Research Square

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Chemical Composition of Boswellia Dalzielli Leaf and Characterisation of Its Magnetite (Fe_3O_4) Nanoparticle

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Abstract

The death toll from cancer, diabetes and other diseases worldwide is increasing daily. The need for urgent and assessable therapies is key to both the scientific community and local population. This study focused on *Boswellia dalzielii* leaf mediated-magnetite (Fe_3O_4) nanoparticle (Np) synthesis. Ten (10) gram dry powder of *Boswellia dalzielii* was mixed with 100 mL water and boiled at 90°C for 15 min, cooled and filtered to yield the aqueous extract of *Boswellia dalzielii* and stored at -4°C until use for nanoparticle synthesis. The leaf of *Boswellia dalzielii* showed the moisture content of 8.8%, total ash content of 4.08%, crude fiber 16.67%, protein content 23.87%, crude fat 12.86% and 33.78% carbohydrate. *Boswellia dalzielii* leaf, is a good source of some minerals with the most abundant mineral found to be potassium, 13.29mg/g, phosphorus 4.60mg/g, sodium 4.44mg/g, Ca 3.37mg/g and small quantities of Fe 0.9mg/g, Mg 0.043mg/g, Zn 0.2mg/g, Mn and Cu having 0.1mg/g. *Boswellia dalzielii* leaf can serve as a source of vitamin B1 and vitamin C when analysed for complete vitamin profile using HPLC. *Boswellia dalzielii* leaf-mediated magnetite nanoparticle was synthesized and characterized using UV-Visible mass spectrophotometer, and the peak absorbance was around 450 nm was accredited to the existence of Fe^{3+} and Fe^{2+} ions at the octahedral sites of the Np. Peak amplification owes to the oxygen to metal charge transfer ($O_2^- - Fe^{3+}$). The FTIR spectrum of the Np exhibited a broad absorption band at 3216 cm^{-1} which is attributed to O-H stretching vibrations, indicating the presence of hydroxyl group. Sharp peaks at 2883 cm^{-1} and 2827 cm^{-1} corresponds to C-H stretching of aliphatic groups. Strong peaks in the region between 2020 – 1994 cm^{-1} were observed, which is characteristics of C = C = C stretching vibrations in alkene. High-resolution transmission electron microscope (HRTEM) coupled with selected area electron diffraction (SAED) observed the particle size with a mean size of 20 nm. There is uniform size distribution, shape with concentric bright circles consisting of small dots confirming that the *Boswellia dalzielii* leaf-mediated Fe_3O_4 synthesized is highly crystalline.

INTRODUCTION

The Burseraceae family comprises 540 species and 18 genera. *Boswellia dalzielii* is used as a medicinal herb in tropical and subtropical areas to treat and cure a range of ailments.. The bark is widely prepared in Northern Nigeria to create a wash that is used to cure ulcers, rheumatism, and fever. For stomachic gastrointestinal diseases, the decoction is taken orally. The stem bark's methanol extract was effective against the saw-scaled viper Echis carinatus. As an anti-snake venom, anti-diarrheal, and broad-spectrum antibacterial agent, the aqueous extract of *B. dalzielli* stem bark has shown great potential. The methanol and aqueous extracts of *B. dalzielli* show a wide range of antibacterial and antifungal characteristics, according to a different study. The stem bark is useful as an adjuvant in the treatment of certain gastrointestinal disorders because it has been demonstrated to have antispasmodic properties. Additionally, it was found to have anti-ulcer properties.

The anti-inflammatory evaluation demonstrated the effectiveness of *B. dalzielii* in reducing inflammation. The current investigation demonstrated the antinociceptive properties of methanolic

stembark in models of both inflammatory and neuropathic pain [1]. Prior studies indicated that extracts of *Boswellia dalzielii* (BD) and *Hibiscus sabdariffa* (HS) significantly decreased hyperglycemia and hyperlipidemia in alloxan-induced diabetic mice. This research evaluated the antioxidant and anti-inflammatory effects of both plants in alloxan-induced diabetic rats [2].

The antibacterial evaluation of *B. dalzielii* demonstrated its potential for pharmaceutical development to address bacterial infections.

Table I. Ethnopharmacology of *B. dalzielii* from different countries [38].

S/N	Medicinal uses	Parts of the Plant	Country
1	The most utilized plants in the traditional system.	Roots	Sudanian Region of Benin
2	Stomachache, piles, and worms	Leaf, bark	Nigeria
3	Snake-bite, fever, and rheumatism	Bark, root	
4	HIV, rabies, chickenpox, and hepatitis	Leaves, bark, and stem	Nigeria
5	Heat rashes, diarrhea, umbilical cord and complications pile	Stem, Bark	Nigeria
6	Ant sickling	Stem bark	Nigeria
7	Malaria	Stem Bark	Nigeria
8	Maternal ailments	Bark	Nigeria
9	Stomachache and Wound healing	Leaf	Burkina Faso
10	Mental disorders	Stem bark	Burkina Faso
11	Arthritis	Stem bark	Nigeria
12	Ethnoveterinary	Bark	Cameroon
13	Anti-tuberculosis	Stem bark	Nigeria
14	Mental illness	Stem bark	Nigeria
15	Antidiabetic	Root	Nigeria
16	Cancer	Bark	Nigeria
17	Inflammatory diseases	Stem-bark	Guinée
18	Many forms of cancers/fibrosis	Stem bark	Nigeria
19	Antidiarrheal	Bark	Nigeria
20	Pharmaceutics industry cosmetics, incense, perfume, and chewing gum	Leaves/ Bark	Nigeria
21	Syphilis	Roots bark	Cameroon
22	Management of hepatic Ailments	Bark	Nigeria
23	Pile and body heat	Stem bark	Nigeria
24	Measles, Vaginal Diseases	Bark, root	Nigeria
25	Malarial management.	Leaves, Bark, flower	Nigeria

S/N	Medicinal uses	Parts of the Plant	Country
26	Rheumatism, venereal diseases	Bark, Root	Cameroon

The methanolic stem bark extract demonstrated the highest level of inhibition against *C. albicans* at a concentration of 100 mg/mL, producing a zone of inhibition of 38 mm [3]. This indicates its antifungal properties [4]. The stembark contains primarily identified chemicals known as flavonoids. Flavonoids represent a significant group of polyphenolic compounds, distinguished by their benzo-pyrone structure. Recent exploratory findings indicate that stembark extract could be a valuable resource for the identification and development of novel antifungal active compounds. The plant has the potential to be harnessed for the production of effective antibiotics targeting fungal infections. The stembark consists of various chemicals, with a primary focus on flavonoids. Compounds with a benzo-pyrone structure are classified as flavonoids [5]. The antidiabetic properties of *B. dalzielii* leaf are enhanced through extraction refinement. The presence of alkaloids, flavonoids, tannins, and terpenoids in the plant may play a role in its antidiabetic effects observed in rats. [6].

