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Potential of Rice Straw as Biotemplate of TiO_2 Nanoparticle Synthesis

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ABSTRACT

Rice straw, a biomass feedstock that is produced at a large rate throughout the world, could be used in an inventive way to create a product with additional value. The goal of this work was to synthesize and characterize TiO_2 nanoparticles making use of this technique. The process involved a reaction between titanium isopropoxide and acetic acid combination with rice straw powder and resultant product was titanium dioxide nanoparticle. The resulting nanoparticles were confirmed by X-Ray diffraction, Scanning Electron Microscopy, UV-VIS spectroscopy, Fourier Transform Infraredand Energy Dispersive X-Ray analysis. Titanium dioxide nanoparticles 24 nm were attained. The results obtained in the characterization techniques showed that the use of rice straw as biotemplate was an environment friendly, cost-effective method for obtaining nanosized titanium dioxide (TiO_2) nanoparticles.

Key words: Rice straw, valorization, bio template, biomass, nanoparticles

INTRODUCTION

Nanotechnology is an emerging field with applications for medicine, computing and manufacturing in a range of fields, from energy and materials to space exploration and robotics (Aithal and Aithal, 2016). An imperative area of nanotechnology research deals with synthesis of numerous nanoparticles. As a result of their physico-chemical properties, which enable their use in a wide variety of applications, nanomaterials are component of the commercial revolution that has led to an explosion of hundreds of new goods (Dobrucka, 2018). Researchers have been looking into the possibility of creating nanomaterials in an aqueous medium with the aid of stabilizing or capping agents in order to avoid the use of hazardous organic solvents and difficult reaction conditions for the manufacture of nanoparticles (Duan *et al.*, 2015).

Recently, titanium dioxide (TiO_2) has established a lot of interest as a green and eco-friendly photocatalyst because of its high adsorption capacity, photoactivity, optical properties, photostability, dye sensitized solar cells, high chemical stability, water splitting devices and nontoxicity (Sun *et al.* 2015; Wei *et al.,* 2016). Titanium dioxide nanoparticles are one of the utmost superior materials for cosmetics, skin care products, pharmaceuticals and whiteness opacity to products like papers, plastics, paints, inks, toothpastes and food colorants (Abisharani *et al.*, 2019).

There are several approaches for synthesis of titanium dioxide nanoparticles like microemulsion, hydrothermal crystallization, chemical precipitation, chemical vapor deposition, and sol-gel (Ghani and Nor, 2022). The use of plant extracts and agricultural waste in biosynthetic processes has recently increased interest and established more consideration than physio-chemical methods (Sorbium *et al.*, 2018). Waste valorization of rice straw has shown outstanding contribution in nanoparticle synthesis in recent times. A wide range of cutting-edge methods are existing to turn the agricultural wastes into new, useful nanomaterials (Omo-Okoro *et al.*, 2018). Following the harvest of the rice grain, the fields are left with two waste materials–rice husk and straw, with a rice straw to paddy ratio 1.0 to 4.3. In spite of rice husk utilization knowledge is worldwide, the rice straw is occasionally employed well-established as a

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source of renewable energy (D'Hondt *et al.*, 2015). Therefore, most rice straw remains unutilized and that is why new research of its utilization as bio template in nanoparticle synthesis. As it is a soft, affordable, and environmentally friendly template, therefore, the rice straw powder affects the characteristics of synthetic TiO_2 nanoparticles was prepared and investigated in the laboratory.

MATERIALS AND METHODS

Rice straw (RS) was collected as a raw material from local farms of Hisar district. The analytical grade chemicals Titanium (IV) isopropoxide and acetic acid were used for the synthesis of titanium dioxide nanoparticle. Deionized water was used to create all of the aqueous solutions.

TiO_2 nanoparticles were prepared by sol-gel method using rice straw powder as biotemplate (Anirudh *et al.*, 2018). Rice straw was properly cleansed with tap water to get rid of any dirt or dust that had adhered to it until the water was clear. It was then rinsed with distilled water to bring to the neutral pH. The cleaned rice straw was dried for two days in the sun and for an additional 6 h in an oven at 80°C. The dry rice straw was grounded. The titanium (IV) isopropoxide was attenuated in distilled water and acetic acid at 1 : 200 : 10 molar ratio, respectively. To protect titanium isopropoxide from the water's nucleophilic invasion, acetic acid functioned as a chelating agent. The mixture was agitated for few hours. Rice straw powder in various concentrations (0.25, 0.5, 1, 2 and 4 g) was added and the mixture was again stirred. At 80°C the aforementioned solution was heated until the gel formed. The resulting gel was dried in an oven overnight at 80°C. The dry gel was then crushed and calcined for 5 h at 500°C in a muffle furnace.

