GREEN SYNTHESIS OF Cr_2O_3 NANOPARTICLES MEDIATED THROUGH *PISUM SATIVUM* AND *CITRUS LEMON* PEELS EXTRACTS AND APPLIED FOR PHOTOCATALYTIC ACTIVITY

Ajay Singh[1]*, Gaurav Gaur[2], Sumit Bhatt[3], Prachi Pant[4]

Abstract

Green synthesis of nanoparticles is emerging trend in present scenario for development of new material. Chromium nanoparticles (Cr Nps) have been synthesized by green technique from peel extracts of selected two plants.viz *Pisum Sativum* and *Citrus lemon* peels**.** Such synthesized nanoparticles have been characterized and used for the degradation of dyes and also compared for antibacterial activity. Energy efficiency, minimal toxicity, high yields, economic effectiveness, and easy accessibility are few benefits of synthesized Cr NPs. Nano particles were characterized by using scanning electron microscopy, Fourier transform infrared spectroscopy (FTIR), ultraviolet-visible spectroscopy, and X-ray diffraction and size was confirmed in the range of 30 to40 nm. Such synthesized particles have shown potential of photocatalytic activity as well as antibacterial nature.

Key words: Green synthesis, Chromium nanoparticles, photocatalytic activity, FTIR, SEM.

[1*]Professor, Department of Chemistry, School of Applied and Life Sciences, Uttaranchal University, Dehradun, Uttarakhand, India, dean.sciences@uumail.in

[2,3,4]Scholar, Department of Chemistry, School of Applied and Life Sciences, Uttaranchal University, Dehradun, Uttarakhand, India, gauravgaur1031999@gmail.com

***Corresponding Author:-** Ajay Singh

*Professor, Department of Chemistry, School of Applied and Life Sciences, Uttaranchal University, Dehradun, Uttarakhand, India, ajay21singh@yahoo.com

DOI: - 10.48047/ecb/2023.12.si5a.0346

Introduction

Nanoparticles are an effective technique to degrade dyes, due to the high concentration of dyes in textile waste, which can cause a number of diseases when they come into contact with human bodies due to the expansion of the textile industry(Gupta et al., 2014). Nanoparticles are tiny things that function as a single entity in terms of transport and properties (109 m). According to studies, antibacterial capabilities of nanoparticles including Chromium nanoparticles are efficient against a range of drug-resistant bacterial, viral, and fungal strains (Liu et al., 2016) Due to their peculiar physical and chemical characteristics, which differ from either those of larger particles or specific atoms, nanoparticles have recently gained a lot of attention. (Teixeira et al., 2001). The use of chromium oxide (Cr_2O_3) in numerous scientific fields has recently garnered a lot of attention. CO and H_2S catalysis, heat protection, and wear resistance, and the colouring of "chrome green" and "institutional green" in glassware, inks, and paints are only a few uses for chromium oxide nanoparticles. Due to the growing use of Cr_2O_3NPs in biological perspectives, a range of bio potentials were investigated in relation to Cr_2O_3NPs. The antibacterial activity of Cr_2O_3 Escherichia coli was used as a test organism for nanoparticles' ability to inhibit gram-negative bacteria. Reduction of potassium dichromate solution with freshly prepared peels extract yields $C_{r2}O_3$nanoparticles. (Ghotekar et al., 2021) .

The antibacterial activity of Cr_2O_3nanoparticles as a representative of gram-negative bacteria was studied against Escherichia coli. The reduction of potassium dichromate solution with freshly prepared plant extract yields Cr_2O_3 nanoparticles. the presence of transition metal nanoparticles attracted a lot of attention due to their potent antibacterial properties. (Rayani Nivethitha & Carolin Jeniba Rachel, 2019)A nanoparticle has the potential to replace antibiotics in the treatment of microbiological illnesses brought on by Salmonella typhi, Klebsiella pneumoniae, Staphylococcus aureus, and Staphylococcus epidermidis. Because textile waste contains a lot of dye (Thakur et al., 2019) Owing to the high concentration of colours in textile waste, which can cause a number of diseases when they come into contact with human bodies due to the growth of the textile industry, nanoparticles are an efficient way to degrade dyes.

Researchers have been researching nanotechnology since the turn of the century(Biswas et al., 2012). Since the notion of "nanotechnology" Richard P. Feynman, a 1959 Nobel Prize winner, initially introduced his speech "There's Plenty of Space at the Bottom," Nanotechnology is a rapidly growing field because it is used in science and technology to produce new materials at the nanoscale. Nanotechnology has had a significant positive impact on both biotechnology and pharmacology (Santhoshkumar et al., 2014) Nowadays, the utilization of nanoscale particles has substantially improved the creation of novel antimicrobial medications for the treatment of hazardous microorganisms. Because to their extraordinary effectiveness and reactivity, nanoscale materials are among the current antibacterial chemicals that are generating a lot of interest(Alarjani et al., 2022) The nanoparticles are utilized in many aspects of daily life and have a variety of chemical and medicinal uses. Both inorganic nanoparticles like magnetic and magnetic nanoparticles as well as biological nanoparticles like liposomes, chitosan, and micelles, may be generally separated into two types(Singh Jassal et al., 2022) The creation and development of various nanomaterials on a nanoscale through the manipulation of matter is the definition of nanotechnology(Montiel et al., 2015). The gap between matrix and dispersed phase is filled by nanomaterials. Because to their diverse sizes, shapes, enormous surface areas, and high reactivity. This field of research has lately grown in prominence due to its many applications. Owing to its minute size, the impact may be seen on many nanoparticles' melting point, dielectric constant, and physical, optical, and chemical properties (Ibarra-Galván et al., 2014). The nanoparticles are utilized in many aspects of daily life and have a variety of chemical and medicinal uses.

