Phyto-Mediated Synthesis of Palladium Nanoparticles Using Solanum Xanthocarpum Fruit and their Antibiofilm Assay

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**Abstract:** *Solanum Xanthocarpum* which is a perennial shrub has endless medicinal values. It is widely being used in treating various diseases like Psoriasis, cancer, diabetes. It has good anti- inflammatory, anti- carcinogenic activity, used as an immunosuppressive agent and excellent wound healing. Green synthesized palladium nanoparticles impart anti- microbial activity against MDR pathogens. The aim of the present study is phyto mediated synthesis of palladium nanoparticles from *Solanum xanthocarpum* and to check for their antibiofilm assay of *S. mutans* and *C. albicans*. *Solanum xanthocarpum* was chosen for our study. In the present study, at the lowest concentrations of the NPs there is a high inhibitory effect on the pathogens; particularly, *S. mutans* have a high inhibitory effect compared to *C. albicans*. FTIR analysis revealed the presence of polysaccharides and diketones which is an indication of good antimicrobial activity. Within the limits of the study, it can be concluded thatPd Nps synthesized from *S. xanthocarpum* have high inhibitory effect at low concentrations and are effective against biofilm formation.

**Keywords:** Palladium nanoparticles, Solanum xanthocarpum, FTIR, SEM, antibiofilm assay

# Introduction

Nanoparticles, which usually measure around one to one hundred nanometers in diameter usually exhibit features according to their size. They have varied applications in medicine, the food industry, agriculture industry, etc. Among them in the medical field, they are being widely researched for drug delivery, diagnostic purpose, tissue engineering and anti- microbial activity. It can be synthesized from herbal plant products which is an advantage over synthetic preparation [(Ao et al., 2023)](https://paperpile.com/c/VcHMG5/8K6D). [(Harsha & Subramanian, 2022)](https://paperpile.com/c/VcHMG5/dYaCT) [(Deepika et al., 2022)](https://paperpile.com/c/VcHMG5/VKxs)

Many nanoparticles are available like Ag, gold, platinum, palladium, zinc, etc and it is also proved that these nanoparticles have good anti-microbial, anti-inflammatory, anti-carcinogenic activities, among them phyto mediated synthesis of palladium nanoparticles from *Solanum Xanthocarpum* to evaluate their anti-microbial activity [(Govindaraj & Dinesh, 2021)](https://paperpile.com/c/VcHMG5/iIHoP). Palladium nanoparticles are so far used in combination with polymers as microgels in biological and environmental remediation and as a catalyst [(Arif, 2023)](https://paperpile.com/c/VcHMG5/NiZV6)[(Ajay, Sasikala, et al., 2022)](https://paperpile.com/c/VcHMG5/tCY7q). In this study palladium nanoparticles are used for antimicrobial assay [(Chidambaram et al., 2022)](https://paperpile.com/c/VcHMG5/NTDe).. In general nanoparticles impart antibiofilm assay by means of generation of ROS, EPS destruction, inhibition of quorum sensing etc [(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/VcHMG5/dcan) .

