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Research Article

Synthesis of Carbon-Nanomaterial from Rice Husk and Its Application as Adsorbent in Pesticide Residues Analysis

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ABSTRACT

This study explores how rice husk, an abundant agricultural by-product, can be transformed into high-performance carbon nanomaterials with exceptional adsorption properties. The findings emphasize the potential of using sustainable and cost-effective resources to develop innovative materials for environmental and analytical applications. The synthesized carbon nano-structure was characterized using XRD, SEM, EDX, and FTIR. Notably, FTIR analysis revealed peaks at 1580.4 cm^{-1}, 1597.79 cm^{-1}, and 1456.38 cm^{-1}, indicating C=C stretching and suggesting alkene or aromatic functional groups. EDX analysis showed varying weight percentages of carbon, oxygen, and sulfur for 30 g, 40 g, and 50 g samples. The rice husk-derived carbon nanomaterials were evaluated in the QuEChERS technique for extracting dichlorvos and bifenthrin from bean samples. The results showed that the sorbent properties were comparable to those of conventional PSA and C18, with high recovery rates for the investigated pesticides. This demonstrates efficient binding and removal of contaminants. The findings highlight the potential of using sustainable, cost-effective resources to develop innovative materials for environmental and analytical applications. Overall, this eco-friendly approach combines minimal environmental impact with high analytical performance, offering a promising alternative to traditional sorbents in sample preparation.

Keywords: Carbon-nanomaterial, rice husk waste, pesticides residues, QuEChERS, XRD, SEM, EDX, FTIR.

1. INTRODUCTION

Nanomaterials have emerged as a rapidly growing technology with vast applications in cosmetics, energy storage, catalysis, disease treatment, and pollutant remediation.[1] Their role in "green technology" is expanding, enhancing environmental sustainability.[2] Carbon nanomaterials, particularly nanotubes, graphene, and nanoporous structures, have garnered significant interest in basic research and practical applications. Among these, carbon nanomaterials are the most prominent carbon nanostructured material in nanotechnology[3]. Carbon nanomaterials can be described as rolled-up graphite sheets with at least one-dimension measuring in the nanometer range[4]. These materials exhibit a wide range of diameters, typically spanning from 4 to 30 nm and lengths reaching up to 100 nm.[4,5] In environmental waste management, carbon nanomaterials unique properties enable versatile applications for detecting, extracting, and adsorbing various contaminants, including pesticides, leveraging their high sorption surface area.[3] Their exceptional surface-area-to-volume ratio and facile derivatization, stemming from precise chemical, mechanical, and electronic properties, make them promising sorbent materials.[2,6] These attributes have been harnessed in analytical procedures, utilizing carbon nanomaterials as sorbents in solid-phase extraction. Notably, pesticide residues have received extensive attention due to their widespread agricultural application to combat pests and diseases. Pesticide residues refer to toxicologically significant organic compounds or mixtures present in farm products, resulting from pesticide use and impurities[7]. Research on synthesizing carbon nanomaterials from rice husk waste has gained significant attention due to its vast potential in nanotechnology and science.[8] This eco-friendly approach offers various environmental applications, including remediation of organic pollutants and removal of heavy metals from water.[9] Rice husk waste is an ideal precursor for carbon nano-material production, being simple, cost-effective, and environmentally friendly. The synthesized carbon nanomaterials can effectively extract pesticides through adsorption, enabling detection and elimination in crops and vegetables.[9] Characterization techniques, such as spectroscopy, energy-dispersive X-ray (EDX), scanning electron microscopy (SEM), X-ray diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR) confirmed the presence of carbon-nanomaterials and other nanomaterials.[10]

This study aims to synthesize carbon nanomaterials from rice husk, characterize using SEM, EDX, FTIR, and XRD, and evaluate their efficiency as sorbents in analyzing pesticide residues in beans

2. MATERIALS AND METHOD

2.1 Reagents and Chemicals

The pesticide standards were obtained from Sigma-Aldrich Co. and prepared as a stock solution at a concentration of 1000 μgmL^{-1} in acetonitrile. Working standard mixtures were subsequently prepared by diluting the stock solution with acetonitrile. Analytical reagents, including methanol, acetonitrile, and formic acid (all HPLC grade), and ultra-high pure water, were purchased from Merck (Darmstadt, Germany). Additional reagents and chemicals used were of analytical grade. Working standard solutions were prepared by diluting the stock solutions with deionized water, and hydrochloric acid and sodium hydroxide solutions were used for pH adjustments. The rice husk used in the study was sourced from a local paddy mill in Ilorin, Kwara State, Nigeria

2.2 Synthesis of Carbon Nanomaterials

Rice husks were thoroughly washed with distilled water for over an hour, until no impurities remained. The clean husks were then air-dried at room temperature for 24 hours. After drying, the husks were sieved and pulverized into a fine powder using mechanical methods. The rice husk powder was measured into 30 g, 40 g, and 50 g portions using a weighing balance. The amount of ferrocene required was determined by the quantity of rice husk powder. For each portion, ferrocene was added in the following ratios: 30 g rice husk with 10 g ferrocene, 40 g rice husk with 15 g ferrocene, and 50 g rice husk with 20 g ferrocene. Each mixture was combined with 100 mL of ethanol and 40g of KOH in a round-bottom flask. To facilitate dissolution, a small amount of distilled water was added to the KOH and ethanol mixture, which was then stirred for 30 minutes. The mixture was added to the rice husk powder and stirred continuously for another 30 minutes to achieve homogeneity. The mixtures were transferred to crucibles, covered with foil paper, and heated in a microwave oven at 400 °C for 2 hours. During stirring, the mixtures emitted a choking smell and turned orange, then brownish upon adding the rice husk powder. After heating, the samples were removed, cooled for 20 minutes, and subjected to characterization methods.[11]

2.3 Characterization Techniques

The materials were studied for identification of the crystalline substance using X-ray diffraction (Rigaku XRD Miniflex-600), surface morphology and micro- structures analysis was carried out using Scanning Electron Magnifier (PhenomWorld-SEM Pro-X), Energy-dispersive X-ray (ThermoScientific XTRA-EFX) was used to determine the elemental composition and Fourier Transform Infrared Spectroscopy (Agilent-ATR Calgary 620 FTIR) analysis was used to determine the functional groups, identification of the synthesized carbon nanomaterial and the histogram representation.

2.4 Application of Carbon-nanomaterial in Pesticide Residue Analysis

2.4.1 Sample Preparation

The bean samples were sourced from Malete market. Approximately 500 g of the collected samples were cut into small pieces and then pulverized using an electric grinder to ensure uniform sample homogeneity.

