl_3$@ZnO nanostructured material: an efficient green catalyst for the one-pot solvent-free synthesis of 1,4-dihydropyridines†

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$AlCl_3$-loaded ZnO nanoparticles have been explored as an efficient catalyst for 1,4-dihydropyridine synthesis under ambient temperature and solvent-free conditions. For this purpose, ZnO nanoparticles were synthesized by a simple solution-based precipitation technique using a stoichiometric amount of zinc sulfate and oxalic acid. The $AlCl_3$@ZnO nanocrystalline catalyst was prepared by loading 20% $AlCl_3$ on ZnO nanoparticles by a simple wet-impregnation technique. This catalyst efficiently performed Hantzsch pyridine reactions with various aromatic aldehydes, ethyl acetoacetate and ammonium acetate. The nanostructured $AlCl_3$-loaded ZnO catalyst was characterized by UV-DRS, XRD, FESEM, EDS, FETEM-STEM-EDS and XPS techniques. The comprehensive characterization reveals the formation of $AlCl_3$-loaded ZnO catalysts with an average particle size of 70–80 nm. The loading of $AlCl_3$ on the ZnO surface was confirmed by minor shifts in the XPS and XRD peaks. FETEM-STEM-EDS also indicates reasonable $AlCl_3$ loading on ZnO nanoparticles. The 20% $AlCl_3$-loaded ZnO nanocatalyst ($AlCl_3$@ZnO) confers 92% yield for the synthesis of 1,4-dihydropyridine under solvent-free and ambient temperature conditions. The synthesized 1,4-dihydropyridines were characterized by ^{1}H-NMR, ^{13}C-NMR, HRMS and FT-IR spectroscopic techniques. The reported catalyst is highly efficient, environmentally friendly and could become an alternative to homogenous and heterogenous catalytic reactions.

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1. Introduction

Solving the recent challenge to obtain a high yield of Hantzsch pyridine synthesis using heterogeneous reactions has become an important task. Due to the significant biological activity of 1,4-dihydropyridines [1,4-DHPs] (Fig. 1), they belong to the important class of six-membered heterocyclic compounds.[1–3] The 1,4-DHP moiety occurs in many drugs and synthetic products.[4] The electron-withdrawing groups at 3 and 5 positions enhance the stability of 1,4-dihydropyridines.[5] Worldwide commercial representatives of DHPs such as nifedipine (Fig. 2A), amlodipine (Fig. 2B), felodipine (Fig. 2C) and nicardipine (Fig. 2D), are important drugs for the treatment of hypertension.[6,7] The 1,4-DHP skeletons have been used as an antimicrobial agent,[8–10] glycoprotein inhibitor,[11] calcium channel blocker,[12–18] anticancer agent,[19] and antitubercular agent.[20] Hantzsch diethyl 1,4-dihydro-2,6-dimethyl-3,5-pyridinedicarboxylate also acts as a good source of hydride for reduction purposes.[21–24] Therefore, the quest for cost-effective and simple methods for the synthesis of DHPs has become a hot topic of current research.

The traditional approach for the preparation of 1,4-dihydropyridines involved the condensation of three components,

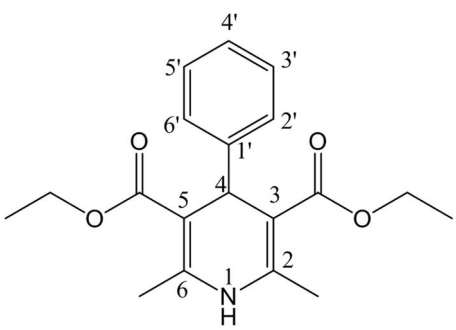

Fig. 1 The 1,4-dihydropyridine [1,4-DHP] moiety.

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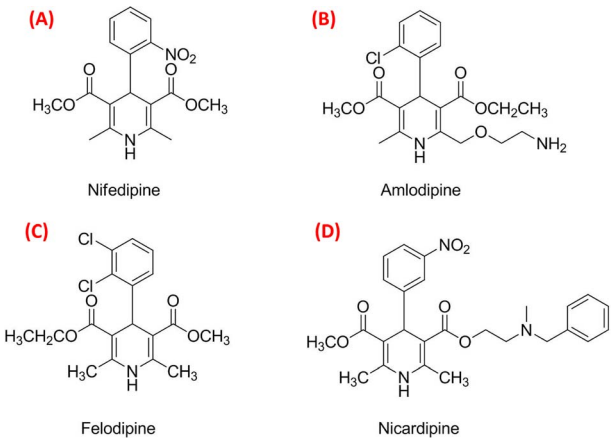


Fig. 2 The best-selling drugs nifedipine (A), amlodipine (B), felodipine (C) and nicardipine (D) that are used in the treatment of hypertension.

viz. aromatic aldehyde, β-keto ester and ammonia, *via* acid-catalyzed organic reactions. The familiar reaction was performed under acid-catalyzed conditions, such as melamine trisulfonic acid,[25] phenylboronic acid[26] or *p*-toluenesulfonic acid.[27] Hantzsch pyridine synthesis has been also performed in the presence of Lewis acid catalysts such as Zn[(L)proline]$_2$,[28] Aluminium(III) chloride hexahydrate[29] and $ZnCl_2$.[30] However, the recyclability of Lewis acid and homogenous organic acid catalysts has become an environmental concern.

To overcome the recyclability of catalysts and environmental issues, the reactions were performed by biodegradable catalysis[31] and heterogeneous catalysis using clay,[32] ZnO,[33] Cu–ZnO,[34] CaO,[35] N-doped TiO_2,[36] V_2O_5/ZrO_2,[37] Fe_3O_4 [38] or CuO/rGO.[39] The comparative features of organic transformations with respect to catalytic conditions are given in Table 1.

However, these reactions are time consuming and need solvents and high temperature, microwave assistance as well as tedious workup procedures. In order to overcome these limitations 1,4-dihydropyridines was recently synthesized in high yield by a green approach using an acidic functional group loaded on nanocrystalline metal oxides.[40] Therefore, as a part of ongoing exploration related to the development of a clean and eco-friendly method, herein we report an environmentally friendly $AlCl_3$-loaded ZnO nanostructured catalyst for the synthesis of 1,4-dihydropyridine.

We report that the use of $AlCl_3$-loaded ZnO nanostructured catalysts not only enhances the yield, but also turns out to be cost effective for the synthesis of 1,4-dihydropyridine. For this purpose, a vital $AlCl_3$@ZnO nanocatalyst was synthesized using a simple solution-based wet-impregnation technique,[41,42] as described in the following experimental section. Notably, our nanocrystalline $AlCl_3$@ZnO material was found not only to be an efficient catalyst but also helps to obtain highly pure 1,4-dihydropyridine derivatives at room temperature under solvent-free conditions.

2. Experimental

2.1. Synthesis of nanocrystalline ZnO

For the synthesis of ZnO nanoparticles, oxalic acid (99.9%, SD-fine chemicals) and zinc sulfate (99.9%, SD-fine chemicals) were used as precursors. To begin with, the oxalic acid (0.1 N) solution was added dropwise into the zinc sulfate solution (0.1 N) with constant stirring until the formation of a zinc oxalate complex. The obtained precipitate of zinc oxalate complex was washed with distilled water and dried at 100 °C in an oven. Then this intermediate complex was decomposed at 500 °C for 5 h in order to obtain nanocrystalline zinc oxide.

2.2. Synthesis of nanostructured $AlCl_3$@ZnO

For the synthesis of nanostructured $AlCl_3$@ZnO, as-synthesized nanocrystalline ZnO was used as a precursor material. The appropriate amounts of nanocrystalline ZnO (80%) and $AlCl_3$ (20%) were mixed in a mortar and pestle and subsequently transferred to a round-bottom flask (500 mL) containing 100 mL of *n*-hexane. The reaction mass was further refluxed for 2 h and excess solvent was removed by vacuum distillation and the resultant solid was dried at 100 °C for 4 h to obtain nanocrystalline $AlCl_3$@ZnO material.

Table 1 Literature survey on biodegradable catalysis and heterogeneous catalysis

Target molecule	Reaction conditions	Yield[a] (%)
2*H*-Indazolo[1,2-β] phthalazine-triones	PEG-OSO_3H, solvent-free, 80 °C	80–93 (ref. 31)
Tetrahydroquinolines	Montmorillonite KSF, water, refluxing conditions, 48 h	87–95 (ref. 32)
3,4-Dihydropyrimidin-2(1*H*)-ones/thiones	ZnO NPs, MW, solvent free, 55 °C	60–75 (ref. 33)
(*E*)-3-Styrylchromones	Cu–ZnO NPs, DMF, reflux conditions	68–80 (ref. 34)
2-Amino-3,5-dicyano-6-sulfanyl pyridines	Nano-CaO, ethanol:water (1 : 1), 50 °C	75–92 (ref. 35)
Diethyl(1-phenyl-3-(thiophene-2-yl)-1*H*-pyrazole-4-yl) (phenylamino) methylphosphonates	N-Doped TiO_2, microwave irradiation for 10–15 min using 420 W	71–95 (ref. 36)
1,4-Dihydropyridine	V_2O_5/ZrO_2 ethanol, RT, 15 min	90–96 (ref. 37)
Pyrazolophthalazinyl spirooxindoles	Fe_3O_4\SiO_2\methylene dipyridine MNPs, RT, solvent-free	90–93 (ref. 38)
Imidazo[1,2-α]pyridines	Cu(0)/rGO, ultrasonicated for 2 min, stirring at 110 °C for 8 h	84–96 (ref. 39)

[a] The comparative features of biodegradable and heterogeneous catalysis for organic transformations.

2.3. Characterization of powdered ZnO and $AlCl_3$@ZnO catalyst

To determine the crystal structure and phase purity of the resultant nanomaterials, X-ray diffractograms (XRD) of the samples were obtained with a Rigaku-D8/MaX-2200V using Ni-filtered Cu-Kα radiation ($\lambda = 1.54$ Å). The surface morphological features along with particle size were determined with a field emission scanning electron microscope (FESEM; HITACHI S-4800 and Nova Nano SEM NPEP303). For this purpose, the powder sample was drop-cast on conducting carbon tape attached to an aluminium stub and the resultant layer was subsequently coated with conducting gold film to minimize the effects due to charging. The FESEM measurements were carried out at an accelerating voltage of 20 kV, working distance of ~10.2 mm and using secondary electron detector mode. Fine-scale microstructural evaluation of the synthesized ZnO sample was carried out by obtaining field emission transmission electron microscopic (FETEM) images using a JEOL-2200EX instrument. This instrument was also employed for energy dispersive spectroscopy (EDS) and associated elemental mapping studies in scanning transmission electron microscopy (STEM) configuration with bright field mode. The UV-Visible diffuse-reflectance spectra (UV Vis-DRS) were recorded using a UV-Vis diffuse-reflectance spectrophotometer (PerkinElmer, model: Lambda 365). To find the electronic states of the elements in the nanocrystalline $AlCl_3$@ZnO material, X-ray photoelectron spectroscopic (XPS) scans were acquired with a Thermo Fisher Scientific instrument, UK (Model K ALPHA+). The X-ray source used during the analysis was Al K alpha (monochromatic) with 6 mA beam current and the spot size on the samples was 400 micrometres. All the XPS spectra were corrected using the adventitious C 1s peak at 284.8 eV.

The progress of the reaction was monitored by the thin layer chromatography (TLC) technique. The ^{1}H NMR and ^{13}C NMR spectra of the Hantzsch reaction products were recorded on a Bruker Ascend 500 NMR spectrometer operating at 500 MHz and 125 MHz, respectively, in $CDCl_3$ solvent. The ^{1}H and ^{13}C chemical shifts (δ) are reported in ppm relative to tetramethylsilane (TMS), as the internal standard substance. The coupling constant (J) values are expressed in Hz. A high-resolution mass spectrometer (Bruker Germany, model: Impact HD, UHR Impact II ESI-Q-TOF) was used for mass analysis of product materials in methanol solvent. The FT-IR spectra were acquired on a Shimadzu FT-IR Affinity 1S.

2.4. Measurement of catalytic activity for Hantzsch pyridine synthesis

Stoichiometric amounts of aromatic aldehydes (4.71 mmol), ethyl acetoacetate (9.42 mmol) and ammonium acetate (5.66 mmol) were taken in a 25 mL round-bottom flask (Scheme 2). Then, nanocrystalline $AlCl_3$@ZnO (1.17 mmol) powder was added as a catalyst in the reaction mixture, which was stirred for 2 h at room temperature. The reaction was monitored by TLC. After completion of the reaction, 10 mL of chloroform was added to the reaction mass in order to separate the product. The catalyst was separated by the centrifugation technique. Subsequently, the filtrate was concentrated to get a solidified compound and then crystallized in diethyl ether to get a pure product. The structural purity of the compounds was confirmed by FT-IR, ^{1}H NMR, ^{13}C NMR and HRMS spectral techniques.

3. Results and discussion

3.1. XRD study of pure ZnO and $AlCl_3$@ZnO

Fig. 3(a–e) furnish XRD patterns of pure ZnO, 5%, 10%, 15% and 20% $AlCl_3$@ZnO, respectively. The peaks appearing in the XRD patterns disclosed the wurtzite hexagonal form of ZnO (JCPDS card: 89-1397). The orientation of the peak at the (002) plane indicates the polycrystalline nature; other XRD peaks corresponding to (100), (101), (102), (110), (103) and (112) planes are in good agreement with the standard data.

Fig. 4 shows small shifts in diffraction angle (2θ) corresponding to (100), (101) and (102) peaks due to the $AlCl_3$ loading in ZnO.[44,45] The relative intensities of the peaks corresponding to the (002) plane of pure ZnO and $AlCl_3$-loaded ZnO imply an increase in crystal size. The XRD reveals only ZnO peaks and no peaks related to aluminium chloride (and its components) are observed. A plausible reason may be the dominance of an amorphous state of aluminium chloride dispersed uniformly on ZnO NPs, so it may be very hard to detect by XRD.

The average crystallite sizes of pure ZnO, 5%, 10%, 15% and 20% $AlCl_3$-loaded ZnO samples were calculated using Scherrer's equation and were found to be 22.41, 28.61, 32.58, 32.98 and 33.62 nm, respectively. The slight increase in crystallite size may be due to loading of $AlCl_3$ on ZnO.

3.2. UV-Vis diffuse reflectance spectroscopy (DRS) of ZnO and $AlCl_3$@ZnO

Fig. 5 shows the UV-Vis (DRS) absorption spectra of pure ZnO and $AlCl_3$@ZnO NPs measured in the range of 200–800 nm. In the absorption spectra, the optical absorption edge in the UV region appears to shift slightly to the higher wavelength region

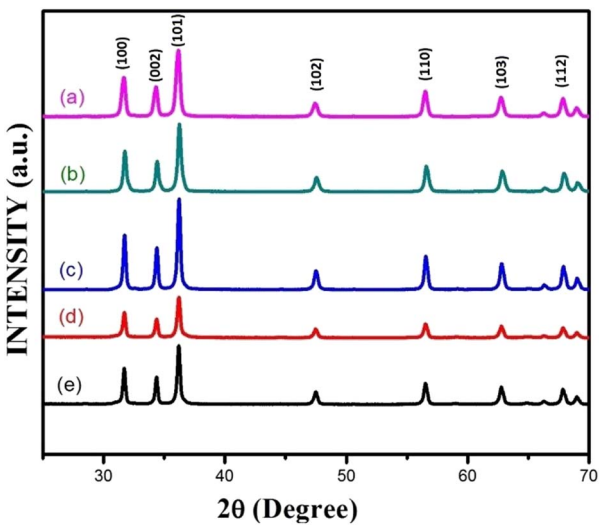


Fig. 3 X-ray diffraction patterns of (a) as-synthesized pure ZnO powder and $AlCl_3$@ZnO powders corresponding to wt% loadings of (b) 5%, (c) 10%, (d) 15%, and (e) 20%.

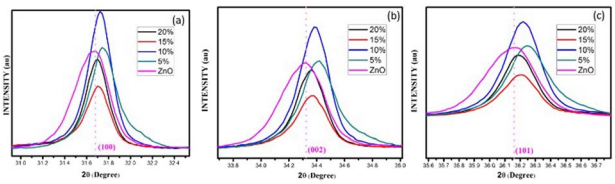


Fig. 4 The shifts in peak position in the X-ray diffraction angles corresponding to (a) (100), (b) (002) and (c) (101) planes for as-synthesized pure ZnO powder and $AlCl_3$@ZnO powders corresponding to wt% loadings of 5%, 10%, 15%, and 20%.

(red shift) with an increase in $AlCl_3$-loading concentration (Table 2).

At higher energy, the transformation of the relatively flat UV-DRS absorption curve for pure nanocrystalline ZnO to increasingly bent ones indicates a subsequent increase in loading of $AlCl_3$. However, broad UV emission is observed for $AlCl_3$-loaded ZnO.

Fig. 6(a–e) present the Tauc plots for pure ZnO and $AlCl_3$-loaded ZnO NPs. The optical energy band gap is calculated using the formula

$$(\alpha\eta\nu)^2 = \beta(h\nu - E_g) \quad (1)$$

where α = absorption coefficient, $\beta = a$ constant (generally known as the band tailing parameter), $h\nu$ = photon energy, E_g = optical band gap energy and 'n' is an index which may take values of 1/3, 1/2, 2, or 3, depending upon the type of band-to-band transition.

The band gaps of each synthesized catalyst material were calculated using the above equation by considering $n = 2$, the case for a direct band gap transition (Fig. 6(a–e)).

The band gap values calculated for pure ZnO and 5%, 10%, 15% and 20 weight % $AlCl_3$-loaded ZnO NPs presented in Table 2 disclose that, as the concentration of $AlCl_3$ increases in ZnO,

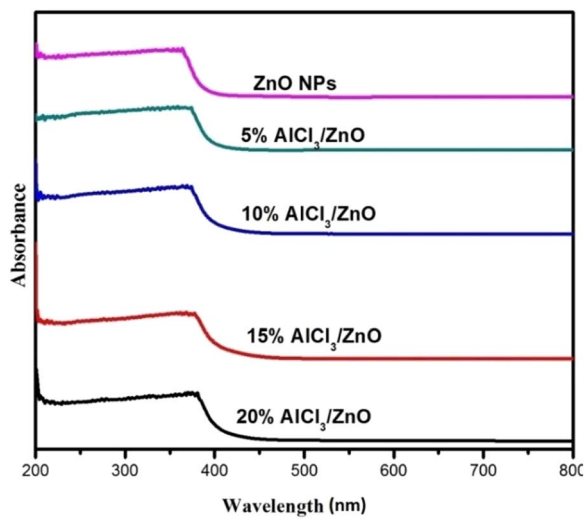


Fig. 5 UV-Vis DRS spectra of as-synthesized pure ZnO NPs, 5% $AlCl_3$@ZnO NPs, 10% $AlCl_3$@ZnO NPs, 15% $AlCl_3$@ZnO NPs and 20% $AlCl_3$@ZnO NPs.

Table 2 Cut-off wavelength and band gap energy of pure ZnO and $AlCl_3$-loaded ZnO samples

Sr. No.	Catalyst	Cut-off wavelength (nm)	Band gap (eV)
1	ZnO	383.75	3.127
2	5% $AlCl_3$@ZnO	385.10	3.116
3	10% $AlCl_3$@ZnO	387.22	3.099
4	15% $AlCl_3$@ZnO	389.86	3.078
5	20% $AlCl_3$@ZnO	416.85	3.059

a continuous decrease in band gap is noticed, which is consistent with the XRD data of a slight increase in grain size with $AlCl_3$ loading.[43]

3.3. Morphology study of ZnO and $AlCl_3$@ZnO by FESEM

The FESEM images of ZnO and $AlCl_3$@ZnO nanomaterials are displayed in Fig. 7. Fig. 7(a and b) show images of nanocrystalline ZnO material at 1 μm and 200 nm scale, which portray the formation of pallet-shaped nano-scale ZnO particles of size 40–80 nm (width-wise) and 80–200 nm (length-wise). Fig. 7(c, d), (e, f), (g, h) and (i, j) are the FESEM images of 5% $AlCl_3$@ZnO, 10% $AlCl_3$@ZnO, 15% $AlCl_3$@ZnO and 20% $AlCl_3$@ZnO, respectively, at the 1 μm and 200 nm resolution. The high-resolution image shows the formation of a flower-like morphology with adjacent spherical shaped particles of size 70–100 nm in some cases.

3.4. Characterization by FETEM

The representative TEM images of as-synthesized nanocrystalline ZnO samples (Fig. 8(a–c)) show predominantly nanorod morphology along with other shapes having faceted growth and having particle sizes in the range of 80–200 nm for length and 40–100 nm for width. The overall size calculated by TEM study is in good agreement with the FESEM study. The average d-spacing as observed from the HRTEM image (Fig. 8(e)) is 0.267 nm, which typically corresponds to the (002) plane of ZnO, hinting at the localized single crystalline lattice pattern of ZnO nanoparticles. The selected area electron diffraction pattern (SAED) shown in Fig. 8(f) reveals bright spots aligned in a particular direction which

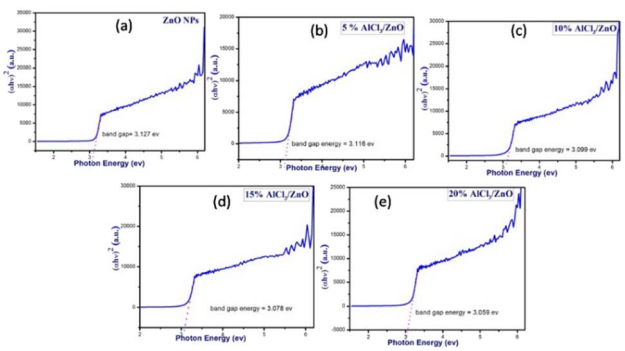


Fig. 6 Tauc plots of (a) as-synthesized pure ZnO NPs and $AlCl_3$@ZnO NPs corresponding to wt% loadings of (b) 5%, (c) 10%, (d) 15%, and (e) 20%.

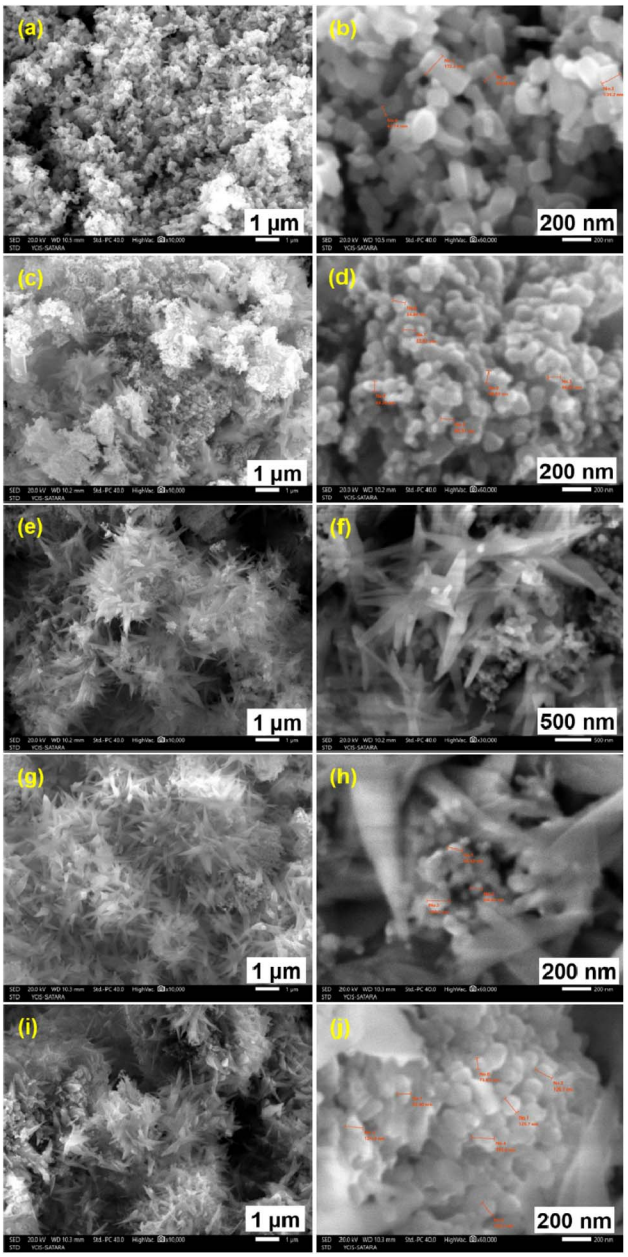


Fig. 7 FESEM images of ZnO (a and b), 5% $AlCl_3$@ZnO (c and d), 10% $AlCl_3$@ZnO (e and f), 15% $AlCl_3$@ZnO (g and h), 20% $AlCl_3$@ZnO (i and j).

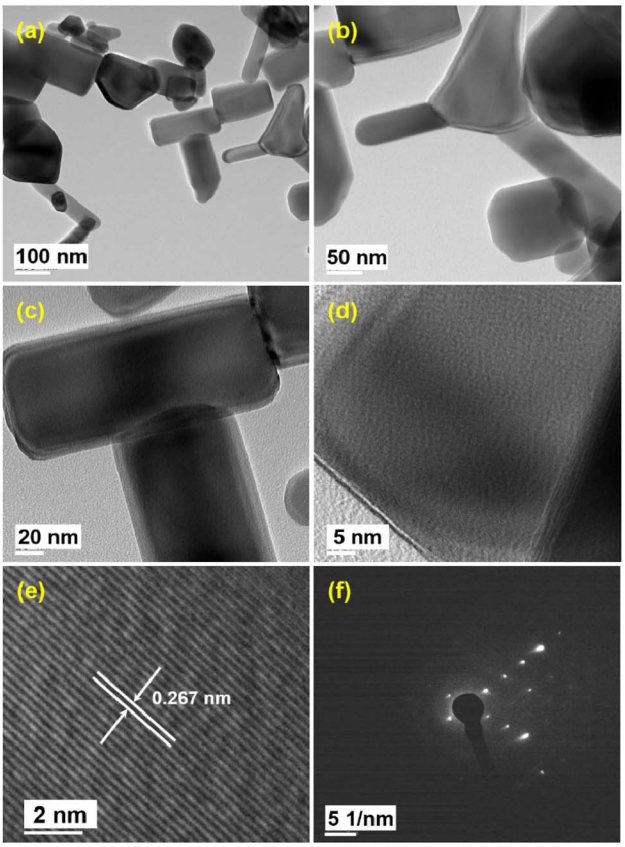


Fig. 8 FETEM images of ZnO nanomaterials at (a–c) low, (d) intermediate, and (e) high magnification and (f) corresponding SAED pattern.

also substantiates the localized single crystalline nature of ZnO nanoparticles.[46]

3.5. FETEM-STEM-EDS analysis of $AlCl_3$-loaded ZnO nanostructure

Energy dispersive X-ray spectroscopy (EDS) analysis was used for validation and quantification of the elements present in the given sample *via* scanning transmission electron microscopy (STEM) mode. In our investigation, weight-by-weight amounts of $AlCl_3$ and ZnO were used in the wet impregnation method. For FETEM-STEM-EDS elemental composition analysis, we considered the 20% $AlCl_3$@ZnO sample, and the associated qualitative elemental mapping as well as quantitative EDS data are reproduced in Fig. 9. The EDS-elemental mapping images of the 20% $AlCl_3$@ZnO sample taken in STEM mode are shown in Fig. 9. The elemental mapping images due to Zn and O (Fig. 9(b and c), respectively) overlap well with the corresponding electron image (Fig. 9(a)). The intensity of the colours assigned to Zn and O is also very high. The elemental mapping images for Al and Cl (Fig. 9(d and e), respectively) also overlap with the corresponding electron image; however, the intensity of the colours attributable to these two elements is low, which is obvious as only 20 wt% $AlCl_3$ is used for the purpose of surface loading. The FETEM results are in agreement with the FESEM results, which comprehensively confirms the surface loading of $AlCl_3$ over ZnO nanoparticles.

For quantitative FETEM-STEM-EDS composition analysis, the relevant EDS spectrum and elemental composition data (in tabular form) are reproduced in Fig. 9. The EDS spectrum discloses that the 20% $AlCl_3$@ZnO nanomaterial contains 24.73 wt% of oxygen, 7.74 wt% of chlorine, 41.16 wt% of zinc and 9.01 wt% of aluminium, even though the XRD pattern did not show any peaks of aluminium and/or its compounds. The EDS spectrum also reveals that the 20% $AlCl_3$@ZnO contains 9.36 atomic% of Al and 10.55 atomic% of Cl. Overall, EDS (qualitative and quantitative) analysis has revealed that the sample is composed of Zn, O, Al and Cl, which is in good agreement with results obtained by XPS (Fig. 10).

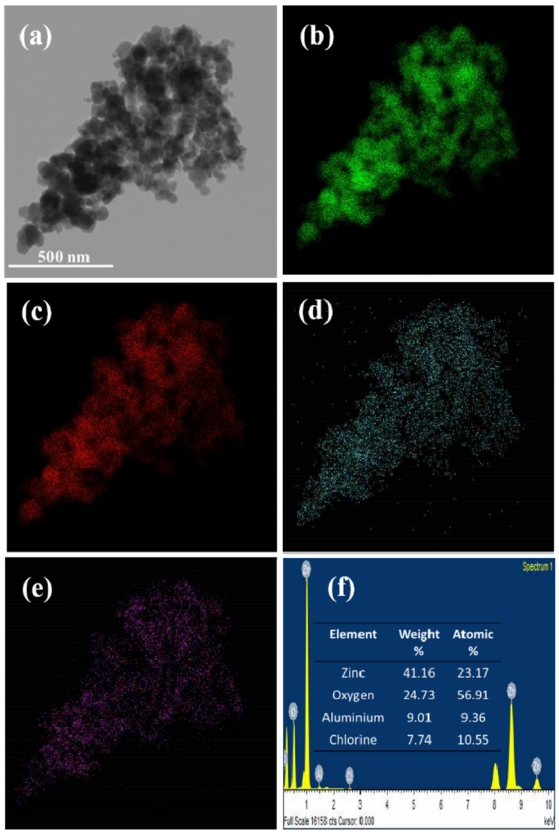


Fig. 9 FETEM-STEM-EDS elemental mapping images of the 20% $AlCl_3$@ZnO catalyst corresponding to (a) electron image, and elemental mapping images corresponding to (b) Zn, (c) O, (d) Al and (e) Cl and (f) STEM-EDS spectrum exhibiting quantitative elemental composition data for nanostructured 20% $AlCl_3$@ZnO.

3.6. XPS study of $AlCl_3$-loaded ZnO nanomaterials

X-ray photoelectron spectroscopy (XPS) detects the elemental composition and chemical state of an element. Fig. 10 shows the XPS spectrum of an $AlCl_3$@ZnO material used to study the surface exposure of ZnO and their respective additives, and their chemical states.

The high-resolution XPS spectra of nanostructured $AlCl_3$@ZnO mainly confirmed the existence of Zn 2p, Al 2p, O 1s and Cl 2p elements in the sample. The Zn 2p peaks appearing at 1021.6 eV and 1044.7 eV are related to Zn $2p_{3/2}$ and Zn $2p_{1/2}$, which are the characteristic features of Zn^{2+} in Zn(II)O. The two O 1s peaks belong to the lattice (O^{2-}) oxide sites (530.3 eV) and the Zn(II)–OH groups of oxygen (531.5 eV). The binding energy peaks at 74.4 eV and 74.7 eV signify the Al $2p_{3/2}$ and Al $2p_{1/2}$ energy states, respectively. This binding energy values can be assigned to Al^{3+} species in Al_2O_3 [47] and $AlCl_3$,[48] respectively. The binding energy at 199.58 eV denotes the Cl $2p_{3/2}$ energy state of metal chloride.[49] The overall appearance of peaks in XPS scans demonstrates the successful loading of $AlCl_3$ on the surface of ZnO nanoparticles.

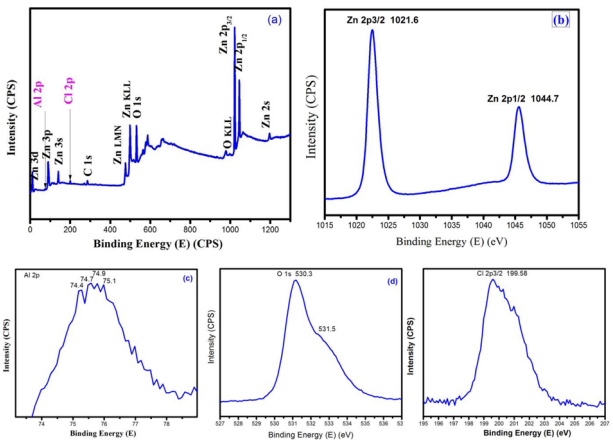


Fig. 10 X-ray photoelectron spectra of $AlCl_3$/ZnO (a) survey spectrum, (b) Zn 2p, (c) Al 2p, (d) O 1s and (e) Cl 2p.

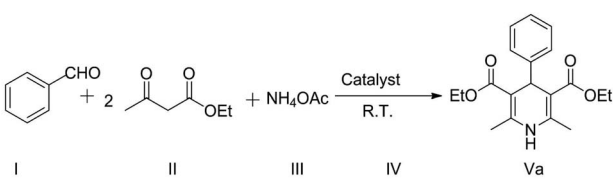
3.7. Measurement of catalytic activity of $AlCl_3$-loaded ZnO NPs for Hantzsch pyridine synthesis

In the present protocol, we began with the optimization of reaction conditions for the synthesis of dihydropyridines. We took 0.5 g of benzaldehyde, 1.22 g of ethyl acetoacetate and 0.43 g of ammonium acetate as starting materials for the model reaction (Scheme 1). The reaction was performed at room temperature under solvent-free conditions.

3.7.1. Catalytic study for the synthesis of 1,4-dihydropyridine. One-pot synthesis of 1,4-dihydropyridine was carried out without using any catalyst, which led to the formation of a trace amount of product in 4 h (Table 3, entry 1), thus pointing out the necessity of a suitable catalyst in such a reaction.

Then the feasibility of the reaction was checked with different catalysts, such as ZnO NPs, anhydrous $AlCl_3$, 5% $AlCl_3$@ZnO NPs, 10% $AlCl_3$@ZnO NPs, 15% $AlCl_3$@ZnO NPs, and 20% $AlCl_3$@ZnO NPs (Table 3, entries 2–7). $AlCl_3$ works as a Lewis acid catalyst with comparative yield to ZnO. The yield of 1,4-dihydropyridine increases after the use of $AlCl_3$@ZnO NPs. The results demonstrated that the yield of 1,4-dihydropyridine increases as the loading % of $AlCl_3$ increases in the ZnO nanocatalyst (Table 3, entries 4–7).

It was observed that the 20% $AlCl_3$@ZnO nanocatalyst is more efficient for the synthesis of 2,6-dimethyl-4-phenyl-1,4-dihydropyridine-3,5-diethylcarboxylate (Table 3, entry 7). It disclosed up to 94% conversion into the product. The enhancement of yield could be due to the availability of more active space on the catalyst, as observed in the FESEM and XPS studies.



Scheme 1

Table 3 Preparation of 1,4-dihydropyridine under different catalytic and solvent-free conditions[a]

Entry	Catalyst	Time (h)	Yield[b]
1	—	4	Trace
2	ZnO	2	54
3	Anhydrous $AlCl_3$	2	60
4	5% $AlCl_3$@ZnO NPs	2	70
5	10% $AlCl_3$@ZnO NPs	2	74
6	15% $AlCl_3$@ZnO NPs	2	83
7	20% $AlCl_3$@ZnO NPs	2	94

[a] Reaction conditions: benzaldehyde (4.71 mmol), ethyl acetoacetate (9.42 mmol), ammonium acetate (5.66 mmol), and catalyst (4.71 mmol, 1 equiv.), room temperature. [b] Isolated yield.

3.7.2. Optimization of reaction in different mole equivalents of $AlCl_3$@ZnO nanocatalyst for the synthesis of 1,4-dihydropyridine. By using model reaction 1, we checked the feasibility of the reaction for different mole equivalent quantities of the catalyst at room temperature and under solvent-free conditions. The obtained results are furnished in Table 4, entries 1–7.

It was found that 20% $AlCl_3$@ZnO gives up to 92% conversion of reactant into product using 0.25 mol equiv. of catalyst (Table 4, entry 6).

3.7.3. Effect of solvents on the synthesis of 1,4-dihydropyridine. We also investigated the effect of solvent on the synthesis of 1,4-dihydropyridine (Va) at ambient temperature (Table 5, entries 1–10) for the model reaction. We observed that water solvent is not suitable for conversion. Methanol, ethanol and acetonitrile are suitable to obtain yields of around 80–84% (Table 5, entries 2–4).