The flavonoids present in Boswellia dalzielli are believed to play a significant role in the plant's antioxidant and therapeutic properties, similar to those found in other species within the Boswellia genus. The combined effects of flavonoids and boswellic acids, present in *Boswellia dalzielli*, could potentially enhance these protective benefits, thereby improving the overall therapeutic effectiveness of the plant [7]. These polyphenolic compounds act as potent antioxidants by neutralizing free radicals and protecting cells from oxidative damage, which is crucial in preventing diseases like cancer, Alzheimer's, and cardiovascular conditions.

The examination of the flavonoid content in *Boswellia dalzielli* could yield important insights regarding its health benefits. Flavonoids have the potential to offer neuroprotection, especially in the context of Alzheimer's disease, inhibit the proliferation of cancer cells, and improve cardiovascular health by reducing oxidative stress and inflammation. Future research should focus on isolating and identifying the specific flavonoids present in this species, assessing their bioactivity, and analyzing their interactions with other bioactive compounds. Examining the pharmacokinetics and toxicity of these flavonoids is essential for their potential therapeutic applications. The antioxidant properties of flavonoids in Boswellia dalzielli suggest considerable potential for further research and development [8].

This study seeks to identify the chemical composition of *B. dalzielli* leaves sourced from the Lau local government area of Taraba State, in addition to synthesizing magnetite nanoparticles utilizing the leaf extract and performing characterization analyses.

Method

Fresh leaves of wild *Boswellia dalzielii* plant were collected from Minda village of Lau local government area of Taraba state, following all guidelines of sample collections. The fresh leaf samples were brought

and identified by Dr. Anongo Jeyol Me'embe, a botanist, and Head of department, the Department of Biological Sciences, Federal University Wukari and it was assigned a specimen number (FUW/FBS000176) according to the institutions sample collection regulations. The sample was subsequently subjected to a cleaning process and allowed to air-dry at ambient temperature. Subsequently, the sample was ground into a fine powder and passed through a locally sourced fine sieve.

The experimental work was conducted at the Central Laboratory of Federal University Wukari, located in Taraba State.

Proximate Analysis

The proximate analysis encompassed moisture, ash, acid-insoluble ash, water-soluble ash, crude fiber, carbohydrates, and food energy. The Central Laboratory of Federal University Wukari employed standard techniques for the proximate analysis of *Boswellia dalzielii* leaf, as outlined by AOAC (2020) [9].

Determination of Phytonutrient Constituents of B. dalzielii using HPLC

Phytonuitrient constituents were determined using High-performance liquid chromatography (HPLC), based on a method described by Fraga *et al*., (1988) [10].

Synthesis of Magnetite Nanoparticles

Preparation of aqueous extract of Boswellia dalzielii

Ten (10) gram dry powder of *Boswellia dalzielii* was mixed with 100 mL water and boiled at 90°C for 15 min. It was cooled and filtered to yield the aqueous extract of *Boswellia dalzielii* and stored at -4°C for further usage.

Synthesis of Fe_3O_4 NPs using Aqueous Extract of Boswellia dalzielii

To 250 mL aqueous extract of *Boswellia dalzielii*, 250mL of 0.2 M ferric chloride hexahydrate ($FeCl_3.6H_2O$) and0.1 M ferrous sulfate heptahydrate ($FeSO_4.7H_2O$) (ratio 2:1) was added and stirred with magnetic stirrer for 1h at room temperature. Further, 0.1 M sodium hydroxide (NaOH) was added dropwise for the precipitation of NPs. Alkaline pH of 11–12 was maintained. It was further stirred and decanted, and evaporated at 70°C using water bath. It was then powdered using hand crusher [11].

Characterization of Fe_3O_4 NPs

UV-Visible spectroscopy

UV-Visible spectroscopy was used to determine the characteristic peaks, to investigate the reduction rate of ferric ions by the leaf extract [12].

High-resolution scanning electron microscope (HRSEM) integrated with energy dispersive X-ray spectrometer (EDX). HRSEM analysis is suitable for visualizing the morphology and dimensions of nanomaterials along with their external texture. The specimen was affixed to a metal stub using gold-coated glue and thereafter examined in the high-resolution scanning electron microscope (Model: F E I Quanta FEG 200). HRSEM in conjunction with EDX was employed for elemental analysis. The high-resolution transmission electron microscope (HRTEM), in conjunction with selected area electron diffraction (SAED), was utilized to examine surface texture and particle size (Model: Jeol/JEM 2100). The sample was manufactured by drop-coating onto carbon-coated TEM grids. High-Resolution Transmission Electron Microscopy (HRTEM) combined with Selected Area Electron Diffraction (SAED) was employed to identify the crystalline phases of Fe_3O_4 nanoparticles [13].

Fourier Transform Infra-Red Spectrometer (FTIR)

Biomolecules adhered to the sample were analyzed using FTIR [14]. Three milligrams of Boswellia dalzielii-mediated Fe_3O_4 nanoparticles were dried at 300°C in a muffle furnace for four days. This was mixed with pure spectroscopic grade potassium bromide (KBr) and ground in an agate mortar. An ultrapure transparent pellet with a diameter of 13 mm was obtained by applying a force weight of 10 tons for approximately 10 minutes. Infrared absorbance was measured within the range of 450 to 4000 cm − 1 [15].

Results

The moisture content of Boswellia dalzielii leaf was measured at 8.8%. Moisture content is a critical factor in food processing, preservation, and storage [16]. Moisture and ash content are essential analytical parameters in food samples, offering insights into key attributes such as nutritional value, shelf-life, appearance, texture, and taste. The low moisture percentage observed suggests that Boswellia dalzielii leaves possess a limited shelf-life, indicating that prolonged storage may result in spoilage due to vulnerability to microbial contamination [17]. Ash content serves as an indicator for the quality grading of leaves and provides insight into the mineral element composition within the plant leaf. The total ash content is critical in assessing the purity of a drug, specifically regarding the presence or absence of foreign organic matter, including metallic salts or silica [18]. The total ash content of Boswellia dalzielii leaves was determined to be 4.08%.

The crude fiber content observed in this study (16.67%) reflects the amount of non-digestible carbohydrates and lignin present in the leaves of *Boswellia dalzielii* [19]. Fiber is noted for its minimal nutritional value; however, its impact on the digestive system may aid in combating diabetes and reducing elevated blood cholesterol levels [20]. Low levels of crude fiber are deemed suitable [17], as elevated levels may lead to intestinal irritation, reduced digestibility, and diminished nutrient utilization

[19]. Proteins serve as a significant source of energy. It includes essential amino acids that facilitate growth and the repair of damaged tissues in humans [21]. The protein content of *Boswellia dalzielii* leaf is 23.87%. Proteins must exhibit the necessary functionality for effective application in diverse food products. The functional properties are inherent physio-chemical characteristics that influence the behavior of properties in food systems throughout processing, manufacturing, storage, and preparation [19]. The leaf comprises 33.78% carbohydrate, providing a readily available energy source for the body [22, 23].