2.4.2 QuEChERS Technique

A 10 ± 0.01 g aliquot of the homogenized sample was weighed and transferred into a 50 ml polypropylene centrifuge tube. The sample was then spiked with a calculated amount of pesticide standard mixture and allowed to stand for 1 hour at room temperature. Next, 10 mL of 1 % acetic acid in acetonitrile was added, followed by 0.1 (mL) of triphenyl phosphate (internal standard). The mixture was subjected to manual agitation for 1 minute. Subsequently, 6 g of ($MgSO_4$) anhydrous magnesium sulphate and 1.5 g of sodium acetate were added. Following vigorous shaking for an additional 1 minute, the mixture was centrifuged at 5000 rpm for 5 minutes to facilitate separation. The supernatant was collected, and 6 ml was transferred into a centrifuge tube containing 150 mg of $MgSO_4$, 300 mg of primary secondary amine (PSA), and 150 mg of the prepared carbon nanomaterial (CNM).[12] The mixture was shaken vigorously for 30 seconds and centrifuged at 5000 rpm for 5 minutes. The final extract was transferred to an amber-colored glass vial. A 20 µL aliquot was injected into a (GC-MS) gas chromatography-mass spectrometry system for separation and quantification.[12]

2.4.3 GC-MS Analysis

Pesticide analysis was performed using a Shimadzu QP2010 Series GC-MS, equipped with a CTC CombiPAL autosampler. The GC operated in split/splitless mode, with an injection temperature of 260 °C. Separation occurred on a DB-5MS fused capillary column (30 m x 0.25 mm i.d., 0.25 µm film thickness), comprising 5% diphenyl and 95 % dimethylpolysiloxane. The injection port featured a high-pressure Merlin Microseal septumless injection kit and a silanized narrow bore liner. Helium (99.999% purity) served as the carrier gas, maintained at a flow rate of 1.3 mL/min and a linear velocity of 42 cm/s. The MS conditions included a transfer line temperature of 300 °C, an ion source temperature of 200 °C, and electron ionization (EI) of 70 eV. Method optimization was conducted in scan mode, while quantitation was performed in selected ion monitoring (SIM) mode. For each target analyte, a target ion (most abundant) and two reference ions were monitored to ensure accurate detection and quantification of pesticides.

2.3.4 Preparation of Calibration Curve

The analytical method was validated using an internal standard incorporated into a matrix-matched calibration standard. Calibration curves for each pesticide were generated by spiking matrix samples with eight concentrations (1-500 μgkg^{-1}) of working standard solutions containing internal standards. GC-MS analysis of the standard mixture provided retention times under the established chromatographic conditions. Calibration curves were constructed by plotting peak area ratios (analyte/internal standard) against concentration, using peak areas obtained from the GC-MS analysis. Triplicate analyses were performed at each concentration point in three different sample matrices. Method validation parameters, including precision, accuracy, selectivity, sensitivity, average recovery, relative standard deviation (RSD), and limit of detection (LOD), limit of quantitation (LOQ) were determined.[13]

2.3.5. Method Development and Validation of Analytical Methodology

The analytical method was validated using internal standards in matrix-matched calibration standards. Calibration curves for each pesticide were constructed by spiking matrix samples at five concentrations (0.25-1000 $\mu g\ kg^{-1}$) with working standard solutions. The peak area ratio, calculated as the ratio (analyte peak area/internal standard peak area) against the corresponding analyte concentration. Each concentration point was analyzed in triplicate across three sample matrices to ensure robust results. Subsequently, method validation parameters, including precision, accuracy, selectivity, sensitivity, average recovery, relative standard deviation (RSD), and limit of detection (LOD), limit of quantitation (LOQ) were determined.[13]

2.6 Data Analysis

The collected data underwent both qualitative and quantitative analysis. Microsoft Excel was utilized for data analysis, which included creating graphs and performing analysis of variance (ANOVA) to identify significant trends and patterns.

3. RESULTS AND DISCUSSIONS

3.1 SEM-EDX Analysis of Carbon Nanomaterial form Rice Husk

Scanning Electron Microscopy (SEM) micrographs (Figures 1-3a-c) revealed slightly irregular spherical Carbon Nanoparticle (CNP) particles with significant agglomeration and large pores. Particle size analysis, conducted using SEM images and Energy-Dispersive X-ray (EDX) spectroscopy (Figure 1d-3d), showed a size distribution ranging from 20 µm to 100 µm, with a mean particle size of 385 nm. The grain size varied with magnification: approximately 20 µm at 10,000x, 50 µm at 9,000x, and 100 µm at 8,000x. The reduction in grain size is attributed to the formation of more crystal nuclei with increased carbon content. This is consistent with the property of carbon nanomaterials containing small amounts of donor impurities, resulting in fine-grained structures.[11] SEM images of the 50 g sample (Figure 1a-d) exhibited carbon nanomaterial structures, characterized by rough, twisted, and randomly oriented web-like networks, coarse surfaces with cracks and crevices. Some particles displayed onion-like carbon nanostructures, with significant agglomeration. Although differences between samples were not distinct in SEM photographs, variations in catalyst nature and amount revealed subtle differences in SEM images.[14]

The surface morphology of the carbon nanomaterials derived from rice husk biomass revealed significant structural variations. The removal of volatiles during the microwave process created gaps and voids on the surface, likely due to decarboxylation and dehydration (Figure. 1a-c). In contrast, the 40 g sample exhibited a highly porous structure with hollow morphology (Figure. 2a-c). Clusters of irregularly shaped flakes of carbon nanoparticles were observed, with slightly irregular spherical shapes, pores, and significant agglomeration. The 30 g sample displayed trapezoidal and porous surfaces with irregular, rough, and coarse textures, featuring various cracks and crevices (Figure. 3a-d). These well-developed pores likely resulted from physical and chemical activation during the synthesis process. The pores can serve as sites for molecular adsorption and trapping, enhancing the material's remediation capabilities. Moreover, the pores facilitate uninterrupted flow of adsorbates. The degree of devolatilization played a crucial role in achieving materials with specific density, higher porosity, and unique pore structures.[11,14] These findings suggest that controlling the synthesis conditions can tailor the properties of rice husk-derived carbon nanomaterials for targeted applications. The structural variations in carbon nanomaterials synthesized via conventional and microwave methods are attributed to differences in heat transfer mechanisms. Energy-Dispersive X-ray (EDX) analysis provided quantitative and qualitative insights into the prepared carbon nanomaterials from rice husk (Figure 1d, 2d, and 3d). The EDX spectra confirmed the presence of carbon, oxygen, and sulfur in all samples, with varying weight percentages: 30 g (C: 43.20 % & C: 25.30 %, O: 15.20 %, S: 15.40 %), 40 g (C: 69.40 %, O: 20.40 %, S: 10.20 %), and 50 g (C: 65.60 %, O: 20.10 %, S: 14.30 %) (Figure 1-3d and Table 1). These results demonstrate the high purity of the carbon nanomaterials, with carbon being the dominant element.[14,15.] Two peaks of elemental carbon was observed in 30 g sample, this may be due to carbon based substrates during preparation.[15]