Among the various solvents, the solvent-free condition is more suitable for the synthesis of 1,4-dihydropyridine using 0.25 mol equiv. of 20% $AlCl_3$@ZnO catalyst at room temperature. Under solvent-free conditions, we obtained 92% yield for the model reaction (Table 5, entry 11).

3.7.4. Synthesis of substituted 1,4-dihydropyridine using 20% $AlCl_3$-loaded ZnO. After optimization of reaction conditions, we found that solvent-free, room temperature and 0.25 mol equiv. of 20% $AlCl_3$-loaded ZnO catalytic conditions are more suitable for the synthesis of 1,4-dihydropyridine. Therefore, we used the same parameters for the synthesis of differently substituted 1,4-dihydropyridines, which is shown in Scheme 2 and the observed yields are provided in Table 6.

The effect of electron donating and withdrawing substitution on aromatic aldehyde at the o/p position has been studied for the synthesis of 1,4-dihydropyridines (4a–4n) under solvent-free conditions and 0.25 mol. equiv. of 20% $AlCl_3$@ZnO NPs at ambient temperature (Table 6, entries 1–14). The presence of an electron donating OH (p) group on aromatic aldehyde reduces the yield of reaction (Table 6, entry 8). Halogenated aromatic aldehydes (Table 6, entries 3–4 and 10–12) gave a better yield. For nitrobenzaldehyde the obtained yields are 80% and 75% (Table 6, entries 6–7). Benzaldehyde, 4-chlorobenzaldehyde and 4-methoxybenzaldehyde gave the best yields (Table 6, entries 1, 2 and 5). The formation of 1,4-dihydropyridines were confirmed ^{1}H-NMR, ^{13}C-NMR, HRMS and FT-IR spectral data (please see ESI†).

3.7.5. Proposed mechanism for the synthesis of 1,4-dihydropyridine derivatives. Worldwide, the synthesis of Hantzsch pyridine has been carried out using organic acids and Lewis acids as catalysts under refluxing conditions. The catalytic activity of nanocrystalline metal oxide has been enhanced by loading/doping those materials with an acidic moiety. We have developed an environmentally friendly $AlCl_3$-loaded ZnO nanostructured catalyst for the synthesis of 1,4-dihydropyridine. $AlCl_3$ is a well-known Lewis acid catalyst with a tendency to accept a lone pair of electrons. We observed that the catalytic activity of $AlCl_3$@ZnO has been enhanced for the proposed reaction. The proposed Hantzsch reaction is the three-component condensation of aromatic aldehyde (1 equiv.), ethyl acetoacetate (2 equiv.) and ammonium acetate (1 equiv.). Ethyl acetoacetate is an electron-rich species with a tendency to donate the lone pair of electrons present in oxygen. It can react with more reactive $AlCl_3$@ZnO, forming an intermediate enolate (as outlined in the proposed mechanism). Subsequently, $AlCl_3$@ZnO makes aromatic aldehyde more electron deficient by withdrawing an electron from the carbonyl group and, in

Table 4 Preparation of 1,4-dihydropyridine under different mole equivalent quantities of 20% $AlCl_3$@ZnO catalyst at ambient temperature[a]

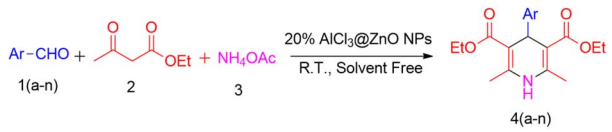
Entry	Amount of catalyst (mol equiv.)	Time (h)	Yield[b]
1	—	4	Trace
2	0.05	2	60
3	0.10	2	72
4	0.15	2	82
5	0.20	2	87
6	0.25	2	92
7	0.30	2	92

[a] Reaction conditions: benzaldehyde (4.71 mmol), ethyl acetoacetate (9.42 mmol), ammonium acetate (5.66 mmol), and catalyst (20%), under solvent-free conditions, room temperature. [b] Isolated yield.

Table 5 Effect of solvents for the synthesis of 1,4-dihydropyridine at ambient temperature using 20% AlCl@ZnO catalyst[a]

Entry	Solvent	Time (h)	Yield[b]
1	H_2O	6	Trace
2	Methanol	2	80
3	Ethanol	2	84
4	THF	2	70
5	Acetonitrile	2	80
6	Acetone	2	78
7	CH_2Cl_2	2	70
9	Toluene	2	60
10	DMF	2	68
11	Solvent-free	2	92

[a] Reaction conditions: benzaldehyde (4.71 mmol), ethyl acetoacetate (9.42 mmol), ammonium acetate (5.66 mmol), and catalyst (1.17 mmol, 0.25 equiv.) in different solvent conditions. [b] Isolated yield.



Scheme 2

Table 6 Synthesis of 1,4-dihydropyridines (4a–n) using 20% $AlCl_3$@ZnO catalyst under solvent-free conditions[a]

Entry	Ar 1(a–n)	Compound 4(a–n)	Yield[b]
1	C_6H_5	4a	92
2	4-ClC_6H_4	4b	93
3	4-FC_6H_4	4c	90
4	4-BrC_6H_4	4d	88
5	4-$OMeC_6H_4$	4e	92
6	4-$NO_2C_6H_4$	4f	80
7	2-$NO_2C_6H_4$	4g	75
8	4-OHC_6H_4	4h	78
9	2-Cl, 6-FC_6H_3	4i	78
10	2-ClC_6H_4	4J	86
11	3-ClC_6H_4	4k	88
12	2-FC_6H_4	4l	88
13	4-$CH_3C_6H_4$	4m	84
14	3-$CH_3C_6H_4$	4n	82

[a] Reaction conditions: 1(a–n) substituted benzaldehydes (4.71 mmol), 2 ethyl acetoacetate (9.42 mmol), 3 ammonium acetate (5.66 mmol), and 20% $AlCl_3$@ZnO (1.17 mmol) under solvent-free conditions, room temperature, 2 h. [b] Isolated yield.

turn, attacking enolate to offer more α,β-unsaturated-enone (A). Whereas another equivalent of ethyl acetoacetate may react with ammonia to form 3-aminobut-2-enoate (B). Thus, further intermediates (A) and (B) can be condensed in the presence of a catalyst to form the desired 1,4-dihydropyridine (Fig. 11). Thus, the ZnO material in the presence of $AlCl_3$ can enhance the catalytic activity by providing more catalytically active sites. Hence, the combined effect of $AlCl_3$@ZnO requires a smaller amount of catalyst in the setting of solvent-free conditions at room temperature. The proposed mechanism of reaction is shown in Fig. 11.

3.7.6. Catalyst recyclability. As discussed in the experimental section, chloroform was added to the reaction mass after completion of the reaction. The chloroform layer was separated by a simple filtration technique and pure 1,4-dihydropyridine product was obtained from it. Simultaneously, the residual solid material was washed with chloroform and ethyl alcohol and then subjected to oven drying at 120 °C for 2 h. The recovered catalyst was again reused for the same reaction three times. The results obtained for 1,4-dihydropyridine synthesis by using the reused catalyst are displayed in Table 7.

The loss of 1,4-dihydropyridine product yield after each catalytic cycle is displayed in Table 7. The decrease in yield might be due to some loss of catalyst after each cycle, which may be associated with the amorphous nature of $AlCl_3$. The durability of the proposed catalyst up to the 3rd cycle is quite good.

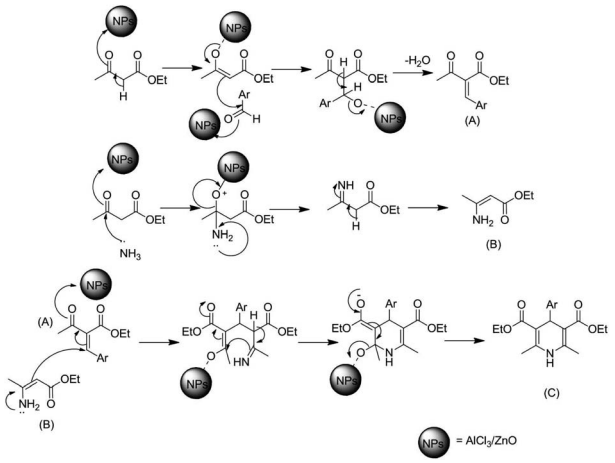


Fig. 11 Proposed mechanism for the synthesis of 1,4-dihydropyridine using $AlCl_3$@ZnO nanocatalyst.

Table 7 Recyclability study of $AlCl_3$@ZnO catalysts[a]

Run	Yield[b] (%)
1	92
2	79
3	62
4	42

[a] Reaction conditions: 1 benzaldehyde (4.71 mmol), 2 ethyl acetoacetate (9.42 mmol), 3 ammonium acetate (5.66 mmol), and 20% $AlCl_3$@ZnO under solvent-free conditions, room temperature, 2 h. [b] Isolated yield.

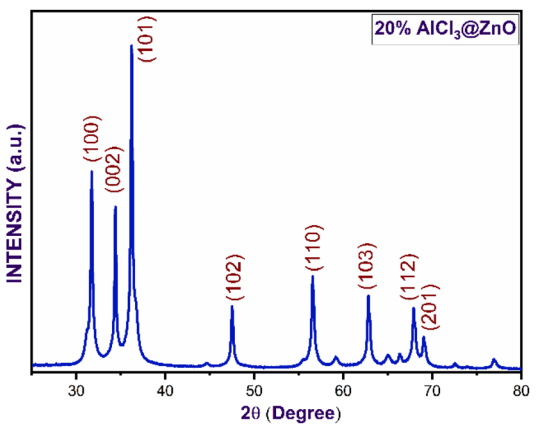


Fig. 12 XRD of recovered 20% $AlCl_3$@ZnO nanocatalyst after 4 h of drying at 120 °C.

However, the activity of the catalyst can be retained by careful washing and drying and maintaining the same reaction time. To check any structural and composition changes in the recovered catalyst, we took XRD of recovered $AlCl_3$@ZnO catalyst materials after 4 h of drying at 120 °C. The XRD of recovered catalyst material fully matches with hexagonal wurtzite phase of ZnO, which is also revealed in the XRD of fresh $AlCl_3$@ZnO catalyst. The particle size of the recovered catalyst was

calculated using Scherrer's equation and was found to be 32.96 nm while it is found to be 33.62 nm for the fresh catalyst (Fig. 12).

4. Conclusion

We successfully accomplished Hantzsch pyridine synthesis using nanocrystalline $AlCl_3$@ZnO nanocatalyst. The reported catalyst is highly efficient, environmentally friendly, and recyclable and could become an alternative to routine homogenous and heterogenous catalytic reactions. The required ZnO nanoparticles were prepared by a simple solution-based precipitation method. Whereas loading of $AlCl_3$ on the ZnO nanocatalyst was carried out by a wet-impregnation technique. The as-synthesized catalyst with an average particle size of 70–80 nm is found to be more effective for the synthesis of dihydropyridine derivatives. The catalyst confers 92% yield for the preparation of 1,4-dihydropyridines under solvent-free and room temperature conditions. The as-synthesized catalyst is stable and easily handled and can be used for scale–up reactions. It is reasonable for us to emphasize that the overall methodology for 1,4-dihydropyridine synthesis is economical and environmentally friendly.

Conflicts of interest

There are no conflicts to declare.

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ANTIMICROBIAL AND ANTIOXIDANT ACTIVITY OF EXTRACTS OF SOURSOP (ANNONA MURICATA L.) LEAVES AND FRUIT PULPS

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ABSTRACT

Annona muricata's role in healthcare has been better understood thanks to recent scientific and technological developments. Acetogenins, coumarins, phenolic acids, alkaloids, and flavonoids are among the phytochemical components. Antioxidants, antimicrobials, anti-diabetes, and a host of other health advantages are provided by the phytochemical composition. The purpose of this research was to detect phenolic and flavonoid phytochemicals in extracts from the leaves and pulp of the Annona muricata plant, as well as to compare and contrast the two components' antioxidant and antimicrobial capabilities. A *Annona muricata* tree was used to harvest the pulp and remove the leaves. The disc diffusion technique was used for antimicrobial testing against S. aureus, and antioxidant assays such as FRAP, DPPH, and TPC were performed. The investigation included samples with concentrations of 25, 50, 100, 200, and 400 µg/ml. The research found that different concentrations of 25µg, 50µ100µg, 200µ, and 400µg of extracts from the leaves and pulp of Annona muricata had a satisfactory level of antioxidants. The antibacterial activity of both extracts is effective at such concentrations, however. When looking at the antioxidant content and sensitivity to microbes in the pulp and leaves extracts, the leaves extract comes out on top.

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INTRODUCTION

Scientists have taken a keen interest in exotic and tropical fruits in the last few years. Additionally, there is a rise in consumer interest in them. The possible medicinal properties of several exotic and tropical plants are the reason for this. [1,2] The Annonacea family includes soursop, graviola, and other members like it (Annona muricata L.). Originally from the hottest parts of North and South America, sour oranges are now a common sight in many tropical and subtropical climates throughout the Americas, Africa, and Asia. The soursop fruits are around 15 to 20 centimeters in diameter. [3,4]

There are 55–170 black seeds encased in green peel in the pulp. Soursop fruit has several by-products, including the inedible peels and seeds, which have not been investigated for their potential medicinal components. Nevertheless, there has been a recent uptick in curiosity in the possible high nutritional and bioactive compound content of fruit and vegetable by-products, including vitamins, dietary fiber, and phenolics. [5,6] There was a time when people thought the exotic fruit waste may be a good source of natural, high-quality food additives. [7]

Aromatic sour sop fruits are versatile in the kitchen. You can make juice, ice cream, or jelly out of pulp, and it's also delicious eaten raw. [8,9] In addition, traditional medicine makes use of other sour-sop elements, such as the leaves, bark, roots, fruit, and seeds, to treat a wide range of illnesses, including malignancies, gastrointestinal issues, inflammation, hypertension, inflammation, diabetes, and inflammatory disorders. Acetogenins, alkaloids, megastigmanes, phenolics, cyclopeptides, and essential oils are some of the phytochemicals that have been linked to the therapeutic and physiological advantages of A. muricata L. [10,11]

Both the leaves and the fruits of soursop contain phytochemicals with antioxidant potential, the most important of which are phenolic compounds. The tannins, phenolic acids (mostly hydroxycinnamic acids), and flavonoids found in A. muricata L. pulp, seeds, and leaves were among these. [12] To get plant extracts containing phenolic chemicals, solvent extractions are often used. The same standard procedures were used on the soursop components as well. When it comes to extraction, the polarity of the solvent is a key aspect. [13,14] Some studies found that the bioactivity of A. muricata extracts varied depending on the solvent used. The majority of phenolic terpenes may be extracted using hexane or petroleum ether. The low-molecular-weight phenolics, such as phenolic acids and flavonoid aglycons, are extracted using ethyl acetate. Hydrogen peroxide, methanol, and ethanol combined with water were able to extract flavonoid glycosides and high-molecular-weight phenolics. [15]

1. RESEARCH METHODOLOGY

- **Chemicals**

Sodium carbonate, glycerol, triethonolamine, paraffin oil, metyl paraban, EDTA, butylated hydroxytoluene (BHT), propyl paraben,

ethanol, 2,2-diphenyl-1-picrylhydrazyl (DPPH), gramme stain safranine, ethanol, Muller Hilton agar, and phthalic acid.

- **The Annona Muricata extract's source**

The powder of Annona Muricata was extracted by using standard method.

- **Discovering flavonoids and phenolics**

A neutral 5% ferric chloride solution was added to the 50 mg extract after diluting it with 5 mL of distilled water. A shade of dark green or blue-green was used to indicate the existence of phenolic chemicals. In a test tube with some magnesium turnings and some test samples, a few drops of hydrochloric acid were introduced. A change from green to red was used to identify flavonoids.

- **The amount of phenolic compounds (TPC)**

A reagent approach developed by Rajkumar et al. Folin-Ciocalteau was used to quantify the total phenolic content (TPC) of the extracts. The following were added to 50 liters of each extract concentration: 25µg/ml, 50µg/ml, 100µg/ml, 200µg/ml, and 400µg/ml. The mixture was then incubated at 45 °C for 30 minutes with 2.5 ml of Folin-Ciocalteau reagent (1/10 dilution) and 2 ml of 7.5 percent Na2CO3 (w/v) solution. Varian, Inc. of California, USA, made the Cary 50 UV-Vis spectrophotometer, which was used to measure the absorbance at 765 nm. Gallic acid equivalent (GAE) in g/ml was the unit of measurement, with gallic acid serving as the reference. Three separate runs of the extraction were carried out. Gallic Acid Equivalent (GAE) was used to determine the phenol concentration.

- **Ferric Ion Reducing Antioxidant Power (FRAP)**

A FRAP reagent was made by combining 200 mL of 300 mM acetate buffer with 20 mL of a solution of 20 mM ferric chloride hexahydrate ($FECl3.6H_20$) in a volumetric ratio of 10:1:1, followed by 20 mL of a solution of 10 mM 2,4,6-tri(2-pyridyl)-s-triazine (TPTZ) dissolved in 40 mM hydrochloric acid (HCL). The FRAP enzyme was produced just before use, heated in a water bath to 37C, and then wrapped in aluminum foil to protect it from light deterioration in the beaker. To make the reaction mixture, combine 0.1 milliliters of pulp and leaves extract (25µ-400µg /ml) with 300µ milliliters of 2% Tween 20 and 3 milliliters of FRAP reagent. Use a sonicator to mix the ingredients while the mixture was in the dark. After 30 minutes of incubation, the reaction mixture was measured in triplicate using a spectrophotometer at 593 nm. The reaction mixtures were compared using ascorbic acid, which ranged from 25µg/ml to 400µg/ml. The standard curve was then produced using ferrous sulphate heptahydrate ($FSO4.7H_2O$) by serial dilution within the range of 0.1 to 2.0 mm. This was done

- **The Method of Disk Diffusion**

The disk diffusion technique, which was slightly modified from the Kirby Bauer method provided by Balouiri et al. (2016), was used to perform the antimicrobial test. The antibacterial properties of several extracts from Annona muricata, including the pulp and leaves, are evaluated using this approach. The antimicrobial investigation was done using concentrations of 100µg and 200µg. The medium utilized for S. aureus is Mueller Hinton agar. The microbial suspensions were made using 0.5 McFarland standard and had a concentration of 1.5 X 108 CFU/ml. Spreading the microbes to be tested across the agar plate surfaces was the process of inoculation. There was an extract-soaked 6-millimeter filter paper disk on top of the agar. After that, the plates were placed in an incubator set at 37 °C for a whole day to enable the bacteria to develop. The negative control group consisted of a 6-mm filter paper disk that included 100µg and 200µg of each extract, along with distilled water. The positive control group employed a conventional antibiotic disc containing Gentamicin. Each step was performed three times.

- **Statistical Analysis**

Triplicates were used for all tests. An analysis of variance (ANOVA) was performed on the collected data. Excel and the Statistical Package for the Social Sciences (SPSS) 20.0 were used. Statistical significance was determined at a p-value less than 0.05, and the data were presented as the Mean ± SEM (Standard error of mean).

2. RESULTS

- **Total Phenolic Content (TPC)**

Table1: The Annona muricata leaf and pulp total phenolic content (TPC) at various concentrations (µg/ml).

Part	Concentrations(µg/ml)	N	TPC value	P value
Pulp	25	3	$0.073 \pm 0.015^{cdegfhij}$	(P<0.05)
	50	3	0.082 ± 0.002^{efghij}	
	100	3	$0.088 \pm 0.002^{aeffghij}$	
	200	3	$0.095 \pm 0.002^{aefghij}$	
	400	3	$0.112 \pm 0.003^{abcdfghij}$	
Leaf	25	3	$0.153 \pm 0.003^{abcdeghij}$	
	50	3	$0.173 \pm 0.006^{abcdefij}$	
	100	3	$0.178 \pm 0.006^{abcdefij}$	
	200	3	$0.235 \pm 0.004^{abcdefghj}$	
	400	3	$0.248 \pm 0.009^{abcdefghi}$	

We used the One-Way ANOVA test. The results are shown as the average amount of gallic acid equivalent (GAE) per gram of dry weight sample (DW), with the standard deviation (SD) of three separate samples. Post hoc Tukey's test is being used to compare means among concentration groups. P < 0.05 was used to establish statistical significance:

a: Divergence with pulp part concentrations of 25 µg/ml that is statistically significant b: Divergence with pulp part

concentrations of 50 µg/ml that is also statistically significant section c: Distinct dissimilarity at 100 µg/ml pulp concentrations Section d: Distinct variation at pulp values of 200 µg/ml Part e: Distinct observed variation at pulp values of 400 µg/ml Section f: At pulp concentrations of 25 µg/ml, g: there is a statistically significant difference. part
There is a noticeable disparity when using 50 µg/ml of the leaf extract. Section h: Distinct variation at 100 µg/ml of the leaf with respect to statistical significance Part i: A statistically significant variation was seen with 200 µg/ml of the leaf There is a notable disparity at doses of 400 µg/ml of leave with respect to art j. Part
The relationship between sample concentration and total phenolic content shows a rising trend. A higher TPC value is indicative of a more concentrated sample. This is backed by many studies that used different plant extracts and found similar results." The results shown in Table indicate that the TPC value is 0.248µg/ml at a concentration of 400µg/ml of leaf extract and 0.113µg/ml of pulp extract, respectively. That leaves extract has a greater TPC value than pulp extract at a given concentration is shown here. According to a research that was carried out by, the TPC value of methanolic pulp extraction was 10.92 µg/ml, lending credence to this discovery. On the other hand, a TPC value of 19.84µg/ml is produced by the methanolic leaves extract. In each given research, TPC values could vary due to a wide variety of causes. Plant, method, and standard variations in TPC expression; non-phenol specificity of the Folin-Ciocalteu reagent color assay; and the possibility that additional components, including ascorbic acid, react with the reagent all have a role in the observed variation in TPC levels. The extraction solvent also has a significant role in determining the TPC value in a given investigation. Extraction yields of total soluble solids and total extractable polyphenolics from plant extracts were shown to rise with increasing solvent polarity, according to several research. Methanol is supposedly the most effective solvent for plant extraction, according to a recent research. "Since methanol is more easily evaporated than water and may inhibit the polyphenol oxidase process, which oxidizes phenolics, it is believed to be the best solvent for extracting phenolic compounds.

A. 2,2-diphenyl -1-picrylhydrazyl (DPPH)

The results of the one way ANOVA test were entered as a (P <0.005). Based on this number, it may be inferred that pulp extract, leaf extract, and ascorbic acid have significantly distinct scavenging activities.

Table 2: displays the findings of the DPPH scavenging activity of the various Annona muricata extracts and the ascorbic acid positive control.

Parts	Concentratio n (µg/ml)	n	%DPPH scavenging	P value
Leaf	25	3	$16.09 \pm 4.72^{bcdeghijklmno}$	(P<0.005)
	50		$27.27 \pm 1.43^{adefhijlmno}$	
	100		$38.72 \pm 3.48^{abdefgijlmno}$	
	200		$50.04 \pm 1.35^{abcfgijkno}$	
	400		$60.37 \pm 4.87^{abcdfghiklno}$	
Pulp	25	3	$15.13 \pm 2.07^{bcdeghijklmno}$	
	50		$25.09 \pm 1.76^{adefhijlmno}$	
	100		$32.79 \pm 1.44^{adefijlmno}$	
	200		$48.66 \pm 3.32^{abcfghjkno}$	
	400		$55.95 \pm 4.22^{abcfghkno}$	
Ascorbic Acid	25	3	$30.73 \pm 2.06^{adefijlmno}$	
	50		$49.75 \pm 1.21^{abcfghjkno}$	
	100		$55.43 \pm 0.74^{abcfghkno}$	
	200		$75.88 \pm 1.77^{abcdefghijklmo}$	
	400		$84.94 \pm 1.39^{abcdefghijklmn}$	

a: Divergence with pulp part concentrations of 25 µg/ml that is statistically significant b: Divergence with pulp part concentrations of 50 µg/ml that is also statistically significant section c: Distinct dissimilarity at 100 µg/ml pulp concentrations Section d: Distinct variation at pulp values of 200 µg/ml Part e: Distinct observed variation at pulp values of 400 µg/ml The data shows a statistically significant variation when the concentration of leaves is 25 µg/ml. section g: A statistically significant variation was observed when using 50 µg/ml of residual Section h: Distinct variation at 100 µg/ml of the leaf with respect to statistical significance Part i: A statistically significant variation was seen with 200 µg/ml of the leaf Statistically significant variation was

seen with 400 µg/ml of the leaf extract in part j. Section k: Variation with 25 µg/ml of Ascorbic Acid shows a statistically significant difference. Part l: Variation with 50 µg/ml of Ascorbic Acid shows a statistically significant difference. Part m: Variation with 100 µg/ml of Ascorbic Acid shows a statistically significant difference. Part n: Variation with 200 µg/ml of Ascorbic Acid shows a statistically significant difference. Part 0: Variation with 400 µg/ml of Ascorbic Acid is not significantly different from Part k.

The percentage of free radical scavenging activity was estimated for Annona muricata leaf, pulp, and ascorbic acid, the reference standard. The graph was constructed using the non-linear equations y=10.861x+6.855 (R^2 =0.9957), y = 10.521x+3.961 (R^2 =0.9028), and y = 13.399x+19.023 (R□ =0.9778).Next, we calculated the effective concentration of each sample required to scavenge the DPPH radical by 50% by determining the IC50 values." The IC50 values are 2.31µg/ml, 3.97µg/ml, and 4.38µg/ml, respectively, as determined by the linear equation of the graphs of ascorbic acid, leaves extract, and pulp extract. Compared to pulp extract, which had an IC50 value of 4.38µg/ml, leaf extract demonstrated superior antioxidant activity with an IC50 value of 3.97µg/ml. Several research have found the same thing.

Acetogenins, a crucial secondary metabolite and the principal bioactive component of the Annonaceae family, are more abundant in the leaf section. An increase in antioxidant activity is likely due to the increased concentration of acetogenins in leaf extracts compared to pulp extracts. Factors such as the method of cultivation used to extract the fruit or plant components also affect the antioxidant content of the final product. The greatest concentration of phenolic chemicals in plant aerial parts is a hallmark of ontogenesis, according to a research. Newly developed plants and their components, as well as those that are developing quickly, have the highest levels of antioxidants.

When compared to leaves that were one or two months old, those that were six months old had significantly lower antioxidant levels. The DPPH assay's ability to measure antioxidant activity is sensitive to a number of variables, such as the compounds' chemical structures, the solvent's properties, the temperature, the pH, and the reactivity of free radicals. "A further drawback of the DPPH test is that it is susceptible to reacting with other radicals present in the substances. Therefore, the rate of change in the amount of antioxidants needed to achieve stability does not follow a straight line.

- **Ferric Ion Reducing Antioxidant Power (FRAP)**

Upon completion of the one-way ANOVA test, a value of (P<0.005) was noted. According to this number, the two kinds of extract have significantly different antioxidant levels. Table shows the results of FRAP assay of the differentextracted parts of *Annona muricata* which is the pulp and leave extract

Table 3: Findings of FRAP assay

Parts	Concentrations(µg/ml)	N	FRAP value (Mm Fe2+/g)	P value
Leave	25	3	0.56 ± 0.25^{cdefghij}	(P<0.05)
	50	3	0.64 ± 0.73^{defghij}	
	100	3	0.76 ± 0.03^{adeghij}	
	200	3	0.95 ± 0.04^{abcefj}	
	400	3	1.15 ± 0.12^{abcdfgh}	
Pulp	25	3	0.19 ± 0.70^{abdeij}	
	50	3	0.28 ± 0.72^{abceij}	
	100	3	0.43 ± 0.62^{abcej}	
	200	3	0.77 ± 0.98^{abcfgj}	
	400	3	1.04 ± 0.58^{abcdfghi}	

We used the One-Way ANOVA test. The FRAP value (Mm Fe2+/g) and the Mean ± Standard deviation (SD) of three replicate samples are used to display the data.

Post hoc Tukey's test is being used to compare means among concentration groups. P < 0.05 was used to establish statistical significance:

A statistically significant variation was seen with 25 µg/ml of the leaf extract. section b: difference with doses of 50 µg/ml of drop portion c: Distinct variation at doses of 100 µg/ml of the Section d: Distinct statistically different results with 200 µg/ml of the leaf Section e: Distinct variation according to doses of 400 µg/ml of mustard Section f: At pulp concentrations of 25 µg/ml, there is a statistically significant difference. section g: Pulp values of 50 µg/ml showed a statistically significant difference. Part h: A discernible variation at pulp values of 100 µg/ml Section I: A statistically significant variation was seen when pulp contents were 200 µg/ml. Part j: A statistically significant variation was seen when pulp contents were 400 µg/ml. Part

The Frap value is shown as a function of the concentration of the Annona muricata pulp and leaves extract, with values ranging from 25g to 400g. The pattern of a rising FRAP value with increasing sample concentration is clearly seen." Both the pulp and the leaves exhibit this pattern. However, at a certain concentration, the FRAP value of the pulp extract differs from that of the leaf extract. Take the FRAP values of 0.635±0.730 and 0.52±0.414 for the leaf extract and 0.289±0.728 and 0.769±0.975, respectively, for the pulp extract, at concentrations of 50µg and 200µg, as an example.

Leaves have an IC50 of 230µg/ml and pulp has an IC50 of 327µg/ml. As the computed IC50 values supported, this showed that the leaf extract had a greater antioxidant content than the pulp extract. For the leaves extract, the IC50 value was determined to be 230µg/ml, but for the pulp extract, it was

327µg/ml. Previous research, such as that, which found that leaf extracts from different solvents had a greater antioxidant content than pulp, lends credence to the current findings. The leaves of the Annona muricata plant are thought to have a greater concentration of antioxidant-rich secondary metabolites such flavonoids, alkaloids, and phenolics.

The findings of the total phenolics content, which were previously addressed, provide support for this. Another factor contributing to the decreased antioxidant content of pulp extract is the inherent fragility of the pulp itself when it is extracted. Some extraction procedures, such as a longer drying time for pulp than for seed and leaves, may reduce the concentration of secondary metabolites. Among the many benefits of the FRAP test is its suitability for assessing the antioxidant activity of various plant extracts; the approach is both easy to use and affordable, and it does not call for any specific reagents. There are certain downsides to the FRAP test, despite its usefulness. The FRAP assay is a timed-based analytical test that requires additional effort and time to prepare the chemicals for the working solution.

- **Antioxidant activity and total phenolic content correlation**

It has long been known that the chemical components of a medicinal plant's beneficial effects are its secondary metabolites. Because of their capacity to contribute hydrogen atoms to free radicals, phenolic compounds are crucial antioxidant components that deactivate free radicals. The structural features of phenols make them excellent free radical scavengers as well. The phenolic content of the extracts and the antioxidant properties assessed by various Annona muricata parts were connected via the use of Pearson's correlation coefficient.

Antioxidant capacity is linearly related to total phenolic content, according to several publications in the literature.The findings from this investigation demonstrated a positive association between total phenolics and antioxidant activities, with correlation coefficients ranging from R2 0.947 to 0.966, N=15 $p<0.001$: this correlation is significant at the 0.01 level (2 tailed). All of the data points from the various assays pointed to the same general pattern of activity. "The total phenolic content of the pulp and leaf extract are positively associated according to the FRAP test, with R2 coefficient values of 0.966 and 0.949, respectively. There was a robust positive correlation (R2) of 0.947 and 0.934 between the total phenolic content of pulp and leaf extract and the DPPH test. The scavenging and ferrous reduction of pulp and leaf extracts may be associated with the presence of phenolic hydroxyl groups in phenolic substances.

Table 4: Antioxidant activity and total phenolic content correlation.

Types of extract / Correlation Variable	Pulp extract	Leave extract
TPC value (µg/ml GAE) and DPPH scavenging activity (%)	0.947	0.934
TPC value (µg/ml GAE) and FRAP value Mm (Fe^{2+}/g)	0.966	0.949

- **A disk diffusion test for microbiological agents**

Anti-S. aureus activity of Annona muricata leaf extract

Table 5: Antimicrobial activity of different quantities of pulp extract from Annona muricata, using both positive and negative controls, against a set of chosen microorganisms, mean ± standard deviation

Microorganism	Zone of inhibition (mm)			
	Concentration		Positive control	Negative control
Gram Positive	200µg/ ml	400µg/ ml		
S.aureus	8.03 ± 0.20^{bcd}	8.73 ± 0.32^{acd}	36.00^{abc} ±0.00	6.00 ± 0.00^{abd}

compared to a 200µg/mL leaf extract, there is a statistically significant difference ($p<0.05$). was shown to be statistically significant ($p<0.05$) when contrasted with a 400 µg/mL extract of leaves. The difference is statistically significant ($p<0.05$) when contrasted with the negative control. As compared to the positive control group, it is statistically significant ($p<0.05$).

Table 6: Anti-S. aureus activity of Annona muricata pulp extract

Microorganism	Zone of inhibition (mm)			
	Concentration		Positivecontrol	Negative control
Gram Positive	200µg/ ml	400µg/m l		
S.aureus	6.00 ± 0.00^{bd}	6.23 ± 0.15^{acd}	36.00^{abd} ±0.00	6.00 ± 0.00^{bd}

This is significantly different from the pulp extract at a concentration of 200µg/mL ($p<0.05$). when contrasted with a pulp extract of 400 µg/mL ($p<0.05$), was shown to be statistically significant. The difference is statistically significant ($p<0.05$) when contrasted with the negative control. As compared to the positive control group, it is statistically significant ($p<0.05$).

The antimicrobial test showed an average zone of inhibition of 6.00±0.00 for a concentration of 100µg of pulp extract and 6.23±0.15 for a concentration of 200µg. On the other hand, results of 8.03±0.20 and 8.73±0.32 were observed in the leaves extract when the concentrations were kept constant. The reported zone of inhibition falls within the low inhibition range of 7–10 mm, according to the research. Inhibition ranges of 11 mm and above indicate strong antimicrobial activity. Both components of the study's low zone of inhibition are somewhat distinct from one another." The absence of inhibition at concentrations of 200µg/ml and 400µg/ml in the low-level zone of inhibition suggested that

the pulp and leaf extract of Annona muricata could not hinder the development of S. aureus. However, there are studies that back up the conclusion, so it's not all bad news.

Even with different doses of 5mg/ml, 10mg/ml, and 50mg/ml of extracts from the same sections, the article demonstrates the low-level inhibitory zone. But according to the same study, the zone of inhibition doesn't begin to grow until concentrations of 150 mg/ml and higher are reached. This demonstrates that antibacterial activity against S. aureus bacteria is not shown at low concentrations of Annona muricata, but is seen at high concentrations above 150 mg/ml. The solvent used to extract the material is one of the variables that affects the inhibition strength.

Research from also indicates that whilst 300 mg/ml of hot distilled water has a significant zone of inhibition, 300 mg/ml of n-hexane extraction has a low one. From this, we might infer that the antimicrobial capabilities of certain extraction solvents are dependent on the inhibitory consequences they produce. According to this research, the antibacterial activity of the leaf extract is greater than that of the pulp extract. Observing the world via the zone of inhibition verifies this claim. The average zone of inhibition for pulp extract at 400µg/ml is 6.23±0.15, but for leaves extract it is 8.73±0.32.

Perhaps the increased concentration of secondary metabolites in the leaf extract explains why it has different antibacterial action from the pulp extract. It is said that the leaf portion contains more flavonoids than the pulp, a secondary metabolite. According to research, flavonoids are the primary metabolites with antibacterial effects against a wide variety of microbes, including S. aureus.

CONCLUSION

The TPC, FRAP, and DPPH assays demonstrated the antioxidant capabilities of an ethanolic extract of Annona muricata pulp and leaves. In addition to exhibiting strong radical scavenging action, the plant extracts also had a high total phenolic content. Hydroxyl groups in the chemical structure of the phenolic molecule may provide the necessary component as a radical scavenger and antioxidant, which may explain the strong scavenging activity of some Annona muricata components. But alkaloids, saponins, tannins, and flavonoids aren't the only phytochemicals that may be boosting the plant's antioxidant activity. Using the TPC, FRAP, and DPPH assays, this research also demonstrated that the methanolic pulp extract had lower antioxidant activity than the methanolic leaves extract. Reason being, leaves are more amenable to the intense extraction methods and have a greater concentration of phytochemicals. At lower doses of 200µg/ml and 400µg/ml, the methanolic extract of Annona muricata leaves and pulp inhibit the growth of Stephylococcus aureus. However, as previously mentioned, inhibition begins to manifest at concentrations greater than 150mg/ml.

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Biosynthesis of Nanoparticles Using Fungi and Their Effect on Plant Pathogenic Microorganisms.