Figure 2 presents the results for the mineral composition of the leaf. Potassium is the most abundant mineral in the leaf, present at 13.29 mg/g, while sodium is found at 4.44 mg/g. Both minerals are essential for regulating body pH, controlling glucose absorption, and aiding protein retention during growth [24]. However, dietary sodium is associated with cardiovascular and renal disorders. Potassium is a monovalent cation commonly found in nature, existing not in metallic form but rather in combination with other substances, particularly chloride. Dietary potassium is primarily sourced from fruits and vegetables, where it typically occurs in conjunction with organic acids, such as potassium citrate [25]. A high concentration of potassium in the body has been reported to enhance iron utilization [26] and is beneficial for individuals taking diuretics to manage hypertension, as well as for those experiencing excessive potassium excretion through bodily fluids [27]. The impact of potassium on the human body is extensive, affecting all cells and tissues, with significant evidence highlighting its role in the cardiovascular system. Numerous studies indicate a negative correlation between potassium intake and blood pressure [25].

Sodium plays a crucial role in maintaining fluid balance within the body and is essential for the proper functioning of muscles and nerves [28]. Calcium is an essential component of bones, facilitating proper muscle contraction, blood coagulation, and nerve signal transmission.

Phosphorus is the second most abundant mineral in Boswellia dalzielii leaf, with a concentration of 4.60 mg/g. It is linked to the development of robust bones and teeth, energy production, and the synthesis of genetic material such as DNA and RNA. It aids in the growth and repair of cells and tissues, regulates the body's pH level, and filters waste from the kidneys.

Magnesium (Mg) is essential for enhancing insulin sensitivity, providing protection against diabetes and its complications, and lowering blood pressure [29]. In this study, its concentration was found to be 0.043 mg/g in Boswellia dalzielii leaf. Magnesium plays a critical role in various enzymatic reactions related to oxidative metabolism of nutrients, synthesis of cellular constituents, transmission of nerve impulses, regulation of body temperature, detoxification processes, energy production, and the development of healthy bones and teeth [30].

Iron facilitates blood production and the transport of oxygen and carbon dioxide between tissues [31]. Hemoglobin is demonstrated to possess a greater proportion of iron in the human body. It is a protein found in erythrocytes that facilitates the passage of oxygen from the lungs to the tissues and contributes to the red coloration of blood. The process of oxygen transfer to the muscles mostly relies

on myoglobin, which contains iron as its crucial element. Additional roles of iron encompass growth, development, the manufacture of connective tissues, and certain hormones. It also aids in normal cellular activity [32]. The present analysis identified the highest average content of Fe as 0.9 mg/g.

Zn is an essential trace element found in nearly 300 unique enzymes, serving as a crucial trace metal that functions as a cofactor for various enzymes engaged in metabolism and cellular development [33]. Zinc enhances the vitality of our hair, contributes to the optimal functioning of certain sensory organs, including taste and smell, aids in the metabolism of carbohydrates and proteins, and supports the mobilization of vitamin A from its storage in the liver. Furthermore, it plays a crucial role in the synthesis of DNA and RNA, which are essential for cellular production [28]. The leaf of Boswellia dalzielii exhibited a zinc concentration of 0.2 mg/g. Zinc is integral to the metabolic processes involving proteins, carbohydrates, lipids, and energy production. Zinc is an essential element involved in numerous metabolic pathways and is crucial for the optimal functioning of various bodily systems [34]. It holds particular significance for the preservation of healthy skin and is essential for a robust immune system and resilience against infections. Zinc plays a crucial role in growth and cell division, in addition to its involvement in insulin activity. It holds considerable importance in the metabolic processes of the ovaries and testes, demonstrating established involvement in protein and DNA synthesis as well as liver function [32]. Prolonged exposure to elevated zinc levels over several months can lead to anemia, pancreatic damage, and a reduction in high-density lipoprotein (HDL) cholesterol levels [35].

Manganese (Mn) aids in the treatment of diabetes by assisting the diabetic in the metabolism of carbohydrates. Mn can support the body's protein metabolism. In the current investigation, the average Mn concentration was 0.1 mg/g, which is equivalent to copper. Energy generation, wound healing, taste perception, and skin and hair color are all influenced by copper [36].

The HPLC spectra of B. dalzielii reveal the presence of vitamin B1 and vitamin C (Fig. 3), which contribute to the plant's antioxidant properties [37]. Vitamin C enhances quality of life and mitigates various diseases, including chronic diseases, cardiovascular diseases, and cancer, and is also utilized in treatments for infections and neurodegenerative diseases [38]. Thiamine (vitamin B1) plays a crucial role in sustaining cellular health and facilitating energy metabolism. Thiamine is essential for the proper functioning of enzymes that facilitate glucose metabolism, which is crucial for cellular energy production, including mechanisms for DNA repair. This is essential for the activity of key enzymes involved in the biosynthesis of pentose sugars, which are crucial for nucleic acid synthesis. Thiamine possesses antioxidant properties that mitigate oxidative stress in cells, thereby indirectly aiding in the preservation of DNA integrity [39].

Optical properties of Boswellia dalzielii leaf-mediated Fe_3O_4 NPs

UV-Visible analysis

The absorbance peaked at 450 nm (Fig. 4) which corresponds to the transition of ligand to metal charge transfer (LMCT) in the tetra-coordinated Fe^{3+} (t1—t2 and t1—e) was credited to the existence of Fe^{3+} and Fe^{2+} ions at the octahedral sites. Peak amplification owes to the oxygen to metal charge transfer (O_2^- – Fe^{3+}) [40]. The versatility of semiconductors is that this optical phenomenon makes these materials appropriate for photocatalytic and antiaging applications.

The FTIR spectrum of the sample exhibited a broad absorption band at 3216 cm^{-1} which is attributed to O-H stretching vibrations, indicating the presence of hydroxyl group. Sharp peaks at 2883 and 2827 cm^{-1} corresponds to C-H stretching of aliphatic groups. Strong peaks in the region between 2020 – 1994 cm^{-1} were observed, which is characteristics of C = C = C stretching vibrations in allene. The band at 1735 cm^{-1} corresponds to C = O stretching, suggesting the presence of ester functionalities. The peak at 1617 cm^{-1} correspond to C = C stretching vibration. Peaks in the region of 1550 – 1500 cm^{-1} corresponds to N-O stretching which is characteristics of nitro compounds. A strong peak at 1474 cm^{-1} corresponds to C-H bending of alkane. A sharp peak at 1384 cm^{-1} was observed which is characteristics of C-H bending in alkene. Finally, a sharp absorption band at 1105 cm^{-1} corresponds to C-O stretching vibrations of secondary alcohols.