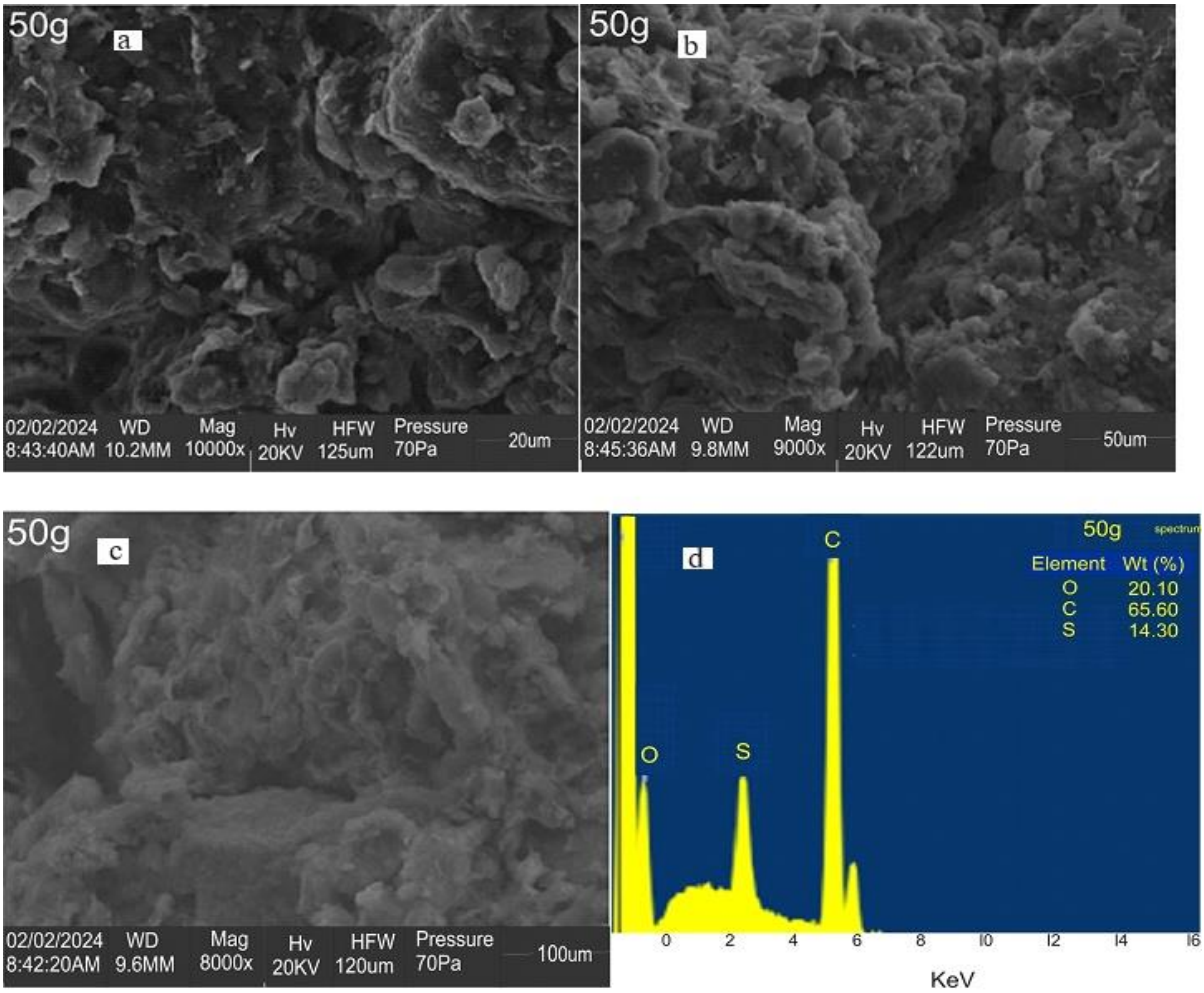

Figure 1. SEM Photograph of 50 g carbon nanoparticle with variation of glucose of a) 20 µm M, b) 50 µm, c) 100µm and d) EDX.

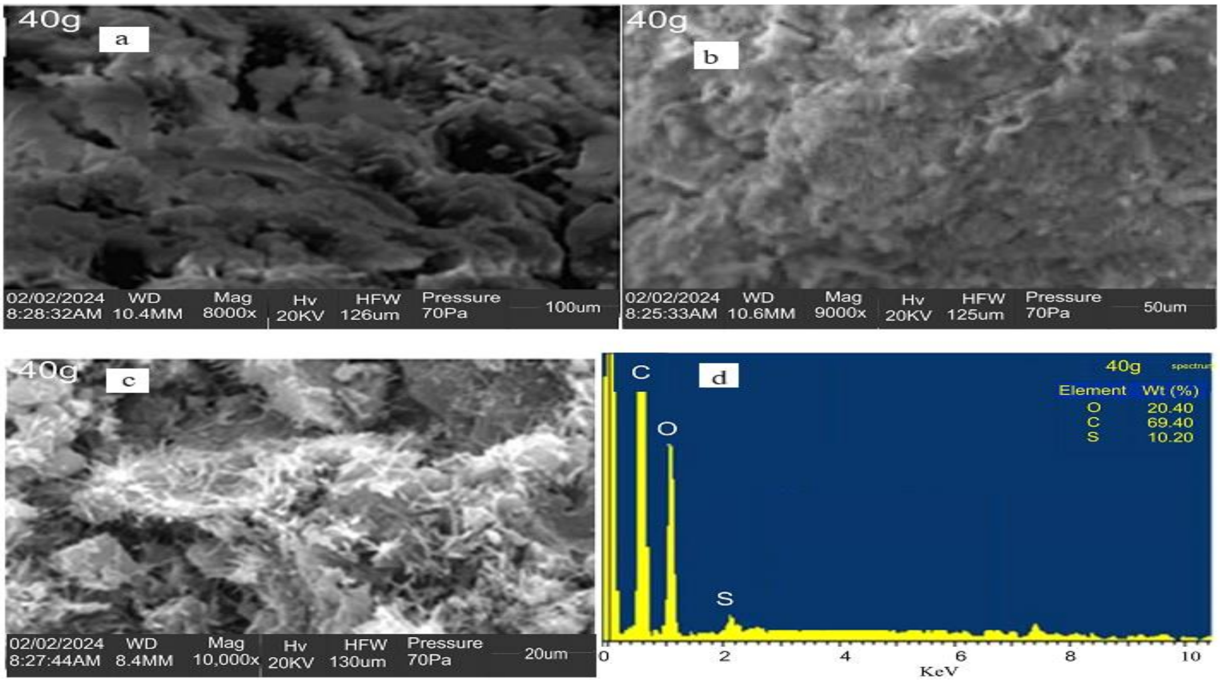

Figure 2. SEM Photograph of 40 g carbon nanoparticle with variation of glucose of a) 20 µm b) 50 µm, c) 100µm and d) EDX.