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ABSTRACT

In the domain of nanotechnology, there has been a great deal of spotlight put on the utilization of different organic units as an option in contrast to the use of hurtful synthetics to lessen and balancing out nanoparticles. The physiologically dynamic mixtures that come from parasite and yeast are incredible frameworks for this reason, and they are just a single illustration of the various practical bio assets. Because of the way that parasite and yeast are especially productive secretors of extracellular chemicals and that different species may quickly duplicate, it is exceptionally simple to culture and keep up with these organic entities in the lab. They can make metal nanoparticles and nanostructures by utilizing lessening proteins either inside the cell or beyond the cell. The utilization of yeast and parasite in the development of harmless to the ecosystem inorganic nanoparticles will be the essential accentuation of this survey. In the in the meantime, the field of biosynthesized nanoparticles is somewhat new; the article surveys the exceptional uses of nanomedicine in different fields, like the vehicle of medications, malignant growth therapy, antimicrobial, biosensors, and X-ray and clinical imaging.

Keywords: Nanoparticle; Fungi; Yeast; Apoptosis; Anti-Angiogenesis

I. INTRODUCTION

Nanotechnology is an arising science that can possibly influence each aspect of human life [1,2]. Because of the way that nanoparticles (NPs) are utilized in a large number of fields, including "nanomedicine," a lot of consideration is dedicated to them in this area [3]. Natural nanoparticles and inorganic nanoparticles are the two general classifications that might be utilized to order nanoparticles. While natural nanoparticles are comprised of carbon nanoparticles, numerous inorganic nanoparticles are comprised of attractive nanoparticles, nanoparticles of respectable metals (like gold and silver), and semi-conduit nanoparticles. Natural nanoparticles are comprised of carbon nanoparticles (like titanium oxide and zinc

oxide). Inorganic nanoparticles have as of late found applications as impetuses [4, 5], semiconductors [5, 6], optical gadgets, biosensors [6, 7], epitome of medications [8, 9], and contrast specialists [10, 10], to give some examples; subsequently, the development of inorganic nanoparticles has gathered a lot of consideration. Moreover, there is a developing interest in the creation of inorganic biomass nanoparticles, in particular respectable metal nanoparticles (like gold and silver), since these nanoparticles take special care of better-quality material characteristics while additionally giving utilitarian adaptability.

Nanoparticles made of metal are presently remembered to be the main bioactive fixings. During the time spent combining the nanoparticles, the components silver, aluminum, gold, zinc, carbon, titanium, palladium, iron, fullerenes, and copper have been utilized on a reliable premise. In the sixteenth hundred years, the Au-NPs were used for different purposes, including medication and coloring [7]. Thus, there is a huge requirement for the improvement of environmentally cordial cycles, like green combination and extra natural methodologies. Photolithography [8, electron, particle pillar lithography [9], plunge pen lithography [10], miniature contact printing, electrochemical blend, and nano engrave lithography are viewed as new strategies for accomplishing such sole calculations in nanomaterials. Various researchers have fostered different synthetic and actual techniques to accomplish such calculations, which can be used in various applications. Using the actual method [11] will permit one to understand the ideal calculations. The decrease of metal particles to metal molecules is the most vital phase in the synthetic cycles, which are then trailed by the directed gathering of iotas [12].

The heft of the compound and actual cycles that are utilized in the creation of nanoparticles are somewhat expensive. Moreover, it utilizes harmful and risky substances, which are the underlying driver of different organic risks (Figure 1). In light of this issue, it is considerably more vital to make harmless to the ecosystem processes utilizing green blend and other extra organic methodologies. In this article, we give an outline of the ongoing review that has been directed generally on the ramifications of microorganisms, for example, yeast and growths in the biosynthesis of inorganic nanoparticles, as well as their proposed flagging pathways and utilizations. This study has been happening for a long while.

II. BIOLOGICAL SYNTHESIS OF NANOPARTICLES

Scientists have been involving extricates from living things as a beginning stage for the production of metallic nanoparticles. They utilized direct strategies, like the methods for diminishing the metal particles, in their work. To do this, they utilized biomass removes as an establishment for either extracellular or intracellular reductants.

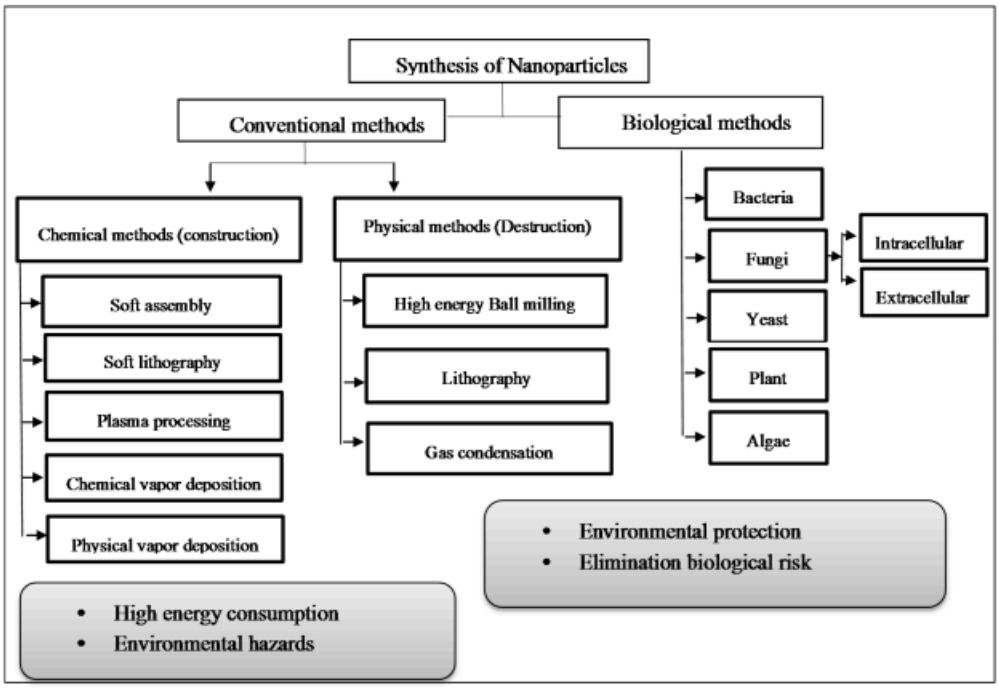

Fig. 1. Different synthetic approaches of metallic nanoparticles

Union of nanoparticles might be brought about by various atoms, like carbonyl gatherings, terpenoids, phenolic, flavones, amines, amides, proteins, shades, alkaloids, and extra factors that are available in plant extricates and microbial cells [13]. These particles incorporate flavones, amines, amides, proteins, colors, and alkaloids. Using biosynthesis to its maximum capacity is one approach to effectively produce more moment particles on a wide scale [14]. It is essential to bring up that organically created NPs have upgraded consistency [15], and they have further developed morphological control [16].

III. BIOSYNTHESIS OF NANOPARTICLES BY MICROORGANISMS

Microorganisms like microbes, cyanobacteria, actinomycetes, yeast, and parasites are referred to deliver inorganic nanoparticles like gold, silver, calcium, silicon, iron, gypsum, and lead. This is a reality that has been laid out. They produce nanoparticles because of the innate potential that they have, and these nanoparticles may exist either intracellularly or extracellularly [17]. It is hard to recuperate the nanoparticles that are made by intracellular biosynthesis attributable to the extra handling stages that should be finished, for example, ultra-sonication and treatment with the suitable cleansers [18]. As an outcome of this, it is expected to lead a screening of the microorganisms that outcome in the extracellular creation of nanoparticles [19,20]. Right now, microbiological strategies for the production of nanomaterials of variable mixtures are as a rule restricted to metals, a couple of metal sulfides, and just a tiny measure of oxides. All of them is limited to the microorganisms that start from the beginning. The organic blend of nanoparticles by means of the double-dealing of still up in the air by

the way of life conditions; subsequently, it is expected to normalize these boundaries to create nanoparticles on a wide scale. It is realized that various sorts of microorganisms are equipped for delivering metallic nanoparticles with attributes that are like those of nanomaterials that are made through substance union [21], in spite of the way that the structure, size, and mix of the particles are exposed to rigid assessment. It is accepted that the hydrolytic action of the microorganisms would consider the arrangement of metal oxides of extra components too. All in all, the creation of nano-sized materials by microorganisms is conceivable in conditions with tensions and temperatures that are humble. Likewise, the utilization of a microbiological method for the combination of nanomaterials isn't just minimal expense yet in addition undemanding, viable, proficient, and helpful to the protection of energy and the common habitat [22].

IV. BIOSYNTHESIS OF NANOPARTICLES BY FUNGI

Parasites are known as eukaryotic creatures that live in different normal territories and frequently structure decomposer organic entities. Organisms might be tracked down in pretty much every climate. About 70,000 of the 1.5 million types of organism that are remembered to exist on Earth have been recognized up to this point. As per gauges in view of additional ongoing information, there are around 5.1 million different growth species on the planet [23]. This gauge was gotten from high-throughput sequencing innovations. It is critical to take note of that these creatures can process extracellular food, discharge explicit compounds to hydrolyze confounded pieces into less difficult particles, which can then be ingested and utilized as a wellspring of energy [23]. Furthermore, it is vital to take note of that these organic entities can deliver explicit catalysts. Growths are remembered to have significant ramifications for nanobiotechnology, subsequently examination into such ramifications is vital. In this regard, parasites have acquired expanding interest in regards to the concentrate on the organic age of metallic nanoparticles [24]. This is reasonable attributable to the way that parasite can endure metals and furthermore can possibly bioaccumulate metals. Using organism in nanoparticle blend has various advantages, one of which is the comfort of increasing creation (e.g., using a dainty strong substrate maturation procedure). Because of the way that organisms are especially productive secretors of extracellular proteins, it is feasible to accomplish gigantic result levels of catalysts [25]. One more benefit of utilizing a green strategy that is intervened by parasitic cycles to create metallic nanoparticles is that it is monetarily practical and simple to involve biomass as a natural substance. Moreover, there are various species that have a fast pace of development, making it very simple to culture them and keep up with them in the research facility [26]. Most of contagious species have the abilities of high wall-restricting and intracellular metal assimilation [27]. Parasites have the ability to fabricate metal nanoparticles/meso and

nanostructures by utilizing decreasing proteins either intracellularly or extracellularly and the course of biomimetic mineralization (Figure 2) [22,23].

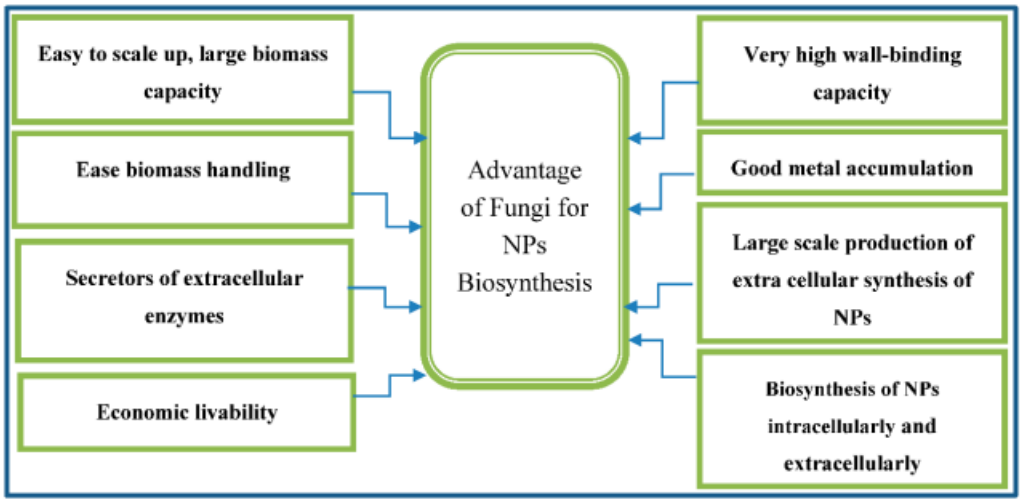

Fig. 2. Fungi have some distinct advantages when used as bio factories for NP production

The examination of parasitic species is a moderately ongoing improvement inside the domain of nanotechnology. The development of extracellular silver nanoparticles by the filamentous organism Verticillium sp. was the subject of one of the primary investigations on the biosynthesis of metallic NPs through parasites [28]. To achieve this objective, the filamentous organism Fusarium oxysporum has been one of the parasitic animal groups found for use in NP union that has seen the most broad use.

Despite the fact that the biomass is frequently presented to metallic particle arrangements, most of the time the development of extracellular NPs is reviewed and distributed [29]. Notwithstanding the amalgamation of PbS, ZnS, and MoS2 NPs, the principal used organism is portrayed as individual Albums NPs. The presence of proteins in the fluid arrangement give some insight that highlighted the chance of a sulfate-diminishing chemical based process being utilized in the production of NPs. A similar parasite was utilized, and the outcome was the creation of silver nanoparticles that arose freely. They are likewise ready to emerge by means of the course of assortment, displaying very factor structure and going in size from 5 to 50 nm [22]. Moreover, the consequences of another review showed that circular silver NPs with a size scope of 20-50 nm were created through the use of F. oxysporum [23]. While looking at the consequences of the two examinations referenced [22,23], the disparity in morphology and estimate could be ascribed to varieties in the temperature that was utilized, in spite of the fact that it gave the idea that the size of NPs didn't rely upon time [40]. Despite the way that NPs with a semi round shape are the ones that grow most normally, it is feasible to deliver NPs with different morphologies by changing the metallic particle arrangement and the brooding circumstances. It has

been shown that F. oxysporum might be utilized to effectively incorporate NPs containing different metals [23]. It has been noticed that extracellular creation might take on various different structures and can fluctuate in size from tiny to extremely huge. It has been shown that a NADH-based reductase and a van Quinone extracellular cycle are liable for the decrease in how much metal particles brought about by this growth [28].

In spite of the utilization of various contagious species, a few NPs are delivered under conditions that are generally indistinguishable from those of the examination. For example, despite the fact that particles acquired from Verticillium sp. shown cubo-octahedral calculations with a size scope of 100 to 400 nm magnetite, NPs produced by F. oxysporum had an unpredictable structure displaying a total semi round morphology and ran in size from 20-50 nm [29]. As a result of this, the sort and buildup of the biomolecules that are created by every types of growth, as well as the different hatching conditions, forerunner goals, and reaction times, all add to the kind of NPs. Huge accomplishments were accomplished in the development of metallic NPs by the utilization of the parasite Rhizopus oryzae. By involving parasitic concentrate as such, it was feasible to apply command over the type of gold nanoparticles while keeping the temperature at room temperature. Along these lines, NPs were fabricated by adjusting essential development factors like the convergence of gold particles in the arrangement, the pH of the arrangement, and the reaction time [30, 31]. The main disadvantage related with the utilization of this living being in the development of NP is the likelihood that it would cause ailment in individuals. A few papers examine the potential utilizations of NPs that are created by parasitic societies; most of these exploration assess the impacts of the NPs on organic frameworks. What's more, the discoveries exhibited that the utilization of silver nanoparticles, either all alone or in mix with anti-toxins, was fruitful in restraining microorganisms, for example, microbes and parasite [32]. The adequacy of delivered silver NPs as an antibacterial specialist against bacterial microorganisms [70,84] and parasitic microbes [84] was explored and affirmed by the work of contagious species. Be that as it may, the nano gold-bio form delivered with the utilization of R. oryzae introduced high antimicrobial action against pathogenic microbes like P. aeruginosa, E. coli, B. subtilis, S. aureus, Salmonella sp., and the yeasts S. cerevisiae and C. albicans [33]. Other metallic NPs framed by using organisms as diminishing specialists are less assessed than different NPs. As of late, it has been shown that the antimicrobial movement of parasite mediated creation of TiO2 NPs might be a clever sort of antibacterial material [34].

V. BIOMEDICAL APPLICATIONS OF GREEN SYNTHESIS NANOPARTICLES

The investigation of various organism species is a somewhat ongoing part of nanotechnology's NP processes. One of the initial examinations into the

assembling of metallic NPs through organisms shows the development of silver NPs extracellularly by the filamentous parasite Verticillium sp. [28], which was one of the principal organisms explored. To achieve this goal, the filamentous growth Fusarium oxysporum has been one of the parasitic animal groups most frequently taken advantage of for NP creation.

The formation of extracellular NPs has been displayed in most of examples, notwithstanding the way that biomass is frequently presented to metallic particle arrangements [29]. Notwithstanding the union of PbS, ZnS, and MoS2 NPs, the principal used parasite has been portrayed as individual Albums NPs. Because of the presence of proteins in the fluid arrangement, it was guessed that a potential sulfate-diminishing chemical based approach might be utilized in the production of NPs. Utilizing a similar sort of parasite, it was feasible to deliver silver nanoparticles that emerged all alone. They are likewise ready to emerge during the course of assortment, and their size might fluctuate somewhere in the range of 5 to 50 nm [22]. Their structure is very factor. Likewise, the consequences of another review showed that circular silver NPs with a size scope of 20-50 nm were created through the use of F. oxysporum [23]. While contrasting the aftereffects of the two examinations referenced [22,23], the disparity in morphology and estimate could be credited to varieties in the temperature that was utilized, regardless of the way that it created the impression that the size of the NPs didn't rely upon time [40]. Disregarding the way that semi round nanoparticles are the ones that will quite often create the most usually, one might get different morphologies by changing the metallic particle arrangement and the hatching conditions. The amalgamation of NPs containing different metals has been done [23] utilizing F. oxysporum as the beginning material. In each example, extracellular creation was portrayed as having various different size ranges notwithstanding different morphologies. This parasite has been connected to a NADH-based reductase as well as a van Quinone extracellular cycle [28], which has been displayed to diminish how much metal particles in the climate.

Similar exploratory circumstances lead to the development of a wide assortment of NPs, notwithstanding the way that few types of parasites are utilized. For example, though particles got from Verticillium sp. shown cubo-octahedral calculations with a size scope of 100 to 400 nm magnetite, NPs created by F. oxysporum had an unpredictable structure uncovering a total semi circular morphology and went in size from 20-50 nm [29]. As a result of this, the sort and buildup of the biomolecules created by every types of organism, as well as the different hatching conditions, forerunner goals utilized, and reaction times, all add to the kind of NPs. Critical accomplishments were achieved during the time spent assembling metallic NPs by utilizing the parasite Rhizopus oryzae. The utilization of contagious concentrate made it conceivable to apply command over the type of gold

nanoparticles in any event, when the temperature was kept steady. Thus, nanoparticles were fabricated by adjusting essential development factors like the centralization of gold particles in the arrangement, the pH of the arrangement, and the reaction time [30, 31]. The main disadvantage related with the utilization of this creature for the development of NP is the likelihood that it might cause disease in individuals. The expected utilization of NPs produced by parasitic societies has been reported in a couple of articles; most of these exploration have assessed the impact that these NPs have on organic frameworks. What's more, the discoveries showed that the utilization of silver nanoparticles, either without help from anyone else or related to anti-infection agents, had the option to effectively smother microorganisms, for example, microbes and growth [32]. Microbes [70,84] and parasitic microorganisms [84] were tried for their defenselessness to the antibacterial impacts of silver nanoparticles that were delivered utilizing contagious species. Nonetheless, the nano gold-bio form delivered with the utilization of R. oryzae introduced high antimicrobial movement against pathogenic microorganisms like P. aeruginosa, E. coli, B. subtilis, S. aureus, Salmonella sp., and the yeasts S. cerevisiae and C. albicans [33]. Other metallic NPs that are shaped by involving parasites as diminishing specialists are less assessed than different NPs. Lately, it has been shown that antimicrobial movement of parasite mediated creation of TiO2 NPs might be an original antibacterial material [34].

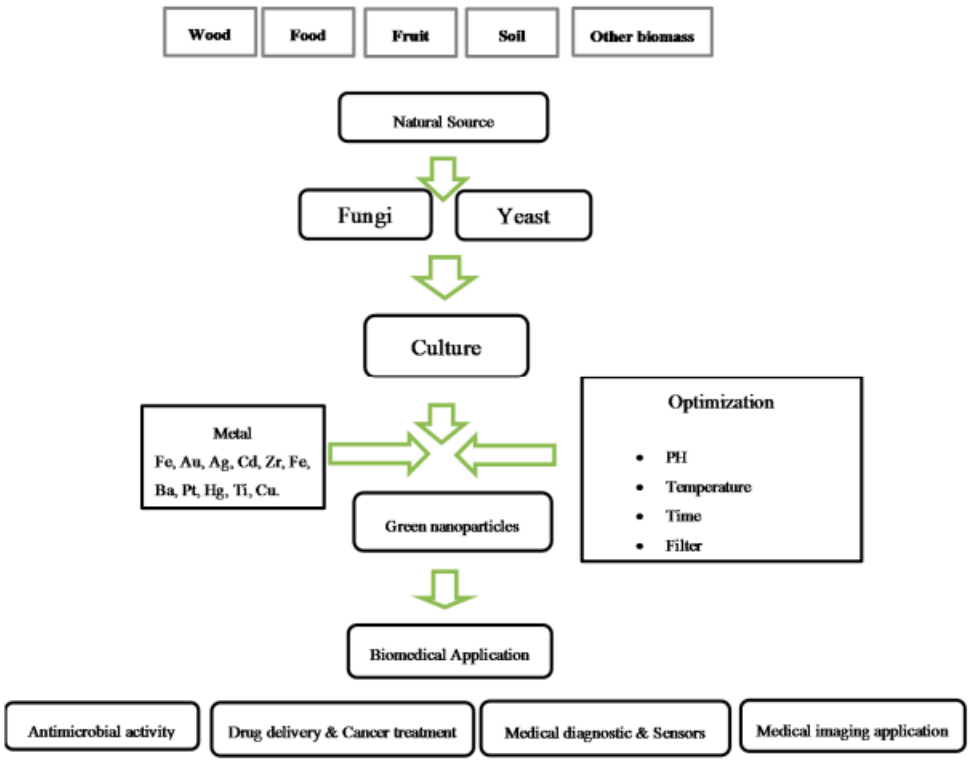

Fig. 3. Biomedical applications of metallic nanoparticles synthesis by fungi and yeast

A. Drug Delivery

With regards to making and creating novel medication conveyance frameworks, one of the essential worries that should be addressed is the means by which to precisely and securely transport prescriptions to the areas and times that are expected for them. The purposes behind this are to have a managed discharge and to have the most potential helpful remedial impact. Focused on nano transports need to explore the boundaries that circulatory tissue presents before they can arrive at their objective cells [40]. Moreover, for designated nano transporters to arrive at their expected cells, they need to connect with cytoplasmic focuses through unambiguous endocytotic and transcytotic move processes that permit them to explore over cell boundaries [41]. To start, the minor size of the Ag-NPs drug carriers permits them to bypass the blood-cerebrum boundary as well as the tight epithelial joints of the skin, the two of which regularly go about as hindrances to the conveyance of prescriptions to the area to which they are expected. Second, nano transports have been displayed to further develop pharmacokinetics and the biodistribution of restorative variables. Subsequently, they can lessen how much toxin that is consumed by the body because of their favored assembling at the designated area [42]. This is made conceivable by their raised surface region to volume proportion. It is well information that attractive nanoparticles, like magnetite (Fe3O4) and maghemite (Fe2O3), are viable with organic frameworks. They have been the subject of much examination for various purposes, including X-ray, quality treatment, the therapy of disease with attractive hyperthermia, the grouping and control of undeveloped cells, prepared medicine conveyance, quality treatment, and the investigation of DNA [43]. It has been found that gold nanoparticles may act as potential platforms for the vehicle of medications and qualities, and that these frameworks play a free capability to more customary conveyance vehicles [44]. The mix of low-intrinsic harmfulness, high-surface part, dependability, and the capability of tunability might lead to novel conveyance techniques that have recognizing properties. These techniques can likewise be made more steady by the job of tunability. There has been research finished in the past on the biomedical purposes of synthetically combined Au-NPs; be that as it may, as far as we could possibly know, there have been no distributions on the utilization of biosynthesized Au-NPs for the conveyance of medications [45]. Silver nanoparticles have tracked down far reaching use as clever restorative components, and their purposes have been extended to incorporate antibacterial, antifungal, antiviral, and calming applications. Bacillus licheniformis is answerable for creating silver nanoparticles that can repress the development of fresh blood vessels.

B. Anticancer NPs

Cytotoxicology concentrates on led on an assortment of malignant growth cell lines have been portrayed as a feature of the examination into biosynthesized

nanoparticles. Amarnath et al. [46] uncovered the aftereffects of specific examinations in which made Au-NPs were joined with normally happening phytochemicals tracked down in grapes (Vitis vinifera). These Au-NPs had an extensive likeness to HBL-100 (human bosom disease cells), and openness to AuNPs caused apoptosis in HBL-100 [47]. Mishra and partners [54] investigated the course of AuNP creation by utilizing the supernatant, live cell filtrate, and biomass delivered by the growth Penicillium brevicompactum. In a different piece of exploration, Jeyaraj et al. [48] examined the impacts of Ag-NPs on malignant growth cell lines.

C. Antibacterial Agent

Lately, there has been an emphasis on germicides that depend on silver as a reaction to the spread and upgrade of microbial protection from different anti-infection agents. This opposition has been brought about by the abuse of anti-toxins. The development of silver nanoparticles was achieved by utilizing the organism Trichoderma viride [49]. It was found that when a filtrate of T. viride was applied to an answer, fluid silver (Ag+) particles were diminished, which prompted the age of phenomenally predictable Ag-NPs with sizes going from 5 to 40 nm. This was found when the filtrate was exposed to T. viride. Furthermore, the nanoparticles' upgraded antibacterial properties against Gram-positive and Gram-negative microscopic organisms were inspected utilizing various drugs. At the point when ampicillin, kanamycin, erythromycin, and chloramphenicol were tried against test strains containing Ag-NPs, the antibacterial action of these anti-microbials were demonstrated to be altogether expanded. Ampicillin appeared to have the best potential for development advancing impacts against the test strains. The outcomes exhibited that the mix of anti-infection agents with Ag-NPs made upgraded antimicrobial impacts and added to a more useful information on the improvement of new antimicrobial elements. It was found by Dur'an and associates that extracellular silver nanoparticles produced by utilizing Fusarium oxysporum might be integrated into material materials [50]. This would take into account the anticipation or decrease of illnesses brought about by hurtful microorganisms, for example, Staphylococcus aureus.

D. Antifungal Activity

A few investigations have recorded the antifungal movement of biosynthesized NPs when they were tried against the microorganisms Aspergillus niger. Antifungal exercises of biosynthesized NPs were archived by Gajbhiye et al. [51] against Phoma glomerata, P. herbarum, Fusarium semitectum, Trichoderma sp., and Candida albicans related to fluconazol (a triazole antifungal medication). The antifungal action of fluconazole was improved against all strains tried except for P. herbarum and F. semitectum when Ag-NPs that were biosynthesized by another parasite called Alternaria alternata were utilized. In another review, to biosynthesize the Ag-NPs productive against the microbes Shigella dysenteriae type I, Staphylococcus aureus, Citrobacter sp., E. coli, Pseudomonas aeruginosa and

Bacillus subtilis, as well as the growths Candida albicans and Fusarium oxysporum, sans mycelia water concentrates of the parasitic strain Amylomyces rouxii were used [52]. Also, the antifungal movement of biosynthesized gold nanoparticles (Au-NPs) has been portrayed. Das et al. [53] created the Au-NPs on the outer layer of the parasite Rhizopusoryzae, and they showed that the development of G+ and G bacterium strains was hindered, notwithstanding the development of the organisms Saccharomyces cerevisiae and Candida albicans. The utilization of a concentrate from banana strip brought about the development of Au-NPs that repressed the development of C. albicans [54]. This was achieved after the biosynthesis was finished.

E. Medical Imaging

There has been developing interest in the examination of the optical parts of metallic miniature precious stones recently. The fuse of biosynthetic strategies has made it conceivable to make metal nanoparticles (NPs) that shift in dielectric properties as well as in sizes, shapes, and structures. Optical properties related with metallic NPs incorporate a low or high-refractive pointer, an incredibly clear appearance, newfound photoluminescence highlights, photonic gems, and Plasmon reverberation [53]. Likewise, Nano photonics is a field wherein the light connects with particles that are more moment than its frequency, which brings about novel peculiarities, for example, a size-subordinate semiconductor band hole and limited surface Plasmon reverberation [55]. The development of parasitic interceded Ag-NPs was achieved by utilizing a filtrate got from Trichoderma viride. In the wake of being energized by a laser, photoluminescence tests showed emanation in the scope of 320-520 nm. This makes such Ag-NPs proper for future applications including naming and imaging. What's more, an examination similar as it was completed by Sarkar et al. [52]. In contemporary laser medication, one of the most difficult perspectives is viewed as the broad communication with tissues that are weak beyond the employable region. Finding colors that empower the turnable obscuring of the radiation onto the outer layer of illuminated tissues is consequently important to conquer this issue so it could be settled. The expression "optical radiation impediment" has been utilized to depict this peculiarities [56]. Different specialists have distributed two further papers concentrating on cadmium telluride quantum dabs (CdTe QDs), which were made by extracellular amalgamation with the assistance of Saccharomyces cerevisiae [57] and Escherichia coli [58]. These specialists explored the size-subordinate optical attributes of the NP. The examination uncovered that CdTe QD were on the more modest side, were covered with protein, and had a phenomenal limit with regards to dissolving in water. The optical qualities of the two materials were dissected by utilizing UV-apparent spectroscopy and spectrofluorimetry with photoluminescence outflow going from 488 to 551 nm. In vitro imaging of

malignant growth cells was performed utilizing CdTe QDs that were combined with folic corrosive. These CdTe QDs were displayed to show biocompatibility subsequent to being exposed to a cytotoxicity test [59].

VI. CONCLUSION

The "green" approach for nanoparticle union, which is rapidly supplanting regular substance combinations, is of gigantic interest due to its eco-benevolence, financial viewpoints, reasonableness, and expansive scope of utilizations in various fields, for example, nano medication and reactant medication. In later times, the combination of bioactive nanoparticles has utilized a wide assortment of natural units, every one of which plays a double capability in the process by going about as both a diminishing specialist and a settling specialist. As per the discoveries of this exploration, physiologically dynamic mixtures got from growth and yeast make for predominant frameworks when utilized for the expected reason. Considering the way that the field of biosynthesized nanoparticles is still in its early stages, the uses of these particles in different fields, like medication conveyance, malignant growth treatment, quality treatment and DNA examination, antibacterial variables, biosensors, expanding reaction rates, partition science, and attractive reverberation imaging (X-ray), are talked about in this article.

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Biosynthesis of Nanoparticles Using Fungi and Their Effect on Plant Pathogenic Microorganisms: A sustainable ecofriendly Method .

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ABSTRACT

This research paper focuses on the biosynthesis of nanoparticles using fungi and their effect on plant pathogenic microorganisms. The study explores the use of fungi as a sustainable and eco-friendly method for synthesizing nanoparticles, with a particular focus on silver nanoparticles. The synthesized nanoparticles were characterized using various analytical techniques, including UV-visible spectroscopy, Fourier-transform infrared spectroscopy, and transmission electron microscopy. The antimicrobial activity of the synthesized nanoparticles was evaluated against three plant pathogenic microorganisms, namely, Fusarium oxysporum, Pythium ultimum, and Rhizoctonia solani. The results of the study indicate that the synthesized nanoparticles exhibited significant antimicrobial activity against the tested microorganisms. The findings of this study suggest that fungi-mediated nanoparticle synthesis can be a promising alternative to conventional methods and can have significant potential in the field of plant pathology.

Keywords: Biosynthesis, Nanoparticles, Microorganisms, Fungi, Pathogenic

I. INTRODUCTION

Nanoparticles have gained significant attention in recent years due to their unique physical, chemical, and biological properties. These properties make them promising candidates for a wide range of applications, including electronics, medicine, catalysis, and agriculture. The use of nanoparticles in agriculture has gained significant interest in recent years due to their potential for enhancing crop growth, improving soil fertility, and controlling plant diseases. In particular, the use of nanoparticles as antimicrobial agents for controlling plant pathogenic microorganisms has gained significant attention in the field of plant pathology.

A. Biosynthesis of Nanoparticles Using Fungi

The biosynthesis of nanoparticles using fungi has emerged as a sustainable and eco-friendly alternative to conventional methods. Fungi can be used to synthesize a variety of nanoparticles, including silver, gold, copper, and zinc oxide nanoparticles. The use of fungi in nanoparticle synthesis has several advantages, including cost-effectiveness, simplicity, and scalability.

B. Effect of Nanoparticles on Plant Pathogenic Microorganisms

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Plant pathogenic microorganisms cause significant damage to crops, resulting in significant economic losses worldwide. The use of nanoparticles as antimicrobial agents for controlling plant pathogenic microorganisms has gained significant interest in recent years. Nanoparticles can act as antimicrobial agents by damaging the cell membrane and disrupting cellular processes. The use of nanoparticles as antimicrobial agents has several advantages over conventional methods, including higher efficacy, lower toxicity, and lower environmental impact.

II. RESEARCH AIM

The aim of this study is to investigate the biosynthesis of nanoparticles using fungi and their effect on plant pathogenic microorganisms. In particular, this study focuses on the biosynthesis of silver nanoparticles using fungi and their antimicrobial activity against three plant pathogenic microorganisms, namely, Fusarium oxysporum, Pythium ultimum, and Rhizoctonia solani.

III. RESEARCH SIGNIFICANCE

The findings of this study can have significant implications in the field of plant pathology, as the use of nanoparticles as antimicrobial agents can offer a promising alternative to conventional methods. The biosynthesis of nanoparticles using fungi can also have significant environmental benefits, as it is a sustainable and eco-friendly method.

IV. LITERATURE REVIEW

The use of nanoparticles as antimicrobial agents for controlling plant pathogenic microorganisms has gained significant attention in recent years. Several studies have demonstrated the potential of nanoparticles as an effective and eco-friendly alternative to conventional methods for controlling plant diseases. In particular, the biosynthesis of nanoparticles using fungi has emerged as a promising approach.

A. Biosynthesis of Nanoparticles Using Fungi

Fungi can be used to synthesize a wide range of nanoparticles, including silver, gold, copper, and zinc oxide nanoparticles. The biosynthesis of nanoparticles using fungi is a simple and cost-effective method that involves the reduction of metal ions to nanoparticles by fungal enzymes and metabolites. Fungi produce a variety of enzymes and metabolites that can reduce metal ions to nanoparticles and stabilize them, making them suitable for various applications.

B. Antimicrobial Activity of Nanoparticles

Nanoparticles can act as antimicrobial agents by damaging the cell membrane and disrupting cellular processes. The antimicrobial activity of nanoparticles has been demonstrated against several plant pathogenic microorganisms, including Fusarium oxysporum, Pythium ultimum, and Rhizoctonia solani. The use of nanoparticles as antimicrobial agents has several advantages over conventional methods, including higher efficacy, lower toxicity, and lower environmental impact.

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C. Mechanism of Action of Nanoparticles

The mechanism of action of nanoparticles as antimicrobial agents involves the production of reactive oxygen species (ROS), which can damage the cell membrane and disrupt cellular processes. The production of ROS is influenced by several factors, including the size, shape, and surface charge of nanoparticles. The antimicrobial activity of nanoparticles can be enhanced by optimizing these factors.

D. Effect of Nanoparticles on Plant Growth and Development

Several studies have demonstrated the potential of nanoparticles for enhancing plant growth and development. Nanoparticles can enhance the uptake of nutrients and water by plants, resulting in improved growth and yield. The effect of nanoparticles on plant growth and development is influenced by several factors, including the type of nanoparticles, concentration, and application method.

V. MATERIAL AND METHODS

A. Materials:

- **Preparation of PDA medium:**

Potato:	250 g
Dextrose:	20 g
Agar:	15 g
Distilled water:	1000 ml

Unpeeled 250 g of potatoes were washed and cut into small pieces potato pieces were boiled in 500 ml double distilled water, the extract separated and the pulp was discarded. To this extract 20 g dextrose was added .in another 500 ml distilled water 15 g of agar was boiled. Then the solutions were mixed together and the volume made up to 1000 ml this was then sterilized autoclaving at 15 Ibps for 20 minutes later, a pinch of streptomycin sulphate was added to this sterile medium.

- **Czapek's dox broth:**

Sodium nitrate:	2.0 g
Dipotassium hydrogen phosphate:	1.0 g
Magnesium sulphate:	0.5 g
Potassium chloride:	0.5 g
Ferrous sulphate:	0.01 g
Sucrose:	30.0 g
Distilled water:	1000 ml

All the ingredients except phosphate were dissolved in half of the water and sucrose was added. Phosphate was dissolved separately and added to the rest; the volume was made up to the 1 litre and sterilized by autoclaving in 121°C.

- **Cotton blue stain**

Lacto phenol

Phenol crystals:	20 g

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Lactic acid: 20 g
Glycerol: 40 g
Water: 20 ml

Phenol was dissolved by heating in hot water bath, lactic acid and glycerol was added.

- **Cotton blue in lacto phenol:**

Anhydrous lacto phenol: 67 ml
Cotton blue: 0.1 g
Distilled water: 20 ml

The above ingredients were mixed well in a clean beaker and stored in bottles. The stain was used for better observation of the fungal mycelium and to arrest the fungal growth.

