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Antibacterial Potential of *Cocos nucifera* Coir Extract and Green Synthesis of Silver Nanoparticles

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Abstract: Since ancient times, humans have used medicinal plants due to their therapeutic properties as the main source of drugs. Because plant extracts have various biological properties, such as anthelminthic, anti-inflammatory, antioxidant, antifungal, and antitumor. *Cocos nucifera*, which is commonly called the coconut tree, is a widespread plant across the world. Its easy availability makes it easy to use. The study aimed to evaluate the antibacterial activity of *Cocos nucifera* extract against bacterial pathogens and to test the phytochemicals using simple chemical qualitative tests. The acetone extract of *Cocos nucifera* coir was prepared using the Soxhlet method. The research showed that the extract contained Saponin, Tannin, Cardiac Glycosides and Flavonoids. The antibacterial assay revealed antibacterial activity in the plant extract, as it was effective against the test organisms. The extract showed the ability to produce silver nanoparticles. The synthesised silver nanoparticles were characterised using UV-visible spectroscopy, FTIR, and XRD. The presence of various phytochemicals in plants suggests their use in folk medicine. The antibacterial properties of the extract suggest it has a wide range of applications across diverse fields.

Keywords: *Antibacterial, Cocos nucifera, Phytochemical, Silver nanoparticles*

Conflicts of interest: None
Supporting agencies: None

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1. Introduction

Cocos nucifera belongs to the family Arecaceae. India contributes 50% of the world's coconut production, with coconut cultivated in over 97 countries (Kumar et al. 2021). The nutritional value of the coconut fruit is high. The coconut fruit consists of three parts: endosperm, endocarp, and Mesocarp. The hard, inner lignocellulose layer that forms a coconut shell is called the endocarp. Mesocarp is the tensile fibre-spongy shuck called coir.

Coconut coir is generated in large quantities as an agro-industrial waste during coconut processing, making its utilisation both economically viable and environmentally sustainable (Gomathi et al. 2019, Hasan et al.2021). Endosperm and endocarp are comparatively less suitable for the synthesis of silver nanoparticles. The endosperm is rich in sugar and has lower phenolic and tannin content, while the endocarp contains lignin, cellulose, and hemicellulose, which can be difficult to process and synthesise into nanoparticles. The aqueous extract of green coconut husk is rich in flavonoids, polyphenols, and other reducing agents, making it ideal for the synthesis of silver nanoparticles (Eker et al. 2025, Nkosi et al. 2024, Jadhav et al. 2024). Therefore, in this study, we used mesocarp for nanoparticle synthesis. Mesocarp and endocarp, which constitute 33–35% of the fruit, are dumped as agricultural waste after consumption of the nutrient-rich liquid from the coconut (Inbarajan et al. 2023). The mesocarp layer of the coconut fruit—also referred to as coir or coconut fibre—is a naturally occurring fibre that is taken from the coconut husk. It can be used in many different ways in construction, manufacturing, and agriculture. It can be used to make ropes, doormats, insulation, brushes, and fishing net string (Ignacio and Miguel 2021 and Henrietta et al. 2022).

The use of antibiotics has increased over the past few years in accordance with demand. Overuse of antibiotics has also led to antibiotic resistance and a shortage of treatment-related medicines. Although antibiotics are chemically modified to address the issue of resistance. These chemically altered antibiotics have adverse side effects in people. To solve this issue, the development of medicines must once again rely on plant-based medicine (Ngaffo et al. 2021). From 1200 to 900 BCE, the Atharva

Veda, a representation of ancient Hindu culture, discusses the use of plants as medicines. Every part of a plant has medicinal value. Apart from this, each plant contains different phytochemicals, such as saponins, alkaloids, and tannins, which help the body's defence against various diseases (Celenk et al. 2023). Plant bioactive substances and phenolic compounds support biological processes in plant cells, including antibacterial and antioxidant activities. So, different antibiotics are also prepared from plant source which have least side effects.