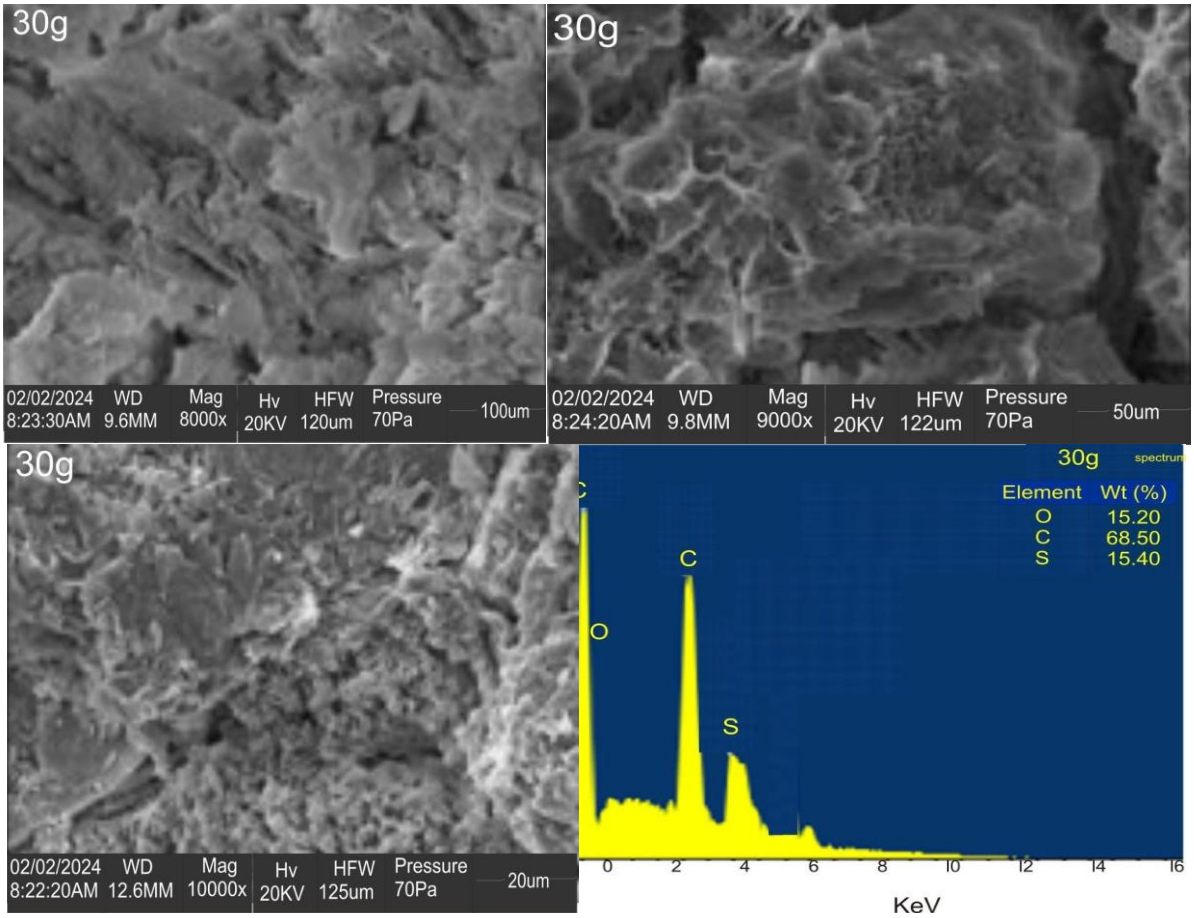

Figure 3. SEM Photograph of 30 g carbon nanoparticle with variation of glucose of a) 20 µm M, b) 50 µm, c) 100µm and d) EDX.

Table 1. Composition of carbon nanoparticle measured by SEM-EDX

Element	**Wt %**		
	30 g	**40 g**	**50 g**
C	43.20 25.30	69.40	65.60
O	15.20	20.40	20.10
S	15.40	10.20	14.30

The chemical composition of carbon powder was confirmed by EDX (Figure 3d), showing the presence of carbon, oxygen and sulphur atom at an atomic ratio of (6.7: 1.8: 1.3). The oxygen atom could be originated from the zinc oxide suspension used to place the specimen. The results have suggested high purity of carbon nanomaterial powder.[15,16]

3.2 XRD Pattern Analysis of Carbon Nanomaterial from Rice Husk (RH)

The X-ray diffraction (XRD) patterns obtained for the carbon nanomaterial samples are illustrated in Figures 4 - 6. For the 30 g sample, three distinct diffraction peaks at 2θ values of 29.5°, 48.5°, and 56° correspond to reflections from crystalline planes (111), (311), and (331), respectively, indicating a mix of crystalline and amorphous structures. In contrast, the 40 g sample exhibited broad diffraction peaks between 28° to 32°, and at 46.5° and 55°, attributed to reflections from crystalline planes (111), (220), (311), and (331), suggesting an amorphous nature with a large surface area. Further analysis (Figure 5) revealed peaks at 2θ values of 28.5° to 30.5° ((111) plane), 32.5° ((220) plane), 45° to 49.5° ((311) plane), and 54° to 58.5° ((331) plane), indicating the presence of carbon and hydroxyl groups with an interlayer spacing of approximately 0.75 nm. The XRD pattern of the 50 g sample (Figure 6) revealed an average crystallite size of 120 µm for the carbon nanomaterial, as calculated from the XRD data.[17]

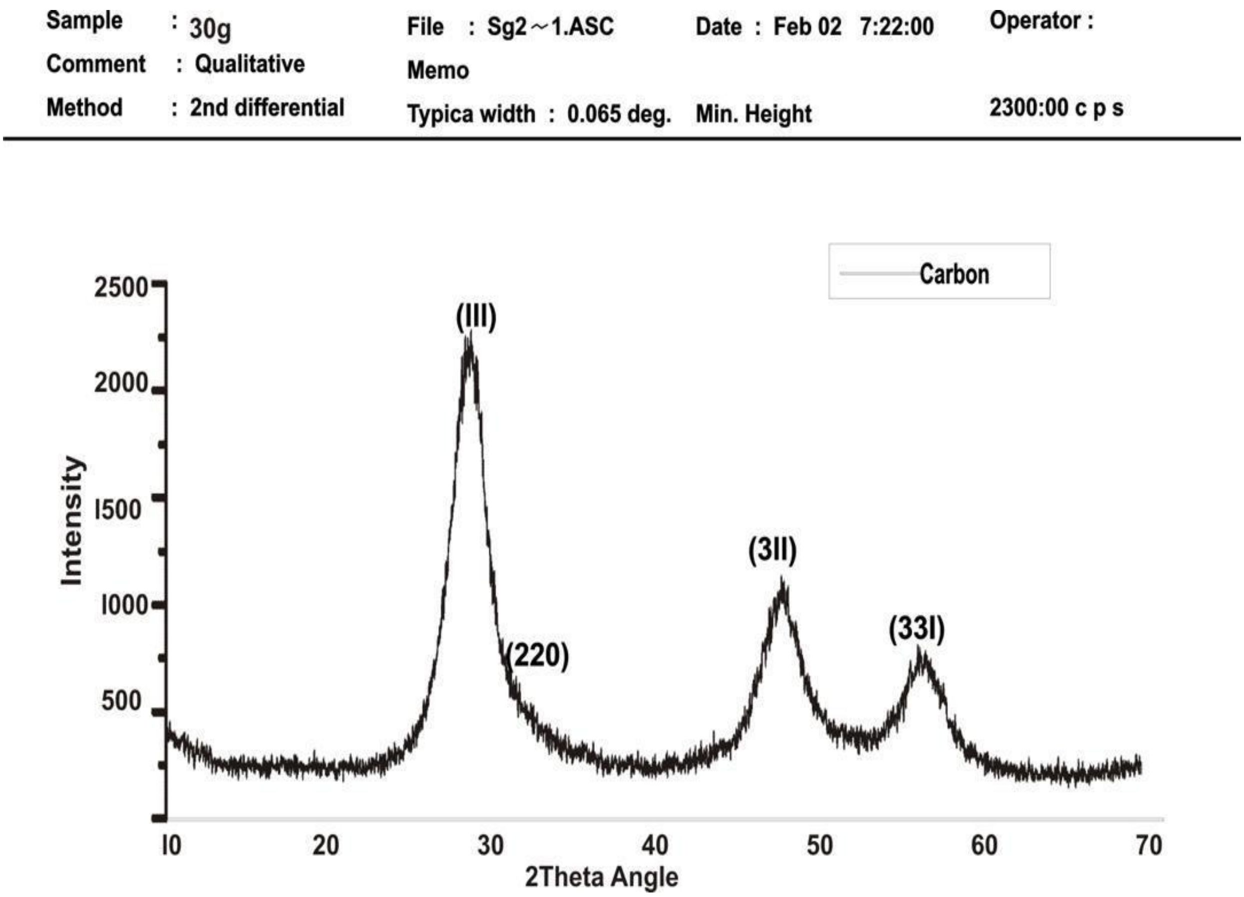

Figure 4. XRD pattern of 30 g carbon nanomaterial.