- **Aqueous 1 Mm Silver nitrate solution:**

Silver nitrate: 0.017 g
Distilled water: 1000 ml

The above net weight of Silver nitrate was dissolved in 1 litter sterilized double distilled water.

- **Nutrient agar media:**

Peptone: 5 g
Beef extract: 3 g
Agar: 15 g
Distilled water: 1000 ml

Peptone and beef extract were dissolved in half of the water, agar was boiled in rest of the water, and both the mixer were homogenized then sterilized in autoclave for 20 minutes.

- **Instruments for Characterization**

The reduction of metal ions was monitored by visual inspection and UV-Vis spectroscopy measurements. Fluorescence measurements were carried out on a Perkin-Elmer LS 50B luminescence spectrophotometer. Nanoparticle films were made on Si substrates to study FTIR, XRD and XPS. Fourier transform infrared spectroscopic (FTIR) studies were performed on a Shimadzu FTIR-8201 PC instrument in the diffuse reflectance mode at a resolution of 4 cm–1. X-ray diffraction (XRD) patterns were recorded in the transmission mode on a Philips PW 1830 instrument operating at 40 kV and a current of 30 mA with Cu K radiation. TEM images were scanned on a JEOL 1200EX instrument operated at an accelerated voltage of 120 kV. These techniques provide important information for understanding different physicochemical features.

B. Methodology

- **Collection of fungi:**

Fungal culture purchase from NCL. The name of fungi listed below,

a) Metarhizium anisopliae
b) Beauveria bassiana
c) Penicillium roquetorti
d) Gibberella fujikuroi
e) Rhizomucor micheil
f) Aureobasidium pullulans 1048

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g) Fusarium lini

- **Metarhizium anisopliae**

Metarhizium fungus is a biological control agent that can be used to control agricultural pests, termites, and biological vectors. It has been widely used and molecular approaches to increase its virulence are discussed.

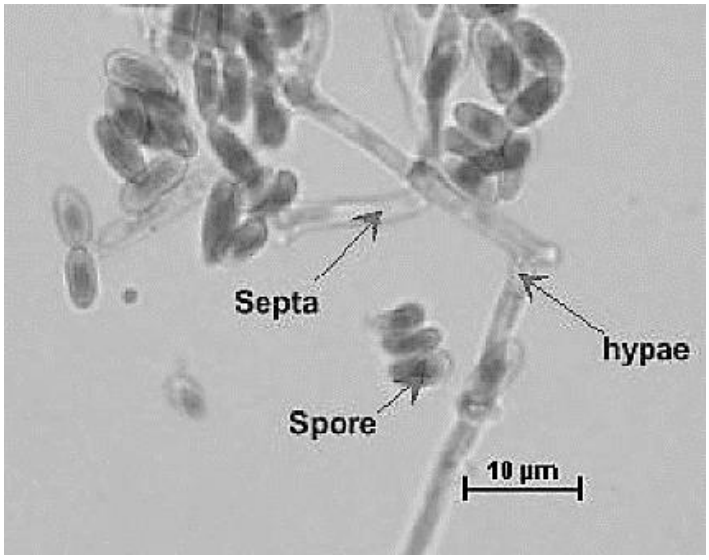

Figure 1: Microscopic view of cylindrical spore of Metarhizium anisopliae

- **Beauveria bassiana**

Beauveria bassiana is a biological insecticide used to control pests and malaria-transmitting mosquitos. It parasitizes a wide range of arthropod hosts, but some strains have a wide host range and should not be applied to flowers.

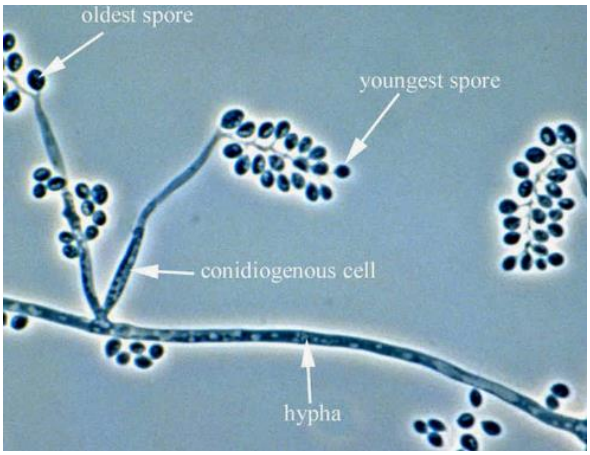

Figure 2: Beauveria bassiana

- **Penicillium roquetorti**

P. roqueforti is a fungus with macromorphological and microscopic characteristics. It produces asexual spores in phialides with a brush-shaped configuration. Evidence for a sexual stage has been found, and it is a genetically diverse species. It is known to be a spoilage mold of silage and bread.

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Figure 3: Penicillium roquetorti

- **Gibberella fujikuroi**

The most important and widely used management solutions are treated seeds, hot water baths and chlorine treatments. Resistance in rice has been studied, with Binam cultivar being the most resistant. Silver nanoparticles, a known antifungal, have been found to reduce the incidence of the disease.

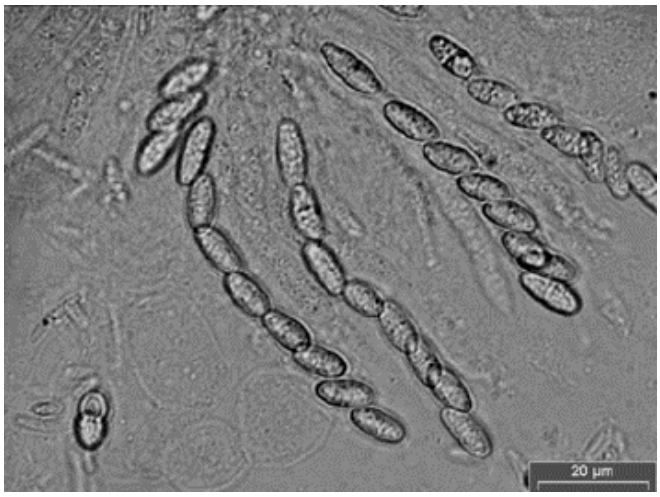

Figure 4: Gibberella fujikuroi

- **Rhizomucor micheil**

Rhizomucor micheil is a fungus used to produce enzymes and lipases.

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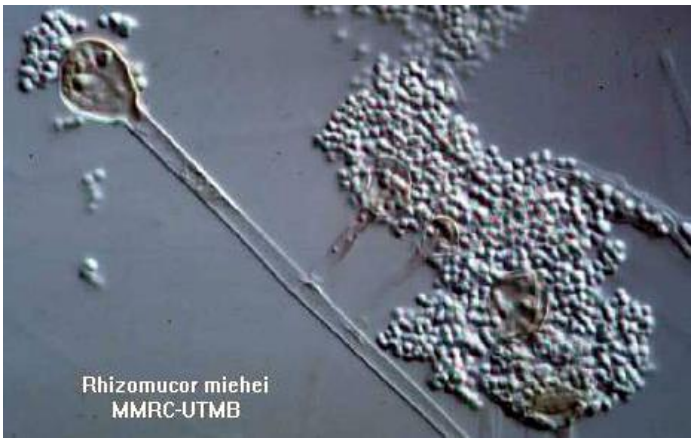

Figure 5: Rhizomucor micheil

- **Aureobasidium pullulans**

Aureobasidium pullulans is an important fungus for biotechnology and biological control of plant diseases.

Figure 6: Aureobasidium pullulans

- **Fusarium lini**

Fusarium is an important agent of biodegradation and food safety, surviving for up to 16 years.

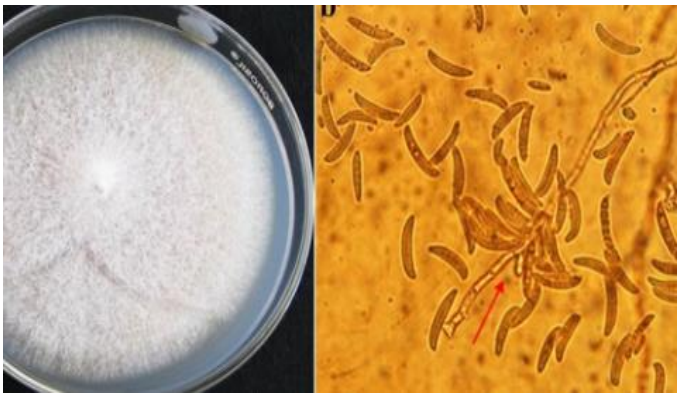

Figure 7: Fusarium lini

- **Isolation and inoculation:**

Soil sample was collected from Shivajinagar, Pune and inoculated into three petri plates containing 20 ml of PDA for 7 days at 28 + 2oC. Average number per gram dry sample was determined and expressed as CFU.

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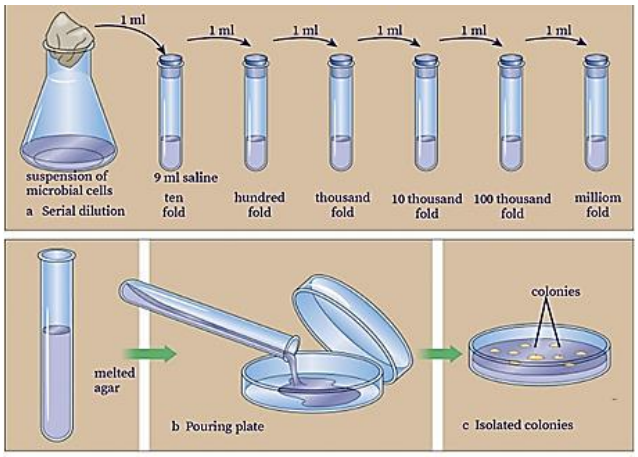

Figure 8: Microbial isolation

- **Biosynthesis of silver nanoparticles:**

The cell filtrate of fungi was mixed with Silver nitrate and agitated at room temperature for 72 hours to produce sliver nanoparticles.

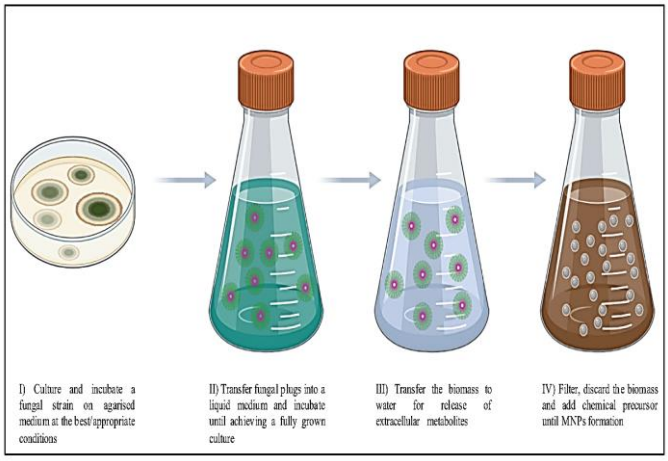

Figure 9: Production of sliver nanoparticles

- **Fungal Biomass:**

Fungal biomass was used to optimize the synthesis of Copper Oxide nanoparticles by incubating different biomasses at 130 rpm and filtering them with whatman filter paper no. 1.

Figure 10: Fungal biomass on the synthesis of Copper Oxide nanoparticles

VI. RESULTS

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A. Biosynthesis of silver nanoparticles

Visual Inspection

The appearance of a yellowish-brown color in solution containing the biomass is due to the formation of silver nanoparticles due to surface Plasmon vibrations in the silver nanoparticles.

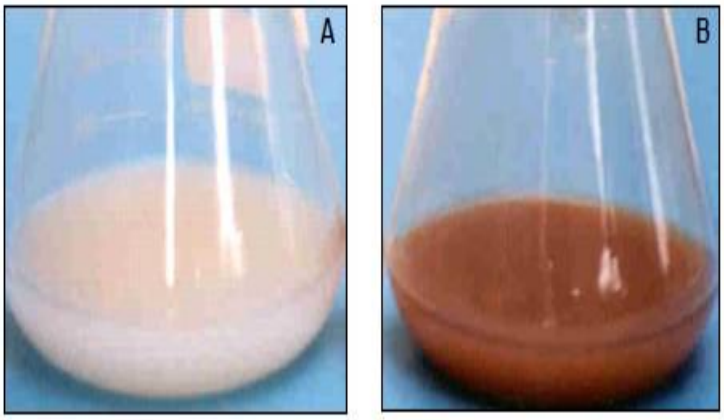

Figure 11: Picture of conical flasks containing Fusarium lini biomass before (A) and after (B) exposure to Ag+ ions for 72 h.

UV-Vis Spectroscopy

The UV-Vis spectra recorded from the Fusarium lini reaction vessel show an increase in intensity of silver solution with time, suggesting the formation of nanoparticles.

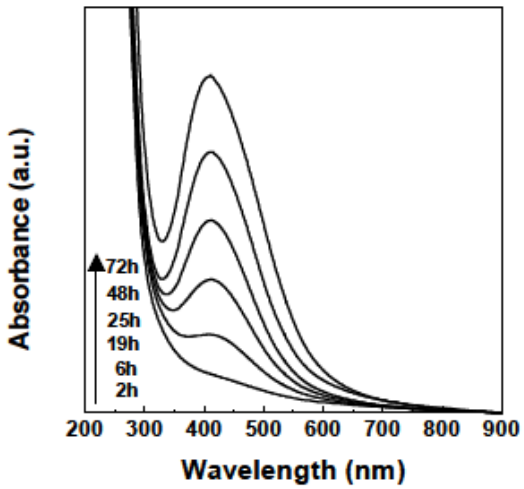

Figure 12: UV-Vis spectra recorded with respect to time after the reaction of 1 mM AgNO3 solution with 20 g Fusarium lini wet biomass for 72 h.

Transmission Electron Microscopy

The silver nanoparticle film deposited on a carbon coated copper TEM grid showed individual silver particles as well as aggregates. The morphology of the nanoparticles was variable, with spherical and occasionally triangular nanoparticles observed. Stabilization of the nanoparticles by a capping agent is likely due to proteins secreted by Fusarium oxysporum. The silver particles are crystalline.

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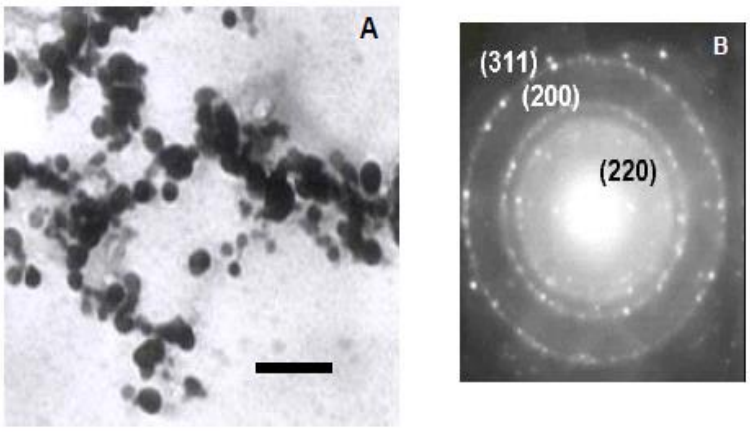

Figure 13: (A) TEM micrograph recorded from a drop-coated film of an aqueous solution incubated with Fusarium lini and reacted with Ag+ ions for 72 h. The scale bar corresponds to 100 nm. (B) Selected area of electron diffraction pattern recorded from one of the silver nanoparticles shown in Figure (A). The diffraction rings have been indexed with reference to FCC silver.

X-ray Diffraction

X-ray diffraction analysis of silver nanoparticles revealed sharp reflections and an estimated size of 11 nm, which is in agreement with the TEM analysis.

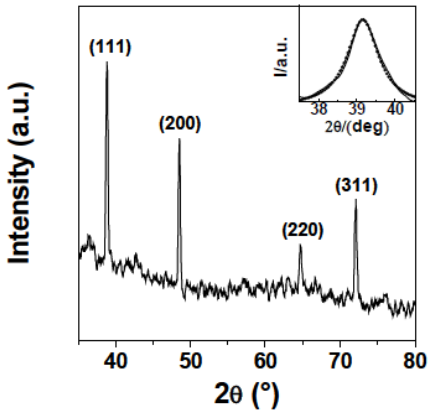

Figure 14: XRD pattern recorded from the thin film prepared by drop coating the silver nanoparticle solution on a Si (111) wafer.

Lorentzian fit used to estimate silver nanoparticle size.

X-ray Photoelectron Spectroscopy (XPS) Measurements

Fusarium lini reduced Ag+ ions to elemental silver by X-ray photoelectron spectroscopy, with the Ag 3d5/2 and 3d3/2 peaks at a binding energy of 368.1 eV and 374 eV respectively..

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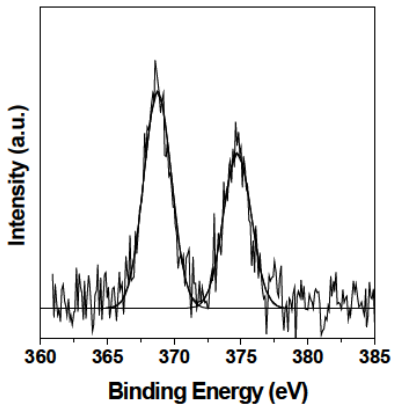

Figure 15: Ag 3d core level spectra recorded from a drop coated silver nanoparticle solution on Si (111) substrate. A single spin-orbit pair is shown in the Figure.

Fourier Transform Infrared Spectroscopy

Amide linkages between amino acid residues in polypeptides and proteins give rise to signatures in the infrared region of the electromagnetic spectrum. Three bands in the FTIR spectrum are due to amide I and II bands, which indicate conformational changes in the protein-secondary structure.

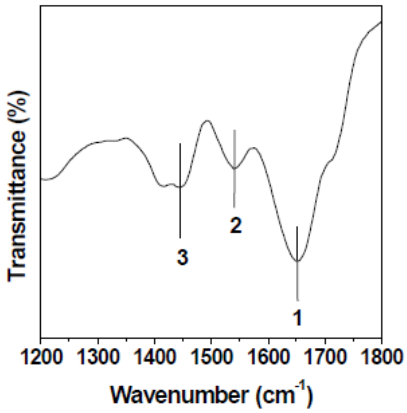

Figure 16: FTIR spectrum recorded from a drop-coated film of an aqueous solution incubated with Fusarium lini and reacted with Ag+ ions for 72 h. The amide bands are identified in the Figure.

Probable Mechanism of Formation of Silver Nanoparticles

The UV-Vis spectrum in low wavelength region recorded from silver nanoparticles 72 h after reaction is due to electronic excitations in tryptophan and tyrosine residues. A control experiment was performed to demonstrate that the reduction of the ions occurs extracellular, possibly through the release of reducing agents by Fusarium lini. It is important to identify the reducing agents responsible for this. A preliminary gel electrophoresis study showed the presence of four high molecular weight proteins released by Fusarium lini mycelial biomass. The protein mixture obtained after dialysis failed to reduce Au+3 and Ag+ ions, but on addition of NADH, the reduction occurs readily.

This suggests that the reduction of Au+3 and Ag+ ions by NADH dependent reductase in the extract and the subsequent formation of nanoparticles may be due to the stabilization of the gold or silver particles by the proteins. Metal nanoparticles have been reported to interact strongly with enzymes.

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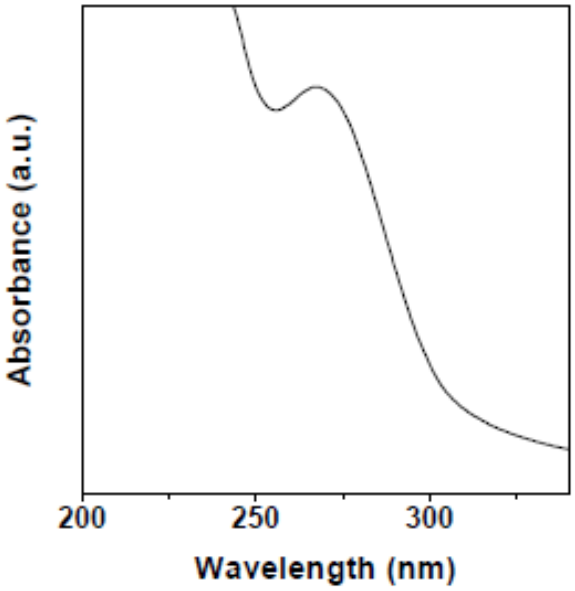

Figure 17: The UV-Vis absorption spectrum in the low wavelength region recorded from the reaction medium of silver nanoparticles 72 h after commencement of the reaction.

Effect of Biomass Concentration

The effect of biomass concentration on the extracellular synthesis of silver nanoparticles was studied by exposing 5 g, 10 g, 20 g and 30 g of wet biomass of Fusarium lini to 1 mM aqueous solution of AgNO3. The absorbance of surface Plasmon resonance showed broadening and red shift at 550 nm, indicating the aggregation of gold nanoparticles.

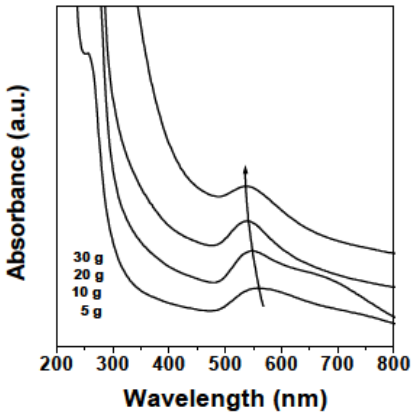

Figure 18: UV-Vis spectra of the reaction mixtures of gold nanoparticles by exposing 5 g, 10 g, 20 g and 30 g respectively of wet biomass of Fusarium lini to aqueous solution of 1 mM HAuCl4. The spectra have been shifted vertically for clarity.

Fusarium lini releases enzyme in an aqueous solution of 1 mM HAuCl4 at pH 3.3, which reduces Au+3 ions to Au0 and aggregates. TEM analysis shows that when low amounts of biomass are used, aggregated nanoparticles of bigger sizes are formed. However, when increased amounts of biomass are used, well separated and polydispersed particles are observed.

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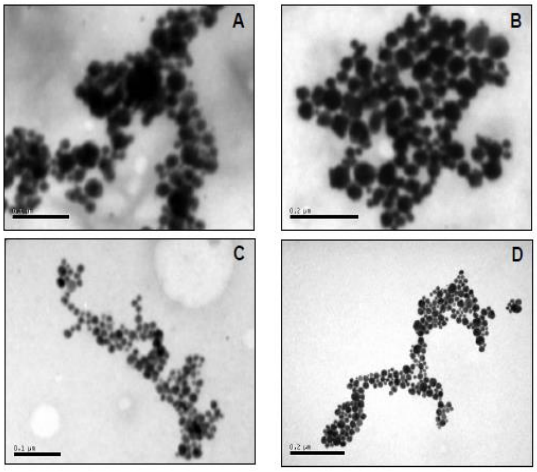

Figure 19: (A-D) TEM micrographs recorded from gold nanoparticle solutions synthesized by exposing 5 g, 10 g, 20 g and 30 g wet biomass of Fusarium lini to aqueous solution of 1 mM HAuCl4.

AgNO3 solution does not broaden or shift absorbance maxima.

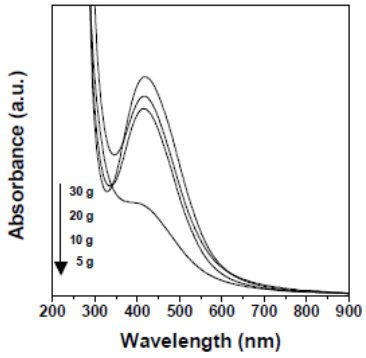

Figure 20: UV-Vis spectra of the reaction mixtures of silver nanoparticles by exposing 5 g, 10 g, 20 g and 30 g respectively of wet biomass of Fusarium lini to aqueous solution of 1 mM AgNO3.

The synthesis of gold and silver nanoparticles using fungus, Fusarium lini is independent of the pH of the reaction mixture. This is due to the differential toxicity of metal ions towards Fusarium lini, which triggers the release of higher amounts of reducing agent and capping proteins. This may explain the higher aggregation of gold nanoparticles at lower biomass.

- **Impact of physical factor on nanoparticles production**

Effect of pH on Stability of Nanoparticle Solution

The effect of pH on the stability of silver nanoparticle solutions synthesized extracellular by exposing Fusarium lini to HAuCl4 and AgNO3 is shown in Figure 4.10. At higher pH, the absorption maxima are uniform, but at lower pH, the absorbance broadens and the protein structure gets denatured, leading to aggregation. This suggests that the proteins secreted by Fusarium lini in solution for the capping of both gold and silver nanoparticles are stable at basic pH but not in acidic pH.

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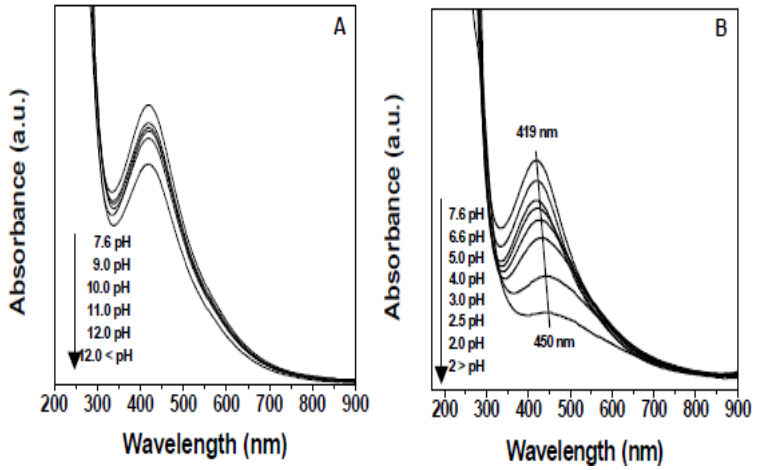

Figure 21: UV-Vis spectra of silver nanoparticle-fungus reaction mixture after 72 h of reaction at higher pH (A) and at lower pH (B).

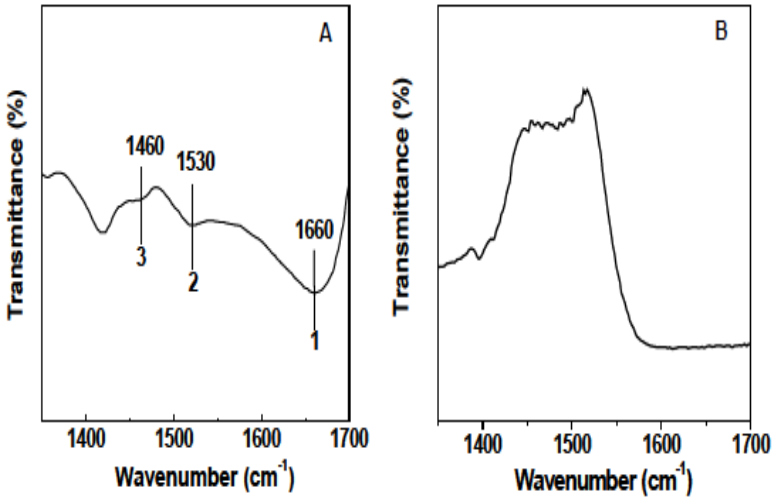

Figure 22: FTIR spectra recorded from a drop-coated film of nanoparticles–fungus reaction mixture after 48 h of reaction (A) at pH higher than 12 and (B) at pH less than 2.

Effect of wavelength

The optimum wavelength for nanoparticle production was determined, reactions being performed at various wavelengths. The reduction of silver ion was confirmed by qualitative testing of nanoparticle sample by UV-visible spectrophometric. 1ml sample of nanoparticles was withdrawn after 24 hours and absorbance was measured in between 300-600 nm. At 400 nm Fusarium oxysporum showed highest peak i.e. maximum production of silver nanoparticles which was followed by Metarhizium anisopliae, Beauveria bassiana and Penicillium roquetorti. The remaining fungi Gibberella fujikuroi, Rhizomucor micheil, Aureobasidium pullulans and Fusarium lini formed highest peak at 450 nm i.e. maximum production of silver nanoparticles comparison with other wavelength.

Table 1: Effect of different wavelength on silver nanoparticle production in fungi

Sr. No.	Name of Fungi	Different wavelength						
		300	350	400	450	500	550	600
1.	*M. anisopliae*	0.445	0.331	0.362	0.365	0.328	0.275	0.188

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2.	*B. bassiana*	0.025	0.010	0.012	0.028	0.005	-0.030	-0.042
3.	*P. roquetorti*	0.272	0.123	0.138	0.135	0.101	0.068	0.039
4.	*Gibberella fujikuroi*	0.385	0.280	0.425	0.459	0.407	0.329	0.213
5.	*Rhizomucor micheil*	0.572	0.468	0.749	0.723	0.604	0.436	0.282
6.	*A. pullulans*	0.392	0.219	0.363	0.351	0.267	0.102	0.059
7.	*Fusarium lini*	0.318	0.241	0.195	0.213	0.204	0.138	0.101

Effect of Temperature

Temperature affects the synthesis of silver nanoparticles in 7 fungi, with Rhizomucor micheil, Beauveria bassiana, Aureobasidium pullulans and Fusarium lini having the highest synthesis.

Table 2: Effect of different temperature on silver nanoparticle production in fungi

Sr. No.	Name of Fungi	Wavelength	Different temperature				
			10ºC	20ºC	30ºC	40ºC	50°C
1	*M. anisopliae*	450	-	0.265	0.362	0.298	0.102
2.	*B. bassiana*	400	-	0.019	0.028	0.022	-
3.	*P. roquetorti*	400	-	0.064	0.138	0.059	-
4.	*Gibberella fujikuroi*	450	-	0.138	0.459	0.143	0.034
5.	*Rhizomucor micheil*	450	-	0.321	0.749	0.456	0.221
6.	*A. pullulans*	400	-	0.121	0.363	0.167	0.023
7.	*Fusarium lini*	450	-	0.137	0.213	0.156	-

Effect of light

Continuous dark favours maximum silver nanoparticle production of Aureobasidium pullulans and Fusarium lini.

Table 3: Effect of different pH on silver nanoparticles production in fungi

Sr. No.	Name of Fungi	Wavelength	Different pH					
			3.5	4.5	5.5	6.5	7.5	8.5
1.	*M. anisopliae*	450	0.183	0.214	0.351	0.365	0.265	0.023

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2.	*B. bassiana*	400	0.001	0.013	0.021	0.028	0.019	0.018
3.	*P. roquetorti*	400	0.109	0.121	0.131	0.138	0.099	0.078
4.	*Gibberella fujikuroi*	450	0.366	0.389	0.455	0.459	0.354	0.148
5.	*Rhizomucor micheil*	450	0.612	0.585	0.711	0.749	0.656	0.267
6.	*A. pullulans*	400	0.205	0.236	0.321	0.363	0.203	0.101
7.	*Fusarium lini*	450	0.078	0.192	0.209	0.213	0.102	0.098

- **Effect of light**

Table 4: Effect of different light on silver nanoparticle production in fungi

Sr. No.	Name of Fungi	Wavelength	Illumination of light		
			Continuous light	Continuous dark	Alternate light/dark
1	*M. anisopliae*	450	0.163	0.362	0.268
2.	*B. bassiana*	400	0.003	0.028	0.023
3.	*P. roquetorti*	400	0.053	0.138	0.121
4.	*Gibberella fujikuroi*	450	0.123	0.459	0.408
5.	*Rhizomucor micheil*	450	0.145	0.749	0.321
6.	*A. pullulans*	400	0.078	0.363	0.198
7.	*Fusarium lini*	450	0.062	0.213	0.100

- **Effect of time interval**

Silver nanoparticle production increases as time interval increases, with color intensity and absorbance increased at 72 hr.

Table 5: Effect of different time interval on biosynthesis of silver nanoparticles

Sr. No	**Name of fungi**	**Time interval**	**Different wavelength**						
			300	**350**	**400**	**450**	**500**	**550**	**600**
1	*M. anisopliae*	24hr	0.445	0.331	0.362	0.365	0.328	0.275	0.188
		48hr	0.576	0.418	0.473	0.499	0.415	0.375	0.263
		72hr	0.678	0.515	0.615	0.650	0.509	0.468	0.379
2	*B. bassiana*	24hr	0.025	0.010	0.012	0.028	0.005	0.030	0.042
		48hr	0.108	0.096	0.102	0.127	0.043	0.063	0.084

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		72hr	0.192	0.142	0.163	0.228	0.098	0.101	0.144
3	*P. roquetorti*	24hr	0.272	0.123	0.138	0.135	0.101	0.068	0.039
		48hr	0.340	0.205	0.258	0.223	0.199	0.125	0.100
		72hr	0.423	0.388	0.405	0.385	0.274	0.223	0.185
4	*Gibberella fujikuroi*	24hr	0.385	0.280	0.425	0.429	0.407	0.329	0.213
		48hr	0.472	0.314	0.513	0.548	0.509	0.415	0.321
		72hr	0.563	0.408	0.600	0.649	0.598	0.500	0.417
5	*Rhizomucor micheil*	24hr	0.572	0.468	0.749	0.723	0.604	0.436	0.282
		48hr	0.675	0.525	0.832	0.805	0.697	0.523	0.343
		72hr	0.696	0.615	0.907	0.899	0.782	0.613	0.409
6	*A. pullulans*	24hr	0.392	0.219	0.363	0.351	0.267	0.102	0.059
		48hr	0.478	0.371	0.493	0.468	0.374	0.199	0.112
		72hr	0.572	0.468	0.568	0.560	0.455	0.253	0.202
7	*Fusarium lini*	24hr	0.318	0.241	0.195	0.213	0.204	0.138	0.101
		48hr	0.405	0.316	0.298	0.312	0.303	0.211	0.198
		72hr	0.513	0.402	0.367	0.400	0.388	0.354	0.263

B. Biosynthesis of Copper Oxide nanoparticles

Visual Inspection

Two conical flasks with fungal biomass before (A) and after (B) reaction with 1 mM HAuCl4 solution for 48 h are shown in Figure 23.

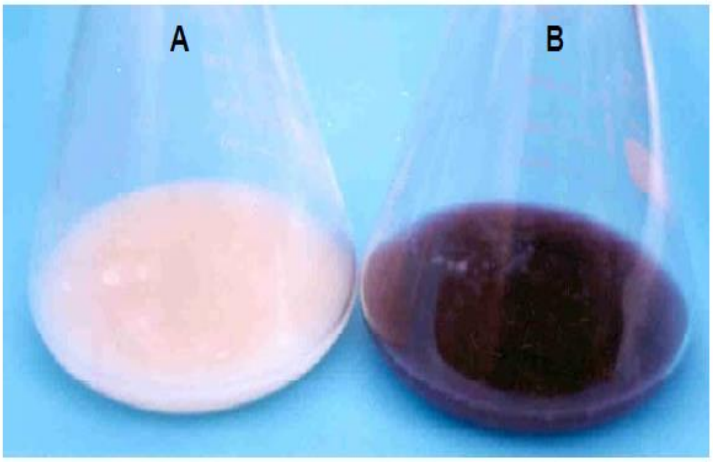

Figure 23: Picture of conical flasks containing fungal biomass before (A) and after (B) exposure to CuO– ions for 48 h.

UV-Vis Spectroscopy

Absorption peak broadens due to wide size distribution of copper oxide nanoparticles.

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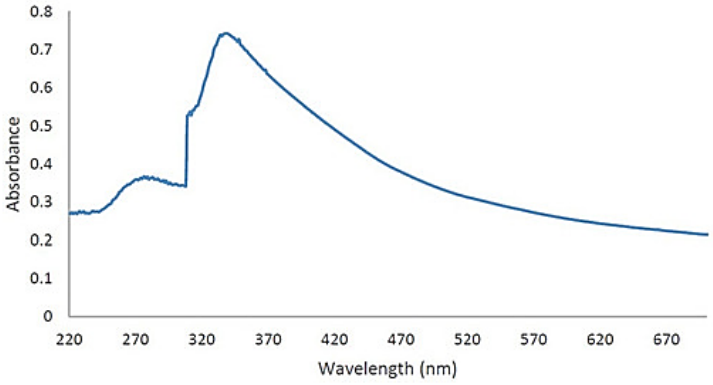

Figure 24: UV/Vis spectrum of the synthesized CuO-NPs.

Transmission Electron Microscopy

The copper nanoparticles biosynthesized using fugal biomass were polydisperse and ranged from 3-10 nm. After dialysis, the particles increased in size to 15-20 nm. Selected area electron diffraction (SAED) and Fourier Transform Infra-red (FTIR) spectroscopy confirmed the crystalline nature of the nanoparticles.