X-ray diffraction analysis (XRD) was carried out using a Japanese Rigaku Miniflex-II Diffractometer with CuKα radiation. Titanium dioxide particles morphology was characterized by scanning electron microscopy JSM-7610F Plus, JEOL Japan. The Energy dispersive X-ray analysis (EDX) was used to determine the elemental composition. Under normal circumstances, Fourier transform infrared spectra recorded a Spectrum using Two Perkin Elmer in the 400-4000/cm range. The optical characteristics were assessed using the UV-VIS-NIR spectrophotometer UV-1800 Shimadzu, Japan.

RESULTS AND DISCUSSION

The functional groups of titanium dioxide nanoparticles were identified via FTIR analysis in the ranges 400-4000 wave number/cm (Fig.1). The peaks at 3430 and 1633/cm in the FTIR spectrum of titanium dioxide nanoparticles were caused by surface-adsorbed water and the -OH group, respectively (Kang *et al.*, 2016). The primary absorption bands in the range of 400-950/cm were visible in the IR spectra of all samples, as indicated in Fig. 1 (Buraso *et al.*, 2018). The formation of bands below 800/cm corresponded to the inorganic Ti–O–Ti network of the intrinsic lattice vibrations (Catauro *et al.*, 2015). The peak at 482/cm confirmed the anatase phase of titanium dioxide nanoparticles (Amanulla and Sundaram, 2019).

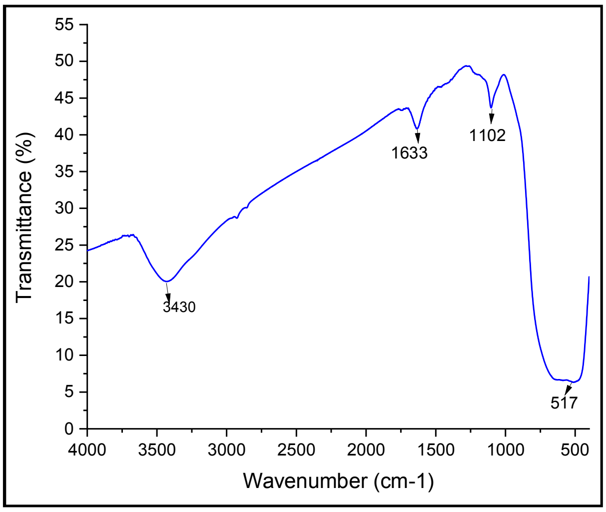

Fig. 1. FT-IR spectra of TiO2 nanoparticles prepared using rice straw biotemplate.

Diffraction pattern was presented in the 2° as shown in Fig. 2. The powdered sample was used by X-Ray diffractometer for confirming the presence of TiO_2 nanoparticle (Kang *et al.*, 2016). Broad diffraction hump was observed at 2° at 25.42^0, 27.6^0, 37.96^0, 48.2^0, 54.1^0, 55.28^0, 67.78^0 and 69.12^0 indicating the formation of anatase phase of TiO_2. The 2° peak at 25.4° verified the anatase structure of TiO_2 (Balamurugan *et al.*, 2022). TiO_2 is in the anatase phase as shown by strong diffraction peaks at 25° and 48°. On the other hand, TiO_2

in the rutile phase is shown by the diffraction peaks at 27°, 36°, 55° and 63°, respectively (Ali *et al.*, 2015; Gautam *et al.*, 2016). As can be seen, the anatase phase is the dominant phase observed in Fig. 2. Peaks at 25.42° and 48.2° and the peaks at 27.6⁰, 37.96⁰, 54.1⁰, 55.28⁰, 67.78⁰ and 69.12⁰ confirmed anatase and rutile phase, respectively. The obtained results closely matched with those of Goutam *et al.* (2018). Broad diffraction peaks indicated very small size crystallites, and the sample's strength of XRD peaks showed that the produced nanoparticles were crystalline. The graph's peaks matched the literature report's findings quite well. The peaks' locations were matched to values from the literature, and the existence of TiO_2 nanoparticles was verified. The scanning electronic microscopy was used to examine the grain size, shape and surface