The modules of a nanoparticle can be roughly categorized as organic nanoparticles, which include liposomes, chitosan, families, including metal oxides (titanium, copper, zinc, chromium, and silicon), carbon nanotubes, which form solid fibres with distinctive electrical properties, fullerenes [C60, C70], used to enhance the optical properties and electrical properties of polymers or for pharmaceutical applications, and Ag NPs, which are used in specific textiles due to their antibacterial properties (Basahi, 2021) The quick development of industry made many chemical substances, including medications, available for common use. Many of the drugs available in modern medicine to treat a wide range of disorders are over-the-counter and can be used without first contacting a doctor(Liu et al., 2016). Due to this fact, less strain is placed on the already stretched-thin health services, and it may also lead to pharmaceutical addiction and improper disposal of drugs that are no longer needed or that have expired. Pharmaceutically active substances come up in the air and in the soil, via landfills due to faulty wastewater cleanup or flushing into water sources. Describing how much we get from medications such as -blockers, cytostatics, analgesics, antibiotics, and many others types of medication (Krakowiak et al., 2022) Trivalent Cr_2O_3 nanoparticles are among the numerous chromium oxides and are thought to be the most stable. Despite being a promising material, Only a few researcher have studied the potential toxicity of trivalent Cr_2O_3 nanoparticles for use in a variety of biological applications.

The biocompatibility of Cr_2O_3 nanoparticles is essential for their usage in a variety of biological systems. The poisonous properties of Cr_2O_3nanoparticles can be reduced by coating or functionalizing their surfaces with biogenic components. One of the most promising methods to do this is to surface coat $Cr_2O_3$with phytomolecules generated from plants. Precursors from plants are used to create nanoparticles has recently attracted a lot of attention. Since it is more cost-effective than traditional chemical and physical techniques, the green production of nanoparticles using vegetables peels could be used as an alternative., dependable, environmentally benign, and easily scaleable. In particular, generated nanoparticles Using plants appears to be more biocompatible than those created by chemical and physical processes(Jaswal et al., 2014). This is due to the fact that standard chemical and physical processes for producing nanoparticles frequently employ potentially harmful materials. Even after numerous washings, it is challenging to simply wash these dangerous substances off the surface of the nanoparticles. Nanoparticles have fewer biological applications and are less biocompatible since they contain hazardous chemicals (Khan et al., 2019) Cr_2o_3NPs have recently attracted attention due to their electrical, optical, and medicinal capabilities. Researchers are drawn to Cr_2O_3 NPs because it has unique properties among the metal oxides. Cr_2O_3NPs are produced for usage in a number of applications because of their antiferromagnetic properties, hardness, chemical resistance, and thermal stability. The attractive adaptive properties of Cr_2O_3 NPs lead to less hazardous synthesis. The significant characteristics of Cr_2O_3have an influence on both science and technology (Wei et al., 2015). Plant parts that differ from one another, such as leaves, fruit, roots, latex, seeds, and stems, may have medicinal advantages. For the synthesis of various materials, a number of techniques have been developed, including solvothermal, thermal, hydrothermal, and microwave irradiation methods are all used for thermal breakdown.(Samadi et al., 2021)

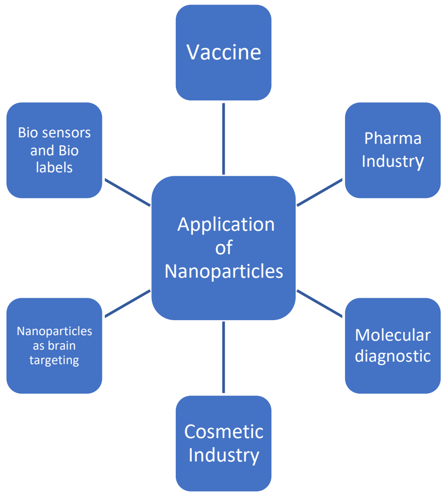
Material and method

All used chemicals are of grade A

Preparation of plant extract

Preparation of *Pisum sativum* peels extract

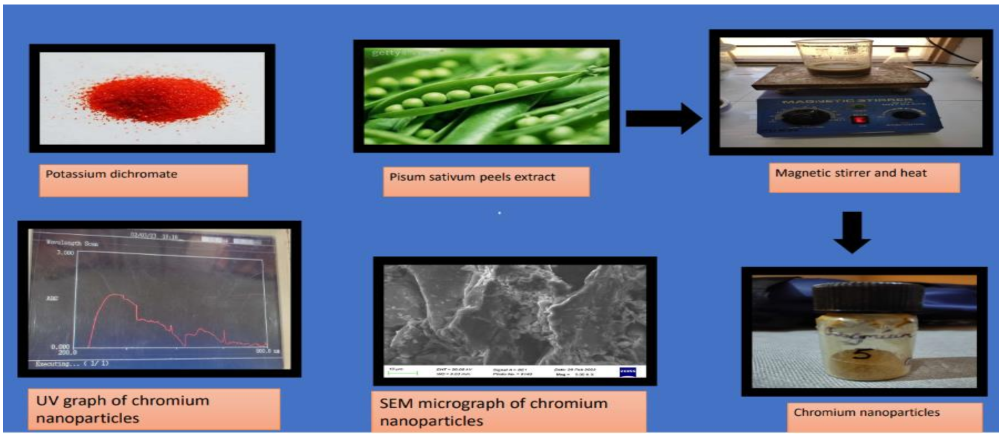
As a capping and reducing agent, *Pisum sativum* peel extract was used in the manufacture of chromium nanoparticles. 15 g of dried crushed peels were placed in 150 ml of ethanol in a round bottom Soxhlet device to prepare the extract, which took 3–4 hours. With the use of a distillation assembly, the extracted ethanol was then recovered.



Preparation of *Citrus lemon* peels extract

As a capping and reducing agent, *Citrus lemon* peel extract was used in the synthesis of Cr_2O_3nanoparticles. To make the extract, 25 g of dried peels were dissolved in 150 ml of ethanol in a round bottom Soxhlet device over the course of 3–4 hours. With the use of a distillation assembly, the extracted ethanol was then recovered.