*Solanum Xanthocarpum* which is a perennial shrub has endless medicinal values. It is widely being used in treating various diseases like Psoriasis, cancer, diabetes. It has good anti- inflammatory, anti- carcinogenic activity, used as an immunosuppressive agent and excellent wound healing [(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/VcHMG5/dcan)[(Sahu et al., 2023)](https://paperpile.com/c/VcHMG5/qQUrw). Silver nanoparticles are being synthesized from *Solanum xanthocarpum* to evaluate the anti- microbial activity in previous studies [(Pungle et al., 2023)](https://paperpile.com/c/VcHMG5/nyEWF), but in this study palladium is synthesized to evaluate anti-biofilm assay. Green synthesized palladium nanoparticles impart anti- microbial activity against MDR and cancer cells [(Jabin et al., 2021)](https://paperpile.com/c/VcHMG5/WkKN1) [(Sonbol et al., 2021)](https://paperpile.com/c/VcHMG5/2no8V). It is used as a catalyst for degradation of methylene blue, methyl orange and rhodamine B by sodium borohydride [(Katyal et al., 2021)](https://paperpile.com/c/VcHMG5/IbeRa) [(Karthik et al., 2019)](https://paperpile.com/c/VcHMG5/wVyaM). It also has good anti- microbial activity, anti- oxidant and anti- diabetic activity [(Saquib et al., 2020)](https://paperpile.com/c/VcHMG5/1nkfP). Biogenetically synthesized palladium nanoparticles are used for degradation of textile dye pollutants as a photocatalyst [(Ajay, Suma, et al., 2022)](https://paperpile.com/c/VcHMG5/FMWza) [(Liang et al., 2022)](https://paperpile.com/c/VcHMG5/h9zX1). So far palladium nanoparticles are extracted from *Solanum nigrum, Solanum trilobatum, Prunus yedoyenesis,* etc and their antimicrobial, anti-oxidant, anti-diabetic and numerous activities were explored [(Solanki et al., 2022)](https://paperpile.com/c/VcHMG5/ohk3). But in this study, palladium nanoparticles synthesized from *Solanum xanthocarpum* are explored for its anti biofilm formation. The aim of the present study is phyto mediated synthesis of palladium nanoparticles from *Solanum xanthocarpum* and to check for their antibiofilm assay of *S. mutans* and *C. albicans* [*(Ajay, Rakshagan, et al., 2022)*](https://paperpile.com/c/VcHMG5/Eidu).

# Materials and methods

*Solanum xanthocarpum* was chosen for our study. It was collected from a nearby organic store and processed accordingly.

## Preparation of fruit extract and synthesis of palladium nanoparticles

The *Solanum xanthocarpum* fruits were thoroughly washed to eliminate all the impurities and dried in sunlight to remove the moisture. In a beaker 25 g of cut and dried fruits were taken with 100 ml of distilled water. It is now boiled at 60 degree celsius using a heating mantle, cooled down and filtered using whatman no. 1 filter paper and the extract was stored for further use.Palladium nanoparticles (Pdcl2) dissolved in 90 ml of distilled water. To that 10 ml of *S. xanthocarpum*  aqueous extract was slowly added. Then, the reaction mixture was kept on a magnetic stirrer at 400 rpm for 2 hours at 60 degree celsius.

## Fourier transform infrared spectroscopy (FTIR)

FTIR was used to determine the functional group of the synthesized palladium nanoparticles which was compared to aqueous extract of *S. xanthocarpum*. To make the pellet, the synthesized samples were assorted by potassium bromide followed by scanning in between 400 and 400 cm-1.

## Scanning electron microscope (SEM)

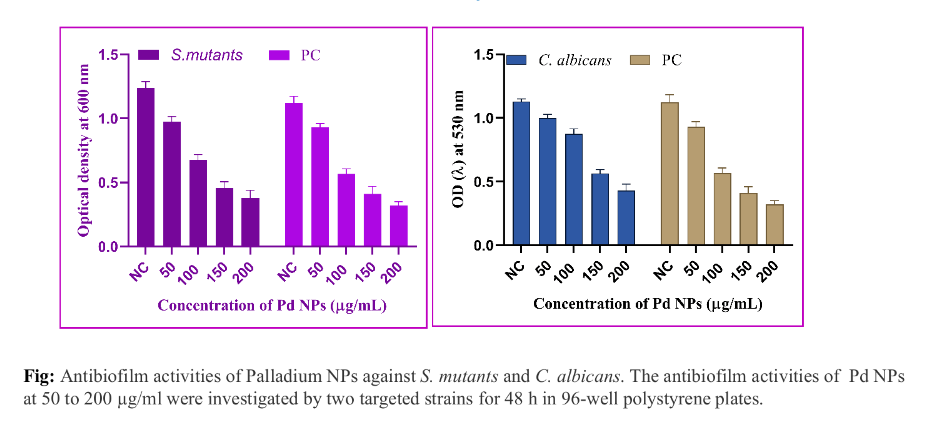
Further verification of dimension and crystal-like nature of palladium nanoparticles using a SEM configuration showed the existence of palladium metal material.