In addition to these characteristics, it allows to synthesize silver nanoparticle which has different application in various field. In recent years, there is a lot of interest in the green synthesis of AgNps because of there is an increasing need to create safe and uncontaminated materials. The process of synthesizing silver nanoparticles from agricultural waste has several applications because it is less harmful, less toxic, eco-friendly. The antimicrobial properties of silver makes it widely used in nanoparticle synthesis and these can be used in a wide range of fields like medicine, treatment of different diseases, cosmetics, biomedical devices, etc. (Islam et al. 2021, Nadaf et al. 2022). The silver nanoparticles also have insecticidal activity against dengue causing vector (Gomathi et al. 2019). Although *Cocos nucifera* has been widely utilized for various traditional, nutritional, and industrial purposes, its bioactive potential remains underexplored in several scientific areas. In particular, limited studies have focused on the phytochemical-mediated antibacterial mechanisms of coconut-derived extracts, especially the role of specific compounds such as tannins and flavonoids. Furthermore, the application of coconut husk extracts in emerging fields such as green synthesis of nanoparticles and novel antimicrobial formulations is still insufficiently investigated (Jadhav et al. 2024, Czerkas et al., 2024, Yan et al., 2024). Hence, the purpose of the present work is to analyse the phytochemical analysis, antibacterial activity and biosynthesis of silver nanoparticles from coconut coir extract. Characterization techniques such as UV-visible spectroscopy, XRD and Fourier-transform infrared spectroscopy (FT-IR) are widely employed to analyze synthesized silver nanoparticles (AgNps).

2. Materials and Method

2.1. Sample Collection

Coconut coir was collected in a container from a coconut seller near Jagruti Maruti Mandir, Solapur, Maharashtra and transported to the Microbiology laboratory, Punyashlok Ahilyadevi Holkar Solapur University, Solapur, Maharashtra, for further analysis.

2.2. Preparation of sample

The collected coconut coir was dried in the sunlight for 2 to 7 days to reduce its moisture content, then mashed into a powder. The powdered sample was subsequently subjected to extraction with acetone as the solvent.

2.3. Solvent extraction procedure

The Soxhlet extraction method was used to extract compounds from coconut coir. A 20 g sample of dried coconut coir powder was extracted with 200ml of acetone at 56°C for 7 hours. After the extraction, the residue was dried, weighed, and the percentage yield was calculated (Parvathy et al. 2020).

2.4. Test organisms

The clinical strains of *Staphylococcus aureus* (NCIM 5345), *Bacillus subtilis* (NCIM 2097), *Pseudomonas aeruginosa* (NCIM 5210) and *Proteus mirabilis* (NCIM 5296) were streaked on Nutrient agar (purchased from HiMedia) and incubated at 37°C for 24 hours.

2.5. Preliminary phytochemical analysis of coconut coir extracts

Detection of Carbohydrates

Benedict's test: The filtrate (0.5 ml) was mixed with 0.5 ml of Benedict's reagent and boiled. The development of a distinct color indicated the presence of carbohydrates.

Detection of Amino acids and proteins

The 10 ml of distilled water were used to dissolve 100 mg of the extract, and filtered through Whatman No. 1 filter paper. The amino acids, proteins present in the filtrate were then examined.

Ninhydrin test: Two ml of aqueous filtrate was mixed with two drops of ninhydrin solution. An appearance of purple colour confirms the presence of amino acids.

Detection of Saponins

Foam test: Extract (50 mg) was mixed in 20 ml of distilled water and shaken vigorously for fifteen minutes. The formation of a two-centimeter layer of foam at the top of the solution indicates the presence of saponins.

Detection of Tannins

Ferric chloride test: In 5ml of distilled water 50mg of extract was added and mixed with 2-3 drops of 5% ferric chloride. Tannins are indicated by a dark green colour.

Detection of flavonoids

Magnesium and hydrochloric acid reduction test

The extract (50 mg) was mixed with alcohol (5 ml), and then fragments of magnesium ribbon and concentrated hydrochloric acid were added. Flavonoids are indicated by a pink to crimson colour.

Detection of anthraquinones

In distilled water, 50mg of extract was dissolved, and then 1 ml of diluted ammonia solution was added to 2 ml of the extract, and the mixture was shaken vigorously. The presence of anthraquinones is indicated by the pink colour in the ammonia layer.

Detection of Cardiac Glycosides

Killer kiliani test: The 50mg extract was mixed in distilled water. The 2 ml of the filtrate was mixed with 1 ml of glacial acetic acid, ferric chloride and a drop of concentrated sulfuric acid. The presence of cardiac glycosides is indicated by a green-blue colour in the upper layer, a reddish-brown colour at the junction of the two layers (Kendeson et al. 2019, Gebila et al. 2020).