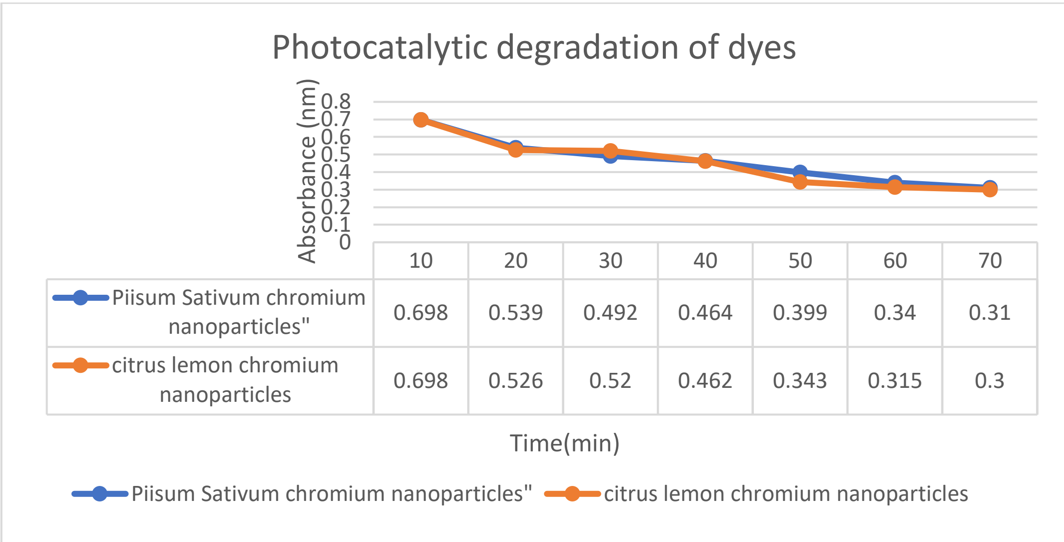
10 ml of 0.1 M K_2CrO_7 solution and 2 ml *of Citrus lemon* peel extract were combined in a conical flask and heated to a temperature between 60 and 80 °C while being continuously stirred at a speed of 400 rpm in a magnetic stirrer. The colour of the solution changed to brown, signifying the creation of nanoparticles, which were then centrifuged and carefully cleaned three times with deionized water to eliminate water-soluble organic waste. The finished product was air-dried and ground into tiny particles. The same procedure was repeated for *Pisum sativum*

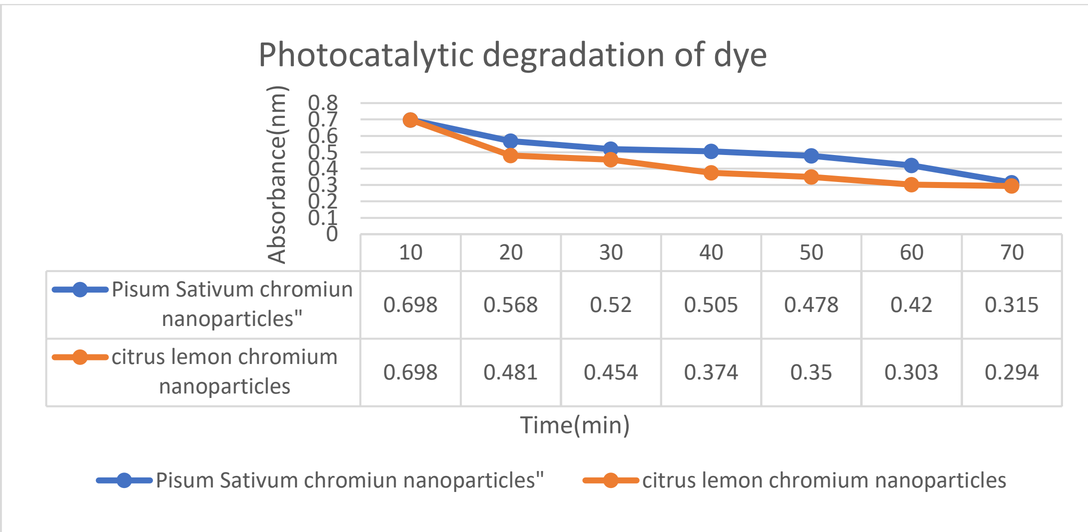


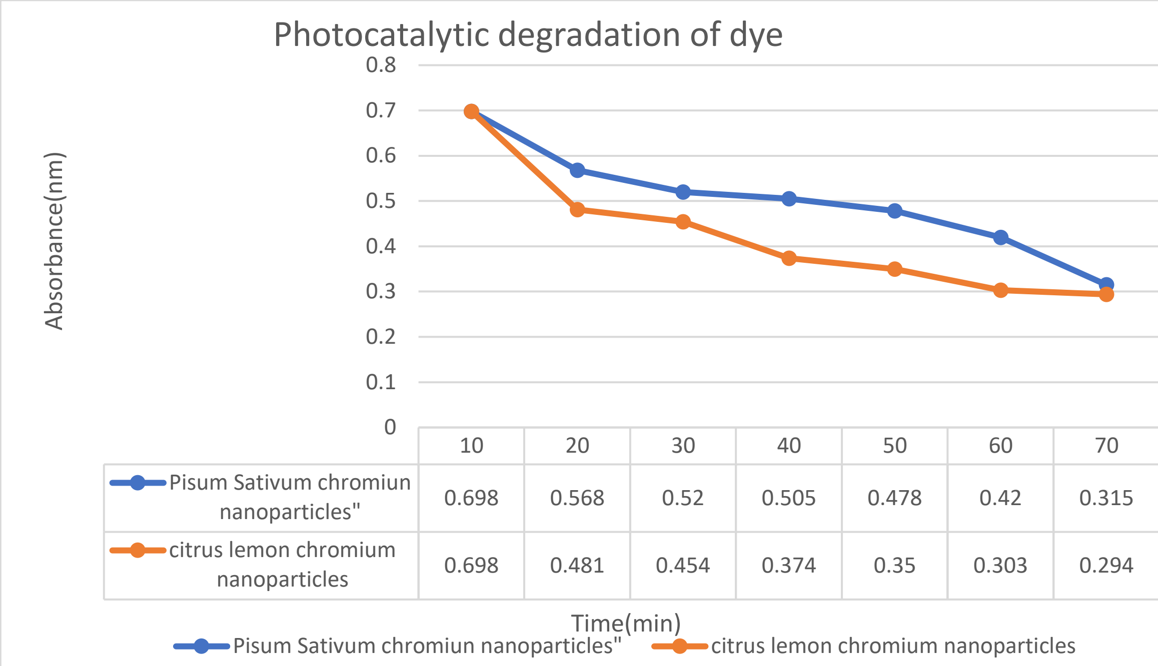
Photocatalytic degradation of dyes

The effectiveness of synthetic materials Cr_2O_3 NPs for removing the dye rhodamine blue was tested in a series of studies. light's existence and absence. After treatment with various synthetic materials, it was discovered that the absorbance of the solution reduced over time as the quantity of rhodamine blue dropped. The surface and structural characteristics of the dye and substance, which are regulated by pH, have a significant impact on how well the sorbent removes the dye. The composition of charges on the surfaces of both dye and material are therefore altered by every change in solution pH, having an impact on material properties including stability, ion exchange capacity, electrolyte interaction, and suspension rheology