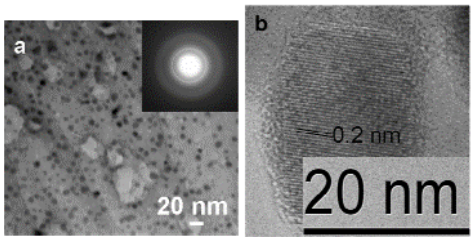

Figure 25: TEM image of biogenic Cu nanoparticles biosynthesized by fugal biomass. The inset shows the SAED ring pattern obtained from these particles. (b) HRTEM image of biogenic Cu particles showing lattice planes.

X-ray Photoelectron Spectroscopy (XPS) Measurements

XPS measurements were carried out using Thermo K-Alpha XPS instrument at a pressure of 1 x 10–9 Torr. Core level spectra were background corrected and chemically distinct species resolved. Core level binding energies were aligned with adventitious carbon binding energy of 285 eV.

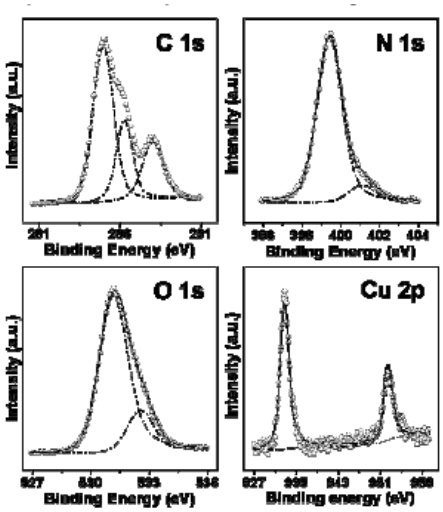

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Figure 26: XPS data showing the (a) C 1s, (b) N 1s, (c) O 1s, and (d) Cu 2p core level spectra recorded from biogenic Cu nanoparticles film cast on to a Si substrate.

XRD Analysis

PXRD was used to assess the structural chemistry of CuO-NPs, with three main characteristic diffraction peaks for Cu at 43°, 50°, 74° and 29° respectively.

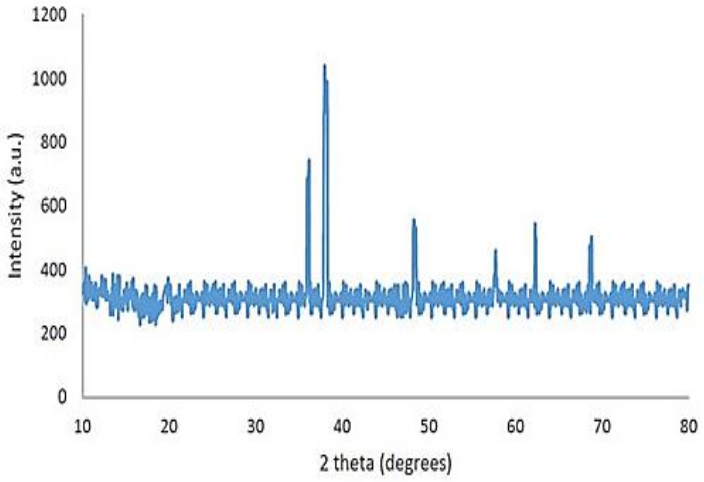

Figure 27: XRD of the synthesized CuO-NPs.

Fourier Transform Infrared Spectroscopy

FTIR spectrum confirmed successful biosynthesis of CuO-NPs based on stretching frequency of hydroxyl group and ester bonds between copper species and hydroxyl groups.

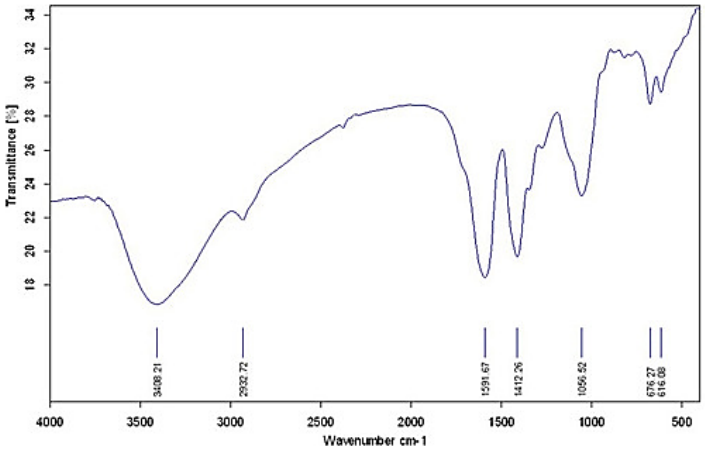

Figure 28: The FT-IR spectra of synthesized CuO-NPs.

VII. DISCUSSION

Microbes are microscopic organisms that play an important role in balancing the ecosystem. They produce hydrolytic enzymes, pigments, and nanoparticles. Nanoparticles have superior properties than bulk materials and are more reactive than larger particles due to their greater surface area per weight. Physico-chemical methods synthesized nanoparticles are not easy to degrade in our ecosystem, while biological methods are nontoxic, cost effective, eco-friendly, modern, and safe. The use of microorganisms to synthesize functional nanoparticles has been of great interest, as it has opened up new opportunities to explore novel applications.

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Silver, gold, cadmium sulphate (CdS), zinc sulphate (ZnS), platinum (Pt), and palladium (Pd) nanoparticles were synthesized by bacteria, fungi, yeast, algae, actinomycetes and plants. Fungi are the most effective candidate for synthesis of metal nanoparticles, as they secrete large amounts of proteins and enzymes for reducing the metal ion and increasing productivity.

The synthesis of nanoparticles using microorganisms is an emerging approach in nanotechnology. Extracellular polymeric substances (EPS) can serve as binding sites for various metal ions and act as a capping agent. Surface functionalization of EPS can enhance the adsorption of metal, and sulphur is used to bind with cadmium ions and synthesize CdS nanoparticles. Silver nanoparticles in the range of 144 nm were synthesized by the supernatant of B. sterothermophilus when silver nitrate was added to it.

Response surface methodology allowed a greater precision in estimating the overall main factor effects and allowed exploration of interaction between different factors. The green synthesis of silver nanoparticles offers a potentially eco-friendly, non-toxic, and cost-effective approach for the synthesis of nanoparticles. The green synthesis of silver nanoparticles using plant extracts has several advantages such as eco-friendliness, biocompatibility and cost-effectiveness. Silver nanoparticles have potential applications such as antimicrobial agents, biomedicine, mosquito control, environment and wastewater treatment, agriculture, food safety, and food packaging. Nanotechnology is an innovative field that influences all aspects of human life, and nanoparticles (NPs) are applied in a variety of majors such as nanomedicine.

VIII. CONCLUSION

Metal nanoparticles are important biomedical agents and Au-NPs were used in the 16th century. Microorganisms like yeast and fungi have been used to biosynthesis inorganic nanoparticles. Fungi are capable of digesting extracellular food and discharging enzymes to hydrolyze complex compositions. Fusarium oxysporum has been used to form individual CdS NPs, PBS, ZnS, MoS2, silver NPs, spherical silver NPs, Au-Ag alloy NPs, and metal nanoparticles with different shapes and sizes. Fusarium oxysporum has been used to synthesize metallic nanoparticles (NPs) with a quasi-spherical morphology. The potential application of NPs has been evaluated and the antimicrobial efficiency of synthesized silver NPs has been ascertained. Fungi can also form extracellular or intracellular metal nanoparticles, alloy nanoparticles, semiconductors, and composite systems. These findings open perspectives for future investigations concerning the use of these nanoparticles as antimicrobials in health and agriculture.

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Millets - Neglected Cereal with High Potential in Health Benefits in Malnutrition

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Abstract

In a world grappling with malnutrition, millets emerge as unsung heroes, offering a beacon of hope for improved global health. This chapter delves into the treasure trove of millets, revealing their often-overlooked potential as a nutritional powerhouse. Millets, a diverse group of cereal grains, hold the promise of mitigating malnutrition on a global scale. Firstly, we explore the exceptional nutritional value of millets, demonstrating how they pack a punch with essential vitamins, minerals, and dietary fiber. A comparative analysis with other grains underscores their superiority in providing a balanced diet. We then uncover the diverse varieties of millets and their suitability for various regions and climates, making them an adaptable and sustainable choice for farmers worldwide. Millet farming techniques, including their resilience to adverse conditions, are discussed, shedding light on their role in food security. The health implications of millet consumption are another focus, revealing their potential in preventing chronic diseases and improving overall well-being. Case studies underscore the tangible impact of millet-based interventions on malnutrition reduction. However, challenges persist, such as limited awareness and policy support. Nonetheless, millets hold immense promise for enhancing global health and nutrition. This chapter advocates for the integration of millets into our diets, promoting sustainable agriculture, and addressing malnutrition's root causes. As we delve into the world of millets, we find not only a neglected cereal but a beacon of hope for a healthier, more sustainable future.

Keywords: Millets, Malnutrition, Nutritional Value, Sustainable Agriculture, Health Benefits

1. Introduction

Millets

Millets are a group of small-seeded cereal grains that have played a significant role in the history of agriculture and human nutrition (Vetriventhan et al.,2020). These ancient grains, though often overlooked in modern times, offer a compelling story of resilience, adaptability, and potential. In this chapter, we will journey through

the historical significance of millets, explore their status as a neglected cereal, and highlight their crucial importance in global agriculture.

Historical Significance

Millets have a rich history dating back thousands of years. They were among the earliest cultivated crops in human history, with evidence of their cultivation dating back to ancient civilizations in Asia and Africa (Spenglar et al.,2015). Millets served as staple foods for many ancient cultures, providing sustenance and nutrition to communities across the globe. Understanding the historical significance of millets allows us to appreciate their enduring legacy and the wisdom of our ancestors in recognizing their value.

Millets as a Neglected Cereal

Despite their historical importance, millets have largely fallen out of favor in modern agriculture and diets (Reed et al.,2019). The rise of other high-yielding cereal crops like rice, wheat, and maize has relegated millets to the periphery of global food systems. This neglect is a significant issue as it has obscured the many benefits and attributes that millets bring to the table, both nutritionally and agriculturally.

Importance in Global Agriculture

In recent years, there has been a resurgence of interest in millets due to their potential to address contemporary agricultural and nutritional challenges. Millets are highly resilient to diverse climates and require fewer resources, making them a sustainable choice for farming (Adhikari et al.,2018). Additionally, they are rich in essential nutrients and possess health benefits that are increasingly being recognized.

Nutritional Value of Millets

Millets, often underestimated in modern diets, stand as a testament to nature's bounty. Their remarkable nutritional composition positions them as a nutrient-rich cereal with unique benefits (Scott et al.,2017) . This section explores millets' nutritional richness, conducts a comparative analysis with other grains, and unravels the extensive health benefits that come with millet consumption.

Millets as a Nutrient-Rich Cereal

Millets are nutritional powerhouses, brimming with essential nutrients that contribute to overall well-being. They are a rich source of dietary fiber, providing excellent digestive health support. Additionally, millets are packed with vitamins, including B-complex vitamins such as niacin, riboflavin, and folate, vital for energy production and neurological health (Godswill et al.,2020). These grains are also a source of essential minerals like iron, magnesium, and phosphorus, which play crucial roles in various bodily functions. Moreover, millets are gluten-free, making them suitable for individuals with gluten sensitivities or celiac disease.

Comparative Analysis with Other Grains

A comparative analysis between millets and other grains showcases their unique nutritional profile. Millets often outshine traditional staples like rice and wheat in terms of protein content, dietary fiber, and micronutrients (Yadav et al.,2023; Sood et al.,2016) . This comparison underscores their potential to fill critical nutritional gaps in diets around the world. Millets' lower glycemic index also positions them as a favorable option for managing blood sugar levels, especially for those with diabetes.

Health Benefits of Millet Consumption

The health benefits associated with millet consumption are multifaceted. Regular inclusion of millets in one's diet can aid in weight management due to their satiating fiber content. Furthermore, they contribute to heart health by lowering cholesterol levels and reducing the risk of cardiovascular diseases. Millets' magnesium content supports bone health and muscle function, while their antioxidant properties combat oxidative stress and inflammation, reducing the risk of chronic diseases (Singh et al.,2020).

Types of Millets

Millets, a diverse group of small-seeded cereal grains, encompass various species and varieties. This section provides insight into the different types of millets, including common varieties, regional preferences, and the overall diversity within the millet species (Bora et al.,2019).

Common Varieties of Millets

Millets are not a monolithic grain but a family of diverse varieties. This subsection explores some of the most commonly cultivated millets worldwide, such as pearl millet, finger millet, foxtail millet, proso millet, and barnyard millet. (Singh et al.,2022). Each of these varieties possesses unique characteristics and adapts to specific environmental conditions, making them essential in various cuisines and farming systems.

Regional Millet Preferences
Millets have strong regional significance, with specific types favored in different parts of the world. This subsection delves into the regional preferences for millets, highlighting their cultural and culinary importance. For instance, pearl millet may be a staple in parts of Africa and India, while finger millet finds favor in regions of East Africa and the Himalayas.

Diversity in Millet Species
Beyond the commonly known varieties, millets exhibit a vast diversity within their species. This diversity is not only limited to grain types but also includes millets used as forage crops and cover crops. Understanding this diversity is crucial for harnessing the full potential of millets in agriculture and nutrition.

Table 1: Types of Millets and Common Culinary Applications

Type of Millet	Common Culinary Applications
Pearl Millet	- Porridge (Bajra khichdi)
	- Flatbreads (Bajra roti/rotla)
	- Fermented foods (Ambali)
Finger Millet	- Porridge (Ragi malt)
	- Finger Millet balls (Ragi mudde)
	- Pancakes (Ragi dosa)
Foxtail Millet	- Upma (Thinai Upma)
	- Rice substitute (Foxtail Millet rice)
	- Desserts (Foxtail Millet payasam)
Proso Millet	- Breakfast cereal (Proso Millet porridge)
	- Proso Millet pulao
	- Flour for baking (Proso Millet flour)
Barnyard Millet	- Barnyard Millet upma
	- Barnyard Millet idli
	- Rice substitute (Barnyard Millet rice)
Little Millet	- Little Millet pongal
	- Little Millet dosa
	- Salads and pilafs (Little Millet salad)

Millets and Malnutrition
This section transitions into the critical topic of malnutrition, exploring its underlying causes and the role millets play in combating this global issue (Banerjee et al.,2020).

Understanding Malnutrition
Malnutrition remains a pressing global challenge, affecting millions of individuals, particularly in vulnerable populations. Here, we delve into the multifaceted nature of malnutrition, encompassing both undernutrition and overnutrition. We explore the consequences of malnutrition on health and well-being, emphasizing the need for comprehensive solutions.

The Role of Millets in Combating Malnutrition
Millets emerge as a sustainable and promising solution to address malnutrition. This subsection highlights how millets, with their exceptional nutritional profile, can serve as a crucial component in alleviating malnutrition, especially in regions where traditional diets lack essential nutrients. Their affordability, adaptability, and accessibility make them an excellent candidate for improving dietary diversity and nutritional outcomes.

Millets as a Sustainable Solution
Millets also offer sustainability benefits, including drought resistance and low resource requirements. By promoting millet cultivation and consumption, we can reduce pressure on the environment and contribute to sustainable agricultural practices. This section underscores the potential of millets not only in combating malnutrition but also in building resilient and sustainable food systems.

Processing and Utilization of Millets

Millets, with their rich history and nutritional benefits, are finding their way into modern diets and industries (Dekka et al.,2023). This section explores the processing and utilization of millets, encompassing traditional recipes, contemporary culinary applications, their role in the food industry, and the health implications of millet consumption.

Traditional Millet Recipes
This subsection delves into the culinary traditions that have embraced millets for centuries. It highlights traditional millet-based recipes from various cultures, showcasing the versatility and cultural significance of these grains in culinary heritage.

Modern Culinary Uses
As dietary preferences evolve, millets are making a comeback in modern cuisine. This part explores innovative and contemporary culinary uses of millets, from incorporating them into gourmet dishes to using millet flour in gluten-free baking. These developments reflect the changing landscape of food preferences and dietary choices.

Millets in the Food Industry
Millets are not limited to home kitchens but also have a role to play in the broader food industry (Shah et al.,2023). Here, we discuss how millets are being utilized in the production of packaged foods, snacks, and processed products. We examine the potential for millets to contribute to a more diverse and nutritious food market.

Health Implications of Millet Consumption
The health benefits of millet consumption are a critical aspect of this chapter, exploring how these grains can positively impact human well-being.

Millets and Chronic Disease Prevention
Millets' nutritional attributes play a crucial role in preventing chronic diseases such as diabetes, heart disease, and obesity. We delve into the scientific evidence behind these health benefits and their potential role in public health strategies.

Dietary Considerations
This subsection provides dietary guidance for individuals interested in incorporating millets into their diets. It covers topics like portion sizes, meal planning, and how to balance millets with other food groups to achieve a well-rounded diet.

Allergies and Sensitivities
While millets are generally considered safe for consumption, some individuals may have allergies or sensitivities. This part addresses potential allergenicity and offers guidance on managing any adverse reactions (Asrani et al.,2021).

Promotion and Advocacy
The final section of this chapter focuses on the promotion and advocacy efforts surrounding millets (Mishra et al.,2014).

Government Initiatives
We discuss how governments in various regions are recognizing the potential of millets and implementing policies to promote their cultivation, consumption, and integration into public nutrition programs.

NGOs and Millet Promotion
Non-governmental organizations (NGOs) play a vital role in advocating for millets (Macauley et al.,2015). This subsection highlights the efforts of NGOs in raising awareness, supporting farmers, and promoting millets as a sustainable and nutritious choice.

Raising Awareness about Millets
Raising awareness is essential to drive millet adoption. We explore various campaigns, educational programs, and initiatives aimed at increasing public awareness of millets' nutritional benefits, culinary versatility, and role in sustainable agriculture.

By examining the processing, utilization, health implications, and advocacy efforts related to millets, this chapter provides a comprehensive view of how millets are making a significant impact on both individual health and global food systems.

Conclusion

In conclusion, millets, often overlooked but inherently significant, have emerged as a beacon of hope in addressing various global challenges. This chapter has explored the multifaceted world of millets, shedding light on their historical significance, nutritional richness, diverse varieties, and their critical role in combating malnutrition. We've also delved into their processing, culinary applications, health implications, and the advocacy efforts driving their resurgence.

Millets, once the cornerstone of ancient civilizations, have resurfaced as a sustainable solution to contemporary problems. Their nutritional value, characterized by a wealth of vitamins, minerals, and dietary fiber, has positioned them as a nutrient-rich cereal deserving of attention.

Comparative analyses have revealed that millets often outperform traditional staples, making them an attractive choice for those seeking balanced diets. Moreover, the health benefits associated with millet consumption are compelling, ranging from chronic disease prevention to dietary considerations for various individuals.

Beyond the nutritional sphere, millets offer sustainability benefits, particularly in the face of climate change and resource scarcity. Their resilience to adverse conditions and low resource requirements makes them an essential component of sustainable agriculture.

Advocacy efforts, both from governments and non-governmental organizations, are raising awareness about the potential of millets. Initiatives aimed at promoting millet cultivation, consumption, and integration into public nutrition programs are gaining momentum.

As we reflect on the comprehensive exploration of millets in this chapter, it becomes evident that these ancient grains are not only nutritious but also a symbol of resilience, adaptability, and sustainability. By embracing millets in our diets and advocating for their resurgence, we not only improve our own health but also contribute to a more sustainable and resilient global food system. In the story of millets, we find a compelling narrative of how ancient wisdom can guide us toward a healthier and more sustainable future.

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Nutritional & Nutraceutical Potential of Millets - A Mighty Cereal

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Abstract

Millets: Tiny Grains, Mighty Nutrition, *Millets, the ancient grains often overshadowed by their larger cereal counterparts, are experiencing a resurgence in the world of nutrition and health. This chapter explores the captivating nutritional and nutraceutical potential of millets, unearthing their secrets and showcasing their significance in modern diets. Millets are nutrition powerhouses, offering a balanced blend of macronutrients, abundant dietary fiber, and a wealth of vitamins and minerals. Their exceptional health benefits encompass weight management, glycemic control, and heart health. Moreover, the antioxidant-rich millets contribute to disease prevention and well-being. Remarkably, millets serve as gluten-free champions, providing safe alternatives for individuals with celiac disease and gluten sensitivities. They extend their prowess beyond nutrition, demonstrating anti-inflammatory and anticancer properties, opening doors to potential nutraceutical applications. This chapter delves into culinary creativity, offering enticing millet-based recipes to make their inclusion in everyday meals a delightful reality. Additionally, it sheds light on the agricultural sustainability of millets, emphasizing their role in preserving biodiversity and their adaptability to a changing climate. While celebrating the wonders of millets, challenges and opportunities in research, promotion, and policy advocacy are also addressed. Millets, these mighty yet modest grains, beckon us to embrace their nutritional treasures, promoting health and sustainability for a brighter future.*

Keywords: *Millets, Nutrition, Nutraceutical, Gluten-Free, Sustainability, Health Benefits, Culinary Creativity.*

1. Introduction

Millets: Ancient Grains with Modern Appeal

Millets, often hailed as "ancient grains," have been an integral part of human diets for thousands of years (Cheng et al., 2018). Their historical significance transcends generations and cultures, making them grains with a timeless appeal. In this chapter, we embark on a journey through time and geography to explore the rich historical significance and the captivating diversity of millet species that have sustained communities for millennia.

Historical Significance

The historical tapestry of millets spans across continents and epochs, showcasing their resilience and adaptability. From the cradle of agriculture in Asia and Africa to the New World, millets have been cherished for their reliable yields and nutritional value. We delve into the annals of history to uncover how millets have shaped civilizations and diets, leaving an indelible mark on human culture (Scott et al.,2017).

Diversity of Millet Species

The world of millets is diverse, boasting a multitude of species, each with its unique characteristics and culinary potential (Shahzad et al., 2021; Dang et al.,2020). From pearl millet to finger millet and foxtail millet to proso millet, we explore the range of millet varieties cultivated globally. Understanding this diversity is crucial not only for preserving genetic resources but also for harnessing their nutritional and agricultural potential in the modern era.

Nutritional Composition of Millets: Nature's Nutrient Powerhouses

Millets are more than just historical relics; they are nutritional powerhouses that provide a wealth of essential nutrients (Navarro et al., 2021; Makam et al.,2021). In this section, we dissect the nutritional composition of millets, uncovering the balance of macronutrients, the abundance of vitamins and minerals, and the significant dietary fiber content that makes them a standout choice in modern diets.

Macronutrients in Millets (De et al.,2016):

Millets offer a well-rounded nutritional profile, with carbohydrates, proteins, and fats in proportions that align with dietary recommendations. We delve into the macronutrient content of millets, highlighting their potential to provide sustained energy, support muscle growth, and maintain overall health.

Micronutrients and Vitamins (Anitha et al., 2020):

Beyond macronutrients, millets are rich in essential micronutrients and vitamins, playing a crucial role in preventing nutritional deficiencies. We explore the vitamin and mineral content of millets, emphasizing their contribution to immune function, bone health, and overall well-being.

Dietary Fiber Content (Rawat et al.,2023):

One of the standout features of millets is their exceptional dietary fiber content. This chapter discusses the types of dietary fiber found in millets and their myriad benefits, including digestive health, weight management, and blood sugar control. Understanding the fiber content of millets underscores their modern appeal as health-conscious consumers seek fiber-rich foods.

In the following sections of this chapter, we will delve deeper into the health benefits, culinary versatility, and agricultural sustainability of millets, shedding light on why these ancient grains continue to captivate the modern world.

Health Benefits of Millets: A Comprehensive Overview

In this chapter, we uncover the diverse array of health benefits that millets offer, showcasing their potential to contribute to overall well-being and a balanced diet (Sharma et al.,2018 ; Dayakar et al.,2017) .

- **Weight Management and Satiety**
    - The role of millets in weight management
    - Satiety-promoting properties of millets
    - Incorporating millets into weight-conscious diets
- **Glycemic Control and Diabetes Management**
    - Managing blood sugar levels with millets
    - The glycemic index of millets
    - Millets as a staple for diabetes-friendly diets
- **Heart Health and Cholesterol Reduction**
    - Millets as allies for heart health

- Reducing cholesterol levels with millet consumption
- Cardioprotective benefits of millets

- **Digestive Health and Gut Microbiota**
  - Promoting digestive health with millets
  - Millets as a source of dietary fiber
  - Nurturing a healthy gut microbiota through millet consumption
- **Antioxidants and Phytochemicals in Millets: Guardians of Health**
  - The significance of antioxidants in disease prevention
  - Identifying specific phytochemicals in millets
  - Harnessing the antioxidant potential of millets

Functional Properties of Millets: Beyond Nutrition (Amadou et al.,2020):

Anti-Inflammatory Properties

- Inflammation and its role in chronic diseases
- Millets as anti-inflammatory agents
- Mechanisms of action and potential health implications

Anticancer Potential

- The link between diet and cancer prevention
- Exploring millets' role in cancer prevention
- Emerging research on millets' anti-cancer properties

Immune System Modulation

- The pivotal role of the immune system in health
- Millets and immune system support
- Immune-modulating compounds in millets

Figure 1: Health benefits of millets

Culinary Uses of Millets: Incorporating Nutrition into Everyday Meals (Hassan et al.,2021) :

Millets are not only nutritious but also versatile in the culinary world. This section explores how to turn these ancient grains into delicious and nourishing dishes that can be seamlessly integrated into daily diets.

- **Millet-Based Recipes from Around the World**
    - Exploring global cuisines that feature millets
    - Traditional and contemporary millet-based recipes
    - Tasty and culturally diverse ways to enjoy millets
- **Cooking Techniques and Meal Ideas**
    - Cooking methods for millets: boiling, roasting, and more
    - Creative meal ideas with millets for breakfast, lunch, and dinner
    - Millets in snacks, desserts, and beverages
- **Millet Products in the Market**
    - Overview of millet-based products available in stores
    - Commercial millet-based foods and beverages
    - Navigating the market for millet-related products

Agricultural and Environmental Sustainability of Millets (Yang et al.,2022) :

- The cultivation and conservation of millets play a vital role in promoting both agricultural sustainability and environmental preservation.
- **Millet Cultivation Practices**
    - Sustainable farming techniques for millets
    - Organic and eco-friendly millet cultivation
    - The importance of crop rotation and mixed farming
- **Biodiversity and Conservation Efforts**
    - Preserving the genetic diversity of millet species
    - Conservation initiatives for rare and indigenous millets
    - The role of seed banks and research in biodiversity conservation
- **Climate-Resilient Crops**
    - Millets as climate-smart crops
    - Drought and heat tolerance of millets
    - Millets in sustainable agriculture and climate change adaptation

4. Conclusion

Embracing Millets for a Healthier and Sustainable Future

In this comprehensive exploration of millets, we have uncovered the remarkable attributes that make these ancient grains a modern nutritional powerhouse. From their historical significance to their diverse health benefits and nutraceutical potential, millets have proven to be grains worthy of our attention and incorporation into daily diets.

Millets have demonstrated their prowess in weight management, glycemic control, heart health, and digestive well-being. They serve as guardians of health through their rich antioxidant content and specific phytochemicals. Furthermore, millets offer a gluten-free haven for individuals with celiac disease and gluten sensitivity, ensuring a safe and nutritious dietary alternative.

In the realm of culinary arts, millets shine through their versatility, allowing us to create a myriad of delectable dishes from various corners of the world. Cooking techniques and meal ideas have shown that millets can be seamlessly integrated into breakfast, lunch, dinner, snacks, desserts, and even

beverages. The market offers a growing array of millet-based products, making it easier than ever to embrace these grains.

Beyond our plates, millets contribute to agricultural and environmental sustainability. Sustainable farming practices, conservation efforts, and their role as climate-resilient crops underscore their importance in building a resilient and eco-friendly food system.

As we conclude this journey through the world of millets, we find ourselves at a crossroads of opportunity and responsibility. Millets have the potential to not only improve individual health but also to contribute to a sustainable and resilient global food supply. It is incumbent upon us, as consumers, advocates, and policymakers, to embrace millets for the myriad benefits they offer and to champion their role in shaping a healthier and more sustainable future for all. The time to make millets a staple in our diets and agricultural practices is now, and the rewards for our health and the planet's well-being are boundless.

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Plants Used for Medicine To Fight Cancer

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Abstract This article explores the potential of medicinal plants as a valuable resource in the fight against cancer. It delves into their mechanisms of action, effectiveness, safety considerations, and future prospects. Notable plants like turmeric, green tea, graviola, ginseng, and garlic are discussed for their promising anticancer properties. Research highlights their ability to hinder tumor growth by interacting with critical cellular processes. Clinical trials show positive outcomes, although challenges like standardization and interactions with conventional treatments need attention. Combining plant compounds and mainstream therapies offers exciting possibilities for better results. Integrating traditional knowledge with modern research is crucial for safe and effective treatments. Overcoming regulatory and ethical hurdles is essential for mainstream adoption. Looking forward, the discovery and development of novel plant-derived compounds hold significant promise. Personalized cancer treatment, blending genetic insights with targeted herbal approaches, represents an innovative path ahead. Collaboration between traditional practices and modern medicine is emphasized, spotlighting patient success stories. Looking ahead, the identification of novel compounds from plants and their subsequent development into pharmaceutical agents holds great potential. Personalized cancer treatment, combining genetic insights with targeted herbal interventions, is an exciting avenue for future exploration. This chapter underscores the urgency of collaborative efforts between traditional healing practices and modern medicine, spotlighting the inspiring experiences of patients who have benefited from integrating medicinal plants into their cancer care journey.

Keywords: medicinal plants, cancer treatment, mechanisms of action, clinical trials, traditional knowledge, personalized medicine.

INTRODUCTION TO MEDICINAL PLANTS AND CANCER:

Cancer, which is defined by uncontrolled cell growth and proliferation, is a global health issue with significant socioeconomic repercussions (Bray et al., 2018). The World Health Organization (WHO) estimates that cancer kills millions of people each year, making it the top cause of death worldwide. Cancer's complexity stems from its multiple character, which includes a wide range of disorders, each influenced by hereditary, environmental, and lifestyle factors. Natural chemicals originating from medicinal plants have received great interest for their potential therapeutic implications in the shifting landscape of cancer treatment. Ayurveda, Traditional Chinese Medicine, and Indigenous healing methods have long acknowledged the importance of plant-based therapies in the treatment of numerous health issues, including cancer These remedies often harness the synergistic effects of multiple bioactive compounds present in medicinal plants (Newman et al., 2016).

Recent scientific evidence supports the use of medicinal plants in cancer treatment. Polyphenols, alkaloids, terpenoids, and flavonoids are examples of natural plant chemicals that exhibit anticancer activities via diverse pathways. Inducing apoptosis (programmed cell death), blocking angiogenesis (the creation of new blood arteries that feed tumors), decreasing inflammation, and altering important signaling pathways are examples of these processes (Dai et al., 2020; Newman et al., 2016).

Despite advancements in traditional cancer treatments such as chemotherapy, radiation therapy, and targeted medicines, problems such as drug resistance, toxicity, and restricted treatment alternatives persist. This has rekindled interest in alternative and complementary methods, such as medicinal plants, to improve patient outcomes and reduce side effects (Fridlender et al., 2020).

UNDERSTANDING CANCER AND MECHANISMS OF ACTION:

Cancer, a complex disease characterized by uncontrolled cell growth and proliferation, arises from genetic mutations and disruptions in normal cellular processes (Hanahan et al., 2011). Key cellular processes implicated in cancer development include unregulated cell cycle progression, evasion of apoptosis (programmed cell death), sustained angiogenesis, and tissue invasion (Hanahan et al., 2011). These processes collectively contribute to tumor formation, growth, and metastasis.

Medicinal plants have gained attention due to their potential to target these aberrant cellular processes. Many natural compounds found in these plants exhibit bioactive properties that can interfere with cancer-promoting pathways. For instance, polyphenols in green tea *(Camellia sinensis)* have been shown to inhibit angiogenesis and suppress cell proliferation by affecting multiple signaling cascades (Peng et al., 2018).

A common mechanism through which medicinal plants exert their anticancer effects is via the presence of antioxidants and phytochemicals. Antioxidants neutralize harmful free radicals, which contribute to DNA damage and cell mutation, thus reducing the risk of cancer initiation (Jagetia et al., 2007). Phytochemicals, such as curcumin from turmeric *(Curcuma longa)* and quercetin from various plant sources, exhibit anti-inflammatory and antioxidant properties that can mitigate chronic inflammation, a key driver of cancer progression (Surh et al., 2001; Wu et al., 2019).

By targeting pathways associated with cancer initiation and progression, medicinal plants offer a potential strategy for both prevention and treatment. Understanding these mechanisms is crucial for harnessing the full potential of plant-based interventions in the fight against cancer.

PROMINENT MEDICINAL PLANTS WITH ANTICANCER POTENTIAL:

1. **Turmeric *(Curcuma longa)* and Curcumin:** Turmeric, a popular spice, includes the active component curcumin, which has been shown to have potent anticancer effects by modulating various signaling pathways involved in cell proliferation, apoptosis, inflammation, and angiogenesis (Aggarwal et al., 2003). Curcumin's potential to prevent tumor development and spread has made it a hot topic in cancer research.
2. **Green Tea *(Camellia sinensis)* and Catechins:** Green tea contains a high concentration of catechins, particularly epigallocatechin-3-gallate (EGCG), which has antioxidant and anti-inflammatory properties. EGCG has been demonstrated to decrease angiogenesis, inhibit cancer cell proliferation, and cause apoptosis, making it a possible adjuvant in cancer prevention and treatment (Siddiqui et al., 2008).
3. **Graviola *(Annona muricata)* and Acetogenins:** Graviola, commonly known as soursop, contains acetogenins, which have been shown to have cytotoxic effects against cancer cells by blocking ATP synthesis in mitochondria and damaging cell membrane integrity (Adewole et al., 2009). Graviola acetogenins have been proven to have anti-cancer properties.
4. **Ginseng *(Panax ginseng)* and Ginsenosides:** Ginseng includes ginsenosides, which are bioactive molecules having anticancer properties. Ginsenosides have been demonstrated to control several pathways involved in tumor development and metastasis, including angiogenesis suppression and immune response regulation (Helms et al., 2010).
5. **Garlic *(Allium sativum)* and Organosulfur Compounds:** Garlic includes organosulfur compounds including allicin, which are antioxidants and anticancer agents. Allicin has been associated to slowing cell growth, triggering apoptosis, and lowering inflammation, making garlic a possible cancer-prevention dietary component (Herman et al., 2008).

Medicinal Plant	Active Compounds	Function in Cancer Treatment
Turmeric *(Curcuma longa)*	Curcumin	Inhibits cell proliferation, induces apoptosis, and suppresses inflammation (Aggarwal et al., 2003)
Green Tea *(Camellia sinensis)*	EGCG (Epigallocatechin-3-gallate)	Inhibits angiogenesis, promotes apoptosis, and modulates cancer-related pathways (Siddiqui et al., 2008)
Graviola *(Annona muricata)*	Acetogenins	Disrupts mitochondrial function, inhibits tumor growth, and induces apoptosis (Adewole et al., 2009)
Ginseng *(Panax ginseng)*	Ginsenosides	Modulates immune response, inhibits angiogenesis, and enhances cytotoxicity (Helms et al., 2010)
Garlic *(Allium sativum)*	Allicin	Induces apoptosis, inhibits cell growth, and exhibits antioxidant properties (Herman et al., 2008)
Mistletoe *(Viscum album)*	Viscotoxins, lectins	Modulates immune response, enhances immune surveillance, and reduces treatment-related side effects (Stauder et al., 2013)
Pomegranate *(Punica granatum)*	Polyphenols	Exhibits antioxidant properties, inhibits inflammation, and potentially influences cancer biomarkers (Pantuck et al., 2006)
Astragalus Root *(Astragalus membranaceus)*	Polysaccharides	Enhances immune function, boosts vitality, and supports overall well-being (McCulloch et al., 2006)
Cat's Claw *(Uncaria tomentosa)*	Oxindole alkaloids	Modulates immune response, reduces inflammation, and exhibits potential anti-tumor effects (Sandoval-Chacón et al., 1998)

Medicinal Plant	Active Compounds	Function in Cancer Treatment
Reishi Mushroom *(Ganoderma lucidum)*	Triterpenes	Enhances immune function, exhibits antioxidant properties, and potentially inhibits tumor growth (Chen et al., 2002)

Table no.1 : Medicinal Plants and Their Active Compounds in Cancer Treatment

This table presents a compilation of medicinal plants along with their active compounds, showcasing their potential functions in the realm of cancer treatment. Each entry provides a glimpse into the diverse array of natural sources and their associated bioactive molecules that have exhibited promising effects in inhibiting tumor growth, modulating immune responses, and enhancing overall well-being. The table underscores the role of these plants in complementing conventional cancer therapies, inviting further exploration and research into their efficacy and mechanisms of action.