Sample : 40g
Comment : Qualitative
Method : 2nd differential
File : Sg2～1.ASC
Memo
Typica width : 0.065 deg.
Date : Feb 02 7:28:30
Min. Height
Operator :
2000:00 c p s

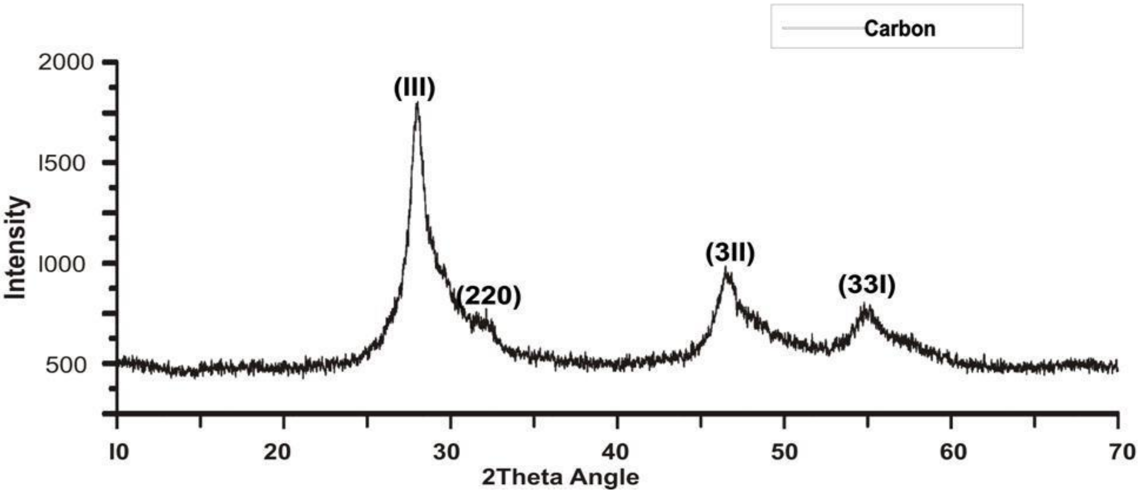

Figure 5. XRD pattern of 40 g carbon nanomaterial.

Sample : 50g
Comment : Qualitative
Method : 2nd differential
File : Sg2～1.ASC
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Typica width : 0.065 deg.
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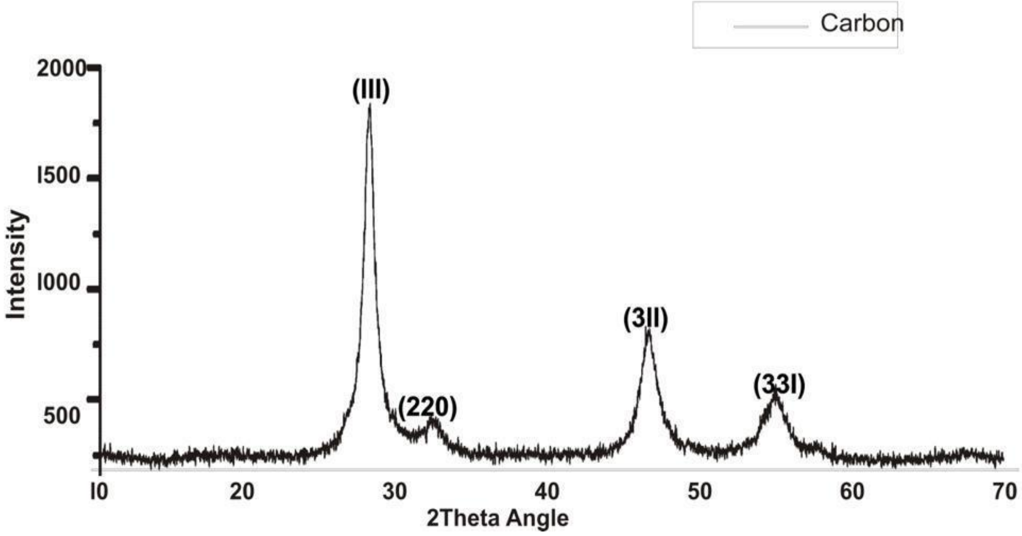

Figure 6. XRD pattern of 50 g carbon nanomaterial.

3.3 FTIR Analysis of Carbon Nanomaterial from Rice Husk (RH)

1. **50 g sample – FTIR (KBr, cm^{-1}):** 3434.44 (O-H), 2898.29 (C-H), 2156.07 (C≡C), 1819.25 (C=O), 1580.4 (C=C) and 728.67 (=C-H).

2. **40 g sample – FTIR (KBr, cm^{-1}):** 3390.95 (O-H), 2726.06 (C-H), 1859.35 (C=O), 1597.79 (C=C), 1131.76 (C-O), 1008.30 (C-O), 767.29 (=C-H bend) and 703.50 (ZnO).

3. **30 g sample – FTIR (KBr, cm^{-1}):** 3460.05 (O-H), 3021.29 & 2897.89 (C-H), 1819.14 (C=O), 1456.38 (C=C), 728.95 (=C-H bend) and 679.29 (ZnO).

Fourier Transform Infrared (FTIR) spectroscopy (Figure 7-9) revealed the surface functional groups of carbon nanomaterials derived from rice husk powder via microwave synthesis. The spectra showed analogous peaks for all samples, but varying transmittance data indicated bond breakage. The O-H stretching peaks at 3434.44 cm^{-1} (50 g), 3390.95 cm^{-1} (40 g), and 3250 cm^{-1} (30 g) suggested moisture, alcohol, or derivative presence.[18] Aliphatic C-H stretching peaks appeared between 3021.29-2726 cm^{-1} for all samples. The 50 g sample exhibited C≡C stretching at 2156.07 cm^{-1}, indicating alkynes. Symmetric/asymmetric vibrations of carboxylate groups were observed at 1819.25 cm^{-1} (50 g), 1859.35 cm^{-1} (40 g), and 1819.14 cm^{-1} (30 g). Peaks at 1580.4 cm^{-1}, 1597.79 cm^{-1}, and 1456.38 cm^{-1} indicated C=C stretching, possibly from alkene or aromatic functional groups.[19] Reduced peaks at 1008.30 cm^{-1} and 1131.76 cm^{-1} in the 40 g sample suggested C-O stretching and O-H bending vibrations, indicating residual hydroxyl groups. The presence of ZnO was confirmed by peaks at 703.5 cm^{-1} (40 g) and 679.29 cm^{-1} (30 g).[20] The =C-H out-of-plane bending vibrations were at a wavenumber of 728.67 cm^{-1} (50 g), 767.29 cm^{-1} (40 g), and 728.95 cm^{-1} (30 g).[21] The FTIR analysis revealed some hydrophilic surface rich in functional groups, consistent with previous reports.[22] These groups originated from lignocellulose breakdown in rice husk.