Morphological properties of Boswellia dalzielii leaf mediated Fe_3O_4 NPs

SEM with EDX analysis and HRSEM analysis (Fig. 6a, b and c) confirmed the irregular shape (at 10,000x, 9,000x, and 8,000x magnification) with minor agglomerates and a rough surface. HRSEM coupled with EDX confirmed the presence of iron at 2.1 keV in higher level with minimum levels of oxygen, copper, magnesium, silicon, calcium, and sodium. Peak at 0.1 keV signifies the occurrence of oxygen with a weight percent of 5.47% (Fig. 6d). The presence of iron and oxygen to maximum denotes the successful synthesis of Fe_3O_4 NPs.

TEM with SAED analysis HRTEM investigation proved the uniform size distribution, shape, and defects in the structure. HRTEM images (Fig. 7a, b, c), confirms the spherical-shaped NPs with a size range between 10 up to 28 nm and a mean particle size distribution of 20 nm. SAED pattern (Fig. 7d) displays well-defined concentric bright circles aligned to the planes obtained from XRD data. Concentric bright circles consisting of small dots confirmed that the *Boswellia dalzielii* leaf-mediated Fe_3O_4 is highly crystalline. The existence of distinctive rings with tiny spots denoted the presence of planes conforming magnetite.

Discussion

The death toll from many diseases such as cancer, diabetes melitus etc, worldwide is increasing daily. Due to the high cost of healthcare for people who are impacted. These diseases are treatable, but the growing likelihood of conditions that are resistant to therapy and effectiveness of the insulin in all types of diabetes emphasizes how urgently stronger medications must be developed, as well as how to find

affordable and accessible therapies. *Boswellia dalzielii*, a member of the Burseraceae family demonstrate numerous medicinal properties [41].

Boswellia dalzielii properties are actively studied in Nigeria and other parts of Africa to explore its potentials as it is rich in nutrients such as vitamin B1 (thiamine) and vitamin C (ascorbic acid). Vitamin B1 which is employed in the body for energy production, nervous system function, cardiovascular health, cellular health, immune function and DNA synthesis can be explored in *Boswellia dalzielii* leaf in the development of both folk and modern medicines. Vitamin C which is also employed by the body as an antioxidant, immune support, connective tissue synthesis, wound healing, metabolic functions, iron absorption and epigenetic regulation, can also be explored in the development of therapies for the treatment of cancer and other tissue degenerative disorders [38].

In combination with the vitamins in *B.dalzielii*, minerals such as potassium, phosphorus, sodium, calcium, and iron which differs in various parts of the plant [42] are available in appreciable quantities with others such as; zinc, copper, manganese and magnesium, are present in low quantities. Their potentials can be harnessed through the development of *B.dalzielii*-magnetite nanoparticle to achieve biological roles [25]. However, few scientific studies are currently examining the *B.dalzielii* plant's potential as an anticacinogenic agent, despite numerous reports of its antibacterial, antifungal, anti-inflammatory, antiarthritic, and antispasmodic qualities, particularly the stem back extract [43].

This study focused on the phytonutrient composition of *Boswellia dalzielii* leaf, mediated with Fe_3O_4 nanoparticle for effective utilization of the nutrient content of the plant leaves, especially by pharmaceutical, food and other industries for both drug developments and nutrients utilization. If *Boswellia dalzielii*-mediated Fe_3O_4 NPs proofs to be an effective delivery agent, the leaf of *Boswellia dalzielii* will be harnessed, by growing large populations in order to mediate in treatment regimens especially in the developing economies like Nigeria, and proper sensitization of the local population for its use to supplement nutrient deficiencies.

Conclusion

The amount of crude fibre, protein and carbohydrate from *Boswellia dalzielii* leaf obtained from this study has shown a promising source of such nutrients and can be harnessed for the benefits of life processes requiring them. The high amount of protein, fat and carbohydrate makes this plant reliable when it is incorporated to daily nutrition of locals. The high mineral composition, particularly potassium, phosphorus, sodium and calcium can be harnessed also for their biological roles in the prevention of disease conditions in cardiovascular health, energy production, fluid/electrolyte balance, healthy teeth and bones. For effective management and utilization of thess nutrients, dose studies can be carried out to provide positive information on the utilization rate.

This plant, *Boswellia dalzielii* leaf first report on the usage for the synthesis of Fe_3O_4 NPs, uses ferric chloride hexahydrate and aqueous extract of *Boswellia dalzielii* leaf at moderate conditions produced

Fe_3O_4 NPs. The biomolecules present in the aqueous extract of *Boswellia dalzielii* leaf played multiple roles as reducing and capping agents for the synthesis of Fe_3O_4 NPs which was proven from FTIR. Crystalline phases were confirmed from XRD with inverse cubic spinel structure. Hydrodynamic size distribution from DLS proved the smaller size of Fe_3O_4 NPs. Iron and oxygen were present. Sphere-shaped with an average particle size of 20 nm and highly crystalline witnessed from HRTEM and SAED techniques.

Declarations

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Credit Authorship Contribution Statement

Arowora, Kayode Adebisi: Conceptualization, Supervision, Resources, Formal analysis, Writing–review & editing, **Umaru, Isaac John**: Conceptualization, Supervision, Writing– review & editing. **Ikwebe, Joseph**: Conceptualization, Supervision, Resources, Formal analysis, Writing–review. **Yohanna, Emochone Roy**: Resources, Formal analysis, Writing–original draft.

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Declaration of Competing Interest

The authors declare that they do not have any conflicting financial interests or personal connections that could have appeared to impact the work presented in this paper.

Consent to Publish Declaration: not applicable

Ethics and Consent to Participate Declarations:

The authors declare that the information in this document is true and correct. I believe it contains no material I would not want to include in my research publication. Furthermore, I acknowledge that this work was conducted under the supervision of all authors and they consent to publish it. There is no consent applicable that we have not explored.

Data Availability Statement

The authors declare that all data generated during this study are included & available in this paper and its supplementary information files. Permission is granted to Springer Nature Limited, to publish the images and data provided under the open access license. All data generated or analysed during this study are included in this published article (and its supplementary information files).