% degrdation $=\{(Ao - Af) /Ao \} X 100$





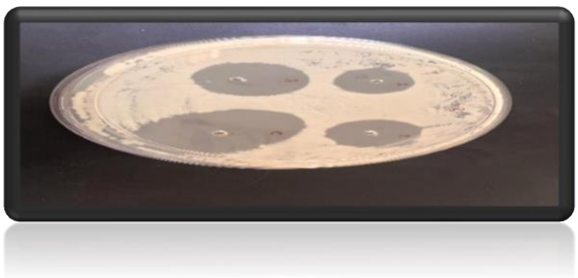


	% degradation	
Radiation	Pisum Sativum Cr_2O_3 NPs	Citrus Lemon Cr_2O_3 NPs
Visible	65	64.03
Short UV	56.8	57
Long UV	54	57

Pisum Sativum Cr_2O_3 NPs was found more useful for the degradation of rhodamine blue in visible light as comparison to Cr2O3 NPs prepared by using Citrus Lemon peels extract where as Cr2O3 NPs prepared by using Citrus Lemon peels extract were found more effective in short UV and long UV region. Study shows that synthesised nano particles have potential of using as photocatalyst, Waseem Ahmed and co-workers also did photocatalytic activity in similar way.

Antibacterial activity

Escherichia coli were employed in this investigation. Comparing synthetic Cr_2O_3 nanoparticle (10 ml) to the widely-used antibiotic Gentamycin (Broad spectrum), inhibition is seen. The highest inhibition for Staphylococcus aureus is up to 55mm. Comparative antibacterial research using several nanoparticles of the same metals made from various extracts of Cr_2O_3 reveals zone inhibition within the range of (30 to 35) mm



	Zone of inhibition (in mm)	
	Pisum Sativum Cr_2O_3 NPs	Citrus Lemon Cr_2O_3 NPs
Control	47	43
0.02g/10ml ethanol	31	43
0.04g/10ml ethanol	34	37
0.06g/10ml ethanol	39	41

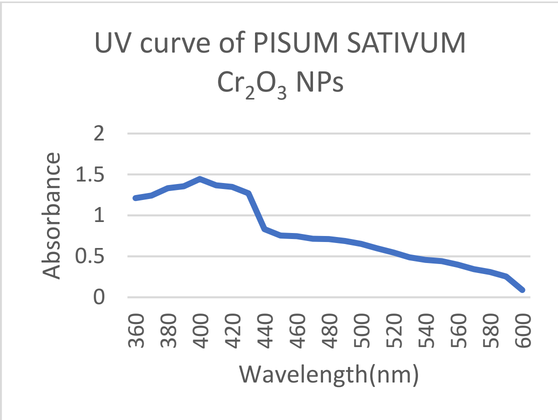
Citrus Lemon Cr_2O_3 NPs was more effective for the inhibition of bacterial growth as comparison to Pisum sativum Cr_2O_3 NPs

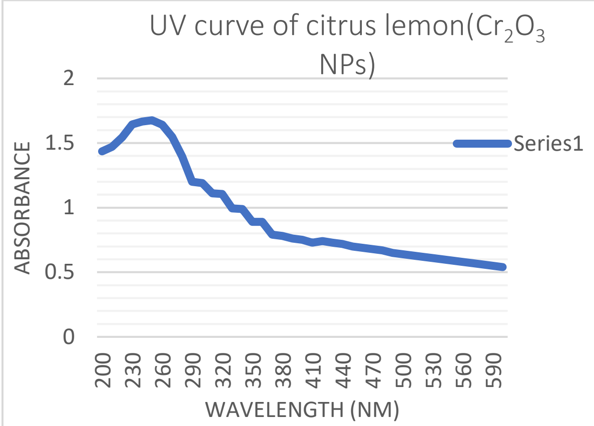
Characterisation technique

Analytical investigations' most important and relevant measurement is the metal NPs' characterization. It divulges the characteristics or attributes that have previously been employed in multifunctional applications. Certain microscopic-based technologies, including UV-Vis, SEM, TEM, AFM, XRD, XPS, and FTIR, provide information about the Morphology , Crystalline nature Size, structure of nanomaterials. These techniques can be used to assess the materials' accessibility, expense, selectivity, precision, simplicity, and affinity. The produced chromium oxide is characterised using a variety of methods.

Uv

In order to confirm how the nanoparticles were created, the aqueous extracts of *Pisum sativum*, *citrus lemon*, as well as the synthesised nanoparticles scanned between 200 and 800 nm using a UV-Vis spectrophotometer. UV study also used by