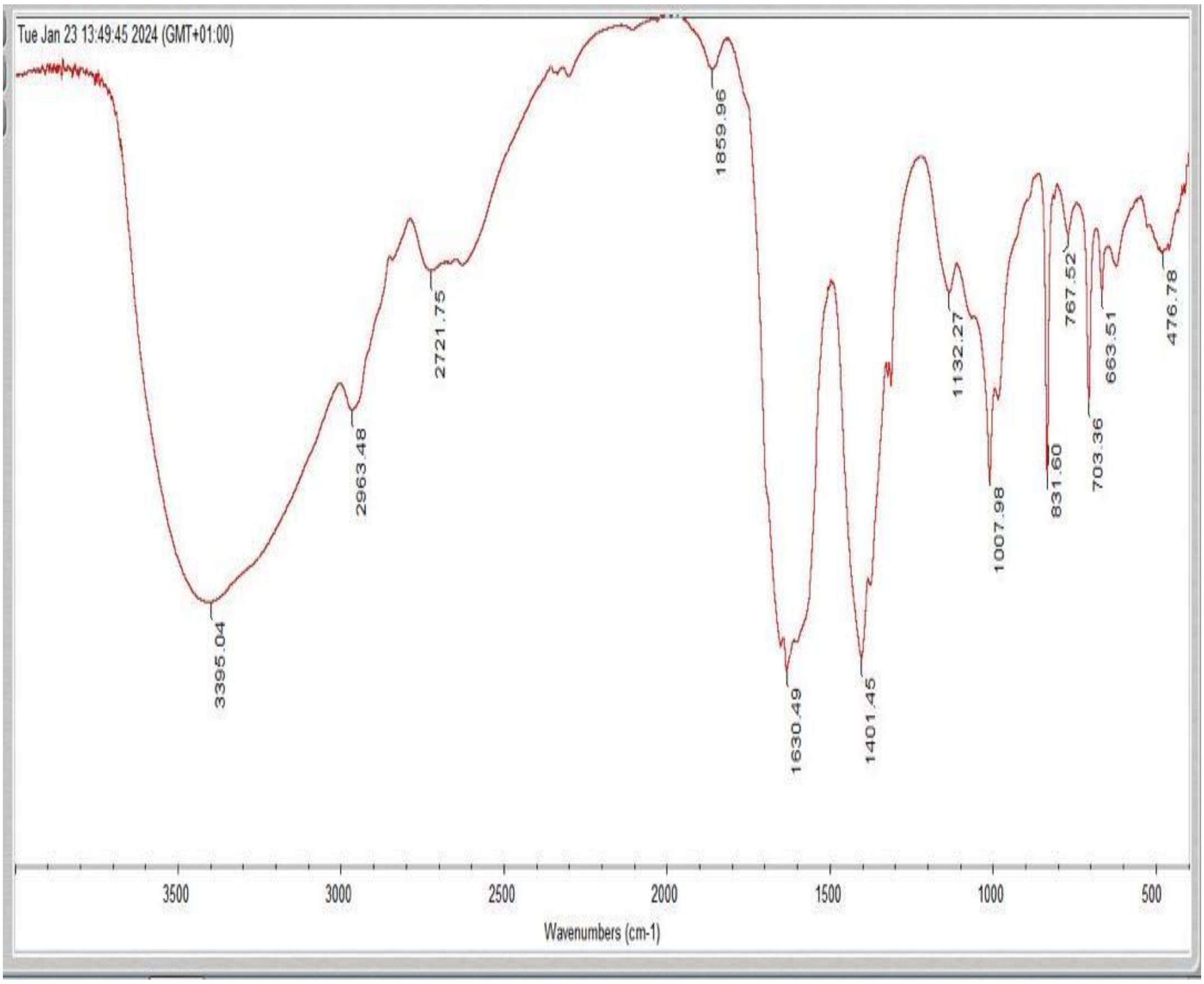

Figure 7. FTIR analysis spectra of 50 g carbon nanomaterial.

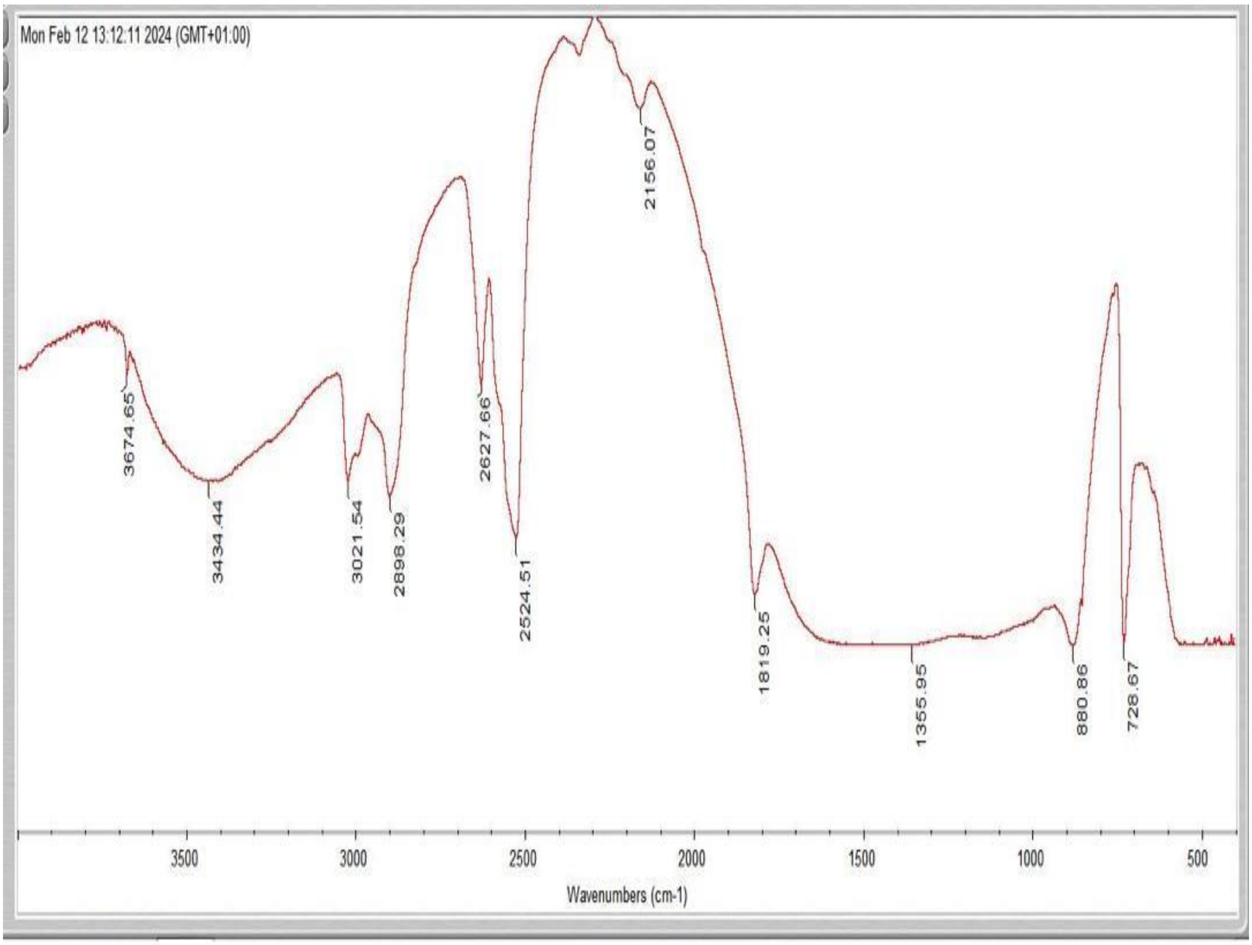

Figure 9. FTIR analysis spectra of 30 g carbon nanomaterial.