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Figures

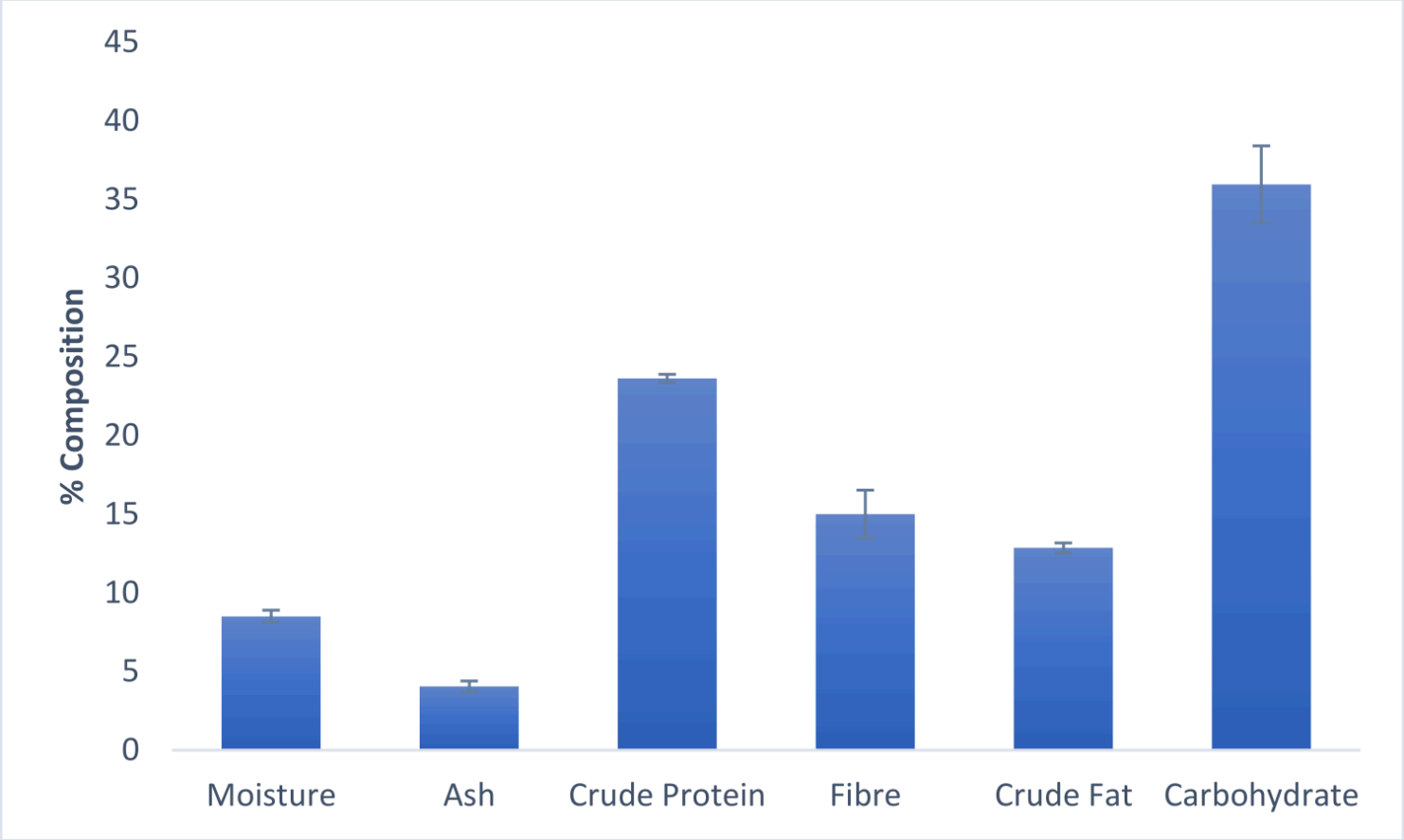


Figure 1

Proximate composition (%) of *Boswellia dalzielii* leaf

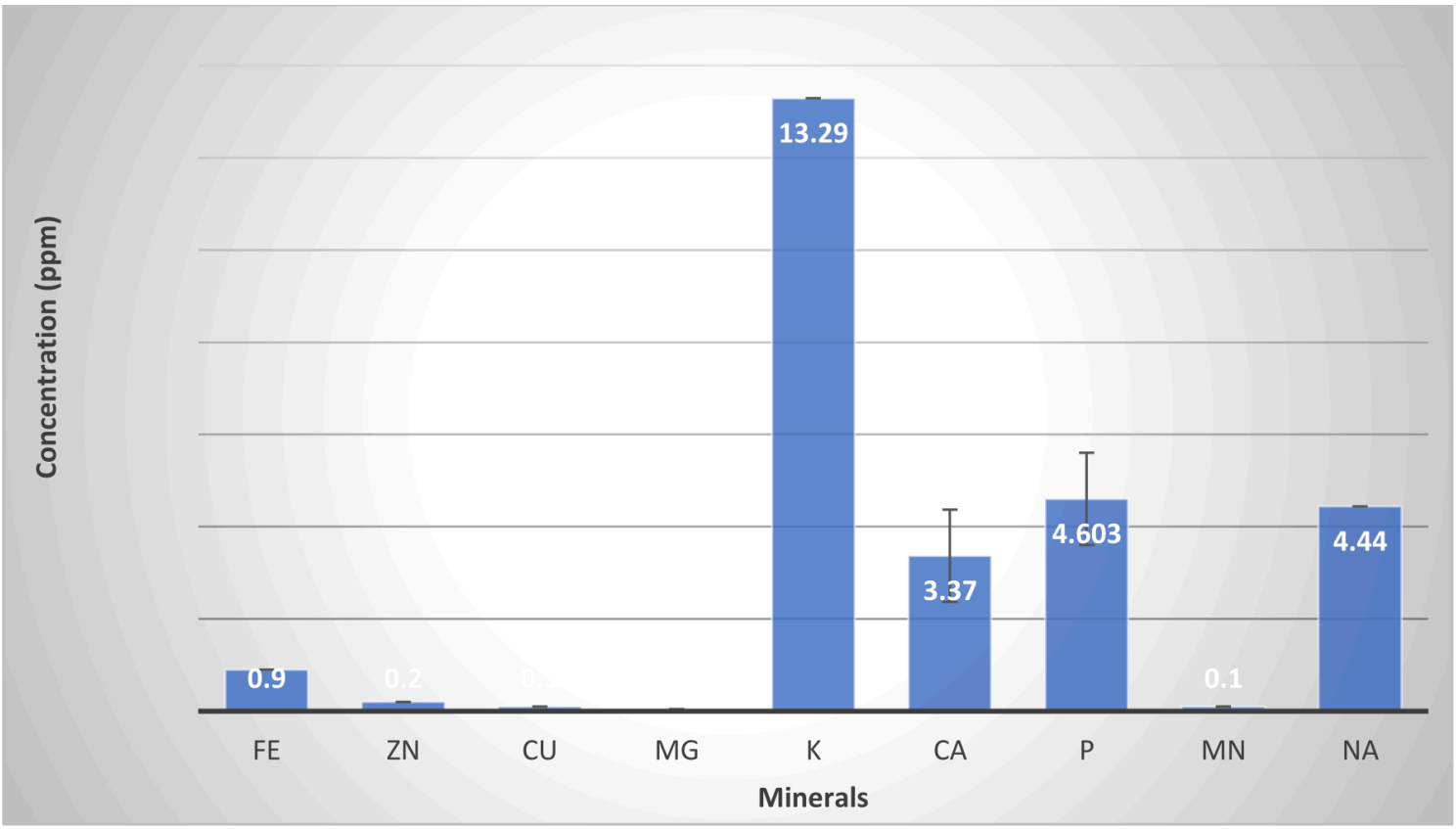


Figure 2

Mineral composition (ppm) of *Boswellia dalzielii* leaf