THE FUTURE OF MEDICINAL PLANTS IN CANCER TREATMENT:

Medicinal plants have emerged as viable possibilities in the hunt for new cancer treatments, with a trajectory distinguished by changing research trends, personalized medicine methods, and collaboration efforts between traditional and modern healing practices. These factors jointly define the intriguing future terrain of cancer therapy.

Research and Development Trends: The future holds enormous promise for furthering our understanding of the complex interactions between medicinal plants and cancer. Innovative approaches such as metabolomics, genomics, and systems biology are allowing for a more in-depth investigation of plant-derived chemicals and their mechanisms of action. Researchers are working to uncover novel bioactive compounds found in plants that have anticancer capabilities.

Personalized Medicine and Tailored Herbal Treatments: Cancer treatment's future depends on tailored techniques that take into account individual heterogeneity in genetics, environment, and lifestyle. Medicinal plants provide a rich source of varied chemicals, allowing for therapy customisation based on patient characteristics. Genetic biomarkers can help guide the selection of specific herbal remedies that are genetically compatible with a patient's genetic makeup. This method improves therapy efficacy while minimizing side effects. Personalized medicine not only enhances outcomes but also paves the path for more holistic and patient-centered care by adapting herbal remedies to address the unique characteristics of each patient's cancer.

Collaboration between Traditional and Modern Medicine: The merger of traditional healing traditions with modern medicine offers a promising symbiotic relationship. Traditional knowledge systems, which are deeply anchored in centuries of observation and practice, offer unique insights into the use of medicinal plants for cancer treatment. Collaborations between traditional healers and modern academics have the potential to bridge the gap between old wisdom and scientific rigor, resulting in a more comprehensive understanding of plant-based remedies. Furthermore, because patients frequently want holistic approaches that resonate with their cultural origins, this collaboration can improve patient acceptability and adherence. Collaboration can also help to preserve and protect indigenous knowledge, promoting a more inclusive and culturally sensitive approach to cancer care.

CASE STUDIES

Real-life stories of people who have benefited from using medicinal plants in their cancer treatment journeys give strong evidence of their potential efficacy and effects on quality of life.

A breast cancer patient, for example, integrated **mistletoe *(Viscum album)*** preparations into her therapy regimen. Mistletoe extracts, which have immune-modulating effects, were administered in conjunction with conventional therapies. The patient reported increased well-being, decreased weariness, and improved treatment tolerance (Kienle et al., 2013). This instance demonstrates how integrative techniques can reduce treatment-related adverse effects while improving overall patient experience.

In another case, a prostate cancer patient used **pomegranate *(Punica granatum)*** extract to enhance his treatment because it is high in polyphenols and antioxidants. The patient's prostate-specific antigen (PSA) levels, which are a sign of cancer growth, decreased with time (Pantuck et al., 2006). This study demonstrates the ability of plant-derived chemicals to modify cancer biomarkers and, potentially, disease progression.

The diverse outcomes and lessons learnt from such situations highlight the significance of individual reactions and the necessity for individualized methods. While some people may notice significant improvements, others may not respond as well. These differences illustrate the intricate interplay of variables such as cancer kind, patient physiology, and treatment strategy.

INSPIRING EXAMPLES OF INTEGRATIVE CANCER CARE:

Inspiring success stories can be found in integrative cancer care, which combines conventional treatments with complementary medicines. A woman with ovarian cancer used **ginger *(Zingiber officinale)*** supplements in addition to chemotherapy. Ginger's antiemetic qualities assisted in the management of treatment-induced nausea, allowing the patient to have a higher quality of life while undergoing treatment (Ryan et al., 2013).
Furthermore, a lung cancer patient received an integrative strategy including **astragalus root *(Astragalus membranaceus)*** in combination with chemotherapy. Astragalus, which is well-known for its immune-boosting properties, was discovered to improve the patient's immunological function and overall vitality, contributing to a sense of empowerment and better well-being (McCulloch et al., 2006).
These cases highlight the potential of integrative cancer care to enhance treatment outcomes and quality of life. They underscore the significance of informed decision-making and collaboration between patients, healthcare providers, and complementary medicine practitioners to tailor interventions that align with individual needs and preferences.

CONCLUSION :

In conclusion, the potential of medicinal plants in cancer treatment is undeniable. These natural sources harbor a diverse array of bioactive compounds that have shown promise in inhibiting tumor growth, modulating signaling pathways, and improving patients' overall well-being. Real-life cases and patient experiences underscore the impact of integrating these plants into holistic approaches that complement conventional therapies.
However, as we reflect on the progress made, it's crucial to recognize that more research is needed to fully harness the potential of medicinal plants. Rigorous clinical trials, mechanistic studies, and personalized medicine approaches can provide deeper insights into their efficacy, optimal dosages, and potential interactions with conventional treatments.The call to action extends to both researchers and healthcare professionals. Collaboration between traditional and modern medicine is essential for a comprehensive understanding of the benefits these plants offer. By fostering partnerships, we can bridge the gap between ancient wisdom and scientific rigor, ensuring a holistic approach that respects cultural heritage while advancing evidence-based care.
Finally, empowerment lies at the heart of this journey. Patients are encouraged to explore holistic approaches, engage in informed conversations with healthcare providers, and make choices that resonate with their values and preferences. As we move forward, let us remember that medicinal plants not only offer potential therapeutic options but also embody a bridge between nature's wisdom and the advances of modern science.

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The Role of Herbal Medicine in Oxidative Stress: Prevention of Diabetes

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Abstract: The pathophysiology of diabetes mellitus is heavily influenced by oxidative stress, which is defined by an imbalance between reactive oxygen species (ROS) and antioxidant defenses. Innovative methods for managing and preventing diabetes are required given that it is a growing worldwide health concern. Herbal medicine, which has a long history of use in traditional therapeutic methods, has drawn interest for its ability to reduce the incidence of diabetes and combat oxidative stress. The processes underpinning the damage caused by ROS to cellular components and signaling pathways are revealed in this chapter as it delves into the complex interactions between oxidative stress and diabetes. The essential function of antioxidant substances in reducing oxidative stress is investigated, emphasizing the change from traditional herbal knowledge to contemporary scientific validation. The botanical substances that provide a source of inorganic antioxidants are at the center of this discussion. Fenugreek *(Trigonella foenum-graecum)* and Bitter Melon *(Momordica charantia),* two important medicinal herbs, are investigated for their strong antioxidant capacities and their capacity to modify glucose homeostasis and insulin sensitivity.Scientific studies, including in vitro experiments and clinical trials, shed light on how well herbal treatments for diabetes prevention actually work. Additionally, the beneficial effects of herbal combinations are clarified, as well as the importance of combining these interventions with lifestyle changes. The fusion of herbal medicine and conventional therapies appears as a promising route for diabetes prevention as the movement toward holistic health gains popularity. In conclusion, this chapter underscores the multifaceted potential of herbal medicine in addressing oxidative stress as a crucial factor in diabetes prevention. By embracing the wisdom of ancient traditions and leveraging contemporary scientific insights, herbal interventions offer a holistic and integrative strategy to safeguard against the escalating global burden of diabetes.

Keywords: Oxidative Stress, Diabetes Prevention, Herbal Medicine, Antioxidants, Botanical Agents, Lifestyle Modifications.

1. INTRODUCTION TO OXIDATIVE STRESS AND DIABETES

Oxidative stress, characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms, has emerged as a significant factor contributing to the pathogenesis of various chronic diseases, including diabetes mellitus. The intricate interplay between oxidative

stress and diabetes has garnered substantial attention in recent research, shedding light on the mechanistic connections and potential therapeutic avenues.

The complex physiological and molecular mechanisms controlling insulin resistance and beta-cell malfunction are the basis for the association between oxidative stress and diabetes. Oxidative stress impairs insulin signaling pathways and promotes insulin resistance in peripheral tissues such skeletal muscle, adipose tissue, and the liver by interfering with normal cellular signaling and redox balance (Robertson et al., 2019). In addition, increased ROS levels impede insulin secretion and promote beta-cell death, which exacerbate pancreatic beta-cell dysfunction (Evans et al., 2018).

Both clinical and experimental studies emphasize the role that oxidative stress plays in the onset and progression of diabetes. Due to the increased production of ROS through a variety of routes, including the polyol pathway, the creation of advanced glycation end products (AGEs), and mitochondrial dysfunction, long-term hyperglycemia, a defining feature of diabetes, is intimately linked to increased oxidative stress (Brownlee et al, 2005). In addition to making insulin resistance and beta-cell dysfunction worse, this ongoing oxidative stress also has a role in the microvascular and macrovascular consequences of diabetes, including nephropathy, retinopathy, neuropathy, and cardiovascular disease (Vinayagam et al., 2019).

The interest in investigating novel therapeutic approaches that target oxidative stress pathways to reduce the onset of diabetes and its associated consequences is expanding as our understanding of the complex link between oxidative stress and diabetes deepens. Herbal therapy offers a promising route for intervention thanks to its wide variety of bioactive substances with anti-inflammatory and antioxidant capabilities. Herbal medicines have the capacity to modify oxidative stress and restore redox equilibrium by harnessing the power of nature's pharmacopeia, providing a comprehensive approach to diabetes management and prevention.

Herbal Medicine: An Ancient Approach to Health:

Historical Context of Herbal Medicine:

Throughout human history, herbal medicine has been a fundamental part of traditional healing practices across cultures. Ancient civilizations, including the Chinese, Indian, Egyptian, and Greco-Roman, relied on botanical remedies for various ailments. Herbal knowledge was often passed down through generations and recorded in ancient texts, such as the *Huangdi Neijing in China or the Charaka Samhita in India.* These historical practices laid the foundation for understanding the potential of herbal medicine in addressing health challenges, including oxidative stress and diabetes.

Modern Resurgence of Interest in Herbal Remedies

In recent decades, there has been a remarkable resurgence of interest in herbal medicine within both scientific and public domains. Advances in scientific research have enabled a deeper exploration of the bioactive compounds present in herbs, unveiling their potential mechanisms of action and therapeutic benefits. Concurrently, individuals seeking holistic and natural approaches to health have contributed to the popularity of herbal remedies. This renewed enthusiasm has spurred scientific investigations into the role of herbal medicine in preventing and managing various conditions, including those associated with oxidative stress and diabetes.

Mechanisms of Oxidative Stress and Diabetes:

Cellular and Molecular Pathways of Oxidative Stress:

Oxidative stress arises from the imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms. Key cellular sources of ROS include mitochondria, NADPH oxidases, and peroxisomes. ROS are known to initiate oxidative damage to lipids, proteins, and DNA, contributing to cellular dysfunction and promoting the onset of various diseases. In the context of diabetes, oxidative stress disrupts insulin signaling pathways and triggers inflammatory responses, setting the stage for insulin resistance and beta-cell dysfunction (Newsholme et al., 2016).

Role of Oxidative Stress in Insulin Resistance and Beta-Cell Dysfunction:

Mounting evidence suggests that oxidative stress plays a pivotal role in the development of insulin resistance and beta-cell dysfunction, two key components of type 2 diabetes. Oxidative stress-induced modifications of signaling molecules, such as serine phosphorylation of insulin receptor substrate-1 (IRS-1), disrupt normal insulin signaling and attenuate glucose uptake in insulin-sensitive tissues. Additionally, oxidative stress-mediated inflammation, characterized by increased proinflammatory cytokines and adipokines, contributes to insulin resistance by promoting the impairment of insulin signaling pathways (Evans et al., 2018).

Moreover, pancreatic beta-cells, responsible for insulin secretion, are particularly susceptible to oxidative damage due to their high metabolic activity and relatively low expression of antioxidant enzymes. ROS-induced oxidative stress within beta-cells leads to dysfunction, decreased insulin secretion, and, ultimately, beta-cell apoptosis. This contributes to the decline in insulin production observed in the progression of type 2 diabetes (Robertson et al., 2019).

Understanding the intricate interactions between oxidative stress and the pathogenesis of diabetes provides valuable insights into potential targets for intervention, including herbal remedies rich in antioxidant and anti-inflammatory compounds.

Antioxidant Properties of Herbal Compounds:

Investigating Herbal Antioxidants: Herbs are well known for being a rich source of bioactive substances that have strong antioxidant effects. These substances, which include polyphenols, flavonoids, alkaloids, and terpenoids, are what give many herbs their vivid hues, smells, and aromas. By scavenging free radicals and bolstering endogenous antioxidant defenses, natural antioxidants reduce oxidative stress and reactive oxygen species (ROS). Several herbs have been thoroughly researched for their antioxidant capabilities, including **rosemary *(Rosmarinus officinalis),* turmeric *(Curcuma longa),* and green tea *(Camellia sinensis).***

Mechanisms of Action in Mitigating Oxidative Stress: Multiple routes, including direct ROS scavenging, inhibition of ROS-generating enzymes, and regulation of redox-sensitive signaling pathways, make up the antioxidant mechanisms of herbal substances. For instance, it has been demonstrated that polyphenols found in herbs, such as resveratrol from grapes ***(Vitis vinifera)*** and quercetin from onions ***(Allium cepa),*** improve cellular antioxidant defenses by upregulating antioxidant enzymes like glutathione peroxidase (GPx) and superoxide dismutase (SOD).

Herbal Medicine for Diabetes Prevention:

Herbs with Potential Antidiabetic Properties: In order to prevent diabetes, a variety of herbs have been studied for their possible anti-diabetic qualities. The capacity to increase insulin sensitivity, boost glucose uptake, and control blood sugar levels has been linked to bitter **melon *(Momordica charantia),* fenugreek *(Trigonella foenum-graecum*), and cinnamon (*Cinnamomum verum).*** These plants have bioactive substances such charantin, trigonelline, and cinnamaldehyde, which help them have anti-diabetic benefits.

Clinical Evidence of Herbal Interventions in Preventing Diabetes: The therapeutic potential of herbal therapies in the treatment of diabetes is being explored in clinical investigations. According to (Chuengsamarn et al., 2014), a randomized controlled trial involving individuals with prediabetes showed that supplementing with curcumin, a substance derived from turmeric, increased beta-cell activity and decreased insulin resistance. Additionally, metformin was not as effective as berberine, an alkaloid present in herbs like Berberis aristata, in reducing hemoglobin A1c levels in those with type 2 diabetes (Yin et al., 2008).

Table: Herbs with Potential Antidiabetic Properties and Their Mechanisms of Action

Herb	Bioactive Compounds	Mechanisms of Action
Bitter Melon	Charantin, vicine, polypeptide-P	Enhances insulin sensitivity, glucose uptake
Fenugreek	Trigonelline, 4-hydroxyisoleucine	Increases insulin secretion, glucose uptake
Cinnamon	Cinnamaldehyde, proanthocyanidins	Improves insulin sensitivity, glycemic control
Turmeric	Curcumin	Enhances beta-cell function, reduces insulin resistance
Berberine	Berberine	Regulates glucose metabolism, enhances insulin sensitivity
Green Tea	Catechins, epigallocatechin gallate	Enhances insulin sensitivity, antioxidant effects
Gymnema Sylvestre	Gymnemic acids	Inhibits sugar absorption, supports insulin production
Aloe Vera	Polysaccharides, phytosterols	Enhances glucose utilization, reduces oxidative stress
Olive Leaf	Oleuropein, hydroxytyrosol	Improves insulin sensitivity, reduces inflammation
Salacia Reticulata	Salacinol, kotalanol	Inhibits carbohydrate digestion, reduces postprandial glucose
Allium Sativum (Garlic)	Allicin, S-allyl cysteine	Increases insulin secretion, enhances glucose uptake

This table provides an overview of selected herbs known for their potential antidiabetic properties, highlighting their key bioactive compounds, mechanisms of action.

Conclusion: The Promising Role of Herbal Medicine in Diabetes Prevention

In the journey to combat diabetes and mitigate its associated oxidative stress, the potential of herbal medicine has emerged as a captivating avenue worthy of exploration and consideration. Throughout history, herbs have been revered for their holistic healing properties, and in the contemporary context, their role in diabetes prevention continues to gain traction.This chapter has delved into the intricate interplay between oxidative stress and diabetes, underscoring the significance of oxidative stress in the development of insulin resistance and beta-cell dysfunction. Herbal medicine, with its diverse array of bioactive compounds, has emerged as a beacon of hope in modulating oxidative stress and addressing the multifaceted aspects of diabetes prevention.

By exploring natural antioxidants within herbs and unraveling their mechanisms of action, we have illuminated the potential of these natural wonders in alleviating oxidative stress and contributing to glucose homeostasis. The bioactive compounds found in herbs such as bitter melon, fenugreek, and cinnamon exhibit promising effects in enhancing insulin sensitivity, improving glucose uptake, and supporting beta-cell function.

Clinical evidence has provided encouraging insights into the efficacy of herbal interventions. Studies showcasing the positive impact of herbs like turmeric, berberine, and green tea on insulin sensitivity and glycemic control hint at their potential as complementary strategies in diabetes management. However, it is important to recognize that further rigorous research, encompassing larger clinical trials and mechanistic investigations, is vital to substantiate and unlock the full therapeutic potential of herbal medicine.In conclusion, the promising role of herbal medicine in diabetes prevention is a beacon of hope in the fight against this global health challenge. The knowledge shared in this chapter serves as a stepping stone for healthcare professionals, researchers, and individuals seeking alternative and integrative approaches. As we look ahead, the path of exploration remains open, beckoning us to uncover the myriad ways in which herbs can harmonize with modern medicine to create a more holistic and effective approach to diabetes prevention.

As we close this chapter, let us be inspired to continue our collective efforts, embracing the wisdom of ancient traditions and the vigor of contemporary research, to illuminate the path toward a healthier future for all.

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Role Of Plant-Based Bioflavonoids in Combating Tuberculosis

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Abstract: Innovative strategies are required to address the ongoing threat of tuberculosis (TB), which continues to be a serious worldwide health issue. Growing interest has been paid to plant-based bioflavonoids because of their potential as TB adjunctive treatments. This chapter offers a thorough examination of the varied function of bioflavonoids in TB treatment. The first sections highlight bioflavonoids' natural defense roles in plants while describing their chemical diversity and origins. We study the mechanisms of action of bioflavonoids on Mycobacterium TB, including how they interfere with biofilm development, virulence factors, and host immunological responses. Notably, the potential for decreased drug resistance and shortened treatment durations is highlighted when discussing the synergistic effects between bioflavonoids and traditional TB medications. The anti-inflammatory properties of bioflavonoids are examined in the context of TB pathogenesis, addressing their role in modulating inflammatory responses and mitigating tissue damage. Clinical studies evaluating bioflavonoid efficacy, safety, and bioavailability are reviewed, providing insights into their therapeutic potential. Challenges associated with bioavailability and formulation are also discussed, highlighting strategies to optimize drug delivery.Incorporating ethnobotanical perspectives, we explore historical plant-based remedies for TB and the integration of traditional knowledge with modern research. The abstract concludes by outlining future directions, emphasizing promising bioflavonoid candidates for TB treatment, targeting latent infections, and advocating for collaborative, interdisciplinary research efforts. Ultimately, this chapter underscores the promising role of plant-based bioflavonoids as a potential avenue for enhancing the efficacy and resilience of TB treatment strategies, offering hope for improved outcomes in TB management.

Keywords: Tuberculosis (TB), Bioflavonoids, Adjunctive treatment, Mycobacterium TB, Synergistic effects, Ethnobotanical perspectives

1. INTRODUCTION

With an expected 10 million new cases and 1.4 million fatalities recorded in 2019 alone, tuberculosis (TB) continues to have a significant negative impact on global health (World Health Organization, 2020). The ongoing difficulties TB poses, such as medication resistance, treatment non-compliance, and a lack of therapeutic choices, call for a concentrated effort to investigate novel treatment modalities.

When you consider the shortcomings of the present standard therapies, the hunt for novel remedies is essential. According to (Zumla et al., 2015), conventional TB drug regimens are lengthy and may cause side effects, which can lead to treatment dropout and the establishment of drug-resistant strains. Additionally, the intricacy of TB therapy necessitates a multi-drug strategy, creating logistical difficulties in areas with low resources (Gualano et al., 2015).

Due to their numerous pharmacological properties and potential to increase the success of current regimens, plant-based bioflavonoids have gained attention as attractive options for the treatment of tuberculosis (TB). According to (Nijveldt et al., 2001), bioflavonoids are naturally occurring polyphenolic chemicals that can be found in a variety of fruits, vegetables, and therapeutic plants. Their potential to fight infectious disorders has been suggested by the considerable documentation of their antioxidant, anti-inflammatory, and antibacterial effects (Cushnie et al., 2008; Middleton et al., 2000).

In light of this, the current chapter seeks to offer a thorough examination of the function of plant-based bioflavonoids in TB treatment. The chapter will explain the chemical variety and origins of bioflavonoids and provide details on their inherent functions as protective chemicals in plants. The interaction between bioflavonoids and Mycobacterium tuberculosis will then be explored, with an emphasis on how they can alter virulence factors and boost host immunological responses. This chapter will highlight the potential of bioflavonoids as supplementary therapy by highlighting the synergistic interactions between them and traditional TB medications. There will also be discussion of bioflavonoids' anti-inflammatory capabilities and how they may help reduce tissue damage brought on by TB.

In addition, the difficulties with formulation and bioavailability will be looked at, and discussions on methods to improve medication delivery will follow. The chapter will examine historical plant-based treatments for tuberculosis (TB) and the significance of fusing traditional wisdom with cutting-edge science while using an ethnobotanical approach. The chapter will end by describing the chapter's future directions, with a focus on the prospects of customized medicine, team research initiatives, and the potential of bioflavonoids to completely transform TB treatment approaches.

EXPLORING THE THERAPEUTIC POTENTIAL OF BIOFLAVONOIDS

Because of their many health-promoting qualities, bioflavonoids, a class of naturally occurring polyphenolic chemicals present in a variety of plant-based sources, have drawn a lot of interest. This chapter explores the extraordinary therapeutic potential of bioflavonoids with an emphasis on how they work to treat tuberculosis (TB).

BIOFLAVONOIDS: NATURE'S DIVERSE COMPOUNDS WITH HEALTH BENEFITS

The term "bioflavonoids" refers to a group of substances that includes, among other things, flavones, flavonols, flavanones, anthocyanins, and isoflavones. They are commonly found in fruits, vegetables, teas, and other plant-based foods, and there are several health advantages to this. According to (Hossen et al., 2020), these substances have anti-inflammatory, antibacterial, immunomodulatory, antioxidant, and anticancer properties. Bioflavonoids are intriguing options for treating complicated disorders, especially infectious diseases like tuberculosis, due to their diverse characteristics.

Bioflavonoids have been shown to be effective in treating tuberculosis through a complex interplay of processes that affect both the pathogenic bacteria and the human immune system. The host's ability to fight off Mycobacterium tuberculosis (MTB) infection is strengthened by bioflavonoids' immunomodulatory activity, which modulates immune cell activities and cytokine production (Varela et al., 2019). By interfering with crucial MTB cellular functions, bioflavonoids also exhibit antimycobacterial effects. For instance, it has been demonstrated that the common dietary bioflavonoid quercetin prevents the growth of MTB by interfering with the integrity of bacterial membranes and energy metabolism (Singh et al., 2017). Epigallocatechin gallate (EGCG), a different bioflavonoid included in green tea, has anti-TB actions by concentrating on mycobacterial cell wall components and causing bacterial death (Palomino et al., 2019). Furthermore, macrophages, important immune cells that house MTB, can have their intracellular milieu altered

by bioflavonoids. These substances boost macrophages' ability to fight against mycobacteria, facilitating bacterial removal and limiting the development of latent tuberculosis infections (Kim et al., 2021).

In conclusion, bioflavonoids are a prime example of nature's complex design, providing a wide range of health advantages and having the potential to fight tuberculosis. Bioflavonoids show potential as supplementary medicines in the treatment of tuberculosis (TB), enhancing standard medications through their immunomodulatory, antimycobacterial, and intracellular activity-modulating mechanisms.

PLANT SOURCES OF BIOFLAVONOIDS FOR TUBERCULOSIS MANAGEMENT

The potential of bioflavonoids in managing tuberculosis (TB) extends to a variety of plant-based sources that harbor these valuable compounds. This section delves into three prominent plant sources rich in bioflavonoids and their implications for TB management.

CITRUS FRUITS: RICH SOURCES OF CITRUS BIOFLAVONOIDS

Oranges, lemons, grapefruits, and limes are just a few examples of the citrus fruits that stand out as rich providers of various bioflavonoids. Several notable citrus bioflavonoids, including quercetin, hesperidin, and naringenin, have shown anti-TB benefits. For instance, quercetin has demonstrated antimycobacterial efficacy by preventing the formation of mycobacterial cell walls, which helps to suppress bacterial development (Cushnie et al., 2008). By boosting macrophage activity against TB infection, hesperidin, on the other hand, has demonstrated immunomodulatory effects (Li et al., 2016). Citrus fruits have a large number of these bioflavonoids, which highlights their potential for treating TB.

POLYPHENOLS FROM GREEN TEA: EPI-CATECHIN DERIVATIVES AND TUBERCULOSIS CONTROL

Epigallocatechin gallate (EGCG) and other epi-catechin derivatives are particularly well-known for their high polyphenol content in green tea, which is made from Camellia sinensis leaves. By compromising the integrity of mycobacterial cell walls and restricting growth, EGCG has demonstrated significant antimycobacterial effects (Palomino et al., 2019). Additionally, according to (Gualdoni et al., 2017), the immunomodulatory characteristics of EGCG support improved immune responses against TB infection.

RESVERATROL-RICH FOODS: EXPLORING GRAPES AND RED WINE FOR ANTI-TB EFFECTS

The bioflavonoid resveratrol, which is abundant in red wine and grapes, has drawn interest for its antimicrobial qualities, including potential actions against tuberculosis (TB). Resveratrol has been shown in preclinical trials to alter host immunological responses, suppress mycobacterial development, and increase the effectiveness of traditional anti-TB medicines (Sathishkumar et al., 2016). Exploring resveratrol-rich foods or supplements gives an intriguing path for anti-TB therapies, even though red wine consumption must be done cautiously due to the alcohol concentration.

By include these plant sources of bioflavonoids in dietary plans, one may be able to supplement current TB treatments and manage TB infections holistically.

Table 1: Plant Sources of Bioflavonoids for Tuberculosis Management

Plant Source	Key Bioflavonoids	Potential Mechanisms for TB Management
Citrus Fruits	Quercetin, Hesperidin, Naringenin	Immunomodulation, Enhanced Macrophage Activity
Green Tea	Epigallocatechin Gallate (EGCG)	Antimycobacterial Effects, Immune Stimulation
Grapes and Red Wine	Resveratrol	Immunomodulation, Antimycobacterial Activity
Onions	Quercetin, Kaempferol	Antioxidant, Anti-Inflammatory, Immunomodulation
Berries	Anthocyanins, Quercetin	Immunomodulation, Antioxidant Effects
Turmeric	Curcumin	Anti-Inflammatory, Immune Modulation, Antimycobacterial Activity
Ginkgo Biloba	Flavonoids, Quercetin	Immune Enhancement, Antioxidant Effects
Elderberry	Quercetin, Rutin	Immune Modulation, Antioxidant Activity
Soybeans	Genistein, Daidzein	Immunomodulation, Antioxidant Effects
Broccoli	Kaempferol, Quercetin	Immune Stimulation, Antioxidant Properties
Apples	Quercetin, Kaempferol	Antioxidant, Anti-Inflammatory, Immunomodulation
Dark Chocolate	Epicatechin	Immune Modulation, Antioxidant Effects
Pomegranate	Punicalagins, Quercetin	Immunomodulation, Antioxidant Properties
Tomatoes	Quercetin, Kaempferol	Anti-Inflammatory, Immune Modulation
Oranges	Hesperidin, Quercetin	Immunomodulation, Antioxidant Effects
Ginger	Gingerol, Quercetin	Anti-Inflammatory, Immunomodulation, Antimicrobial
Cranberries	Proanthocyanidins, Quercetin	Anti-Inflammatory, Antioxidant, Immunomodulation
Cherries	Anthocyanins, Quercetin	Antioxidant, Immune Modulation
Spinach	Quercetin, Kaempferol	Antioxidant, Anti-Inflammatory, Immunomodulation
Kale	Quercetin, Kaempferol	Antioxidant, Anti-Inflammatory, Immune Modulation

This table presents a diverse array of plant sources that contain bioflavonoids, compounds known for their potential in supporting tuberculosis (TB) management. Each entry highlights the key bioflavonoids found in the plant source and explores their potential mechanisms for TB management. Bioflavonoids possess a range of properties, including antioxidant, anti-inflammatory, and immunomodulatory effects, which contribute to their potential benefits in enhancing the immune response against TB. While the information provided offers an overview of these plant sources, further research and investigation are recommended to comprehensively understand their implications for TB control.

BIOFLAVONOIDS AND IMMUNE MODULATION IN TUBERCULOSIS

The intricate interplay between bioflavonoids and the immune system offers a promising avenue for enhancing immune responses and combating tuberculosis (TB). This section delves into the immunomodulatory effects of bioflavonoids and their role in host-pathogen interactions to bolster immunity against TB.

IMMUNOMODULATORY EFFECTS OF BIOFLAVONOIDS: BALANCING IMMUNE RESPONSES

Bioflavonoids possess the unique ability to modulate immune responses, promoting a delicate balance between pro-inflammatory and anti-inflammatory reactions. This immunomodulatory capacity is of paramount importance in TB management, as an optimal immune response is essential for containing mycobacterial growth while preventing excessive tissue damage. Quercetin, for example, has been shown to regulate cytokine production, enhancing interferon-gamma (IFN-γ) secretion while inhibiting interleukin-10 (IL-10), thus promoting an environment conducive to mycobacterial elimination (Almeida et al., 2013). Similarly, EGCG has been found to stimulate dendritic cell maturation and promote Th1 immune responses, crucial for efficient TB control. By fine-tuning immune reactions, bioflavonoids contribute to the orchestration of a robust defense against TB infection.

BIOFLAVONOIDS AND HOST-PATHOGEN INTERACTIONS: ENHANCING IMMUNITY AGAINST TUBERCULOSIS

The interactions between host cells and mycobacteria form a critical battleground in TB infection. Bioflavonoids, with their multifaceted effects, play a pivotal role in modulating these interactions to tip the balance in favor of the host's immune defense. Hesperidin, present in citrus fruits, has exhibited the potential to enhance macrophage activity by promoting phagocytosis and nitric oxide production . This heightened antimycobacterial function is a testament to the immunostimulatory prowess of bioflavonoids. Furthermore, the unique structural properties of bioflavonoids, such as their ability to chelate metal ions, contribute to altering the intracellular environment, disrupting mycobacterial survival strategies.

The intricate crosstalk between bioflavonoids and host-pathogen interactions provides a fertile ground for therapeutic interventions aimed at enhancing the immune system's arsenal against TB. By bolstering immune responses and influencing cellular interactions, bioflavonoids hold promise as adjunctive agents in TB management.

CONCLUSION: HARNESSING NATURE'S POTENTIAL IN TUBERCULOSIS CONTROL

In the quest for innovative and effective approaches to tuberculosis (TB) control, the role of plant-based bioflavonoids emerges as a beacon of hope. This chapter has underscored the remarkable potential of bioflavonoids derived from various plant sources in bolstering TB management. Through their multifaceted properties, bioflavonoids offer a holistic and complementary avenue for enhancing existing treatment strategies.

THE PROMISE OF PLANT-BASED BIOFLAVONOIDS: A HOLISTIC APPROACH TO TUBERCULOSIS MANAGEMENT

Plant-based bioflavonoids, with their intricate mechanisms of action, demonstrate an impressive ability to address multiple facets of TB pathogenesis. From immunomodulation that balances immune responses to antimycobacterial effects that directly target the pathogen, bioflavonoids exemplify nature's intricate design to combat TB. The chapters preceding this conclusion have unveiled the diverse array of bioflavonoids found in fruits, vegetables, teas, and other botanical sources, each with its unique potential to contribute to TB control.

EMBRACING BIOFLAVONOIDS FOR ENHANCED TUBERCULOSIS TREATMENT STRATEGIES

The integration of bioflavonoids into TB treatment strategies represents a synergistic blend of traditional wisdom and modern science. By harnessing the power of bioflavonoids, healthcare professionals, researchers, and policymakers can usher in a new era of comprehensive TB care. The anti-inflammatory, antioxidant, and immunomodulatory effects of bioflavonoids hold the promise of optimizing host immunity while simultaneously exerting direct antimycobacterial effects. Embracing bioflavonoids as adjunctive therapies has the potential to enhance treatment outcomes, mitigate drug resistance, and improve overall patient well-being.

As we journey forward, it is imperative to foster collaborative efforts between researchers, clinicians, and traditional healers to unlock the full potential of bioflavonoids in TB management. Rigorous scientific studies, clinical trials, and epidemiological investigations will further elucidate the safety, efficacy, and optimal usage of these natural compounds. By embracing the promise of plant-based bioflavonoids, we embark on a path toward a more comprehensive, effective, and holistic approach to tuberculosis control that draws inspiration from the healing powers of nature.

In this symbiotic relationship between human endeavor and the bounties of the natural world, the potential to reshape the landscape of tuberculosis control stands as a testament to the remarkable resilience and adaptability of the human spirit.

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Advances in Bioresearch

SHORT COMMUNICATION

Study of Bioactive Nutrients in *Annona muricata* L. Leaves.

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ABSTRACT
The native plant of Central America, Annona muricata, produces a fruit that is now cultivated widely for its delicious flavor, high pulp content, nutritional value, and antioxidant characteristics. The purpose of study was to establish a quantitative and qualitative evaluation of soursop. Several procedures, including extraction and analysis of phytochemicals, made up the research. The leaves were extracted using three different solvents: water, Ethanol, and chloroform. Proximate analysis of the leaves revealed the following macronutrient and micronutrient content percentages: dry matter (88.99%), moisture (11.01%), crude protein (25%), ash (14.96%), crude fiber (22.20%), fat (21.22%), and carbohydrates (16.62%). Flavonoids, alkaloids, cardiac glycoside, tannins, triterpenoid, saponin, and reducing sugar were found in ethanolic leaf extracts. The results suggest that leaves from Annona muricata could be used as a source of both high-quality feed and phytomedicine. Considering the wide range of ethnopharmacological applications of the plant, they have important dietary, clinical, and veterinary implications.
KEYWORDS: *Quantitative, Triterpenoids, Phytochemicals, Ethnopharmacological Phytomedicine etc.*

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INTRODUCTION

Annona muricata Linn. (Annonaceae) is commonly known as "Soursop" or "Graviola." It is a terrestrial deciduous tree and produces an edible fruit. This species of *Annona* has been grouped with the "cherimoya" plants of the Annonaceae family. Numerous illnesses and health issues have long been treated using plants. Which are vital to the health and healing of 70–80% of the world's population in low-income countries. The pharmaceutical industry relies heavily on the secondary metabolites produced by medicinal plants. Herbal plants are the primary focus of many of the world's oldest medical systems. Many of the industries we rely on today to treat a wide range of medical conditions have their origins in the study of plants and the development of medicines derived from plants. It is naturally deciduous, grows at a medium rate, and is quite resilient. Fresh fruit is the most common application, while custard powder and pulp from blended fruits are used to flavor frozen desserts. When eaten raw and cold, it can be enjoyed as a dessert or blended into a shake. Except for making jams or preserves, fruit is rarely cooked. When sliced, this fruit complements a fruit salad quite well. Annonaceae is one of the most significant plant families, and it is widely believed to include medicinal and pharmacological characteristics. Among these, *Annona muricata* stands out for its many beneficial effects as a medicinal herb. The range of *A. muricata* includes much of Central America. This is commonly referred to as guanabana or soursop. It is an evergreen tree that grows to a height of 5–6 meters and has huge, glossy, dark green leaves. Its enormous, edible heart-shaped fruit ranges in size from 5 to 20 centimeters in diameter and is a bright yellow green with white flesh on the interior. The Graviola contains the potent phytochemical annanaceous acetogeneins. Graviola's leaves, roots, and seeds have all been shown to be insecticidal, with the seeds showing particularly potent efficacy against insect pests [1]. Annona muricata contains a wide variety of phytochemicals, including alkaloids, flavonoids, carbohydrates, cardiac glycosides, saponins, tannins, phytosterol, terpenoids, and protein [2]. . Because it has both hypoglycemic and antioxidant characteristics without any side effects, Annona muricata is the ideal antidiabetic medication [3]. "Annona muricata has molluscicidal and anti-parasitic properties in its leaves [4].

Inflammatory disorders like the flu and cough were treated with *Annona muricata*. Extracts from the Annona muricata tree's roots, leaves, and stem were traditionally combined to treat a wide range of medical conditions using tea and other solutions. Rheumatism, arthritis, and other joint discomfort were all alleviated with topical application of an Annona muricata extract solution [5]. The leaves of the *Annona muricata* tree are used to make oil. Crushed leaves and uncooked fruit from the plant can be blended with olive oil for a tasty snack. Rashes, boils, and blisters are just some of the many skin conditions that this oil can alleviate [5]). Annona muricata's phytochemical components were analyzed here.