3.4 Application of the Prepared CNM in QuEChERS for the Extraction of Pesticide Residues in Beans

The optimized QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) method, as described by Qazum,[23] was employed to determine pesticide residues in bean samples. The method's performance was evaluated based on linearity ranges, average recovery, correlation coefficient, limit of quantitation (LOQ), and limit of detection (LOD). Table 2, presents the results, comparative analysis revealed that the synthesized carbon nanomaterials yielded comparable figures of merit to traditional QuEChERS cleanup materials, $MgSO_4$ and PSA, in terms of analytical methodology (Table 2). Notably, the results met the method validation requirements of the European Union,[13] validating the effectiveness of the carbon nanomaterials in pesticide residue analysis.

3.5 Calibration Curve

Calibration curve is a plot of how the instrumental response changes with the concentration of the analyte. A series of standards across a range of concentration near the expected concentration of analyte in the unknown is prepared. The mixed standard solution of the pesticides was analyzed to obtain their retention time and was used to calibrate the calibration curve (Figure 10 and 11). Figure 10 shows that the regression equation of bifethrin is $y= 0.0273x + 0.031$ with R^2 of 0.9997 while Figure 11, shows the regression equation in dichlorovos is $y = 0.0128x + 0.0458$ with R^2 of 0.9996.

3.6 Selectivity

In this study, the selectivity was determined by extracting a blank matrix containing the internal standard and a sample spiked with the target analyte. The resulting chromatograms are as shown in Figure 12, which indicates a good selectivity with no interference at the retention times of the target analytes. Triphenylphospate acts as an internal standard.

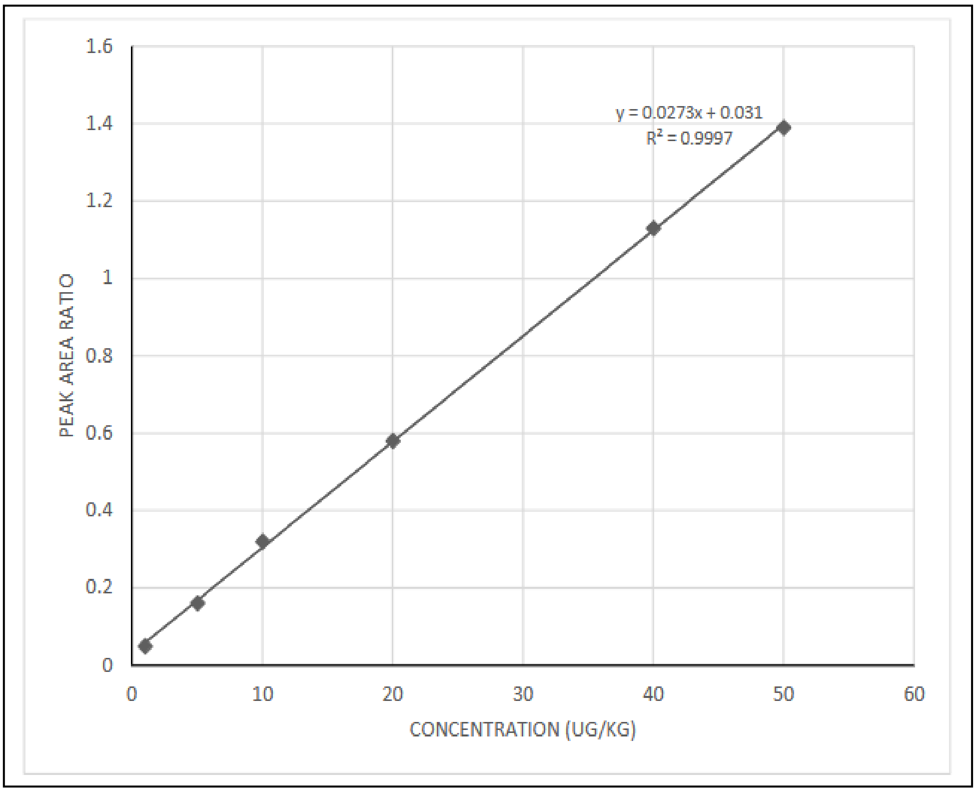

Figure 10. Calibration Curve for Bifenthrin.

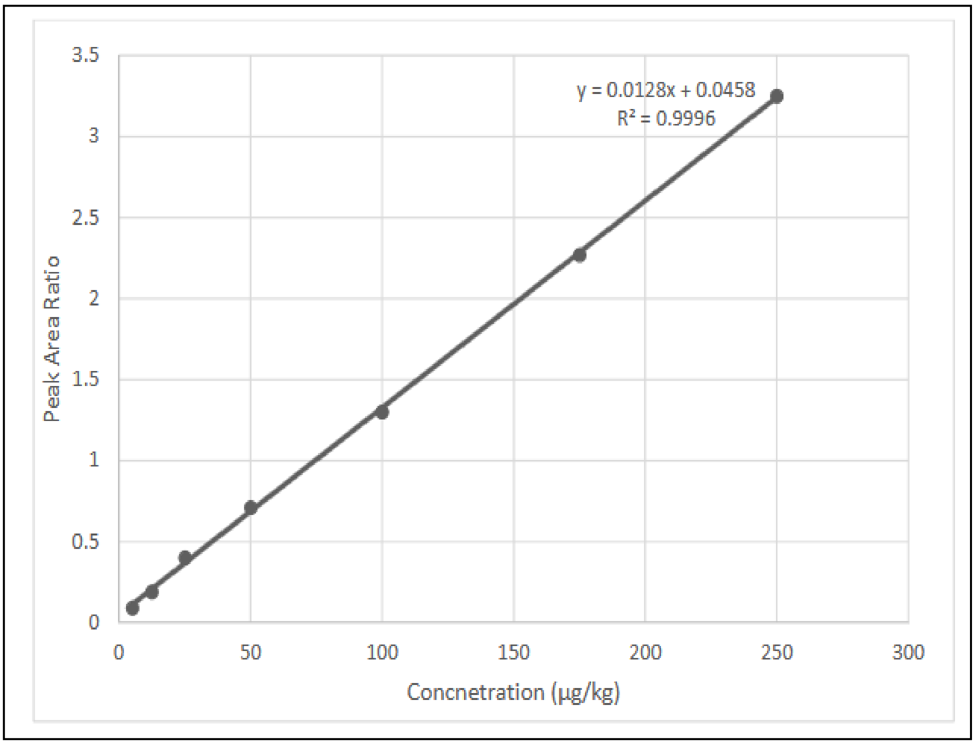

Figure 11. Calibration Curve for Dichlorvos.