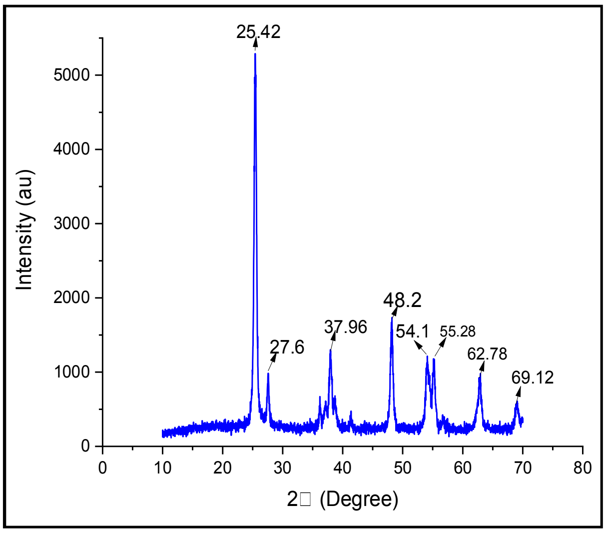

Fig. 2. XRD of TiO_2 nanoparticles prepared using rice straw biotemplate.

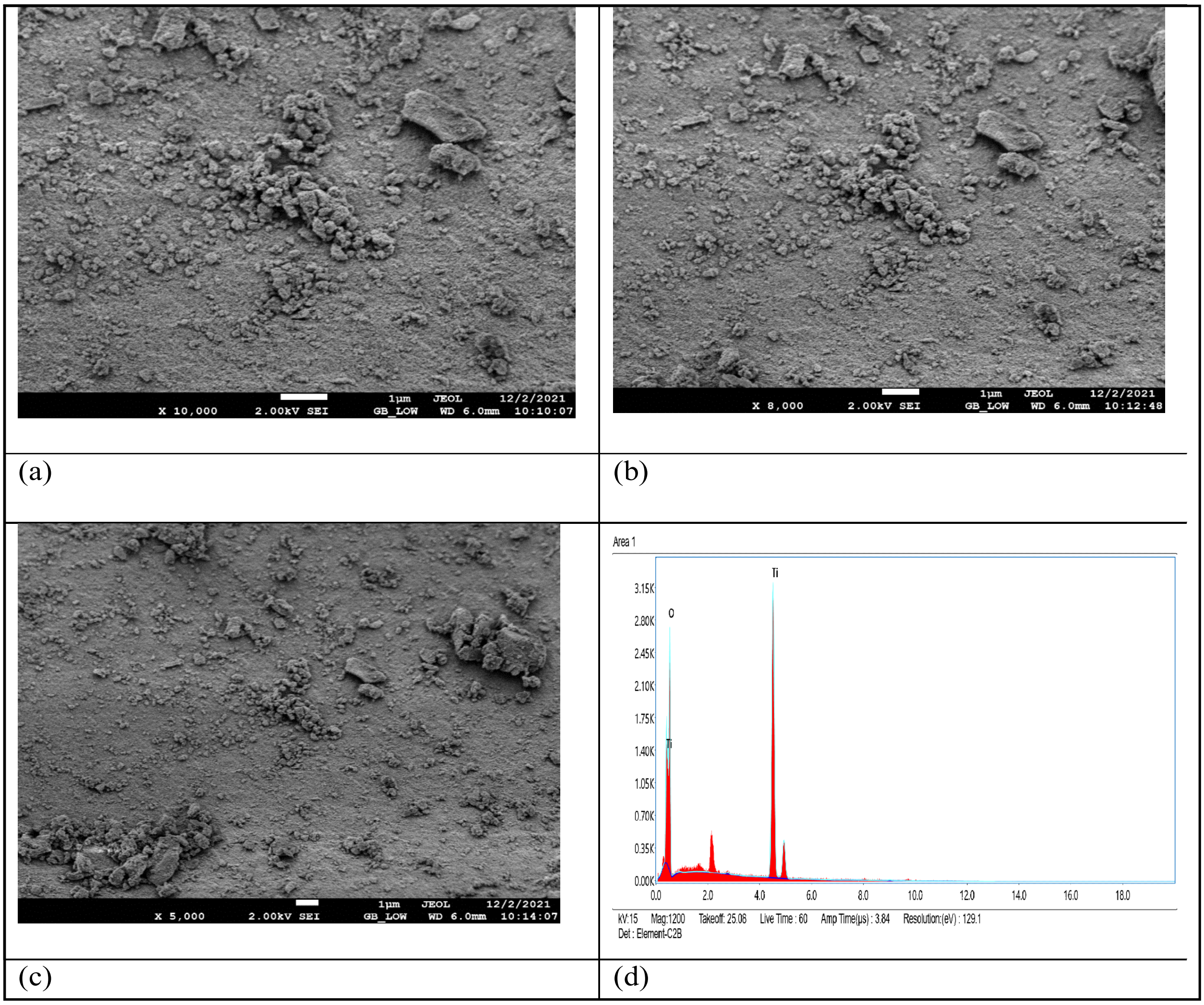

Fig. 3. SEM images taken with 1 μm (a) 10000, (b) 80000, (c) 5,000 index and (d) EDX of TiO_2 nanoparticles prepared using rice straw as biotemplate.

characteristics such as morphology of TiO_2 nanoparticles (Fig. 3a, b and c). The image was detected with in 1 µm magnification range. Irregular particle's structure was shown by the TiO_2 nanoparticles (Rao *et al.*, 2015). The SEM images showed that TiO_2 nanoparticles with diameters 24 nm had been successfully synthesized. The SEM images made it abundantly clear that several small, discrete TiO_2 nanoparticles were found together with fewer, rather large-sized agglomerated nanoparticles (Muniandy *et al.*, 2017). The low pH value of the TiO_2 NPs solution may have contributed to their agglomeration (Goutam *et al.*, 2018).

The Energy Dispersive X-ray Spectrometer (EDX) was used to determine the elemental composition of the produced TiO_2 nanoparticles (Khade *et al.*, 2015). Fig. 3d reveals the EDX spectrum of the sample's purity by demonstrating the presence of both titanium (Ti) and oxygen (O) in the sample. This confirmed the synthesis of TiO_2 nanoparticles. Analysis of the sample's absorption spectra was also done in order to examine the optical characteristics and to verify the green production of the TiO_2 nanoparticles. The TiO_2 nanoparticles' absorption spectra showed a significant absorption peak at 335 in the absorption range of 200-800 nm, providing evidence that the metallic TiO_2 nanoparticles were manufactured (Fig. 4). Setthaya *et al.