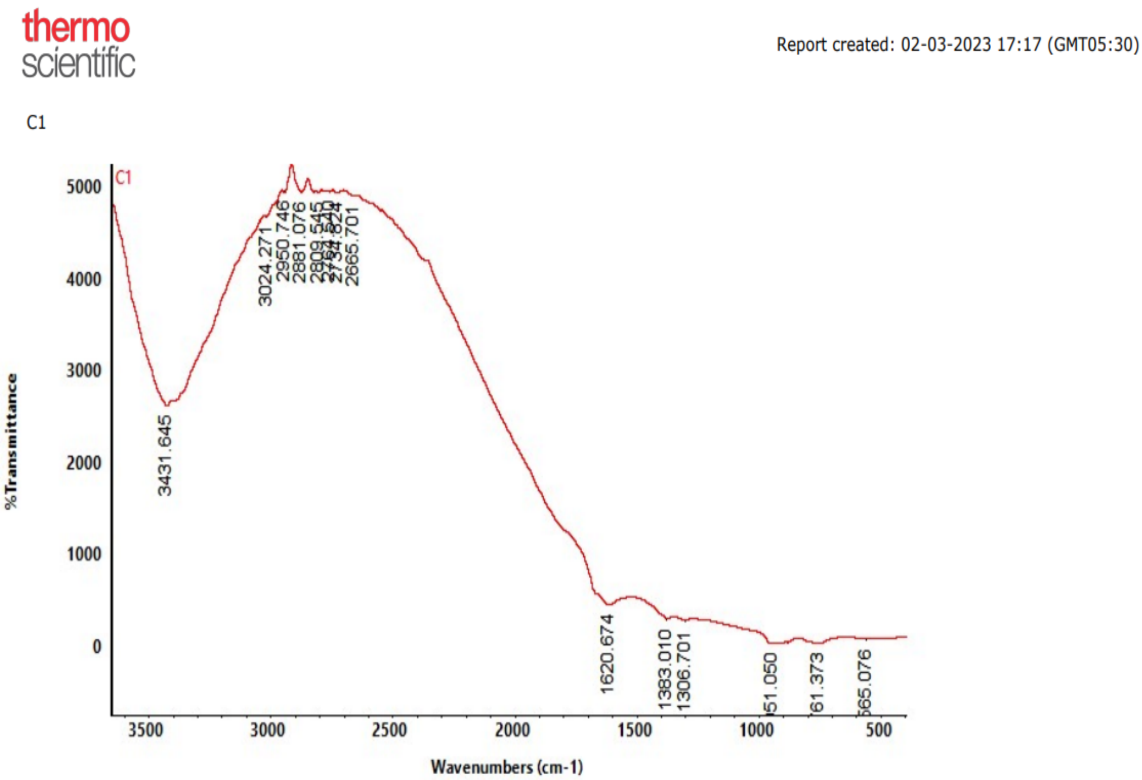




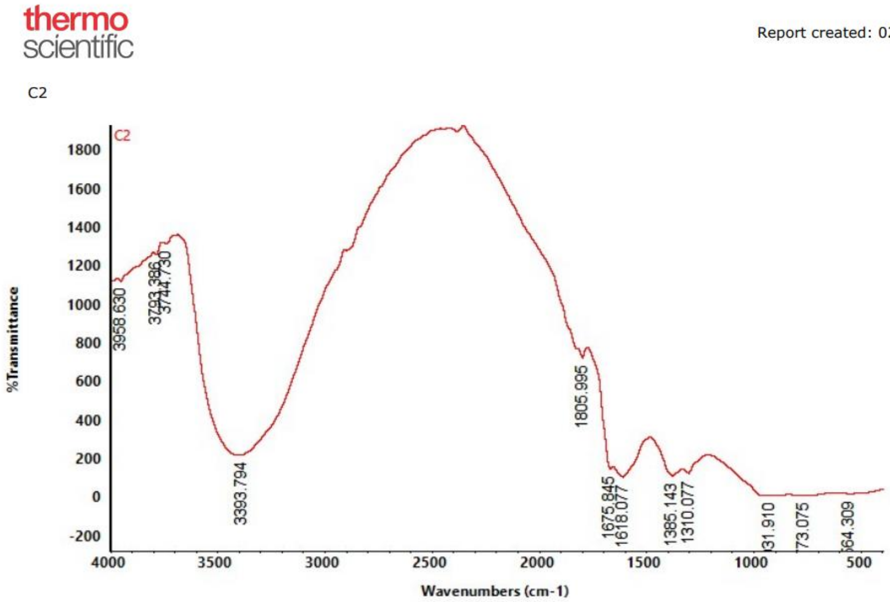
FTIR

To confirm the functional groups responsible for the degradation and preservation of the nanoparticles, FT-IR analysis was performed on the extracts and the nanoparticles.

	Pisum Sativum Cr_2O_3 NPs stretching frequency(cm^{-1})	Citrus Lemon Cr_2O_3 NPs stretching frequency(cm^{-1})
Cr-O-Cr	1383.010	1385.143
Cr=O	1620.674	1618.077
C=O	1674	1675.845
C=C	1547	1520
C-O-C	1098	1310.077
N-H	1590	1580
O-H	3431.645	3393.794