2.6. Determination of antibacterial activity of *Cocos nucifera* extract

The antibacterial study of the extract was determined using the agar well diffusion method. *Staphylococcus aureus* (NCIM 5345), *Bacillus subtilis* (NCIM 2097), *Pseudomonas aeruginosa* (NCIM 5210), and *Proteus mirabilis* (NCIM 5296) were used to determine the antibacterial potency of the prepared extract. Muller-Hinton agar media plates were covered with 0.1 mL of the corresponding bacterial suspension. A sterile stainless-steel cork borer was used to create wells under aseptic conditions. Coconut coir extract and controls were added to their respective wells. The plates were incubated at 37°C for 24 hrs. After incubation clear zone of inhibition in mm was measured. All experiments were performed in triplicate. (Temikotan et al. 2021, Karseno et al. 2023, Saklani et al. 2025).

2.7. Resistance of bacterial pathogens

Resistance of test organisms was checked by using the Hexa universal poly disc of antibiotics. Spread a 0.1 ml suspension of *Staphylococcus aureus* (NCIM 5345), *Bacillus subtilis* (NCIM 2097), *Pseudomonas aeruginosa* (NCIM 5210) and *Proteus mirabilis* (NCIM 5296) on nutrient agar plates, which were adjusted to a 0.5 McFarland standard and then incubated the plates at 37°C for 24 hrs. After incubation, the resistance of bacterial pathogens against a particular antibiotic was determined by measuring the zone of inhibition in mm.

2.8. Synthesis of Silver Nanoparticles by using coconut coir extracts (AgNPs)

A significant amount of prepared extract was dissolved in 1ml of acetone, and the mixture was subsequently added to a conical flask containing 10ml of 1 mM $AgNO_3$. The mixture was agitated for 2 min, and the flask was kept in the dark for 3days. The conical flask was examined over 3 days, and it showed a colour change from light brown to dark brown. The solution was then centrifuged at 10,000 rpm for 10 minutes, and the pellet was collected, dried, and stored in tubes for further use (Sinsinwar et al. 2018 and Rizwana et al. 2023).

2.9. Characterisation of Silver Nanoparticles (AgNPs)

Characterisation of synthesised silver nanoparticles was carried out using visual observation and techniques such as UV-visible spectroscopy, FT-IR, and XRD. To confirm the formation of Ag-NPs, the absorbance was measured using a UV-Visible spectrometer over the wavelength range of 300–700 nm. To determine the presence of a functional group, FT-IR spectroscopy was performed. Further characterisation of nanoparticles was made by X-ray diffraction pattern using an X-ray diffractometer to determine crystallinity, purity, etc. (Das et al. 2021, Nahar et al. 2020 and Jadhav et al. 2024)

3. Results

3.1. Percentage yield of coconut coir

Coconut coir extract obtained in acetone was weighed, and the percentage yield of the prepared extract is shown in Table 1. Five grams of acetone-based coconut coir extract were obtained, resulting in a 25% acetone extract yield.

Table 1. Percentage yield of coconut coir

Sample used	Solvent used (200 ml)	Amount of sample (g)	Amount of extract (g)	Percentage yield(%)
Coconut coir powder	Acetone	20	5	25

3.2. Physical characteristics of extracts

Table 2 shows that the acetone extract of *Cocos nucifera* exhibited a sticky consistency, a dark brown colour, and a phenolic odour.

Table 2. Physical characteristics of the extract of *Cocos nucifera* in acetone

Physical character	Solvent used (Acetone)
Colour	Dark brown
Consistency	Sticky
Odour	Phenolic

3.3. Preliminary phytochemical screening

The acetone extract of *Cocos nucifera* coir revealed the presence of saponin, tannin, glycosides and flavonoids, whereas proteins, carbohydrates and anthraquinone are absent (Table 3). The production of a variety of secondary metabolites by *Cocos nucifera* is known to have unique biological activities. So, *Cocos nucifera* coir preparations have been utilised for many remedies in traditional medicine.