* (2017) observed similar results at 335.2 nm for titanium dioxide nanoparticles green synthesis. The optical band gap and absorption edge have the following relationships:

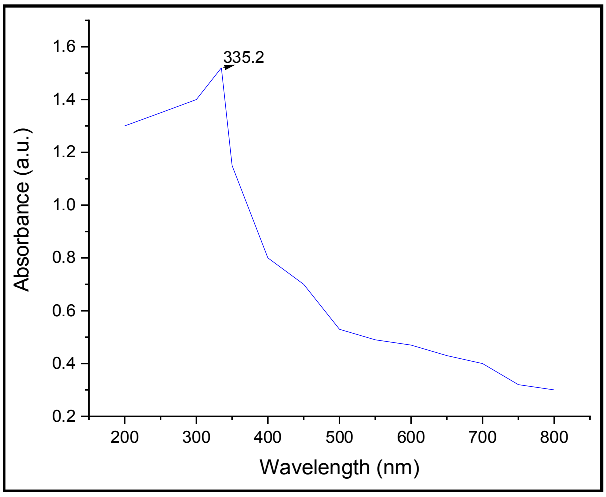

Fig. 4. UV-Visible Spectrum of TiO_2 nanoparticles prepared using rice straw biotemplate.

$$Eg = 1293/\lambda,$$

Where, Eg = band gap and λ = absorption.

The band gap for TiO_2 was 3.86 eV.

CONCLUSION

The use of rice straw as a biotemplate resulted in highly crystalline anatase TiO_2 nanoparticles with unaltered physical dimensions and little agglomeration. It was confirmed by utilizing the traditional sol-gel process. XRD analysis confirmed the anatase and rutile phase of titanium dioxide with valorized rice straw powder as biotemplate was highly effective in preparation of TiO_2 nanoparticles. The tetragonal irregular particles structure of titanium dioxide nanoparticles using rice straw as biotemplate during the synthesis were observed in SEM image, with a diameter of 24 nm. These findings demonstrated that the TiO_2 nanoparticles synthesized were in the nano range. All these characteristics demonstrated that the TiO_2 nanoparticles were effectively and efficiently created using valorized rice straw powder as biotemplate which created a new route to use rice straw waste material in environment-friendly sustainable manner with sophisticated end products by employing green chemical technology.

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