Development and Characterisation Of Morinda Citrifolia Coupled Hydroxyapatite Nano Particle as an Anticariogenic and Remineralising Agent – FTIR EDX and SEM Analysis

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**Abstract:** To evaluate and assess the development and characteristics of *Morinda citrifolia* coupled hydroxyapatite nanoparticle as an anticariogenic agent. Fresh *Morinda citrifolia* (Noni) fruit was dried and ground into a fine powder, yielding 5g of *M. citrifolia* powder for further analysis. Simultaneously, 5g of hydroxyapatite (HAP) was synthesized using the wet chemical precipitation method. The obtained HAP was finely ground using a mortar and pestle to achieve uniform particle size. To characterize the synthesized HAP nanoparticles, Scanning Electron Microscopy (SEM) was performed to analyze their morphology and structural features, while Energy Dispersive X-ray Spectroscopy (EDX) was used to determine the elemental composition and confirm the presence of hydroxyapatite. After Completion of HAP is coupled with *Morinda citrifolia* and sent for FTIR for detection of the functional groups to determine the constituents present in the given extract. Finally *Streptococcus mutans* and *Lactobacillus* broth were prepared and sent for PCR analysis and compared with control and HAP+Morinda samples. From the FTIR there is strong adhesion between *Morinda citrifolia* and hydroxyapatite nanoparticles.From this EDX result it provides the chemical composition of your *Morinda citrifolia*-coupled hydroxyapatite nanoparticles.From the SEM results, we can see the strong physical characteristics of your *Morinda citrifolia*-coupled hydroxyapatite nanoparticles. Real-time PCR analysis reveals a fold change indicating a decrease in the nucleic acid expression of *Lactobacillus* and *Streptococcus mutans* after treatment with *Morinda citrifolia*-coupled hydroxyapatite nanoparticles. In conclusion,our study demonstrates strong adhesion between Morinda citrifolia and hydroxyapatite nanoparticles, confirmed by FTIR and EDX analyses. SEM results reveal robust physical characteristics, highlighting their potential as effective biomaterials. Notably, real-time PCR analysis indicates a significant reduction in nucleic acid expression of *Lactobacillus* and *S. mutans* after treatment, suggesting antimicrobial properties. Overall, *Morinda citrifolia*-coupled hydroxyapatite nanoparticles show promise for dental and biomedical applications, warranting further investigation into their mechanisms and clinical potential.

**Keywords:** Dental Caries; [Hydroxyapatites](https://www.ncbi.nlm.nih.gov/mesh/68006882) ;Morinda citrifolia ; Nanobiotechnology ;Tooth Remineralization

# INTRODUCTION

Nanobiotechnology utilizes biological materials to create nanoparticles with unique properties. These tiny particles,smaller than 100 nanometers, have various applications across different fields[(Subramani & Ahmed, 2019)](https://paperpile.com/c/aHCPcX/TfoXU). Compared to traditional chemical and physical methods, nanobiotechnology offers a more sustainable and cost-effective approach to nanoparticle synthesis[(Venditti, 2020)](https://paperpile.com/c/aHCPcX/vLFqc).Nanotechnology has emerged as a vital asset in dentistry, especially in endodontics[(Ganapathy et al.,2021)](https://paperpile.com/c/aHCPcX/NPZCV). Nanoparticles play a crucial role in tissue regeneration, drug delivery, and antimicrobial treatments, contributing to improved oral health by effectively eliminating biofilms and bacteria[(Kumar Singh et al., 2025)](https://paperpile.com/c/aHCPcX/0iua)[(Krishnan et al., 2024)](https://paperpile.com/c/aHCPcX/8EfR).

Dental caries, a prevalent oral health issue characterized by the demineralization of tooth enamel, remains a significant global health concern[(Al-Dulaijan et al., 2018)](https://paperpile.com/c/aHCPcX/xSE0R)[(Karobari et al., 2022)](https://paperpile.com/c/aHCPcX/XW71). Despite advancements in dental care, the search for effective and sustainable preventive strategies continues[(Alania et al., 2019)](https://paperpile.com/c/aHCPcX/YXnbA). Natural compounds and nanomaterials have emerged as promising avenues in this regard[(Aljabo et al., 2015)](https://paperpile.com/c/aHCPcX/VMuJo).

Plants provide a simpler and more efficient method for producing nanoparticles compared to using microbial cells[(M. S. Hameed et al., 2024)](https://paperpile.com/c/aHCPcX/3GHA). Unlike microbial methods, plant-based nanoparticle synthesis doesn't involve complex processes like intracellular synthesis and multiple purification steps[(Koul et al., 2021)](https://paperpile.com/c/aHCPcX/6pIly).

*Morinda citrifolia*, commonly known as Indian mulberry, is a tropical plant with a rich history of traditional medicinal use[(Adel et al., 2023)](https://paperpile.com/c/aHCPcX/bFe75). It contains a variety of bioactive compounds, including anthraquinones, iridoids, and terpenoids, which have been reported to possess antibacterial, anti-inflammatory, and antioxidant properties[(S. Hameed et al., 2024)](https://paperpile.com/c/aHCPcX/FyKG). These properties suggest the potential of *Morinda citrifolia* as a component in dental products for caries prevention [(Subramanian & Harikrishnan, 2023)](https://paperpile.com/c/aHCPcX/ArS4J).