## Antibiofilm assay

A 96-microtiter well plate was used to conduct a quantitative investigation on biofilm development (Basumatari et al., 2021). Freshly grown bacteria were added to Brain Heart Infusion (BHI) broth and the mixture was then incubated for 72 h at 37 ºC. The cell suspensions were diluted at a ratio of 1:100 in the freshly made BHI broth medium after 24 h (Chehelgerdi et al., 2023). Bacterial cells that were not exposed to Pd NPs were regarded as the positive control. Pd NPs were also added to the treated bacterial cultures at a concentration ranging from 25, 50, 75 to 100 µg/mL. The sterile BHI broth medium remained empty (Saadh et al., 2024). Then, 200 µL culture suspensions with and without Pd NPs treatment were added to the sterilised 96-well microplates, which were then incubated for a further 24 h at 37 ºC without shaking. Three replicates of each bacterial suspension were stored. By rotating the plates over, all of the treated and untreated cells in the microtiter wells were discarded. Free-floating cells and undesirable material were then removed by washing the plates three times in phosphate buffered saline (PBS, pH 7.2).

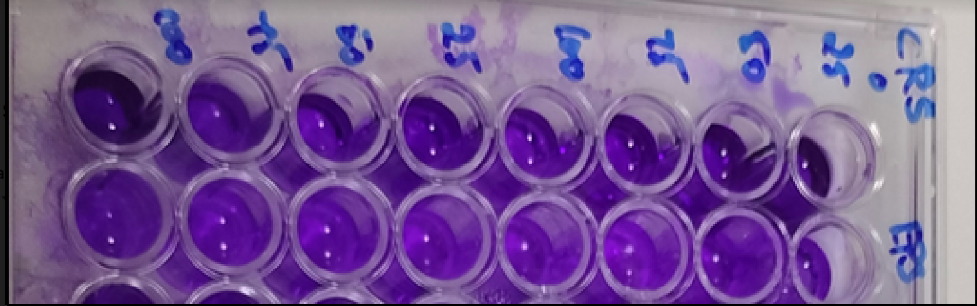
# Results

Fig. 1 represents the antibiofilm activities of pd Nps against *S. mutans* and *C. albicans.* The antibiofilm activities of Pd Nps at 50 to 200μg/ ml were investigated by two targeted strains for 48 hours in 96- well polystyrene plates. At the lowest concentration of the Nps there is high inhibitory effect on the pathogen, particularly *S. mutans* have high inhibitory effect compared to *C. albicans.* Fig. 2 represents the antibiofilm activity with crystal violet staining applied to *S. mutans*.

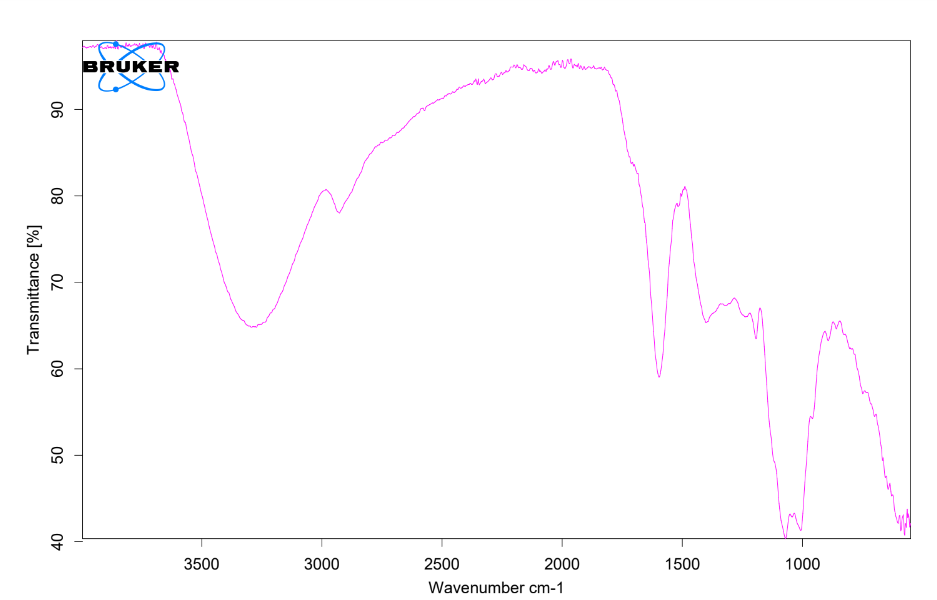
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1. (b)

**Fig. 1.** Antibiofilm activities of Palladium NPs against *S. mutans* and *C. albicans*. The antibiofilm activities of Pd NPs at 50 to 200μg/ mL were investigated by two targeted strains for 48h in 96 well polystyrene plates.