Table 3. Preliminary phytochemical study of acetone extract of coconut coir

Sr. no.	Phytochemical	Name of the Test	Acetone extract
1.	Proteins	Ninhydrin test	-
2.	Saponin	Foam test	+
3.	Tannin	Ferric chloride test	+
4.	Anthraquinone	Ammonia test	-
5.	Cardiac Glycosides	Killer kiliani test	+
6.	Flavonoids	Magnesium and hydrochloric acid reduction test	+
7.	Carbohydrates	Benedict's test	-

3.4. Determination of antibacterial activity

Table 4 shows a comparative study of the antibacterial activity of Coconut coir extract and standard antibiotics against bacterial pathogens. The acetone extract showed the highest zone of inhibition against *Bacillus subtilis*, followed by *Staphylococcus aureus*. In contrast, the acetone shell extract exhibited the smallest inhibitory zone against *Pseudomonas aeruginosa* (Fig. 1). The results revealed that the extract showed activity against both Gram-positive and Gram-negative organisms, which correlates with the work carried out by Rusdi et al. (2019). Compared to standard antibiotics, namely Tetracycline, Ampicillin, Chloramphenicol, Kanamycin, Streptomycin and Penicillin (Table 4), the extract of Coconut coir showed potent antibacterial activity against Gram-positive organisms, namely *Bacillus subtilis* and *Staphylococcus aureus*, while moderate activity against Gram-negative organisms, namely *Proteus mirabilis* and *Pseudomonas aeruginosa* (Fig. 2).

Table 4. Comparative study of antibacterial activity of coconut coir extract and standard antibiotics against bacterial pathogens

Test organisms	**Diameter of zone of inhibition (in mm)**						
	Tetracycline	**Ampicillin**	**Chloramphenicol**	**Streptomycin**	**Kanamycin**	**Penicillin**	**Coconut coir extract**
S.aureus (NCIM 5345)	20	0	19	21	18	19	20
P.mirabilis (NCIM 5296)	15	24	22	23	21	27	17
B. subtilis (NCIM 2097)	15	12	25	25	11	18	27