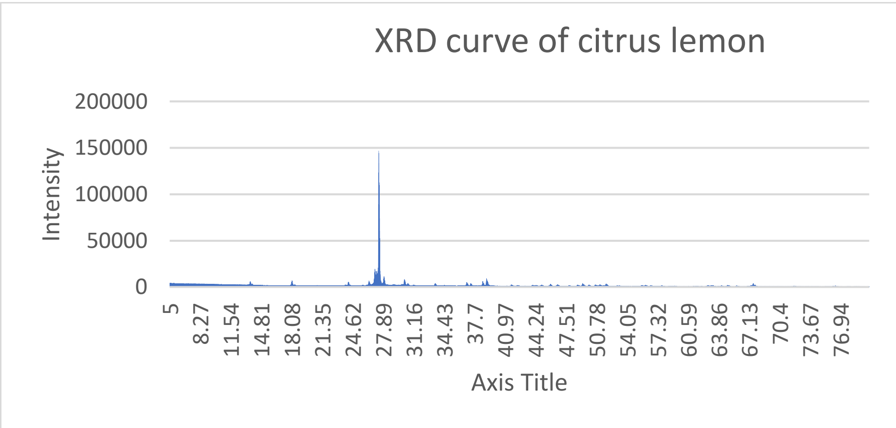
Pisum sativum FTIR curve

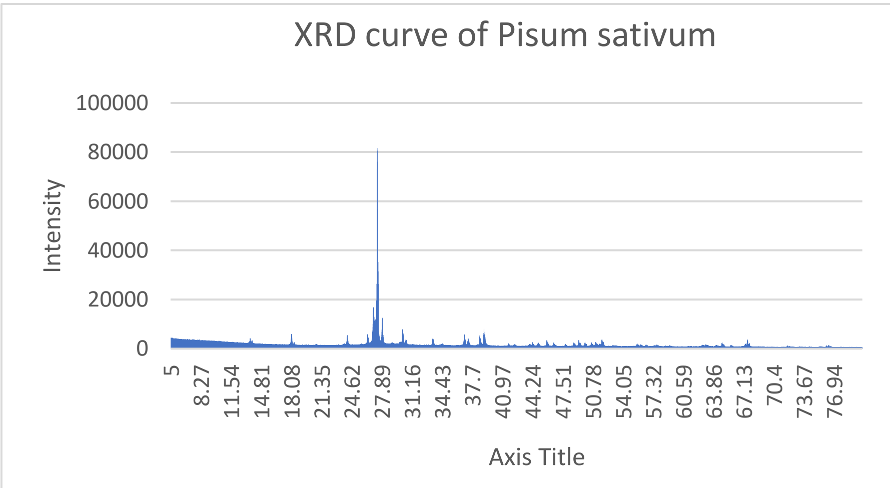


Citrus Lemon FTIR curve

Crystalline XRD

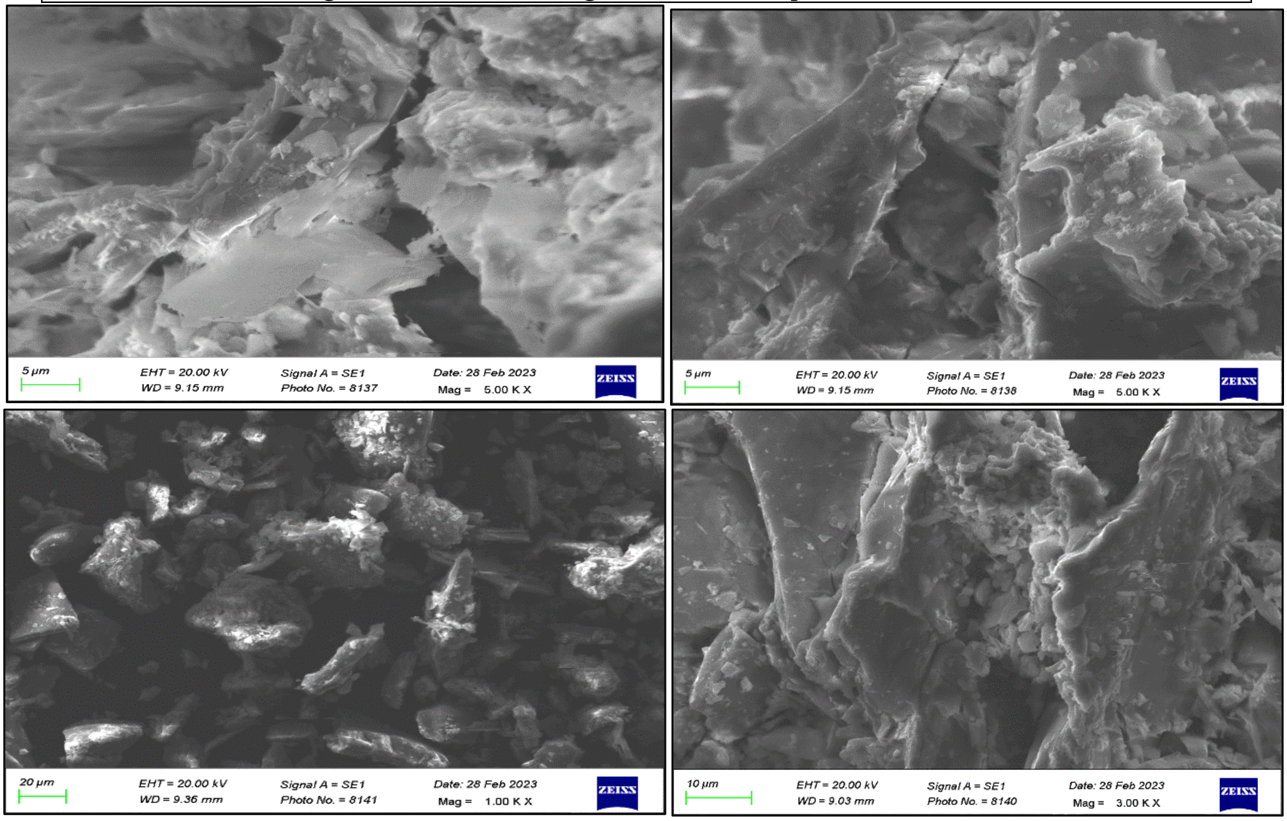
The standard deviation of the chromium nanoparticles' crystalline size was calculated using X-ray powder diffraction



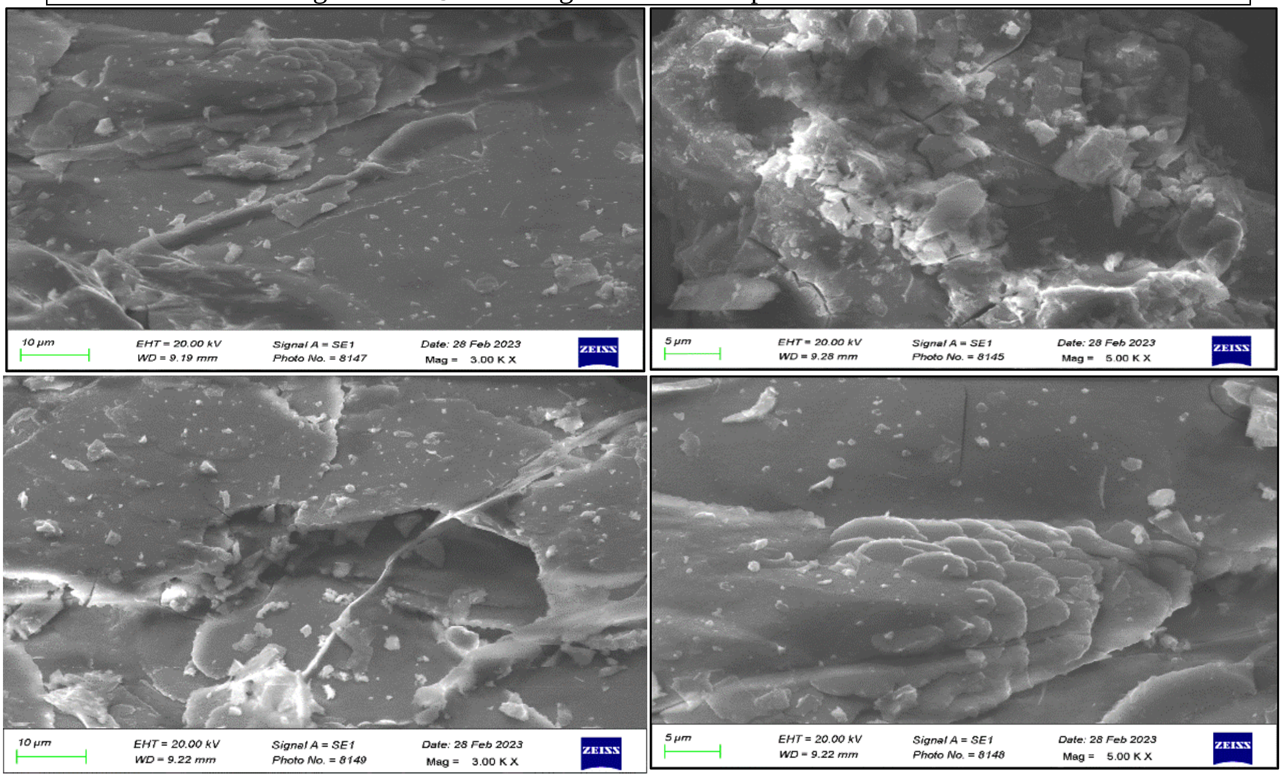


SEM- Sem Using morphological examination with a scanning electron microscope operating at an applied potential of 3 Kv, the morphologies of the nanomaterials was reported. The samples were gold-sputtered prior to observation to reduce the influence of charging.