MATERIAL AND METHODS

Collection, identification and preparation of *Annona muricata*

Fresh leaves of *Annona muricata* were collected. The *Annona muricata* leaves were separated from the stalk, washed and air-dried at room temperature (24°C) and then pulverized, crushed into fine powder and weighed. Aliquot portions of the powdered leaves were weighed and used for proximate analysis.

Extraction of the plant leaves

After 12 hours of soaking 5gm of dry powder in 100ml of distilled water, the resulting aqueous extract was boiled for two hours to remove any remaining solids. In order to use the extract for research, it was filtered through Whatmann filter paper. 48 hours of room temperature soaking 5 grams of dry powdered plant leaves in 100 milliliters of 100% ethanol and chloroform yielded an ethanolic extract and a chloroform extract, respectively. Cotton wool and Whatmann filter paper No. 42 (125mm) were used to further purify the extract. A rotary evaporator with a water bath heated to 60 degrees Celsius was then used to reduce the volume of the extract to one tenth before it was freeze dried. The leftover powder (the crude extract) was then kept in a refrigerator. The leftover residue from the crude plant extract was measured out and subjected to a phytochemical screening.

Methods for phytochemical screening

Phytochemical screening was performed using standard procedures.

Qualitative Analysis

The technique for testing for alkaloids, flavonoids, carbohydrates, glycosides, saponins, tannins, Terpenoids, proteins, and anthraquinone was analysed by using standerd methods. Alkaloids were tested with the Mayers method, flavonoids with the Shinodas method, carbohydrates with the Benedict and Molisch methods, cardiac glycosides with the Keller-Killani method, saponins with the Froth method, tannins with the Lead acetate method, terpenoids with the Salkowski method, proteins with the Ninhydrin and Biuret methods, and anthraquinone with the ammonia method [6].

Quantitative analysis

The Anthrone technique was used for a quantitative analysis of the starch content [7].

Lowry's technique was used for a quantitative analysis of protein estimation [3].

Singleton's approach was used for a quantitativeanalysis of the phenol content[8].

RESULTS AND DISCUSSION

The extraction results of *A. Muricata* leaf phytochemical contents in several solvents (H2O, ethanol, and chloroform) are shown in Table 1. Alkaloids, coumarin, tannin, cardiac glycosides, flavonoids, carbohydrates, and phenols were found in A. squamosa leaves after a chemical analysis.

Alkaloids, oils, tannins, phenols, and flavonoids were more successfully extracted from leaf using ethanol and chloroform.

Table.1Qualitative Phytochemical screening of Aqueous, Ethanol and Chloroform extract of *Annona muricata.*

S.No	Test /Leaf Extract	Water	Ethanol	Chloroform
1	**Test for Alkaloids**			
	a) Mayers test	-	+	+
	b) Wagner s test	-	+	+
	c)Dragendorffs test	-	-	-
2	**Test for flavonoids**			
	a) Shinoda test	**+**	**+**	**+**
	b) Alkaline reagent test	-	-	-
3	**Test for carbohydrates**			
	a) Benedicts test	**+**	**+**	**+**
	b) Molischs test	**+**	**+**	**+**
4	**Test for glycosides**			
	a)Borntrager s test	-	-	-
	b)Keller Killani test	**+**	**+**	**+**

5	**Test for Proteins**			
	a)Ninhydrin test	+	+	+
	b)Biuret test	+	+	+
6	**Test for saponins**			
	a) Froth test	+	+	+
	b) Lead acetate test	+	+	+
7	**Test forTannins**			
	a) Ferric chloride test	-	-	-
	b) Lead acetate test	+	+	+
8	**Test for Terpenoids**			
	a)Salkowski test	+	-	-
9	**Test for Anthraquinones**			
	a)Ammonia test	+	-	-

Table.2 Quantitative analysis of aqueous extract of *Annona muricata*

S.No	Parameters	Aqueous extract	
		Leaf (mg%)	Seed (mg%)
1	Protein	8.6	36.66
2	Phenol	134.28	45.6
3	Carbohydrates	19.8	13.1

Alkaloids, flavonoids, carbohydrates, glycosides, proteins, saponins, tannins, terpenoids, and anthraquinones are just some of the phytochemical constituents found in different solvent extracts of the Annona muricata plant, as shown in Table 2 below. Annona muricata leaves have a larger protein and phenol content than previously thought, according to quantitative study of an aqueous extract of the plants' leaves.

CONCLUSION

Alkaloids, flavonoids, sugars, glycosides, saponins, tannins, Terpenoids, Proteins, and Anthraquinone are just some of the phytochemicals found in abundance in Annona muricata, as shown by this study. Both enzymatic and non-enzymatic antioxidant activity was observed, suggesting potential application in cancer prevention. This study provided conclusive evidence of the antibacterial activity of Annona muricata against a panel of test pathogens including Staphylococcus aureus, Pseudomonas, Bacillus, Klebsiella, and Escherichia coli". The abundance of promising anecdotes suggests further investigation into *Annona muricata*'s potential as a wonder medicine for a wide range of conditions.

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Sulfated tungstate: A highly efficient, recyclable and ecofriendly catalyst for synthesis of Flavones under the solvent-free conditions

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A B S T R A C T

Sulfated tungstate efficiently catalyzes the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones to flavones under solvent-free conditions. Utilization of conventional heating, simple reaction conditions, short reaction time, ease of product isolation and purification makes this manipulation very interesting from an economic and environmental perspective. Under these conditions, twelve examples were obtained with good yields (85-94%).

1. Introduction

Due to the growing concern over environmental pollution, Green chemistry has attracted increasing attention in recent years.[1–4] Intensive efforts have been focused on designing and developing economical and environmentally benign syntheses. Major environmental pollution arises from the use of solvents since the amounts of solvents used are usually much larger than the amounts of reagents and products. The problem may be addressed by recycling the solvents which is economically as well as practically difficult. Much of the research is being pursued vigorously for the replacement of conventional organic solvents which are highly volatile, environmentally harmful, and/or biologically incompatible with environmentally benign solvents. Ionic liquids and fluorous solvents have been used with their limitations in organic syntheses. The poor solubility of organic molecules in water has restricted its use as a benign solvent in organic synthesis. Due to the toxicity of organic solvents and the limitations of environmentally benign solvents, the most promising approach is to perform organic reactions under solvent-free conditions. Solvent-free reactions have received considerable attention in recent years, not only for ecological and economic reasons, but also for simplicity of reaction conditions, high yields and short reaction times. Another source of environmental pollution is the use of large amounts of acid catalysts in organic reactions which generates toxic waste that is harmful to the environment. The development of cheap, acid catalysts could change the traditional procedures into green ones, thus minimizing chemical waste further. Therefore, the use of Sulfated tungstate as a catalyst under solvent-free condition would be a better solution to environmental pollution.

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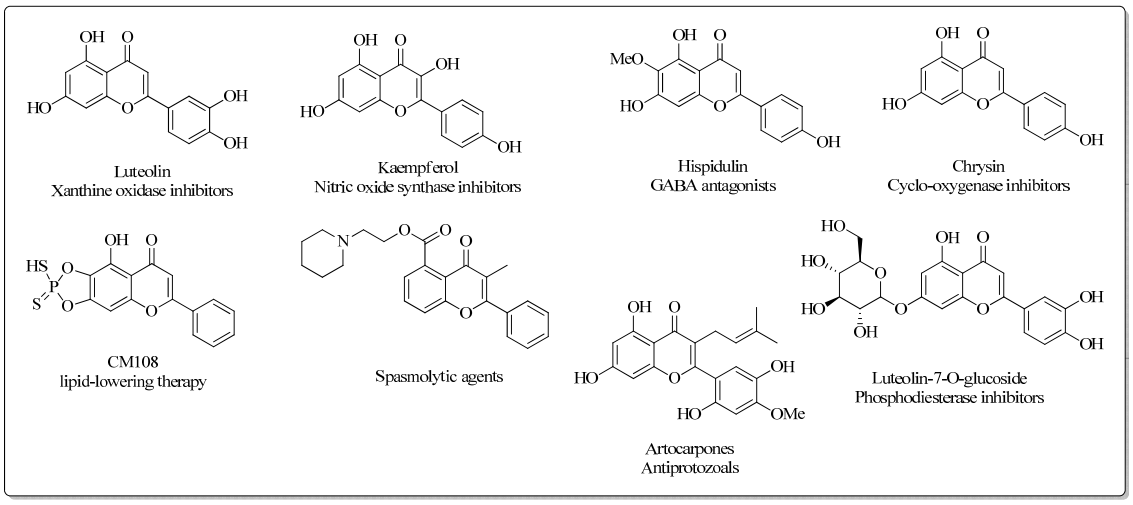


Fig. 1. Biologically active flavones.

The synthetic potential, as green catalysts in organic reactions, has been ignored to a large extent except for a few scattered reports like a simple and environmentally benign method for the synthesis of flavones described via dehydrative cyclization of o-hydroxydibenzoylmethane using silica gel supported $NaHSO_4$ catalyst in the literature.[5]

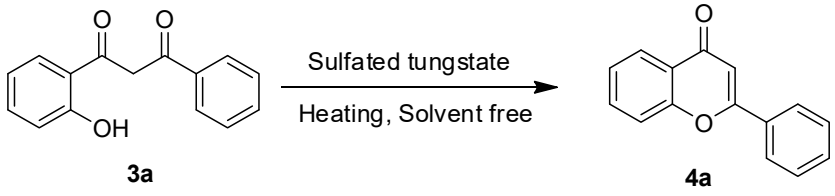
Flavonoids are present plentifully in plants of the families Leguminosae, Compositae, and Moraceae. They display a broad spectrum of biological activity[6] like anti-inflammatory, antitumor,[7] antioxidant and estrogen receptor modulator activities.[8](**Fig. 1)** In addition, they also inhibit the activity of cyclooxygenase/lipoxygenase.[9] The thioflavanone derivatives have been used in the synthesis of biologically active compounds such as benzothiazepine and thiochroman-4-one.[10] One of the most commonly used methods for the synthesis of flavones is the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones. Many of these procedures use strong acids such as H_2SO_4[11], HCl,[12] HBr, HI,[13] natural organic acids,[14] ammonium acetate, [15] or ascorbic acid,[16-17]. However, all above reported methods suffer from certain drawbacks such as the use of toxic/costly solvents, expensive reagents, co-catalysts, production of considerable amounts of byproducts, long reaction times and low yields. Therefore, the development of simple, inexpensive, highly efficient yet eco-friendly catalysts for acid-catalyzed organic transformations is worthwhile.[18] The ionic liquids and sulfonic acid in which sulfonic group bonded with positive charged nitrogen in organic compounds have been efficiently used as catalysts and reagents in organic conversion. In recent years, several groups have introduced sulfated tungstate as a heterogeneous green catalyst because of its easy-to-prepare, moderately acidic, recyclable, nontoxic and efficient. At room temperature and under solvent-free circumstances, it is used as a heterogeneous and ecologically friendly catalyst in a range of chemical reactions. The sulfated tungstate was effectively used as a catalyst in several organic transformations for the synthesis of various organic compounds.[19-20] We report herein a simple and highly efficient protocol for the synthesis of flavones by the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones.

In this article, we would like to report that Sulfated tungstate, without any functionalization, could be used as a useful catalyst for the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones to flavones in conventional heating.

2 Result and discussion

2.1 Synthesis of flavones: Synthesis of flavones from 1,3- propanediones was studied. For screening of the catalysts, cyclodehydration of propanedione **3a** was selected as a model reaction (**Table 1**). To evaluate the synergy between dry media and conventional heating in this reaction, several experiments were tried. As described in table 1, the heating of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones without Sulfated tungstate was unsuccessful (**entry 1**). Although Sulfated tungstate catalysed the reaction at room temperature, the yield was only 20% after 1h of reaction (**entry 2**). Only in the case of conventional heating at 100 ^{o}C, the 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones condensation proceeded efficiently after 30 min of reaction (**entry 5**). These results indicate that Sulfated tungstate is as effective catalyst to deliver flavones **4a** in good to excellent yields.

Table 1. Screening of catalysts in synthesis of flavones from 1,3- propanediones under solvent free condition.[a]



3a **4a**

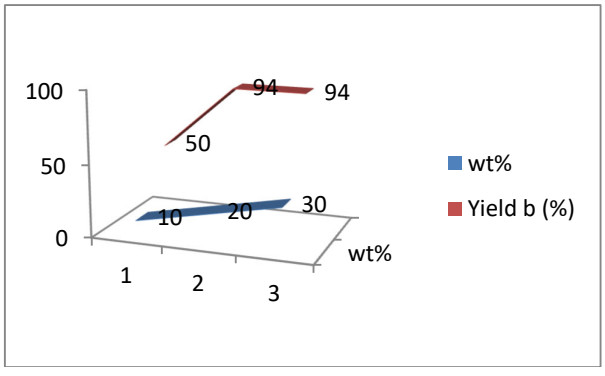
Entry	Catalyst	Temp. (° C) [b]	Time (Min)	Yield[c] (%)
1	-	r.t.	60	-
2	Sulfated tungstate	r.t.	60	20
3	Sulfated tungstate	50	60	75
4	Sulfated tungstate	100	60	94
5	Sulfated tungstate	100	30	94
6	Sulfated tungstate	100	15	79

[a] Reagents: **3a** (0.5g), Sulfated tungstate Catalyst (1.0 eq.). [b] Conventional Heating. [c] Isolated yields.

Next Sulfated tungstate was used to test the scope of the above methodology. Thus various 1, 3-propanediones were used under the above reaction condition. The corresponding flavones (**4a-l**) were obtained in good to excellent yields under conventional heating conditions (**Table 2**).

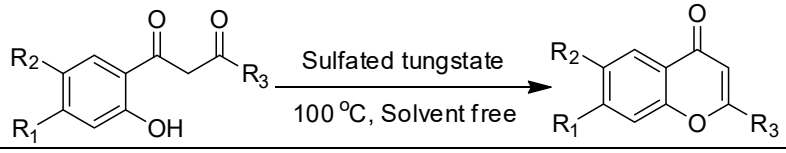
2.2 Effect of Sulfated tungstate catalysts for the formation of flavones

Next, the effect of the amount of Sulfated tungstate on the model reaction was investigated. It was found that 20 wt% of Sulfated tungstate is essential for the completion of the reaction. However, the use of less than 20 wt% of the Sulfated tungstate resulted in low yield of the product along with the recovery of the starting material even for extended reaction time.

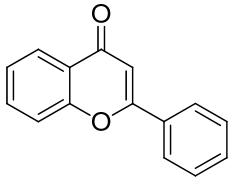
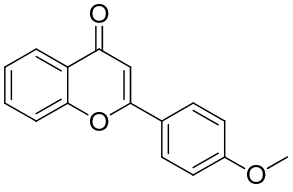
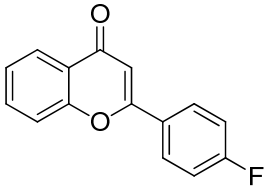
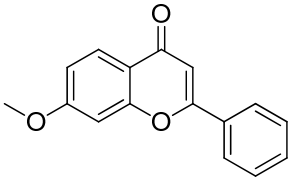
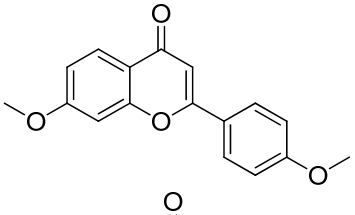
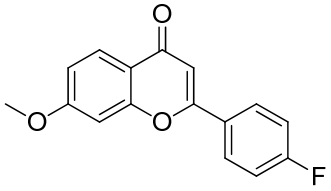
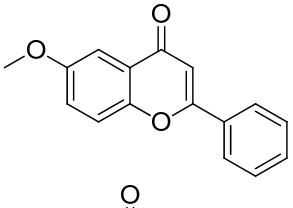
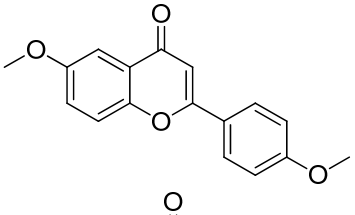
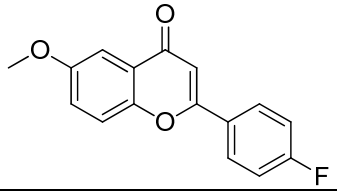


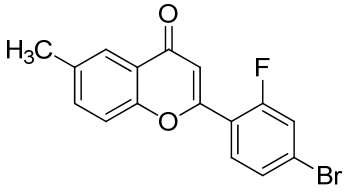
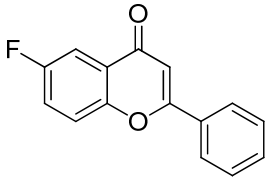
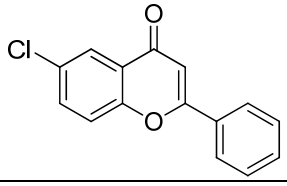
To check the generality and scope of this protocol, various 1,3-propanedione were subjected to the flavone synthesis with Sulfated tungstate under the above reaction conditions at 100 °C. Results indicated that the flavones synthesis reaction proceeded smoothly under conventional heating within 30 minutes to give the corresponding flavones in good to excellent yields.

Table 2. Sulfated tungstate catalyzed synthesis of flavones from 1,3-propanedione under solvent free condition.[a]



Entry	Compd.	R_1	R_2	R_3	(%)Yield[d]

1		H	H	Ph	94
2		H	H	*p*-$MeOC_6H_4$	92
3		H	H	*p*-FC_6H_4	91
4		OMe	H	Ph	92
5		OMe	H	*p*-$MeOC_6H_4$	92
6		OMe	H	*p*-FC_6H_4	85
7		H	OMe	Ph	90
8		H	OMe	*p*-$MeOC_6H_4$	92
9		H	OMe	*p*-FC_6H_4	90

10		H	Me	*o*-F-*p*-BrC_6H_3	89
11		H	F	Ph	90
12		H	Cl	Ph	88

[a] Reagents: **3** (0.5g), Sulfated tungstate (1.0 eq.). [b] 30 min. in conventional heating. [d] Isolated yields. [e]All the products were identified spectroscopically (IR, ^{1}H, ^{13}C NMR and LCMS)

3. Conclusion

In conclusion, we found that the Sulfated tungstate can be used as an environment-friendly catalyst for the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones to flavones under solvent-free condition in a short time. Sulfated tungstate showed superior reactivity in the cyclodehydration of 1-(2-hydroxyphenyl)-3-aryl-1,3-propanediones to flavones under conventional heating. The operational simplicity, use of commercially available, biodegradable and renewable catalysts, solvent-free reaction condition, short reaction time, easy work up and high yields make these catalysts a more convenient alternative to the reported catalysts. This technique not only improves yields and reaction rates significantly, but it also avoids the use of harmful solvents or catalysts. This work confirms the high value resulting from the use of organic and inorganic compounds in different fields as reported before in different scientific papers. [28-29]

4. Experimental section

4.1 General information

All reagents were used as obtained from commercial sources. Melting points (m. p., uncorrected) were determined in open capillary tubes using a paraffin oil bath. All the microwave-assisted reactions were performed in Discover LabMet microwave system (CEM Corporation, USA) at the specified temperature using the standard mode of operation. Infrared (IR) spectra were recorded on Perkin Elmer Model 1600 series Fourier Transform (FT) instrument. ^{1}H NMR and ^{13}C NMR were recorded on Bruker Avance II 400/ Varian Mercury 300 and 100/75 MHz respectively in DMSO/$CDCl_3$ solution and tetramethylsilane (TMS) as internal reference (δscale). Mass spectra were recorded on Agilent 1200SL – 6100 LC/MS (ESI).

4.2 General Procedure for Flavones

In a typical experiment, the mixture of 1,3- propanedione (0.5 g) and Sulfated tungstate (20 wt%) was heated at 100 ºC for 30 min. After completion of reaction (TLC check). Ethyl acetate and hexane is used as mobile phase for TLC. The reaction mixture was allowed to cool at room temperature and ethyl acetate (10 mL) was added. Then the resulting solid was filtered off and washed with 5 mL ethylacetate. After the concentration of ethyl acetate, the resulting products with more purity, but more purification, if necessary, can be accessed by recrystallization of the products from ethanol.

4.3 Spectral data for the synthesized compounds 4(a-l)

2-Phenyl-chromen-4-one (Table 2, entry 1): M.p. 96-97 °C (lit.[21] m.p. 96-97 °C), IR (KBr) $\tilde{\nu}$: 1645, 1604, 1568, 1130, 756 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 6.81 (s, 1 H, CH), 7.39 (t, J = 7.8 Hz, 1H, Ar-H), 7.46-7.55 (m, 4H, Ar-H), 7.65-7.70 (m, 1H, Ar-H), 7.88-7.91 (m, 2H, Ar-H), 8.21 (d, J = 7.2 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 107.3 (CH), 117.9 (Ar-C), 123.7 (Ar-C), 125.1 (Ar-C), 125.5 (Ar-C), 126.1 (Ar-C), 128.9 (Ar-C), 131.5 (Ar-C), 131.6 (Ar-C) , 133.7 (Ar-C), 156.1 (Ar-C), 163.3 (=C-O), 178.3 (C=O), LCMS (ES-API) m/z: 223 $(M+H)^+$.

2-(4-Methoxy-phenyl)-chromen-4-one (Table 2, entry 2): M.p. 157-158 °C (lit.[21] m.p. 157-158 °C), IR (KBr) $\tilde{\nu}$: 1649, 1608, 1465, 1133, 767 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.87 (s, 3H, OMe), 6.80 (s, 1H, CH), 6.99-7.03 (m, 2H, Ar-H), 7.40 (t, J = 7.2 Hz, 1H, Ar-H), 7.53 (d, J = 8.1 Hz, 1H, Ar-H), 7.65-7.70 (m, 1H, Ar-H), 7.80-7.90 (m, 2H, Ar-H), 8.21 (dd,

J = 8.1 & 2.1 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.4 (O-CH_3), 105.9 (CH), 114.4 (Ar-C), 117.9 (Ar-C), 123.7 (Ar-C), 123.9 (Ar-C), 125.1 (Ar-C), 125.6 (Ar-C), 127.9 (Ar-C), 133.6 (Ar-C), 156.1 (Ar-C), 162.4 (Ar-C), 163.5 (=C-O), 178.5 (C=O), LCMS (ES-API) m/z: 253 $(M+H)^+$.

2-(4-Fluoro-phenyl)-chromen-4-one (Table 2, entry 3): M.p. 148-150 °C (lit.[22] m.p. 134-135 °C), IR (KBr) $\nu\tilde{}$: 1663, 1608, 1574, 1467, 1234, 1134, 869, 806, 755 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 6.79 (s, 1H, CH), 7.23 (m, 2H, Ar-H), 7. 47 (t, *J* = 7. 1 Hz, 1H, Ar-H), 7.58 (d, *J* = 7.1 Hz, 1H, Ar-H), 7.72 (m, 1H, Ar-H), 7.94 (m, 2H, Ar-H), 8.24 (d, *J* = 7. 2 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 107.1 (CH), 116.6 (Ar-C), 117.0 (Ar-C), 118.5 (Ar-C), 123.9 (Ar-C), 125.5 (Ar-C), 126.0 (Ar-C), 127.1 (Ar-C), 128.1 (Ar-C), 134.2 (Ar-C), 156.0 (Ar-C), 162.6 (=C-O), 178.1 (C=O), LCMS (ES-API) m/z: 241 $(M+H)^+$

7-Methoxy-2-phenyl-chromen-4-one (Table 2, entry 4): M.p. 109-110 °C (lit.[23-24] m.p. 105-106 °C), IR (KBr) $\nu\tilde{}$: 1647, 1626, 1606, 1450, 1163, 908, 767 cm^{-1}. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.91 (s, 3H, OMe), 6.77 (s, 1H, CH), 6.95 (m, 2H, Ar-H), 7.51 (m, 3H, Ar-H), 7.88 (m, 2H, Ar-H), 8.11 (d, *J* = 8.7 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.8 (OCH_3), 100.3 (Ar-C), 107.3 (CH), 114.9 (Ar-C), 117.6 (Ar-C), 126.0 (Ar-C), 126.9 (Ar-C), 128.9 (Ar-C), 131.4 (Ar-C), 131.6 (Ar-C), 157.8 (Ar-C), 162.9 (Ar-C), 164.1 (=C-O), 177.7 (C=O), LCMS (ES-API) m/z: 253 $(M+H)^+$.

7-Methoxy-2-(4-methoxy-phenyl)-chromen-4-one (Table 2, entry 5): M.p. 194-195 °C (lit.[25-26] m.p. 180.5 °C) , IR (KBr) $\nu\tilde{}$: 1629, 1593, 1516, 1379, 1260, 1186, 977, 862 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.82 (s, 3H, OMe), 3.86 (s, 3H, OMe), 6.60 (s, 1H, CH), 6.86-6.95 (4H, m, Ar-H), 7.77 (d, *J* = 8.4 Hz, 2H, Ar-H), 8.05 (d, *J* = 8.4 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.3 (OMe), 55.7 (OMe), 100.2 (Ar-C), 105.9 (CH), 114.0 (Ar-C), 114.2 (Ar-C), 117.6 (Ar-C), 123.8 (Ar-C), 126.7 (Ar-C), 127.6 (Ar-C), 157.7 (Ar-C), 162.1 (Ar-C), 162.8 (Ar-C), 163.9 (=C-O), 177.6 (C=O), LCMS (ES-API) m/z: 283 (M+H

2-(4-Fluoro-phenyl)-7-methoxy-chromen-4-one (Table 2, entry 6) M.p. 172-173 °C (lit.[14]), IR (KBr) $\nu\tilde{}$: 1660, 1631, 1577, 1456, 1294, 1022, 923, 841, 781 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.84 (s, 3H, OMe), 6.41 - 6.48 (m, 2H, Ar-H), 6.64 (s, 1H, CH), 7.15 (t, *J* = 8.7 Hz, 2H, Ar-H), 7.89 (m, 1H, Ar-H), 7.90 (m, 2H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.6 (OMe), 101.3 (Ar-C), 108.0 (CH), 110.0 (Ar-C), 112.4 (Ar-C), 115.7 (Ar-C), 116.0 (Ar-C), 128.9 (Ar-C), 128.9 (Ar-C), 129.9 (Ar-C), 130.1 (Ar-C), 165.3 (Ar-C), 165.9 (=C-O), 174.8 (C=O), LCMS (ES-API) m/z: 271 $(M+H)^+$.

6-Methoxy-2-phenyl-chromen-4-one (Table 2, entry 7): M.p. 160-161 °C (lit.[24] m.p. 165-167 °C) , IR (KBr) $\nu\tilde{}$: 1641, 1618, 1488, 1361, 1255, 1030, 846, 658 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.89 (s, 3H, OMe), 6.79 (s, 1H, CH), 7.28 (dd, *J* = 6.7 & *J* = 3.5 Hz, 1H, Ar-H), 7.46-7.51 (m, 4H, Ar-H), 7.57 (d, *J* = 2.7 Hz, 1H, Ar-H), 7.88-7.91 (m, 2H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.8 (OMe), 104.7 (CH), 106.7 (Ar-C), 119.4 (Ar-C), 123.6 (Ar-C), 124.4 (Ar-C), 126.1 (Ar-C), 128.8 (Ar-C), 131.4 (Ar-C), 131.7 (Ar-C), 150.8 (Ar-C), 156.9 (Ar-C), 163.0 (=C-O), 178.2 (C=O), LCMS (ES-API) m/z: 253 $(M+H)^+$.

6-Methoxy-2-(4-methoxy-phenyl)-chromen-4-one (Table 2, entry 8): M.p. 195-196 (lit.[21] m.p. 194-195 °C), IR (KBr) $\nu\tilde{}$: 1647, 1607, 1584, 1454, 1268, 1196, 1014, 817, 558 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.88 (s, 3H, OMe), 3.90 (s, 3H, OMe), 6.73 (s, 1H, CH), 7.01 (d, *J* = 9.0 Hz, 2H, Ar-H), 7.27 (m, 1H, Ar-H), 7.58 (d, *J* = 3.0 Hz, 1H, Ar-H), 7.60 (d, *J* = 9.0 Hz, 1H, Ar-H), 7.86 (d, *J* = 9.0 Hz, 2H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.4 (OMe), 55.9 (OMe), 104.8 (Ar-C), 105.4 (CH), 114.4 (Ar-C), 119.3 (Ar-C), 123.5 (Ar-C), 124.1 (Ar-C), 124.4 (Ar-C), 127.8 (Ar-C), 150.9 (Ar-C), 156.8 (Ar-C), 162.3 (Ar-C), 163.1 (=C-O), 178.2 (C=O), LCMS (ES-API) m/z: 283 $(M+H)^+$.

6-Methoxy-2-(4-fluoro-phenyl)-chromen-4-one (Table 2, entry 9) M.p. 172-173 ^{0}C (lit.[22] m.p. 172-173 °C), IR (KBr) ν: 1660, 1631, 1608, 1577, 1456, 1419, 1514, 1294, 1163, 1022, 923, 841, 781 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 3.84 (s, 3H, OMe), 6.41-6.48 (m, 2H, CH), 6.64 (s, 1H, Ar-H), 7.15 (t, *J* = 8.7 Hz, 2H, Ar-H), 7.89 (m, 1H, Ar-H), 7.90 (m, 2H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 55.6 (OMe), 101.3 (Ar-C), 108.0 (CH), 110.0 (Ar-C), 112.4 (Ar-C), 115.7 (Ar-C), 116.0 (Ar-C), 128.9 (Ar-C), 128.9 (Ar-C), 129.9 (Ar-C), 130. 1 (Ar-C), 165.3 (Ar-C), 165.9 (=C-O), 174.8 (C=O), $C_{16}H_{11}FO_3$, LCMS (ES-API) m/z: 271 $(M+H)^+$.

2-(4-Bromo-2-fluoro-phenyl)-6-methyl-chromen-4-one (Table 2, entry 10) M.p. 153-155 °C (lit.[14]), IR (KBr) $\nu\tilde{}$: 1679, 1603, 1571, 1480, 1257, 1192, 1050, 760, 613 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 2.55 (s, 3H, CH_3), 7.23 (s, 1H, CH), 7.25-7.45 (m, 3H, Ar-H), 7.58 (m, 1H, Ar-H), 7.88 (d, *J* = 7.8 Hz, 1H, Ar-H), 8.02 (t, *J* = 8.1 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 29.2 (CH_3), 116.9 (CH), 120.7 (Ar-C), 120.7 (Ar-C), 121.7 (Ar-C), 123.8 (Ar-C), 126.4 (Ar-C), 127.7 (Ar-C), 127.8 (Ar-C), 128.9 (Ar-C), 130.5 (Ar-C), 133.6 (Ar-C), 148.7 (Ar-C), 163.7 (=C-O), 183.3 (C=O), LCMS (ES-API) m/z: 334 $(M+H)^+$.

6-Fluoro-2-phenyl-chromen-4-one (Table 2, entry 11): M.p. 128-129 °C (lit.[25]), IR (KBr) $\nu\tilde{}$: 1660, 1624, 1570, 1359, 1176, 835, 767 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 6.82 (s, 1H, CH), 7.39-7.46 (m, 1H, Ar-H), 7.50-7.61 (m, 4H, Ar-H), 7.85-7.93 (m, 3H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 106.7 (CH), 110.7 (Ar-C), 120.0 (Ar-C), 120.2 (Ar-C), 121.7 (Ar-C), 122.0 (Ar-C), 126.2 (Ar-C), 129.0 (Ar-C), 131.3 (Ar-C), 131.7 (Ar-C), 152.3 (Ar-C), 163.1 (=C-O), 177.5 (C=O), LCMS (ES-API) m/z: 241 $(M+H)^+$.

6-Chloro-2-phenyl-chromen-4-one (Table 2, entry 12): M.p. 183-184 °C (lit.[26-27] m.p. 185-186 °C), IR (KBr) $\nu\tilde{}$: 1651, 1601, 1567, 1457, 1438, 1307, 1132, 908, 682 cm^{-1}, ^{1}H NMR ($CDCl_3$, 300 MHz): δ 6.82 (s, 1H, CH), 7.50-7.56 (m, 4H, Ar-H), 7.61-7.65 (m, 1H, Ar-H), 7.88-7.90 (m, 2H, Ar-H), 8.17 (d, *J* = 2.3 Hz, 1H, Ar-H), ^{13}C NMR ($CDCl_3$, 75 MHz): δ 107.3 (CH), 119.7 (Ar-C), 124.7 (Ar-C), 125.1 (Ar-C), 126.3 (Ar-C), 129.1 (Ar-C), 131.1 (Ar-C), 131.2 (Ar-C), 131.8 (Ar-C), 133.0 (Ar-C), 154.4 (Ar-C), 163.7 (=C-O), 177.1 (C=O), LCMS (ES-API) m/z: 257 $(M+H)^+$.

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The Role of Herbal Medicine in Oxidative Stress: Prevention of Diabetes

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Abstract: The pathophysiology of diabetes mellitus is heavily influenced by oxidative stress, which is defined by an imbalance between reactive oxygen species (ROS) and antioxidant defenses. Innovative methods for managing and preventing diabetes are required given that it is a growing worldwide health concern. Herbal medicine, which has a long history of use in traditional therapeutic methods, has drawn interest for its ability to reduce the incidence of diabetes and combat oxidative stress. The processes underpinning the damage caused by ROS to cellular components and signaling pathways are revealed in this chapter as it delves into the complex interactions between oxidative stress and diabetes. The essential function of antioxidant substances in reducing oxidative stress is investigated, emphasizing the change from traditional herbal knowledge to contemporary scientific validation. The botanical substances that provide a source of inorganic antioxidants are at the center of this discussion. Fenugreek *(Trigonella foenum-graecum)* and Bitter Melon *(Momordica charantia),* two important medicinal herbs, are investigated for their strong antioxidant capacities and their capacity to modify glucose homeostasis and insulin sensitivity.Scientific studies, including in vitro experiments and clinical trials, shed light on how well herbal treatments for diabetes prevention actually work. Additionally, the beneficial effects of herbal combinations are clarified, as well as the importance of combining these interventions with lifestyle changes. The fusion of herbal medicine and conventional therapies appears as a promising route for diabetes prevention as the movement toward holistic health gains popularity. In conclusion, this chapter underscores the multifaceted potential of herbal medicine in addressing oxidative stress as a crucial factor in diabetes prevention. By embracing the wisdom of ancient traditions and leveraging contemporary scientific insights, herbal interventions offer a holistic and integrative strategy to safeguard against the escalating global burden of diabetes.

Keywords: Oxidative Stress, Diabetes Prevention, Herbal Medicine, Antioxidants, Botanical Agents, Lifestyle Modifications.

1. INTRODUCTION TO OXIDATIVE STRESS AND DIABETES

Oxidative stress, characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms, has emerged as a significant factor contributing to the pathogenesis of various chronic diseases, including diabetes mellitus. The intricate interplay between oxidative

stress and diabetes has garnered substantial attention in recent research, shedding light on the mechanistic connections and potential therapeutic avenues.

The complex physiological and molecular mechanisms controlling insulin resistance and beta-cell malfunction are the basis for the association between oxidative stress and diabetes. Oxidative stress impairs insulin signaling pathways and promotes insulin resistance in peripheral tissues such skeletal muscle, adipose tissue, and the liver by interfering with normal cellular signaling and redox balance (Robertson et al., 2019). In addition, increased ROS levels impede insulin secretion and promote beta-cell death, which exacerbate pancreatic beta-cell dysfunction (Evans et al., 2018).

Both clinical and experimental studies emphasize the role that oxidative stress plays in the onset and progression of diabetes. Due to the increased production of ROS through a variety of routes, including the polyol pathway, the creation of advanced glycation end products (AGEs), and mitochondrial dysfunction, long-term hyperglycemia, a defining feature of diabetes, is intimately linked to increased oxidative stress (Brownlee et al, 2005). In addition to making insulin resistance and beta-cell dysfunction worse, this ongoing oxidative stress also has a role in the microvascular and macrovascular consequences of diabetes, including nephropathy, retinopathy, neuropathy, and cardiovascular disease (Vinayagam et al., 2019).

The interest in investigating novel therapeutic approaches that target oxidative stress pathways to reduce the onset of diabetes and its associated consequences is expanding as our understanding of the complex link between oxidative stress and diabetes deepens. Herbal therapy offers a promising route for intervention thanks to its wide variety of bioactive substances with anti-inflammatory and antioxidant capabilities. Herbal medicines have the capacity to modify oxidative stress and restore redox equilibrium by harnessing the power of nature's pharmacopeia, providing a comprehensive approach to diabetes management and prevention.