P.aeruginosa (NCIM 5210)	15	13	9	23	0	27	16

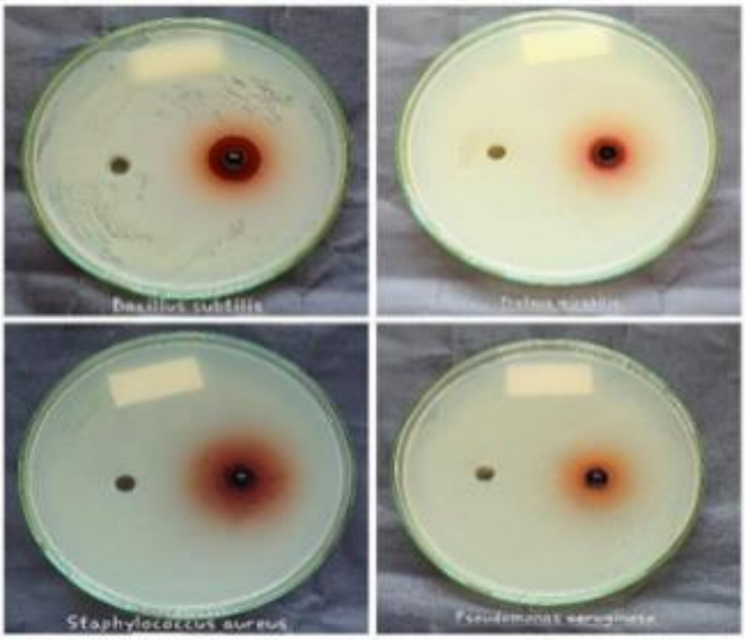


Figure 1. Antibacterial activity of coconut coir extract against test organisms

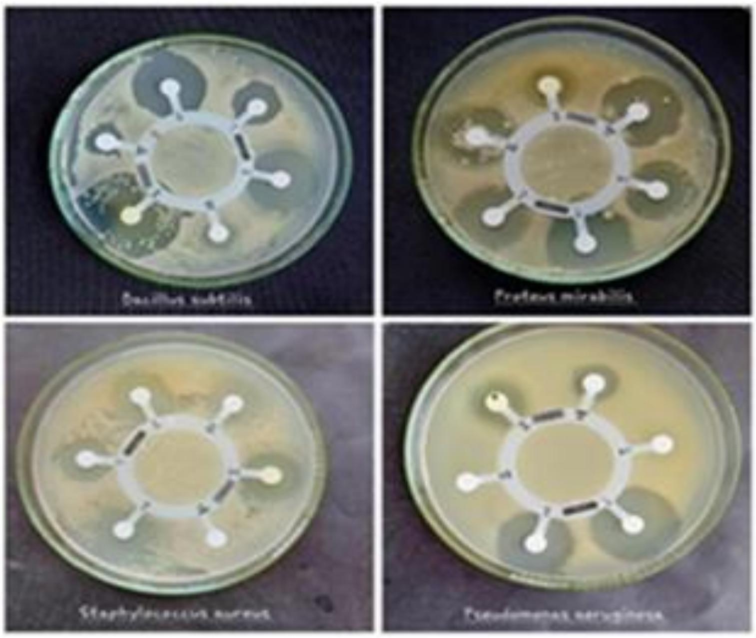
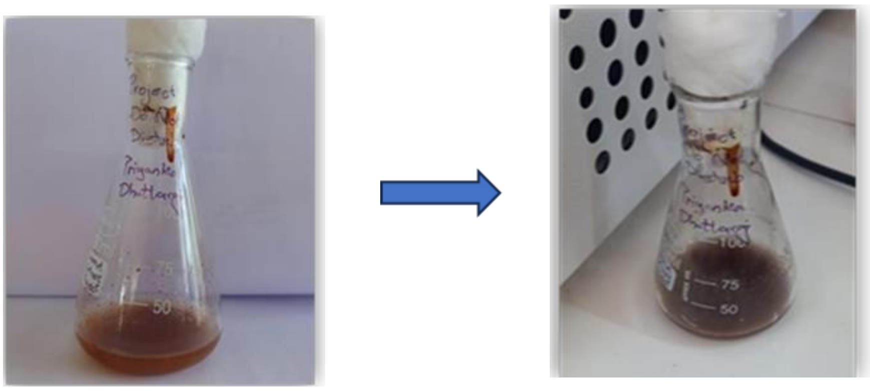


Figure 2. Antibacterial activity of hexa polydisc antibiotics against test organisms

3.5. Synthesis of $AgNO_3$

The green-synthesised AgNPs turned dark brown, indicating the successful synthesis of silver nanoparticles (Fig. 3).



a. Before the addition of $AgNO_3$ b. After the addition of $AgNO_3$

Figure 3. Synthesis of Silver nanoparticles

3.6. Characterisation of Silver Nanoparticles (AgNPs)

3.6.1. UV-vis–spectrophotometer

The optical absorption spectrum of green-synthesised silver nanoparticles (AgNPs) exhibited a prominent peak at 421 nm, as determined by UV-vis–NIR spectrophotometry, confirming the presence of AgNPs. The formation of a colloidal dark brown suspension in the reaction mixture of $AgNO_3$ and coconut coir extract provided a clear visual indication of nanoparticle synthesis. The sharp and narrow surface plasmon resonance (SPR) peak observed at 421 nm (Fig. 4) further corroborates the successful formation of AgNPs (Biswas et al. 2020).