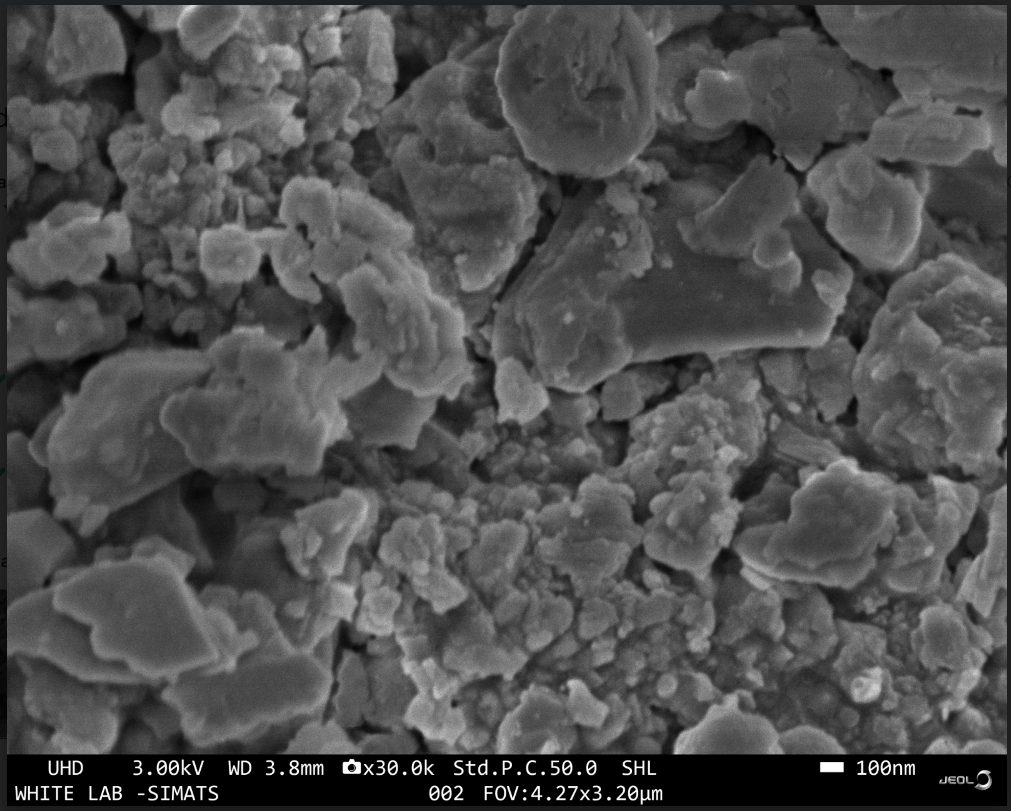
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**Fig. 2.** Antibiofilm activity with crystal violet staining applied to *S. mutans.*

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**Fig. 3.** FTIR spectral study of biosynthesized palladium nanoparticles.

The FTIR spectral study of biosynthesized palladium nanoparticles. It revealed a total of many peaks with the most influential peaks at 1000 cm-1, 1100 cm-1 and 1600 cm-1. These absorption bands correspond to stretching vibrations of amines, aliphatic groups, carboxylic acids, amides and proteins.



**Fig. 4.** SEM image of synthesized Palladium nanoparticles.

The shape, size distribution, and surface properties of produced palladium nanoparticles are shown by the SEM picture. Usually ranging in size from a few nanometers to tens of nanometers, the nanoparticles appear as round or irregular formations that are either well-dispersed or somewhat aggregated. Their homogeneity and crystallinity, which are crucial for catalytic and electrical applications, may be shown by high-resolution imaging.