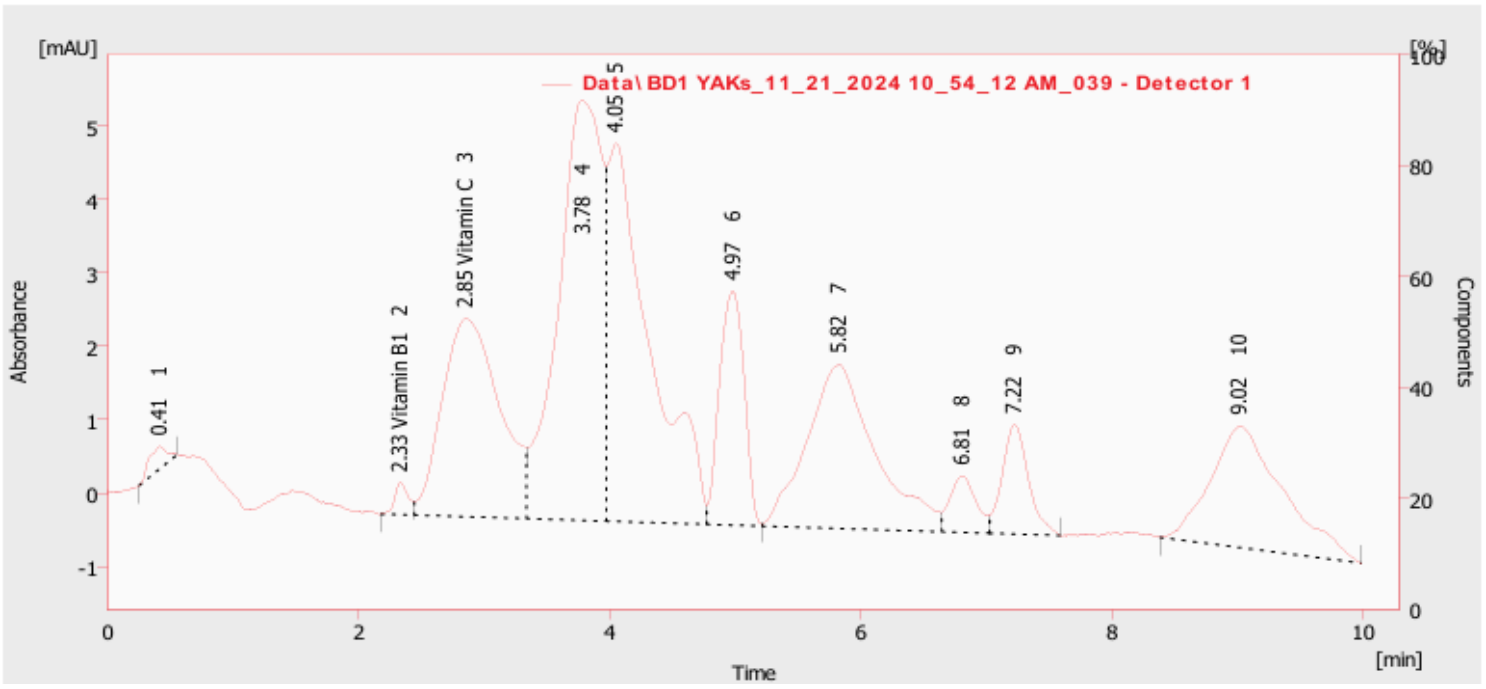


Figure 3

HPLC spectrum of identified phytonutrient of *Boswellia dalzielii* leaf

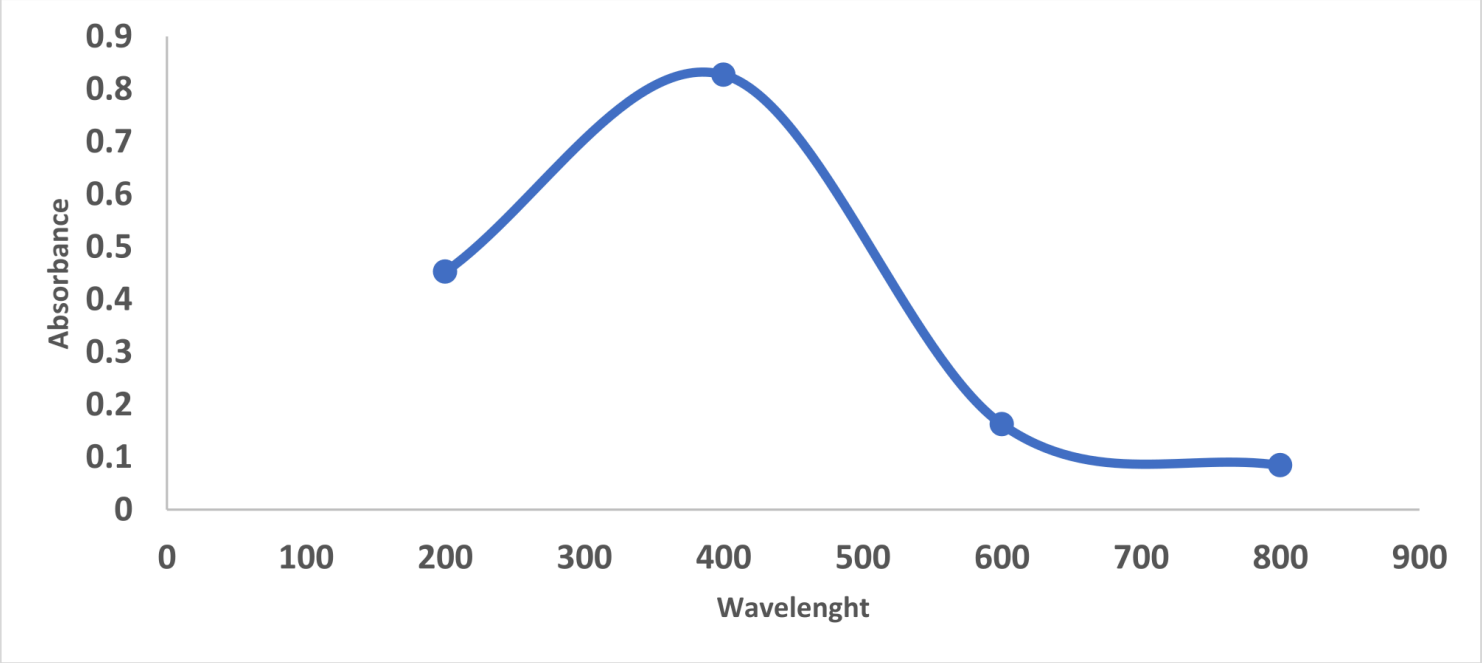


Figure 4

Ultraviolet–visible spectrum of *Boswellia dalzielii* leaf aqueous extract-mediated Fe_3O_4 NPs.