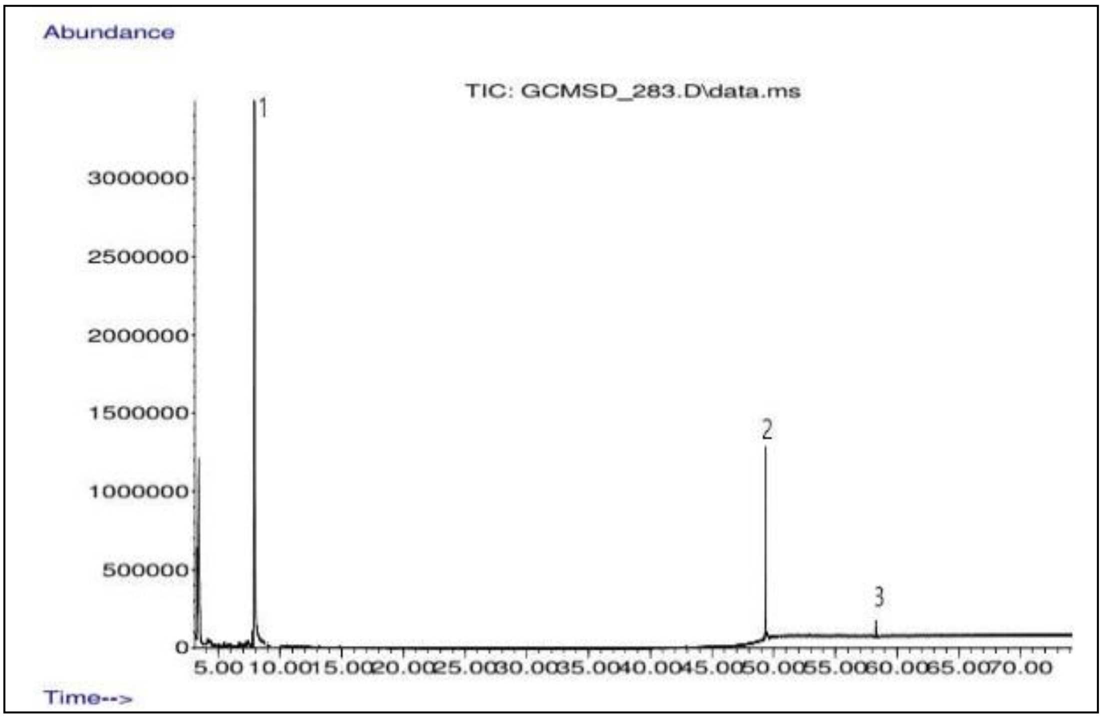

Figure 12. Chromatograms of beans sample spiked with mixed standard of dichlrovos and bifenthrin1: Dichlorvos2: Triphenylphosphate3.

Table 2. Comparison of present study with the previous study.

Pesticide	**Linearity Range (µg kg^{-1})**	**R^2**	**Ave. Rec. (%) (RSD, %)**	**LOQ (µg kg^{-1})**	**LOD (µg kg^{-1})**	**Ref**
Dichlorovos	0.5 – 1000	0.9996	89.66 (9.57)	16.96	5.29	Present study
Dichlorovos	1-1000	0.9986	96.67 (7.64)	16.05	4.82	[23]
Bifenthrin	0.25 - 1000	0.9997	101.43 (7.54)	6.56	2.83	Present study
Bifenthrin	0.25 -1000	0.9997	99.78 (5.1)	5.96	1.79	[23]

A comparative analysis of the QuEChERS technique for detecting Dichlorvos and Bifenthrin pesticides was conducted between the present study and Qazum's study.[23] For Dichlorvos, both studies demonstrated similar linearity ranges (0.5-1000 µgkg^{-1} and 1-1000 µgkg^{-1}, respectively), indicating effectiveness across a wide concentration range. The correlation coefficients (R^2) of 0.9996 (present study) and 0.9986 by Qazum,[23] revealed excellent linearity. Average recovery was 89.66 % in the present study, slightly lower than Qazum's 96.67 %. However, relative standard deviation (RSD) values of 9.57 % (present study) and 7.64 % by Qazum,[23] indicated acceptable precision. The quantitation limit (LOQ) and limit of detection (LOD) for Dichlorvos were 16.96 µgkg^{-1} and 5.29 µgkg^{-1}, respectively, in the present study, comparable to Qazum's values of 16.05 µgkg^{-1} and 4.82 µgkg $^{-1}$.[23] These results suggest that both methods are reliable and effective for Dichlorvos detection.

For bifenthrin, both studies reported an identical linearity range of 0.25–1000 µgkg^{-1}, with high correlation coefficients (0.9998 for the present study and 0.9997 for Qazum,[23] demonstrating exceptional linearity. The average recovery of bifenthrin was slightly higher in the present study (101.43 %) compared to Qazum,[23] (99.78 %), indicating that the current method provided more efficient recovery. The RSD values were 7.54 % and 5.1 %, respectively, suggesting both methods are precise, with Qazum[23] showing slightly superior precision. The present study reported LOQ and LOD values of 6.56 µgkg^{-1} and 2.83 µgkg^{-1}, respectively, while Qazum's values were 5.96 µgkg^{-1} and 1.79 µgkg^{-1}, indicating that Qazum's method had better sensitivity for Bifenthrin detection.[23]

Overall, both studies demonstrated reliable performance with minor differences, highlighting the efficacy of the methods used in the present study compared to those of Qazum.[23] The synthesis of carbon nanomaterials from rice husk involved a series of processes, including carbonization, activation, and purification, which resulted in materials with high surface area, porous structure, and abundant functional groups. Various characterization techniques, including energy-dispersive X-ray (EDX) for identifying and quantifying the elemental composition of the materials, scanning electron microscopy (SEM) for examining the internal structure of the materials, X-ray diffraction (XRD) for evaluate the size and strain of crystallites of the carbon-materials, and Fourier transform infrared spectroscopy (FTIR) for determines the presence of C-C, C=C and other functional groups in the carbon-nanomaterials, all these confirmed the successful transformation of rice husk into carbon nanomaterials with desirable physicochemical properties. The presence of oxygen-containing functional groups, as identified by FTIR, further contributed to the material's affinity for various analytes, enhancing its effectiveness as a sorbent. The synthesis and characterization of carbon nanomaterials derived from rice husk, and their subsequent application as sorbent materials in the clean-up step of QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) technique, represent a significant advancement in both waste valorization and analytical chemistry. Since their discovery, carbon nanomaterials have been considered as a promising material, being extensively studied in order to make use of their structure and properties. Wider application of this nanomaterial in the adsorption analysis of pesticides have been facilitated by the modification in their preparation. In all carbon nanomaterials, cost has been a main factor in limiting commercialization. However, preparation from agriculture waste such as rice-husks would decrease cost markedly[3].

4. CONCLUSION

This study successfully transformed rice husk, a ubiquitous agricultural waste, into high-performance carbon nanomaterials with exceptional adsorption properties. By leveraging sustainable and cost-effective resources, this research demonstrates the potential for innovative materials in environmental and analytical applications. The synthesis and characterization of rice husk-derived carbon nanomaterials, and their application as sorbent materials in QuEChERS, seamlessly integrate waste valorization, nanotechnology, and analytical chemistry. Notably, these eco-friendly nanomaterials exhibited excellent sorption properties, significantly enhancing QuEChERS method performance in pesticide residue analysis. This approach offers a compelling alternative to conventional sorbents, providing a cost-effective and environmentally friendly solution. Beyond pesticide analysis, this innovative method holds promise for efficient extraction and cleanup processes in various fields, underscoring its vast potential for broader applications.

Conflict of Interest

Authors declare that there is no conflict of interest with any person, institute, company, etc.

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