# Discussion

Antibiofilm activity evaluation is a much required study in dentistry, Since it pays way for many oral associated diseases such as periodontitis and caries formation[(Graf et al., 2023)](https://paperpile.com/c/VcHMG5/TsJ6S). Pharmacological management in prevention of biofilm is less harmful and less time consuming and a painless treatment for patients that could help the health care professionals to choose an alternate for the invasive procedures and the people with comorbidities and many contraindications to dental treatment exposure will get it done easily with no side effects since these nanoparticles are synthesized from herbal ingredients[(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/VcHMG5/XORx3)[(Sushanthi et al., 2021)](https://paperpile.com/c/VcHMG5/KyWMK)[(Harsha et al., 2022)](https://paperpile.com/c/VcHMG5/LXBr1)[(Neha et al., 2021)](https://paperpile.com/c/VcHMG5/cP6dK)[(Maliael et al., 2021)](https://paperpile.com/c/VcHMG5/Jgp9B)[(Lakshmi, 2021)](https://paperpile.com/c/VcHMG5/mjlmW)[(Dharman et al., 2021)](https://paperpile.com/c/VcHMG5/UJFhZ). Many studies evaluated different nanoparticles extracted from different herbal ingredients [(Cheng et al., 2016)](https://paperpile.com/c/VcHMG5/4AieJ) [(Al-Fakeh et al., 2021)](https://paperpile.com/c/VcHMG5/jKMuR).

Rohini et al in their study extracted silver Nps from *S. xanthocarpum* and evaluated them for their antimicrobial activity against MDR. Multi drug resistant organisms are really posing a great threat to mankind and pharmacotherapy for the MDR is really a difficult work. Pharmacotherapy for MDR with least side effects is like a great innovation. Aminophenyl acetic acid, clomipramine, and fonisopril metabolites present in the extract were found to be the principal elements for their antimicrobial activity [(Pungle et al., 2023)](https://paperpile.com/c/VcHMG5/nyEWF). Sumaira et al in their study concluded that Ag Nps extracted from *S. xanthocarpum* has varied biomedical applications [(Saquib et al., 2020)](https://paperpile.com/c/VcHMG5/1nkfP) like food industry, textile and organic fabrics, genetic engineering etc. Amin et al in their study extracted silver Nps from *S. xanthocarpum* were successfully able to prove its urease inhibitory activity against *H. pylori.* This organism is chiefly responsible for causing colon cancer and this is at the trend. Anti- bacterial activity against this particular micro- organism is specific drug therapy which doesn't harm the gut flora [(Kanchi & Ahmed, 2018)](https://paperpile.com/c/VcHMG5/AmHo7).Palladium Nps are not only synthesized from *S. xanthocarpum* but also from many leaf and fruit extracts. Prakash kumar et al in their study proved that biocompatible neem coated palladium nanoparticles showed excellent antimicrobial and anticancer properties [(Murthy, 2022)](https://paperpile.com/c/VcHMG5/rYbHL). Hazrika et al in their study proved that at the lowest concentration there is increased antimicrobial activity of palladium nanoparticles synthesized from GarciniapedunculataRoxb[(Liang et al., 2022)](https://paperpile.com/c/VcHMG5/h9zX1). Hana et al in their study concluded that Pd Nps extracted from *Padina boryana* showed antimicrobial activity against MDR pathogens and breast cancer cells[(Sonbol et al., 2021)](https://paperpile.com/c/VcHMG5/2no8V).

In the present study, at the lowest concentrations of the Nps there is high inhibitory effect on the pathogens particularly, *S. mutans* have high inhibitory effect compared to *C. albicans*. FTIR analysis revealed the presence of polysaccharides and diketones which is an indication of good antimicrobial activity.

# Conclusion

Within the limits of the study, it can be concluded thatPd Nps synthesized from *S. xanthocarpum* have high inhibitory effect at low concentration and are effective against biofilm formation. This study is a more cost effective and eco friendly research study. Pd Nps characterization is done by many characterization techniques such as SEM, FTIR and anti- biofilm activity. According to this research, *S. xanthocarpum* can be incorporated in dental products to reduce biofilm formation.

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