SEM image of CR_2O_3 NPS using Pisum Sativum peels extract



SEM image of Cr_2O_3 NPs using Citrus Lemon peels Extract



Result and Discussion

The creation of Chromium oxide nanoparticles was confirmed by scanning electron microscopy, X-ray diffraction found a two major peaks at an angle 27.38 and 27.94 while other NPs have also two major peaks at an angle 26.99 and 26.36, Fourier transform-infrared spectroscopy (FTIR) showed the various peaks at O-H (3431.645cm^{-1}) C-H(2734.824 cm^{-1}) , C=O(1620.674 cm^{-1}), N-H(1590 cm^{-1}) , C=C (1547 cm^{-1}), and C-O-C (1098

cm^{-1}), Cr-O-Cr at (1383.010 cm^{-1}) and , Cr=O at (1620.674 cm^{-1}) so all the peaks were in accordance with the other literature , so the formation of Cr_2O_3 NPs was confirmed UV-Vis spectroscopy shows the maximum absorption at229nm 456nm , and XRD study showed that the highest peak was absorbed at an angle at 27.38 and 27.94 while in another graph the highest peak was observed at 26.99, and 26.36. And the average crystalline size was determined by Scherrer equation Chromium oxide nanoparticle synthesis was confirmed (SEM) they were found to be agglomerated and irregular in shape, the average particles size of prepared Cr_2O_3 NPs were calculated with the help of J Software and found to be 43 nm and 29 nm respectively. Such prepared nano particles are appropriate for using as antimicrobial properties. Particle size variation may be due to presence of various reducing agents present in two pant extracts taken for green synthesis. Kumar, D et al.2021, and Ajay Singh2020 also used SEM, FTIR to characterise the materials.

Photocatalytic Degradation

Pisum Sativum Cr_2O_3 NPs was found more useful for the degradation of rhodamine blue in visible light as comparison to Cr_2O_3 NPs prepared by using Citrus Lemon peels extract where as Cr_2O_3NPs prepared by using Citrus Lemon peels extract were found more effective in short UV and long UV region

Antibacterial activity

Citrus Lemon Cr_2O_3NPs was more effective for the inhibition of bacterial growth as comparison to Pisum sativum Cr_2O_3 NPs as their particle size were also comparatively smaller.

Conclusion-

From the study , it can be concluded that chromium oxide nanoparticles can by synthesised by using green technological methods mediated through *Pisum Sativum* and *Citrus lemon* peels extract. Such synthesized nano particles have particle size in the range of 30 to 40 nm , which have significant photocatalytic activity and antibacterial activity.

References

1. Ajay Singh & Mansi Gupta , Phytochemical Investigation of Different Solvent Extracts of Berberis lycium Fruits, Rasayan Journal of Chemistry,vol.11(1),2018,228-231. http://dx.doi.org/10.7324/RJC.2018.1111999.
2. Ajay Singh and Mahima Chaudhary, An Overview of Physical Properties of Fruit Wastes Mediated Green Synthesized Transition Metal Oxide Nanoparticles and Its Applications, Asian Journal of Chemistry, Vol.35, (1), 2023.
3. Alarjani, K. M., Huessien, D., Rasheed, R. A., & Kalaiyarasi, M. (2022). Green synthesis of silver nanoparticles by Pisum sativum L. (pea) pod against multidrug resistant foodborne pathogens. Journal of King Saud University - Science, 34(3). https://doi.org/10.1016/j.jksus.2022.101897
4. Basahi, M. (2021). Seed germination with titanium dioxide nanoparticles enhances water supply, reserve mobilization, oxidative stress and antioxidant enzyme activities in pea. Saudi Journal of Biological Sciences, 28(11), 6500–6507. https://doi.org/10.1016/j.sjbs.2021.07.023
5. Biswas, A., Bayer, I. S., Biris, A. S., Wang, T., Dervishi, E., & Faupel, F. (2012). Advances in top-down and bottom-up surface nanofabrication: Techniques, applications & future prospects. In Advances in Colloid and Interface Science (Vol. 170, Issues 1–2, pp. 2–27). https://doi.org/10.1016/j.cis.2011.11.001
6. Ghotekar, S., Pansambal, S., Bilal, M., Pingale, S. S., & Oza, R. (2021). Environmentally friendly synthesis of Cr2O3 nanoparticles: Characterization, applications and future perspective ─ a review. Case Studies in Chemical and Environmental Engineering, 3. https://doi.org/10.1016/j.cscee.2021.100089
7. Ajay Singh and Asima Imtiyajm Asian J. Chem. /2023, 35(5) , pp 1049-1062, https://doi.org/10.14233/ajchem.2023.27735.
8. Gupta, R. K., Mitchell, E., Candler, J., Kahol, P. K., Ghosh, K., & Dong, L. (2014). Facile synthesis and characterization of nanostructured chromium oxide. Powder Technology, 254, 78–81. https://doi.org/10.1016/j.powtec.2014.01.014
9. Ibarra-Galván, V., López-Valdivieso, A., Villavelazquez-Mendoza, C. I., Santoyo-Salazar, J., & Song, S. (2014). Synthesis of eskolaite (α-Cr2O3) nanostructures by thermal processing of Cr2O3-loaded activated carbon. Particulate Science and Technology, 32(5), 451–455. https://doi.org/10.1080/02726351.2013.878774
10. Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. Green Chemistry, 13(10), 2638–2650. https://doi.org/10.1039/c1gc15386b.
11. Jaiswal K.K., Kumar V., Vlaskin M.S., Sharma N., Rautela I., Nanda M., Arora N., Singh A., Chauhan P.K. Microalgae fuel cell for

wastewater treatment: Recent advances and challenges, Journal of Water Process Engineering, Vol.38, 2020, 10.1016/j.jwpe. 2020.101549.