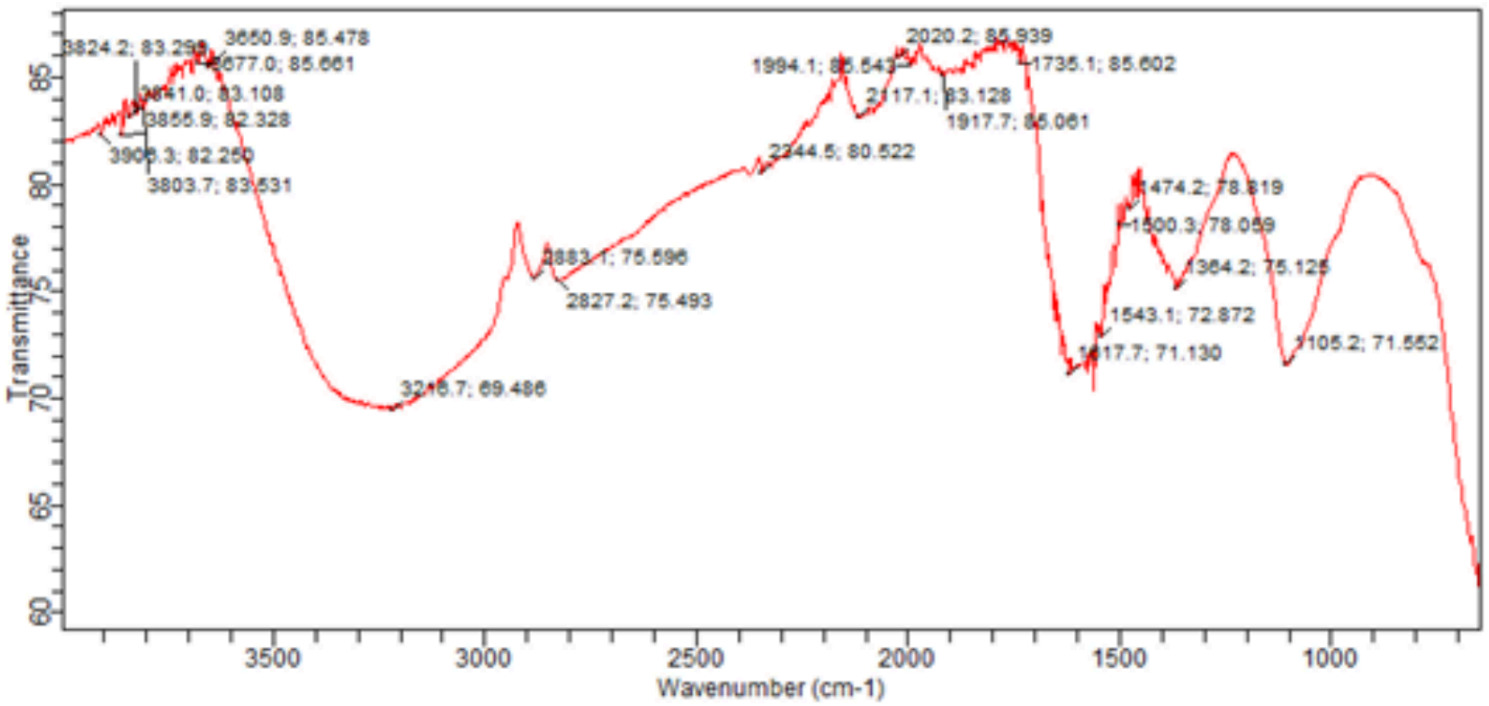
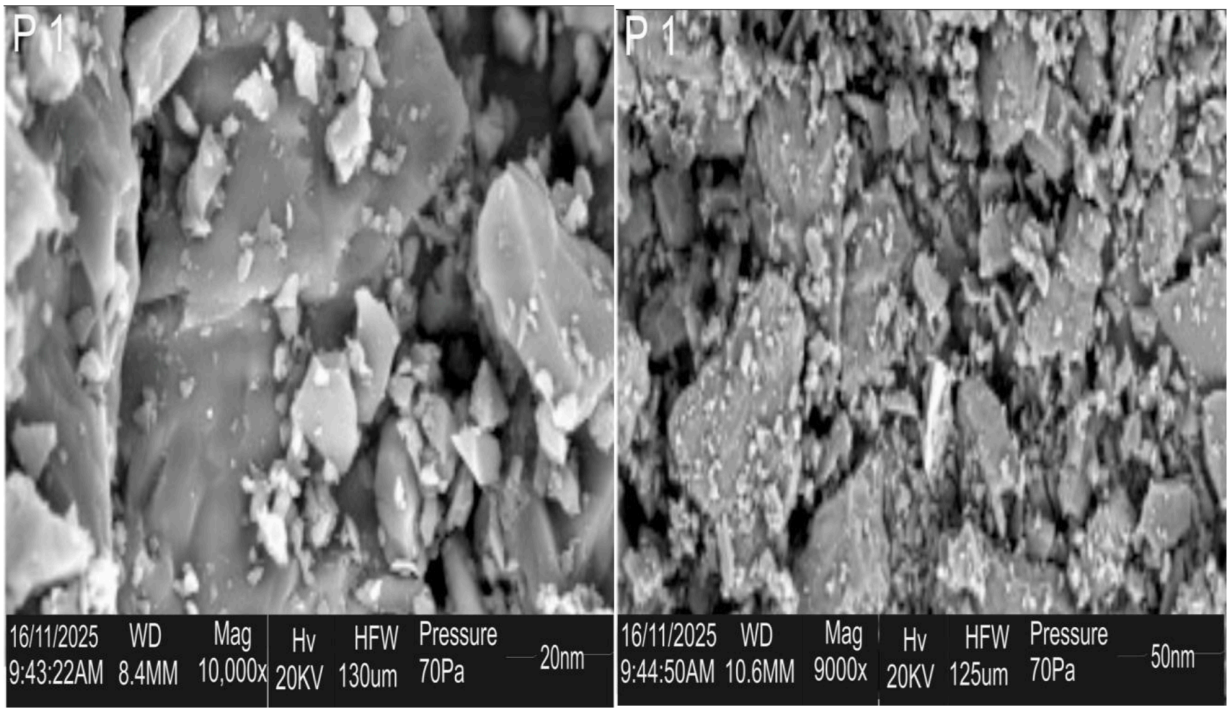
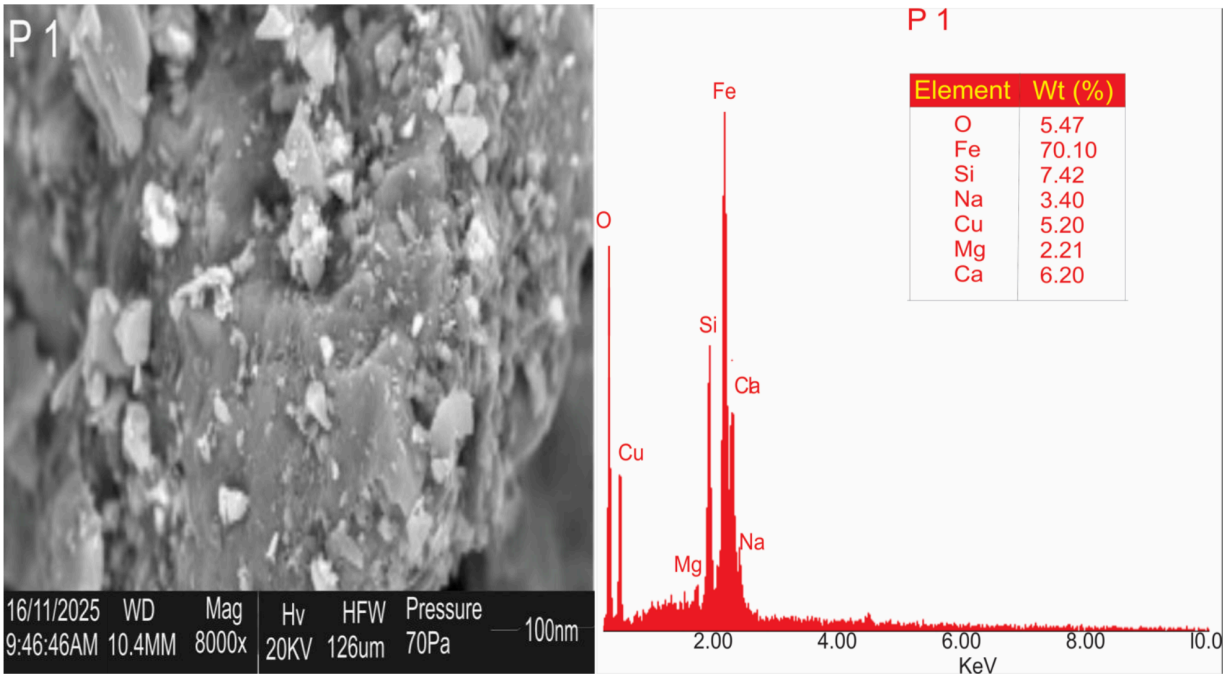