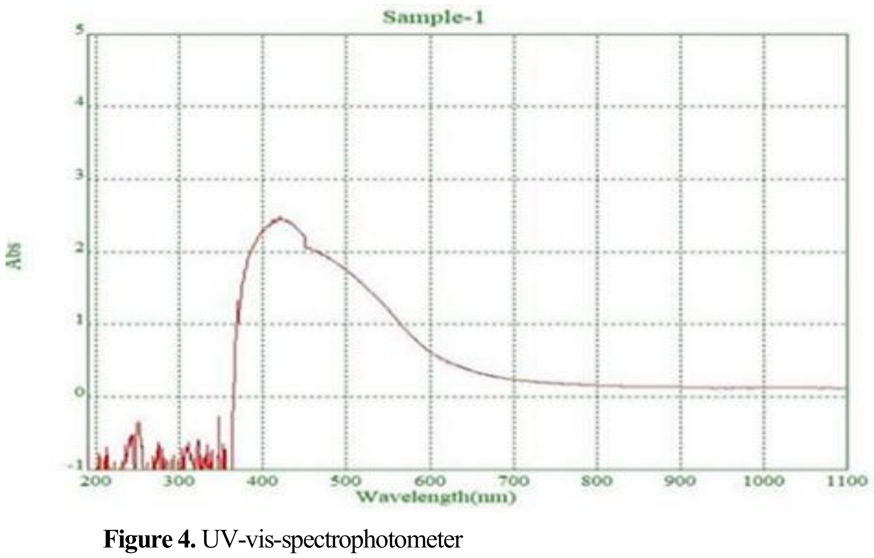


Figure 4. UV-vis-spectrophotometer

3.6.2. FTIR Spectroscopy

The functional groups involved in the reduction (Phenolic and carbonyl groups) and stabilization (e.g., proteins and carbohydrates) of AgNPs was determined by using FTIR spectroscopy which was taken in the range of 500-3500 cm^{-1} (Fig.5). From FTIR it concludes that peak present at 3400 cm^{-1} shows that existence of O-H, N-H stretching indicating presence of hydrogen-bonded hydroxyl groups, possibly from phenolic compounds, flavonoids, or water molecules associated with the plant extract. The peaks at 2923.87 and 2852.84 cm^{-1} reflect the presence of C-H stretching, which is of aliphatic C–H bonds, likely from long-chain hydrocarbons or fatty acids in the *Cocos nucifera* extract. The absorption peak at 1711.63 cm^{-1} is connected with the stretching vibration of −C = O. Stretching vibration at 1608.40 cm^{-1} indicates the presence of C=C stretching (alkenes) or amide (C=O stretching coupled with N–H bending in proteins). The peak at 1383.89 cm^{-1} is associated with C–H bending (methyl groups), commonly associated with the bending vibrations of CH_3 or CH_2 groups. Furthermore, peaks at 1035.89 cm^{-1}, 1115.70 cm^{-1}, 1167.09 cm^{-1}, and 1009.60 cm^{-1} are commonly associated with C–O stretching from alcohols, esters, or ethers. These peaks may be attributed to alcohols, phenols, or ethers in the capping agents derived from the extract. The peak at 468.36 cm^{-1} is the most significant, indicating the presence of silver metal along with biomolecules (Uddin et.al.,2020).

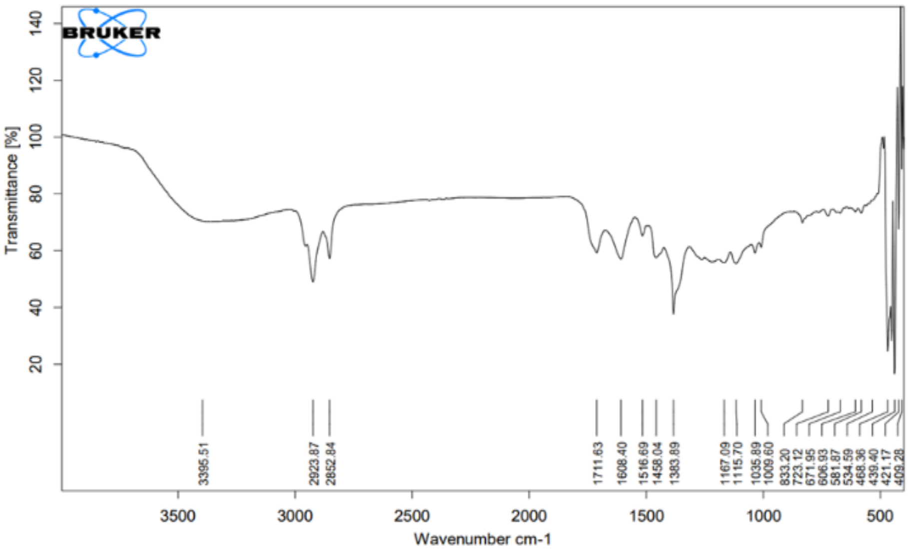


Figure 5. FTIR spectroscopy

3.6.3. XRD Analysis

The phase purity of the prepared silver nanoparticles was confirmed by XRD pattern. Fig. 6 shows the XRD pattern of the silver nanoparticles, with sharp, intense peaks indicating crystallinity. The peaks obtained at 2θ values of 38.22°, 44.43°, 64.40°, and 77.50°, indexed to the (111), (200), (220), and (311) planes, indicate that silver nanoparticles were successfully synthesised using *C. nucifera* extract. Three unidentified peaks at 27.77°, 46.19°, and 32.24° were observed, which are due to biomolecules present in *Cocos nucifera* (Roopan et al., 2013).