12. Jaswal, V. S., Arora, A. K., Kinger, M., Gupta, V. D., & Singh, J. (2014). Synthesis and characterization of chromium oxide nanoparticles. Oriental Journal of Chemistry, 30(2), 559–566. https://doi.org/10.13005/ojc/300220
13. Jeetu Dubey & Ajay Singh, Green Synthesis of TiO_2 Nanoparticles Using Extracts of Pomegranate Peels for Pharmaceutical Application ,Int.J .Pharmaceutical and Phytopharmacological Research, Vol.9,1.2019 ,85-87.
14. Kumar, D., Chhibber, V.K. & Singh, A. Adding ZnO Nanoparticle in Mahua Oil Methyl Ester (MoME) Biodiesel for Eco-Friendly and Better Performance in DI Engine. Natl. Acad. Sci. Lett. (2021). https://doi.org/10.1007/s40009-021-01090-7.
15. Khan, I., Saeed, K., & Khan, I. (2019). Nanoparticles: Properties, applications and toxicities. In Arabian Journal of Chemistry (Vol. 12, Issue 7, pp. 908–931). Elsevier B.V. https://doi.org/10.1016/j.arabjc.2017.05.011
16. Krakowiak, R., Frankowski, R., Mylkie, K., Kotkowiak, M., Mlynarczyk, D. T., Dudkowiak, A., Stanisz, B. J., Zgo1a-Grzeskowiak, A., Ziegler-Borowska, M., & Goslinski, T. (2022). Titanium (IV) oxide nanoparticles functionalized with various meso-porphyrins for efficient photocatalytic degradation of ibuprofen in UV and visible light. Journal of Environmental Chemical Engineering, 10(5). https://doi.org/10.1016/j.jece.2022.108432
17. Kumar, D., Chhibber, V.K. & Singh, A. Adding ZnO Nanoparticle in Mahua Oil Methyl Ester (MoME) Biodiesel for Eco-Friendly and Better Performance in DI Engine. Natl. Acad. Sci. Lett. (2021). https://doi.org/10.1007/s40009-021-01090-7
18. Liu, D., Zhou, W., & Wu, J. (2016). CuO-CeO2/ZSM-5 composites for reactive adsorption of hydrogen sulphide at high temperature. Canadian Journal of Chemical Engineering, 94(12), 2276–2281. https://doi.org/10.1002/cjce.22613
19. Montiel, H., Alvarez, G., Conde-Gallardo, A., & Zamorano, R. (2015). Microwave absorption behavior in Cr2O3 nanopowders. Journal of Alloys and Compounds, 628, 272–276. https://doi.org/10.1016/j.jallcom.2014.11.198
20. Nikky Kaur, Ajay Singh, Waseem Ahmad, Microwave Assisted Green Synthesis of Silver Nanoparticles and Its Application: A review, Journal of Inorganic and Organometallic Polymers and Materials, August 2022, https://doi.org/10.1007/s10904-022-02470-2.
21. Rayani Nivethitha, P., & Carolin Jeniba Rachel, D. (2019). A study of antioxidant and antibacterial activity using honey mediated Chromium oxide nanoparticles and its characterization. Materials Today: Proceedings, 48, 276–281. https://doi.org/10.1016/j.matpr.2020.07.187
22. Samadi, Z., Yaghmaeian, K., Mortazavi-Derazkola, S., Khosravi, R., Nabizadeh, R., & Alimohammadi, M. (2021). Facile green synthesis of zero-valent iron nanoparticles using barberry leaf extract (GnZVI@BLE) for photocatalytic reduction of hexavalent chromium. Bioorganic Chemistry, 114. https://doi.org/10.1016/j.bioorg.2021.105051
23. Santhoshkumar, T., Rahuman, A. A., Jayaseelan, C., Rajakumar, G., Marimuthu, S., Kirthi, A. V., Velayutham, K., Thomas, J., Venkatesan, J., & Kim, S. K. (2014). Green synthesis of titanium dioxide nanoparticles using Psidium guajava extract and its antibacterial and antioxidant properties. Asian Pacific Journal of Tropical Medicine, 7(12), 968–976. https://doi.org/10.1016/S1995-7645 (14)60171-1
24. Singh Jassal, P., Kaur, D., Prasad, R., & Singh, J. (2022). Green synthesis of titanium dioxide nanoparticles: Development and applications. Journal of Agriculture and Food Research, 10. https://doi.org/10.1016/j.jafr.2022.100361
25. Teixeira, V., Sousa, E., Costa, M. F., Nunes, C., Rosa, L., Carvalho, M. J., Collares-Pereira, M., Roman, E., & Gago, J. (2001). Spectrally selective composite coatings of CrCr O and 2 3 MoAl O for solar energy applications 2 3. In Thin Solid Films (Vol. 392).
26. Thakur, B. K., Kumar, A., & Kumar, D. (2019). Green synthesis of titanium dioxide nanoparticles using Azadirachta indica leaf extract and evaluation of their antibacterial activity. South African Journal of Botany, 124, 223–227. https://doi.org/10.1016/j.sajb.2019.05.024
27. Thara, K., Karthika, I. N., Ramesh, C., & Dheenadayalan, M. S. (2021). Chromium oxide regulated nanoparticles biosynthesis in Manihot esculenta leaf extract. Materials Today: Proceedings, 49, 1448–1452. https://doi.org/10.1016/j.matpr.2021.07.224.
28. Ahmad, Waseem & Singh, Ajay & Jaiswal, Krishna & Gupta, Prasansha. (2021). Green Synthesis of Photocatalytic TiO2 Nanoparticles for Potential Application in Photochemical

Degradation of Ornidazole. Journal of Inorganic and Organometallic Polymers and Materials. 31. 10.1007/s10904-020-01703-6.

29. Wei, G., Qu, J., Yu, Z., Li, Y., Guo, Q., & Qi, T. (2015). Mineralizer effects on the synthesis of amorphous chromium hydroxide and chromium oxide green pigment using hydrothermal reduction method. Dyes and Pigments, 113, 487–495. https://doi.org/10.1016/j.dyepig.2014.09.021