Herbal Medicine: An Ancient Approach to Health:

Historical Context of Herbal Medicine:

Throughout human history, herbal medicine has been a fundamental part of traditional healing practices across cultures. Ancient civilizations, including the Chinese, Indian, Egyptian, and Greco-Roman, relied on botanical remedies for various ailments. Herbal knowledge was often passed down through generations and recorded in ancient texts, such as the *Huangdi Neijing in China or the Charaka Samhita in India.* These historical practices laid the foundation for understanding the potential of herbal medicine in addressing health challenges, including oxidative stress and diabetes.

Modern Resurgence of Interest in Herbal Remedies

In recent decades, there has been a remarkable resurgence of interest in herbal medicine within both scientific and public domains. Advances in scientific research have enabled a deeper exploration of the bioactive compounds present in herbs, unveiling their potential mechanisms of action and therapeutic benefits. Concurrently, individuals seeking holistic and natural approaches to health have contributed to the popularity of herbal remedies. This renewed enthusiasm has spurred scientific investigations into the role of herbal medicine in preventing and managing various conditions, including those associated with oxidative stress and diabetes.

Mechanisms of Oxidative Stress and Diabetes:

Cellular and Molecular Pathways of Oxidative Stress:

Oxidative stress arises from the imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defense mechanisms. Key cellular sources of ROS include mitochondria, NADPH oxidases, and peroxisomes. ROS are known to initiate oxidative damage to lipids, proteins, and DNA, contributing to cellular dysfunction and promoting the onset of various diseases. In the context of diabetes, oxidative stress disrupts insulin signaling pathways and triggers inflammatory responses, setting the stage for insulin resistance and beta-cell dysfunction (Newsholme et al., 2016).

Role of Oxidative Stress in Insulin Resistance and Beta-Cell Dysfunction:

Mounting evidence suggests that oxidative stress plays a pivotal role in the development of insulin resistance and beta-cell dysfunction, two key components of type 2 diabetes. Oxidative stress-induced modifications of signaling molecules, such as serine phosphorylation of insulin receptor substrate-1 (IRS-1), disrupt normal insulin signaling and attenuate glucose uptake in insulin-sensitive tissues. Additionally, oxidative stress-mediated inflammation, characterized by increased proinflammatory cytokines and adipokines, contributes to insulin resistance by promoting the impairment of insulin signaling pathways (Evans et al., 2018).

Moreover, pancreatic beta-cells, responsible for insulin secretion, are particularly susceptible to oxidative damage due to their high metabolic activity and relatively low expression of antioxidant enzymes. ROS-induced oxidative stress within beta-cells leads to dysfunction, decreased insulin secretion, and, ultimately, beta-cell apoptosis. This contributes to the decline in insulin production observed in the progression of type 2 diabetes (Robertson et al., 2019).

Understanding the intricate interactions between oxidative stress and the pathogenesis of diabetes provides valuable insights into potential targets for intervention, including herbal remedies rich in antioxidant and anti-inflammatory compounds.

Antioxidant Properties of Herbal Compounds:

Investigating Herbal Antioxidants: Herbs are well known for being a rich source of bioactive substances that have strong antioxidant effects. These substances, which include polyphenols, flavonoids, alkaloids, and terpenoids, are what give many herbs their vivid hues, smells, and aromas. By scavenging free radicals and bolstering endogenous antioxidant defenses, natural antioxidants reduce oxidative stress and reactive oxygen species (ROS). Several herbs have been thoroughly researched for their antioxidant capabilities, including **rosemary *(Rosmarinus officinalis),* turmeric *(Curcuma longa),* and green tea *(Camellia sinensis).***

Mechanisms of Action in Mitigating Oxidative Stress: Multiple routes, including direct ROS scavenging, inhibition of ROS-generating enzymes, and regulation of redox-sensitive signaling pathways, make up the antioxidant mechanisms of herbal substances. For instance, it has been demonstrated that polyphenols found in herbs, such as resveratrol from grapes ***(Vitis vinifera)*** and quercetin from onions ***(Allium cepa),*** improve cellular antioxidant defenses by upregulating antioxidant enzymes like glutathione peroxidase (GPx) and superoxide dismutase (SOD).

Herbal Medicine for Diabetes Prevention:

Herbs with Potential Antidiabetic Properties: In order to prevent diabetes, a variety of herbs have been studied for their possible anti-diabetic qualities. The capacity to increase insulin sensitivity, boost glucose uptake, and control blood sugar levels has been linked to bitter **melon *(Momordica charantia),* fenugreek *(Trigonella foenum-graecum*), and cinnamon (*Cinnamomum verum).*** These plants have bioactive substances such charantin, trigonelline, and cinnamaldehyde, which help them have anti-diabetic benefits.

Clinical Evidence of Herbal Interventions in Preventing Diabetes: The therapeutic potential of herbal therapies in the treatment of diabetes is being explored in clinical investigations. According to (Chuengsamarn et al., 2014), a randomized controlled trial involving individuals with prediabetes showed that supplementing with curcumin, a substance derived from turmeric, increased beta-cell activity and decreased insulin resistance. Additionally, metformin was not as effective as berberine, an alkaloid present in herbs like Berberis aristata, in reducing hemoglobin A1c levels in those with type 2 diabetes (Yin et al., 2008).

Table: Herbs with Potential Antidiabetic Properties and Their Mechanisms of Action

Herb	Bioactive Compounds	Mechanisms of Action
Bitter Melon	Charantin, vicine, polypeptide-P	Enhances insulin sensitivity, glucose uptake
Fenugreek	Trigonelline, 4-hydroxyisoleucine	Increases insulin secretion, glucose uptake
Cinnamon	Cinnamaldehyde, proanthocyanidins	Improves insulin sensitivity, glycemic control
Turmeric	Curcumin	Enhances beta-cell function, reduces insulin resistance
Berberine	Berberine	Regulates glucose metabolism, enhances insulin sensitivity
Green Tea	Catechins, epigallocatechin gallate	Enhances insulin sensitivity, antioxidant effects
Gymnema Sylvestre	Gymnemic acids	Inhibits sugar absorption, supports insulin production
Aloe Vera	Polysaccharides, phytosterols	Enhances glucose utilization, reduces oxidative stress
Olive Leaf	Oleuropein, hydroxytyrosol	Improves insulin sensitivity, reduces inflammation
Salacia Reticulata	Salacinol, kotalanol	Inhibits carbohydrate digestion, reduces postprandial glucose
Allium Sativum (Garlic)	Allicin, S-allyl cysteine	Increases insulin secretion, enhances glucose uptake

This table provides an overview of selected herbs known for their potential antidiabetic properties, highlighting their key bioactive compounds, mechanisms of action.

Conclusion: The Promising Role of Herbal Medicine in Diabetes Prevention

In the journey to combat diabetes and mitigate its associated oxidative stress, the potential of herbal medicine has emerged as a captivating avenue worthy of exploration and consideration. Throughout history, herbs have been revered for their holistic healing properties, and in the contemporary context, their role in diabetes prevention continues to gain traction.This chapter has delved into the intricate interplay between oxidative stress and diabetes, underscoring the significance of oxidative stress in the development of insulin resistance and beta-cell dysfunction. Herbal medicine, with its diverse array of bioactive compounds, has emerged as a beacon of hope in modulating oxidative stress and addressing the multifaceted aspects of diabetes prevention.

By exploring natural antioxidants within herbs and unraveling their mechanisms of action, we have illuminated the potential of these natural wonders in alleviating oxidative stress and contributing to glucose homeostasis. The bioactive compounds found in herbs such as bitter melon, fenugreek, and cinnamon exhibit promising effects in enhancing insulin sensitivity, improving glucose uptake, and supporting beta-cell function.

Clinical evidence has provided encouraging insights into the efficacy of herbal interventions. Studies showcasing the positive impact of herbs like turmeric, berberine, and green tea on insulin sensitivity and glycemic control hint at their potential as complementary strategies in diabetes management. However, it is important to recognize that further rigorous research, encompassing larger clinical trials and mechanistic investigations, is vital to substantiate and unlock the full therapeutic potential of herbal medicine.In conclusion, the promising role of herbal medicine in diabetes prevention is a beacon of hope in the fight against this global health challenge. The knowledge shared in this chapter serves as a stepping stone for healthcare professionals, researchers, and individuals seeking alternative and integrative approaches. As we look ahead, the path of exploration remains open, beckoning us to uncover the myriad ways in which herbs can harmonize with modern medicine to create a more holistic and effective approach to diabetes prevention.

As we close this chapter, let us be inspired to continue our collective efforts, embracing the wisdom of ancient traditions and the vigor of contemporary research, to illuminate the path toward a healthier future for all.

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उत्सव

प्रकाशक : इतिहासाचार्य वि.का.राजवाडे संशोधन मंडळ, धुळे

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।। संशोधक।।

पुरवणी अंक ४९ – मार्च २०२४ (त्रैमासिक)

- शके १९४५
- वर्ष : ९२
- पुरवणी अंक : ४९

*** प्रकाशक ***

श्री. संजय मुंदडा

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कार्यालयीन वेळ

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A kaleidoscopic survey of Indian Classical Drama (Sanskrit Theatre): Its Historical significance and Development

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Abstract:

The present research paper is an attempt to study and survey elaborately the Indian Classical Drama (*Sanskrit Theatre*) and its historical significance and development. For the assessment of the development of Indian theatre we need to critically evaluate and observe the basic nature of Indian classical theatre chronologically. If we try to trace the origin of Indian theatre, it goes back to the centuries where ancient rituals and seasonal celebrations used to take place in the country. We find the origin of Indian Theatre in the traditional work *Natya Shastra* by Bharat Muni which has answered the origin of Indian theatre. In *Natya Shastra*, Bharat Muni has referred a legend that, when the world passed through the ages and in the times flow the common folk got addicted to common sensual pleasures of life, they developed jealousy, hatred, anger and all evil things in their hearts. Seeing this, God Indra, (King of heaven) with all other gods went to God Brahma (Creator of the Universe) and requested Him for other desirable form of entertainment for the human beings. God Brahma, accepting the request of Indra and other Gods, accepted it and thought of composing fifth Veda on Natya. Earlier there were four Vedas, so Brahma extracted the four elements from four earlier Vedas which were Speech, song, mime and Sentiment and out of this he created a one of the holy books of Natya and that was Natya Veda. Bharat Muni, is the only source of enlightenment for the comprehension of Indian Theatre. *Natya Shastra* is a complete guide to unveil the rich tradition of Indian Dramatic Art. *Natya Shastra* is a masterpiece of authentic and definite historical information of the dramatic and theatrical traditions of ancient India.

Key Words: *Indian Classical Drama, Indian theatre, Historical Development, Indian Dramatic Art, Theatrical traditions, Natya Shastra.*

Introduction with Objectives:

This research paper aims to thoroughly examine and analyze Indian classical drama, also known as Sanskrit theater, as well as its historical background and evolution. We must objectively analyze and observe the fundamental elements of Indian classical theatre in a chronological manner in order to assess the evolution of Indian theater. The history of Indian theater may be traced back to the many years the nation spent celebrating the seasons and performing ancient rites. The classic text *Natya Shastra* by Bharat Muni provides the solution to the issue of where Indian theater originated. Following are the objectives of this study..

1. To study the Indian tradition of drama considering the Indian Classical Theatre.
2. To evaluate and observe the contribution of Sankrit Classical Drama in the development of Indian Theatrical Tradition.
3. To understand and to search the origin of Indian Drama through its development.
4. To explain and elaborate the contribution of various Indian Sankrit dramatists in the evolution of Indian Theatrical Tradition

5. To observe the contribution of Sanskrit Classical Drama and Indian Theatre in the light of Indian Knowledge System(IKS).

Literature review:

All the required and necessary primary sources and all available quality secondary sources in different media have been carefully taken into consideration with the minute comprehension to study the various aspects of Indian Theatrical Tradition for the present research work. A wide and broad search of The Online Union Catalogue of Indian Universities 'INFLIBNET, INDCAT' and Shodhganga , a reservoir of books and thesis, for getting the current status and information of the research, revealed that there are many titles till date, which deal with varied aspects such as ; Indian Drama, Indian English Drama ,Modern Indian Drama, Postcolonial drama, etc.

After going through the review process of all the mentioned sources, there was sufficient ground to assert that the Indian Classical Drama/ Theatre has not yet been studied from the angle of decolonization

There are some books, articles and few book reviews available on the selected topic. Some of the articles are written about the Indian Classical Drama are also available for the present studies. Ram Gopal's *Kâlidâsa: His Art and Culture* gives us the clear idea of the Sanskrit classical theatre. At the same time, M. L. Varadpande's *History of Indian Theatre* is a masterpiece of the chronological development of Indian Theatre. Whereas, M.K Naik's book *A History of Indian English Literature* puts forth the thorough picture of Indian English Drama. There are many article and books which deal with the issues discussed in the present research article.

Discussion/ Argument :

'Drama' the word which has its roots in Greek language got originated from the Greek word 'dra' which means 'do'. So 'doing', this word relates to an action which is an essential component of any drama.

John Dryden defines and elaborates drama as:

"Just and lively image of human nature representing its passion and humans and the changes of fortune to which it is subject for delight and instruction of mankind"

Here, according to Dryden, drama is an image of 'human nature', which is the image of 'just' and 'lively', he seems to imply that any literature which just imitates human actions and hence human actions play an important role in any dramatic representation.

The shorter oxford dictionary defines drama as:

"Drama is a composition in verse or prose and verse, adapted to be acted on the stage in which a story is related by means of dialogue and action and is represented with accompanying gesture and scenery as in real life"

Thus, this definition gives us vivid nature of drama as a literary form which pays more attention to dialogue and action representing real human life.

According to M.H. Abrams

"...Drama is composition designed for performance in the theatre, in which actors take the roles of the characters, perform the indicated action and utter the written dialogue..."(48)

All these definitions of drama conspicuously focus on the importance of dialogue, action and human nature and its representation through performance. Few definitions of drama also add to the performance value and its representation through actions on the stage which is rather essential to any dramatic pieces.

G.S. Tennyson rightly puts "Drama is a story that people act out before spectators"

This definition also puts forth the importance of action which is performed within the story before the audience.

According to Marjorie Boulton, drama essentially is an exceptional form of presentation of human actions and it surpasses all the literary genres and it stands on high pedestal in all the literary representations. As she says-

"...However, no play makes the same demands on our visual imaginations and any novel, descriptive

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or narrative poem, or short story. The actions and conversations take place before our very eyes; or if their actions in the play so violent or distressing that they cannot be represented on the stage, they can be described by characters who are present on the stage and show all the appropriate signs of horror and revulsions. Even this more violent in emotional impact than the experience of merely reading a description in the third person....To see a play is, for most people, a more exciting and memorable experience than to read a novel.....The concentration and intensity of emotion is caused by our actually seeing and hearing the events represented; but the special character of drama also lays considerable limitation upon it..." (4)

Here, Boulton emphasizes the importance of the drama as representational art, which can be visualized and which has live narrative experienced by the spectators with all the senses.

For the assessment of the development of Indian theatre we need to critically evaluate and observe the basic nature of Indian classical theatre chronologically. The development of Indian classical theatre is roughly is being surveyed by the researcher in the following manner.

This period is an important period in the beginning and development of Indian dramatic tradition. This period is also known as the period of Sanskrit theatre because the dramatist mostly wrote in Sanskrit language. The medium of literary expression was in Sanskrit. All the great scholars contributed their works in Sanskrit language. The exact period and century of the origin of the Sanskrit theatre is not known to the scholars and hence in the words of Benham:

"...It is difficult to affix an exact date or even to determine the precise century of the origin of Sanskrit theater. Fragments of the earliest known plays have been traced to the 1st century AD..." (471-482)

If we try to trace the origin of Indian theatre, it goes back to the centuries where ancient rituals and seasonal celebrations used to take place in the country. We find the origin of Indian Theatre in the traditional work *Natya Shastra* by Bharat Muni which has answered the origin of Indian theatre. In *Natya Shastra*, Bharat Muni has referred a legend that, when the world passed through the ages and in the times flow the common folk got addicted to common sensual pleasures of life, they developed jealousy, hatred, anger and all evil things in their hearts. Seeing this, God Indra, (King of heaven) with all other gods went to God Brahma (Creator of the Universe) and requested Him for other desirable form of entertainment for the human beings. God Brahma, accepting the request of Indra and other Gods, accepted it and thought of composing fifth Veda on Natya. Earlier there were four Vedas, so Brahma extracted the four elements from four earlier Vedas which were Speech, song, mime and Sentiment and out of this he created a one of the holy books of Natya and that was Natya Veda. The first drama was therefore was enacted before Indra. Hence *Natya Shastra*, by Bharat Muni, is the only source of enlightenment for the comprehension of Indian Theatre. *Natya Shastra* is a complete guide to unveil the rich tradition of Indian Dramatic Art. *Natya Shastra* is a masterpiece of authentic and definite historical information of the dramatic and theatrical traditions of ancient India.

Bharat Muni's, *Natya Shastra,* being regarded as the foundation of the Indian dramatic art, hence it has given a new dimension to the future of the theatre in India. *Natya Shastra* deals with all the essential technical aspects like, plot, setting, dialogue, characterization so and son. This theatre was known as Classical Sanskrit Theatre where predominantly Sanskrit plays were acted. Other addition to this theatre, which was again a significant contribution of Bharat Muni to this Classical theatre, was Rasa, literally means flavor and in real sense of the term *Rasa* deals with aesthetic pleasure. In *Natya Shastra*, Bharat Muni, has talked of eight basic *Rasas,* which are Love, sadness, humour, pride, fear, anger, pride, aversion and wonder. After all these eight basic *Rasas* are resolved into the ninth holistic Rasa and is known as "peace'.

Many Researchers have tried in comparing Aristotle with Bharatmuni, and they have found that the western drama is based on the dramatic theory of Aristotle from the 'Poetics', which gives much prominence to the theory of tragedy from the Greek concept of the tragedy. On the other side, Bharatmuni's ideology of drama is based on the concept of 'Karma', which is an Indian theory of drama. This theory puts forth the opinion about the man's fate which is not destined or governed by fate; on the other hand, man himself is responsible for his own destiny and fate. Man's fate is merely dominated by his own actions i.e 'Karma'. This difference in theoretical views of Bharatmuni and Aristotle has been much chewed and studied by many scholars around the world.

In the passage of time, many great scholars contributed in the development of Sanskrit classical drama. The great scholars like Bhasa, Kalidasa, Bhavbhuti, Sudraka, Vishakhadatta and Harsha greatly contributed in the development of Sanskrit classical drama. Creative vigour and technical excellence can be seen in their works. Sanskrit classical drama reached to new heights in the hands of these scholars. Gupta and Das hive rightly put their opinion as:

The dramatic genius of the Hindu reached its perfection between the second century B.C. and the ninth century A.D. Various dramas rich in poetry, and perfect in execution have been traced to this period. Bhasa, Kalidasa, Bhavbhuti, Sudraka, Vishakhadatta Shri Harsha all belong to this august period of the Sanskrit Drama; their very structures differ from that of Greek drama (52)

In the development of Sanskrit classical drama, as I have stated earlier that the contribution of these scholars is highly appreciated by all the historians and critics and their significant contribution has paved a new pathway for the future dramatists. Let me further analyse the contribution of these scholars in an elaborative manner.

The first and one of the most important scholars, whose works have greatly and significantly contributed in the development of Sanskrit classical drama is Bhasa. Bhasa is one of the oldest dramatists of this tradition who belongs to the era from 500 to 50 B.C. In his lifetime he wrote around thirty five plays out of which at presents only thirteen plays are available for the studies. *'Svapnavasavadatta'* is one of the most significant works of Bhasa. His other famous contributions in the development of Sanskrit classical drama are, *'Pratijna-Yaugandharayan'*, *'Charu Duttam'*, *'Pancharatral'*, *'Karnabhara'* *'Dootvakya'*, and *'Bat Charit'*, *'Abibharaki. Prupuk'*. These works are written in Prakrit language and were staged by common folks on the occasion of social ceremonies which were based on the incidents from Ramayana, Mahabharata and Puranas.

Kalidasa is another great poet and dramatist of the Sanskrit classical drama. He is regarded as the most famous classical dramatist of the times. He was an ardent devotee of Lord Shiva and works are highly indebted to Hindu mythology and philosophy.

"Kalidasa, the immortal poet and playwright, is a peerless genius whose works have won world-wide fame. The matchless qualities of his work have been lavishly praised both by the ancient Indian critics and modern scholars. (...) In modern times the translations of Kalidasa's works in numerous Indian and foreign languages have spread his fame all over the world and now he ranks among the few topmost poets and playwrights of the world". (Ram 1)

Kalidasa's works are replete with philosophy of human nature and life and hence he is compared with William Shakespeare, the bard of Avon and Monarch of British literature. Critics rightly regard Kalidasa as Shakespeare of India. Very little is known about his biography and the era in which he wrote, but he is regarded as the gem of Sanskrit classical Drama. In his lifetime he wrote three plays and these plays are still popular among all the generations. The famous plays which were penned by Kalidasa are *'Malvikagnimitram'*, *'Vikramorvsaiyam'* and *'Abhigyan Shakuntalam'*.

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Bhavabhuti, is another prominent playwright and scholar, a famous poet of the King of Kannauj named Yashovarma. Bhavbhuti wrote Sanskrit plays and poetry in the 8th century of later phase of classical era. He is playwright who significantly contributed through his Sanskrit works in the development of Indian dramatic tradition. Some of the critics have rightly compared Bhavbhuti with renowned scholar Kalidasa for his writing skills. His famous dramatic poems are '*Mahavircharita*' '*Uttararamacharita*' and '*Malti Madhav'*, a love story conveyed through the tantric rites. '*Mahavircharita*', written on the life of Rama from Ramayana, where Bhavbhuti describes the development of the character of Rama from his childhood , his conquest with Ravana, king of Lanka and till Rama becomes the king of Ayodhya. Bhavbhuti is considered to be one of the great masters of dramatic poems in Sanskrit tradition.

Another name which comes to our mind is Sudraka, whose works greatly contribute in the Indian dramatic tradition. Sudraka wrote a monumental drama '*Mrichakatikam' or 'The Little Clay Cart'* which means, earthen vehicle. This play is about a love story of Brahmin Charudatta and a prostitute Basantsena. According to Farley P. Richmond, Shudraka was simply a mythical figure, and the authorship of the play is uncertain.

"Various critics after the eighth century mention Sudraka as the author of '*Mrichakatikam'* or *'The Little Clay Cart'*, but give no details about his personality or the kingdom over which he ruled. A fourteenth century text attributes the play to a pair of collaborators, Bhartrimentha and Vikramaditya. The former was reported to have been one of the great poets living in the city of Ujjain about the time of Kalidasa, and later may have been none other than King Chandragupta II of the Gupta dynasty. However, these references are so far removed from the probable date of composition of *'The Little Clay Cart'* that considerable doubt is cast on their validity....The General consensus is that Sudraka was a mythical figure who had no place in history. Thus, unless we take prologue at face value and the possibility that it was revised after the death of the king, we must assume that Sudraka never lived and the authorship of one of the most famous plays ancient India is uncertain!" (Richmond et all 57)

Thus, Sudraka still remains the most important figure in the times of the development of Indian dramatic tradition.

Vishakhadatta, a renowned Sanskrit poet and playwright contributed to the Indian dramatic tradition at a great scale through his dramatic pieces. He was one of the most prominent playwrights of Gupta period. His famous works *are 'Mudrarakshasa'* and *Devichandra Guptam*. In *'Mudrarakshasa'* which deals with the story of the great emperor of Nanda dynasty Dhanananda and founder of Mauryan Empire none other than Chandragupta Maurya. *'Devichandragupta'* gives us the poetic narration about the life of the Gupta emperor Chandragupta and his brother Ram Gupta.

Another scholar and playwrights of the times was Harshvardhana, a king of Kannauj. In his lifetime he composed three plays. These three famous plays are *Nagananda, Ratnavali'*, and *'Priyadarshika'*. *Naganand* is a play which deals with the prohibition of snake sacrifice. The play *Ratnavali* is about love affair between prince Udayan and his lover Ratnavali and the last play *'Priyadarshika'* is another play deals with the love story of Udayan and Priyadarshika.

There are other few poets and playwrights who enriched the Indian classical dramatic tradition and their contribution to the development of Indian theatre is praiseworthy. These playwrights are Banabhatta, who belonged to seventh century A.D. and Bhattanarayana, another famous playwright of the age. He belonged to the seventh to eighth Century A.D., whose contribution has given new dimension to the development of classical Indian theatre.

Conclusion:

The Indian classical Sanskrit theatre is having its close relationship with religion. All the forms of art like arts-music, painting and literature are highly

influenced by religion were and hence we see that all in these forms god is at the centre and proclaiming the authority of the god is done by all these arts. Most of the plays contained religious themes and plots and so, the plays were highly indebted to *Ramayana* and *Mahahharata* .

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नियतकालिकांची संकल्पना, प्रकार व प्रेरणा

प्रा.डॉ. बी.पी. गार्डी

प्रस्तावना

नियतकालिकांनी आधुनिक मराठी वाङ्याच्या जडणघडणीत मोलाची भर घातली आहे. नवोदितांच्या लेखनाला वाचकापर्यंत पोहोचविण्याचे नियतकालिक हे प्रभावी साधन आहे. मराठीतील नियतकालिकांचा विचार करावयाचा झाल्यास इंग्रजी राजवट, मुद्रणकलेची झालेली सोय, इंग्रजी राजवटीत झालेला शिक्षणाचा प्रचार आणि प्रसार या गोष्टींचा विचार करणे क्रमप्राप्त ठरते. अगदी सुरुवातीच्या काळात इंग्रजांनी आपल्याकडे शिक्षण आणले. वर्तमानपत्रे आणली. ही वर्तमानपत्रे इंग्रजी भाषेतील होती. त्यांचेही अनुकरण भारतीय भाषेतील नियतकालिकांमध्ये झालेले आहे. नियतकालिके आपल्याला जीवनाच्या सर्व बाजूंचे आवश्यक ते आणि आवश्यक तेवढे दर्शन घडवितात. नियतकालिक हा वाङ्मयप्रकार आपल्याकडे अगदी नवा होता. नियतकालिकांचा उदय युरोप खंडात सतराव्या शतकाच्या उत्तरार्धात झाला. त्यानंतर पुढील दोनचार वर्षात फ्रान्स, इंग्लंड, इटली, या देशात नियतकालिके निघू लागली. या सर्व नियतकालिकांची महत्वाची प्रेरणा ज्ञानप्रसार हीच होती. पाश्चात्य देशात ज्याप्रमाणे नियतकालिकांचा उदय ज्ञानप्रसारासाठी झाला त्याप्रमाणे महाराष्ट्रातही धार्मिक, सामाजिक व राजकीय विषयांच्या ज्ञानप्रसारासाठी झाला. लोकरंजन, लोकशिक्षणाबरोबरच ज्ञानप्रसाराचे मोठे कार्य नियतकालिकांनी केले.नियतकालिक म्हणजे ठराविक काळाच्या अंतराने उपलब्ध केले जाणारे वाङ्मय. त्यात त्या त्या काळाचे महत्वाचे तपशील

असतात. तसेच काही महत्वाच्या विषयावरही प्रकाश टाकलेला असतो. इ.स. १६६३ साली जर्मनीतील हँबर्ग येथे प्रसिद्ध झालेले 'Erbauliche Monaths Unterre Dumgen' हे जगातील ज्ञात असलेले पहिले नियतकालिक होय. भारतीय भाषांतील नियातकालिकांचा उगम होण्यास एकोणिसाव्या शतकात सुरुवात झाली. बंगालमधील श्रीरामपूर मिशनच्या डॉ. विल्यम केरी यांनी इ.स. १८१८ मध्ये 'समाजदर्पण' नावाचे बंगाली भाषेतील नियतकालिक प्रसिद्ध केले. मराठी भाषेतील 'दर्पण' ६ जानेवारी, १८३२ रोजी बाळशास्त्री जांभेकरांनी प्रसिद्ध केले. त्यानंतर त्यांनी 'दिग्दर्शन हे मासिक १ मे १८४० साली प्रसिद्ध केले. मराठी नियतकालिकांचा प्रारंभ होतो न होतो तोच १८७० मध्ये इंग्रज सरकारला वर्तमानपत्रांच्या मुस्कटदाबीचा कायदा पास करावालागला, यावरून नियतकालिकांनी अल्पावधीतच कशा प्रकारे सामर्थ्य संपादन केले याची कल्पना येते. मराठी नियतकालिकांनीच मराठी निबंध वाङ्मय समृद्ध केले.

नियतकालिकाची संकल्पना व स्वरूप

नियतकालिक या संकल्पनेचा विचार करताना सर्वात प्रथम 'नियतकालिक' या शब्दाचा अर्थ लक्षात घेणे गरजेचे आहे. वेगवेगळ्या शब्दकोशात, विश्वकोशात तसेच अभ्यासकांनी मांडलेल्या मतांचाही परामर्श घेणे क्रमप्राप्त आहे.मराठी शब्दकोशानुसार नियतकालिकाचा अर्थ "नियत (सं.क्रि.) निश्चित (अ) निरंतर कालिक (सं.क्रि.) कालासंबंधीचे मुदतीचे"* ([१].आपटे वा.गो., मराठी शब्दरत्नाकर, सरस्वती ग्रंथ भांडार, पुणे, पृष्ठ ३२२) असा होतो. यावरून निश्चित काळ अथवा निरंतर काळाने सुरु असणारी कृती होय. मराठी विश्वकोशानुसार विचार केला तर नियतकालिक म्हणजे "जे प्रकाशन एकाच शीर्षकाखाली किमान एक आठवड्याच्या किंवा त्याहून अधिक कालावधीने सामान्यतः नियमितपणे प्रसिद्ध होते आणि ज्यात अनेक लेखकांचे विविध विषयांवरचे किंवा प्रकाशन विशिष्ट विषयाला राहिलेले असल्यास त्या एकाच विषयावरचे साहित्य संकल्पित केलेले असते ते नियतकालिक"* ([२]. http://www.marathivishvakosh.org.com) अशी व्याख्या मराठी विश्वकोशात दिलेली आहे. यावरून नियतकालिकाची संकल्पना अधिक स्पष्ट होत जाते. "नियतकालिक म्हणजे ठराविक काळाच्या अंतराने उपलब्ध केले जाणारे वाङ्मय त्यात तात्कालिक महत्वाचे तपशील असतात व काही चिरस्थायी महत्वाचे विषयही आलेले असतात. लौकिक घटना तीवरील भाष्य, काही स्फुट जीवनविचार, व्यवहारोपयोगी शास्त्रे आणि विद्या यांची माहिती इत्यादींनी या नियतकालिकांची जागा व्यापलेली असते" (कुलकर्णी व. दि., मराठी नियतकालिकांचा वाङ्मयीन अभ्यास, पृ.४) वेबस्टर वर्ल्ड युनिवर्सिटी डिक्शनरी "A Publications Put out at regular mterials than a day a weekly, monthly, quarterly" (Wester Noub westers, third New international Dictionary, ADEI America Third Edition, १९६० P. ७२०) अशी व्याख्या केलेली आहे. आठवड्यातून एकदा किंवा दरमहा प्रकाशित होणारे असे ते नियतकालिक होय.

नियतकालिकांचे प्रकार

लेखकांना वाचकांशी जोडणारा दुवा म्हणून नियतकालिक महत्वपूर्ण ठरते. आज नवोदीत लेखनाचे हक्काचे व्यासपीठ अशी नियतकालिकांची सर्वसाधारण ओळख बनली आहे. आज नियतकालिकांची संख्या जशी जशी जास्त आहे तसेच त्यांचे प्रकारही तितकेच आहेत. नियतकालिकांचा विचार केला तर नियतकालिकांचे वेगवेगळे प्रकार पडतात. १८३२ साली सुरु झालेले 'दर्पण' हे प्रारंभी पाक्षिक होते, नंतर ते साप्ताहिक झाले.एकोणविसाव्या शतकात ज्ञानाची

भूतपूर्व प्रगती झाली. प्रसिदीच्या कालावधीनुसार, विशिष्ट वाचकवर्गानुसार, आशयानुसार नियतकालिकांचे ढील प्रकार पडतात.

१) प्रसिद्धीच्या काळानुसार :

प्रसिद्धीच्या काळानुसार नियतकालिकांचे साप्ताहिक, पाक्षिक, मासिक, द्वैमासिक, त्रैमासिक, ण्मासिक, वार्षिक असे प्रकार पडतात.

२) विशिष्ट वाचकवर्गानुसार

विशिष्ट वाचकवर्गानुसार मुलांची, स्त्रीयांची, प्रौढ, वसाक्षरांची, श्रमिकांची, क्रीडाप्रेमींची इत्यादी प्रकार डतात.

३) नियतकालिकाचे आशयानुसार प्रकार

सुरुवातीच्या काळात नियतकालिकांचे स्वरूप हे सर्वसमावेशक होते. कला, ब साहित्य, मनोरंजन, वैचारिक लेख, समीक्षा हे सर्व प्रसिद्ध होत होते. नंतरच्या काळात मात्र लोकांच्या अभिव्याक्तीनुसार, अभिरुचीला अनुसरून त्या त्या प्रकारची नियतकालिके प्रसिद्ध होऊ लागली. मनोरंजनात्मक मजकूर प्रसिद्ध करण्याचे काही नियतकालिकांनी ठरवले. तर काही नियतकालिके ही शैक्षणिक क्षेत्रातील विविध घडामोडी, बदल यांना प्रकाशित करताना दिसतात. काही नियतकालिके ही संशोधनात्मक लेखन प्रसिद्ध करणारी आहेत, धर्माला व धार्मिक तत्वाला महत्व देणारी नियतकालिके, शेतीविषयक माहिती देणारी नियतकालिके, आरोग्याच्या संदर्भात माहिती देणारी नियतकालिके, महत्वाच्या सामाजिक प्रश्नांचा आढावा घेणारी नियतकालिके, पर्यटन स्थळांचे महत्व सांगणारी नियतकालिके, ज्ञानप्रसारासाठी वाहिलेली नियतकालिके, विज्ञानविषयक नियतकालिके असे नियतकालिकांचे आशयानुसार विविध प्रकार पहावयास मिळतात.

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22. Role of NEP in Employment Generation in Maharashtara

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Introduction

The New Education Policy (NEP) 2020, introduced by the Indian government, has been a game-changer in the education sector. With its focus on providing quality education and creating job-ready graduates, NEP 2020 has a significant role to play in the employment generation in the state of Maharashtra.

One of the key objectives of NEP 2020 is to make education more industry-oriented. The policy focuses on providing practical training to students, making them job-ready by the time they graduate. This is achieved by incorporating industry-related projects, internships, and real-world experience into the curriculum. In this way, students are equipped with the necessary skills and knowledge to enter the workforce upon graduation, thereby increasing their chances of securing employment.

Additionally, NEP 2020 promotes vocational education and training, which will help to address the skill shortage in certain industries. By providing students with hands-on training in a specific trade or skill, they will be better equipped to secure employment in their chosen field.

Another important aspect of NEP 2020 is its emphasis on multilingual education. This policy recognizes the importance of learning in mother-tongue or regional languages, and encourages the use of local languages as mediums of instruction. This will help to create job opportunities for language teachers and other education professionals, thereby boosting employment generation in the state.

Moreover, NEP 2020 promotes the setting up of new educational institutions, including colleges, universities, and vocational training centers. The establishment of these institutions will create job opportunities for teachers, administrators, support staff, and other professionals in the education sector.

Maharashtra is one of the most developed states in India and is home to a large number of industries and businesses. However, despite its economic progress, the state is facing a challenge in terms of employment generation. The NEP aims to address this challenge by promoting vocational education and job-oriented training programs.

Key Feature of the NEP

The integration of vocational education into the school curriculum. This will provide students with the opportunity to develop practical skills and gain hands-on experience in their chosen fields. This will not only make them more employable but also help them make informed decisions about their careers.

The NEP also emphasizes the importance of promoting entrepreneurship and self-employment. The policy encourages the establishment of incubation centers and innovation hubs that will provide students with the necessary support and resources to start their own businesses. This will help to create new job opportunities and contribute to the growth of the economy.

In addition to promoting vocational education and entrepreneurship, the NEP also lays stress on the need for reorienting higher education towards employability. This will involve a shift away from the traditional focus on theoretical knowledge and towards practical skills and real-world experience. This will make students more attractive to employers and better prepared for the demands of the job market.

The NEP also recognizes the importance of skill development in meeting the demands of the rapidly changing job market. The policy provides for the establishment of National Skills Universities, which will offer job-oriented training programs in areas such as engineering, technology, and management. These programs will equip students with the skills and knowledge required to succeed in the 21st-century job market.

Conclusions

1. The New Education Policy holds great potential for employment generation in the state of Maharashtra. By promoting vocational education, entrepreneurship, and job-oriented training programs, the NEP will help to create new job opportunities and contribute to the economic growth of the state.

2. It is important that the implementation of the NEP be carried out in a timely and effective manner to ensure its success in addressing the employment challenge in Maharashtra.
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