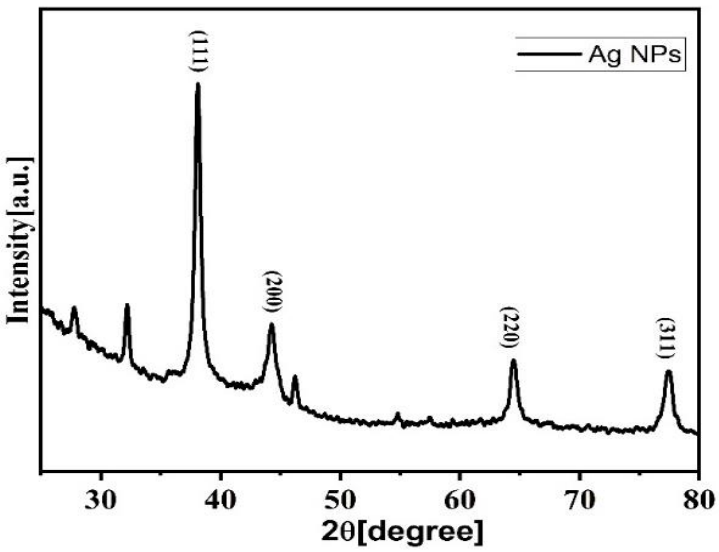


Figure 6. XRD Analysis

4. Discussion

This study investigated the phytochemical analysis, nanoparticle synthesis, and antibacterial properties of the extract and silver nanoparticles obtained from coconut coir. Plant extracts have the potential to yield new antimicrobial compounds, particularly those that inhibit bacterial infections (Temikotan et al. 2021). Phytochemical study showed that the plant contains saponin, tannin, cardiac glycosides and flavonoids, whereas proteins, anthraquinone and carbohydrates were absent. Several authors observed the presence of flavonoids, alkaloids, proteins, tannins, and cardiac glycosides in coconut husk, which are similar to some of the phytochemicals found in this research. The presence of phytochemicals holds great promise for pharmacological applications due to their diverse biological activities and therapeutic potential. In addition, these phytochemicals are also responsible for the plant's pigmentation, flavour, and disease resistance. They play a crucial role in plant defence and ecological interactions and have attracted significant attention due to their antioxidant, anti-inflammatory, antimicrobial, and anticancer activities (Akhter et al. 2025). The presence of saponins enhances immune function and reduces cholesterol; tannins offer antioxidant and antimicrobial effects; and cardiac glycosides regulate heart function and treat heart diseases, while flavonoids protect against oxidative stress, inflammation, and chronic diseases. Flavonoids are known to exert antibacterial effects through multiple mechanisms, including disruption of bacterial cell membrane integrity, inhibition of nucleic acid synthesis, and interference with energy metabolism. These actions ultimately lead to the leakage of cellular contents and the suppression of bacterial growth (Yan et al., 2024). Czerkas et al. (2024) also reported that tannins can bind to bacterial surface proteins and enzymes, thereby inhibiting essential metabolic processes and suppressing bacterial growth. This study explored the synthesis of silver nanoparticles using coconut coir extract, suggesting their potential applications across various fields. The prepared silver nanoparticles were confirmed by using UV-Vis spectroscopy, XRD, and FTIR analysis. The optical absorption spectrum of green-synthesised silver nanoparticles (AgNPs) from coconut coir, obtained via UV-Vis spectroscopy, exhibited a prominent peak at 421 nm (Biswas et al. 2020). Similarly, Liu et al. (2018) synthesised silver nanoparticles using the aqueous extract of rice husk and obtained peaks at 445–450 nm in UV–Vis Spectra. The present study showed XRD peaks at 2θ values of 38.22°, 44.43°, 46.19°, 64.40°, and 77.50°, which were indexed to the (111), (200), (220), and (311) planes. Likewise, the findings of the present study are consistent with earlier research, as reported by Thenmozhi et al. (2025), who synthesised and characterised silver nanoparticles using agro-waste derived from *Paspalum scrobiculatum* husk. FTIR analysis revealed O-H, N-H, C-H, and −C=O stretching vibrations. These results confirm that silver nanoparticles were successfully synthesised using *C. nucifera* extract (Uddin et al. 2020, Roopan et al. 2013).

5. Conclusion

Cocos nucifera exhibits noteworthy inhibitory activity against harmful pathogens, indicating the presence of highly effective antimicrobial compounds. Preliminary phytochemical analysis exhibited the presence of saponins, tannins, flavonoids and cardiac glycosides. The extract exhibited potent antibacterial activity. The observed antibacterial profile of *Cocos nucifera* coir extracts against the test bacteria supports the use of the plant in folk medicine. It also revealed that it can synthesise silver nanoparticles, which can be used to further enhance antimicrobial activity. These nanoparticles may have promising applications in various fields, such as cosmetics, the beverage and food industries, the pharmaceutical and agricultural sectors, etc.

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