SINTESIS DAN KARAKTERISASI V-DOPED TiO_2 UNTUK APLIKASI PRETREATMENT FOTOKATALITIK LIGNOSELULOSA LIMBAH KULIT PISANG DALAM PRODUKSI BIOETANOL

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PADANG

2026

ABSTRACT

Synthesis and Characterization of V-Doped TiO_2 for the Photocatalytic Pretreatment of Banana Peel Waste Lignocellulose in Bioethanol Production

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The global energy crisis and increasing dependence on fossil fuels have accelerated the development of sustainable renewable energy, particularly second-generation bioethanol derived from lignocellulosic biomass. Banana peel waste is a promising feedstock for bioethanol production due to its relatively high cellulose and hemicellulose contents. However, the presence of lignin hinders biomass degradation, necessitating an efficient pretreatment process. This study aimed to synthesize, characterize, and evaluate the photocatalytic performance of V-doped TiO_2 for the pretreatment of lignocellulosic banana peel waste to enhance bioethanol production. The photocatalysts were synthesized using a combined sol-gel and solvothermal method with vanadium doping concentrations of 5 wt% (VTO-5), 10 wt% (VTO-10), and 15 wt% (VTO-15), while undoped TiO_2 (TO) was used as the control. X-ray diffraction (XRD) and Raman spectroscopy confirmed that all samples possessed the anatase phase, whereas Fourier-transform infrared (FTIR) spectroscopy revealed structural modifications induced by vanadium incorporation. Scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDX) demonstrated a reduction in particle size from 375 nm for TO to 190 nm for VTO-5 and verified the successful incorporation of vanadium into the TiO_2 structure. Brunauer–Emmett–Teller (BET) analysis showed increased specific surface area and pore volume following vanadium doping. These structural improvements enhanced the optical properties of the photocatalysts, as evidenced by photoluminescence (PL) and UV–Vis diffuse reflectance spectroscopy (UV–Vis DRS), which revealed suppressed PL intensity, indicating more efficient charge carrier separation, and a narrowed band gap from 3.20 eV for TO to 2.28 eV for VTO-5 and 2.40 eV for VTO-10, while increasing to 3.17 eV for VTO-15, thereby improving visible-light absorption. The enhanced material properties resulted in superior photocatalytic performance, with VTO-5 producing the highest fermentable sugar concentration of 33.18 mg/mL compared with 25.95 mg/mL for the sample without a photocatalyst. Gas chromatography–mass spectrometry (GC–MS) analysis further demonstrated that VTO-5 achieved the highest ethanol peak area percentage of 79.50%. Overall, the results indicate that 5 wt% vanadium doping (VTO-5) represents the optimum composition for improving the physicochemical properties and photocatalytic performance of TiO_2, thereby enhancing sustainable bioethanol production from banana peel waste.

Keywords: Banana peel waste, photocatalytic pretreatment, V-doped TiO_2, bioethanol