Figure 5

FTIR spectra of *Boswellia dalzielii* leaf aqueous extract-mediated Fe_3O_4 NPs.



a. b.



c. d.

Figure 6

High resolution images of *Boswellia dalzielii* leaf-mediated Fe_3O_4 NPs at different resolutions; a, b, c and the elemental composition of the Np (d)

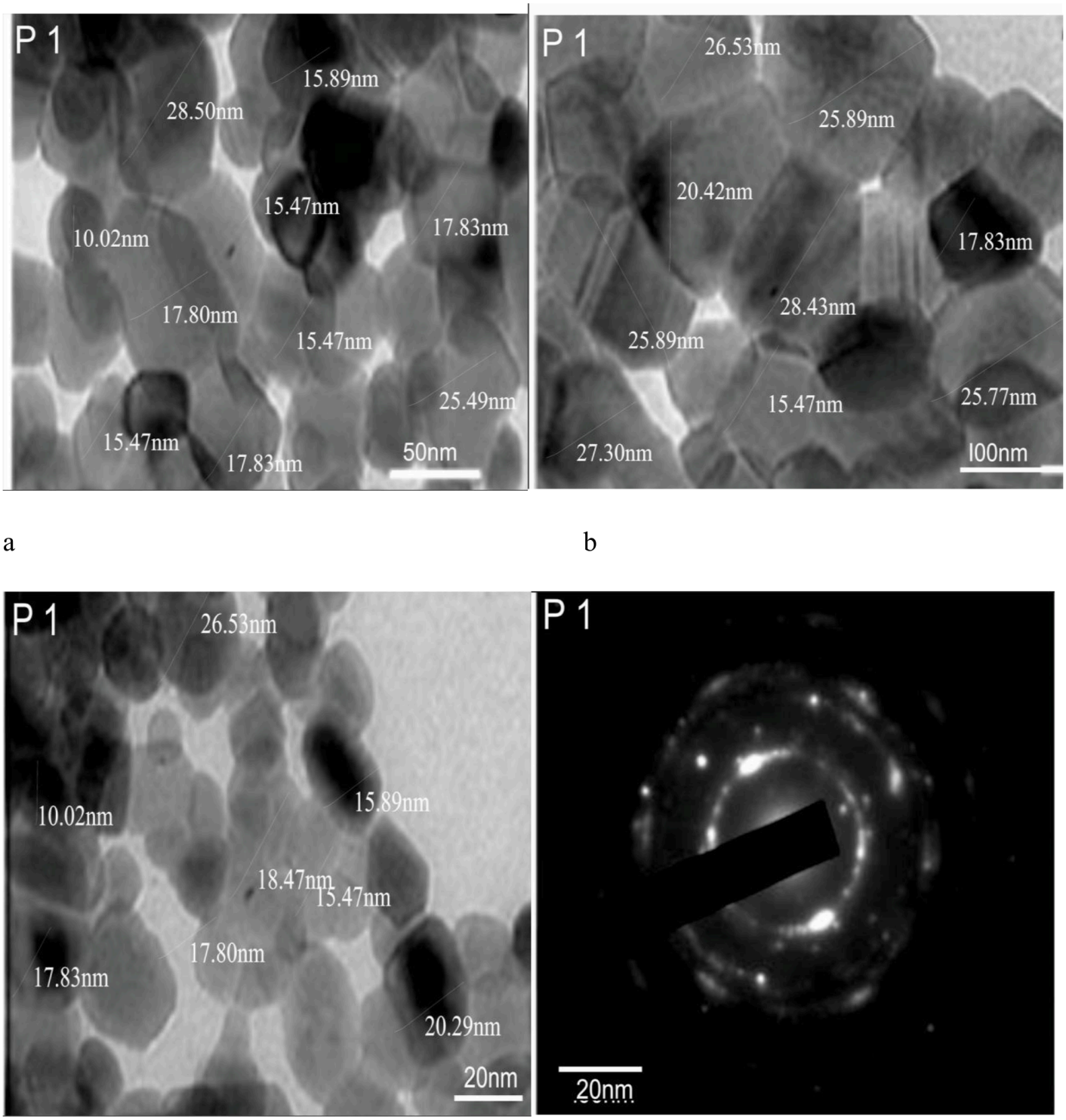


Figure 7

High-resolution transmission electron microscope (HRTEM) images showing Particle size at 50nm (7a), at 100nm (7b), at 20nm (7c), coupled with selected area electron diffraction (SAED) pattern of *Boswellia dalzielii*-mediated Fe_3O_4 NPs at 20nm (7d).