*Morinda citrifolia* has shown a range of anticancer effects in various cancer models, working through multiple mechanisms such as inhibiting tumor growth, reducing proliferation, promoting apoptosis, preventing angiogenesis, inhibiting migration, and modulating inflammation and immune responses[(Kumar et al., 2022)](https://paperpile.com/c/aHCPcX/Z4G0t). This suggests that *Morinda citrifolia* may be a valuable medicinal plant for cancer treatment, targeting numerous biological pathways[(Sreevarun et al., 2023)](https://paperpile.com/c/aHCPcX/einBm). However, more rigorously designed preclinical studies focusing on efficacy and safety are necessary to enhance the translation into future clinical trials, which could further validate the potential of *Morinda citrifolia* in cancer therapy [(Laghari et al., 2023; Ramakrishnan et al., 2023a)](https://paperpile.com/c/aHCPcX/xaoCU+Wr2Ic)[(Muthuswamy Pandian et al., 2022a)](https://paperpile.com/c/aHCPcX/VqlMV).

Hydroxyapatite (HA) is a biocompatible mineral that closely resembles the inorganic component of human tooth enamel [(Chokkattu et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/aHCPcX/lkv6W+wxRDL). HA nanoparticles have been extensively studied for their potential applications in dentistry, including tooth remineralization and the development of dental materials [(Marya et al., 2022)](https://paperpile.com/c/aHCPcX/zStbR). The nanoscale size of HA particles enhances their bioactivity and allows for better penetration into the oral cavity[(Ulian et al., 2021)](https://paperpile.com/c/aHCPcX/XsM37).

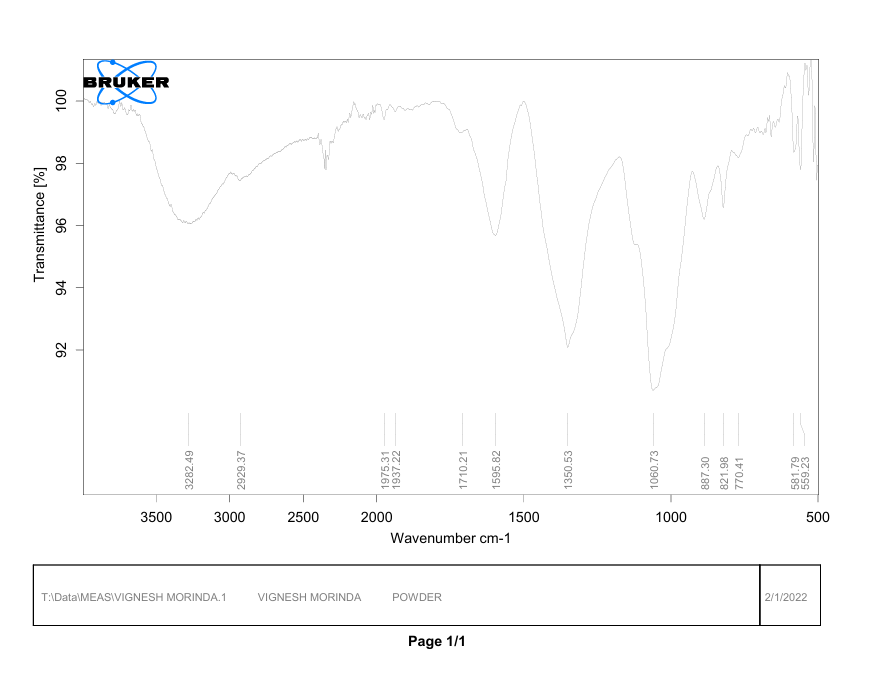
By combining the bioactive properties of *Morinda citrifolia* with the remineralization potential of HA nanoparticles, we hypothesized that *Morinda citrifolia*-coupled HA nanoparticles could serve as a novel and effective anti-cariogenic agent[(Jain & Verma, 2022; Marya et al., 2022)](https://paperpile.com/c/aHCPcX/zStbR+rxAtJ). This study aimed to investigate the synthesis, characterization, and in vitro anti-cariogenic efficacy of *Morinda citrifolia*-coupled HA nanoparticles

# MATERIALS AND METHODS

5g of *Morinda citrifolia* (noni) powder is obtained by grinding and drying the fruit. Separately, 5g of hydroxyapatite (HAP) is synthesized using the wet chemical condensation method, then finely ground with a mortar and pestle (Chehelgerdi et al., 2023). The HAP nanoparticles are then analyzed using SEM for morphological examination and EDS for elemental composition analysis. After Completion of HAP is coupled with *Morinda citrifolia* and sent for FTIR for detection of the functional groups to determine the constituents present in the given extract. Finally *S.mutans* and LB broth is prepared and sent for PCR analysis and compared with control and HAP+Morinda sample.

# RESULTS

# FTIR



**FIGURE 1:** The FTIR analysis for *Morinda citrifolia*-coupled hydroxyapatite nanoparticles

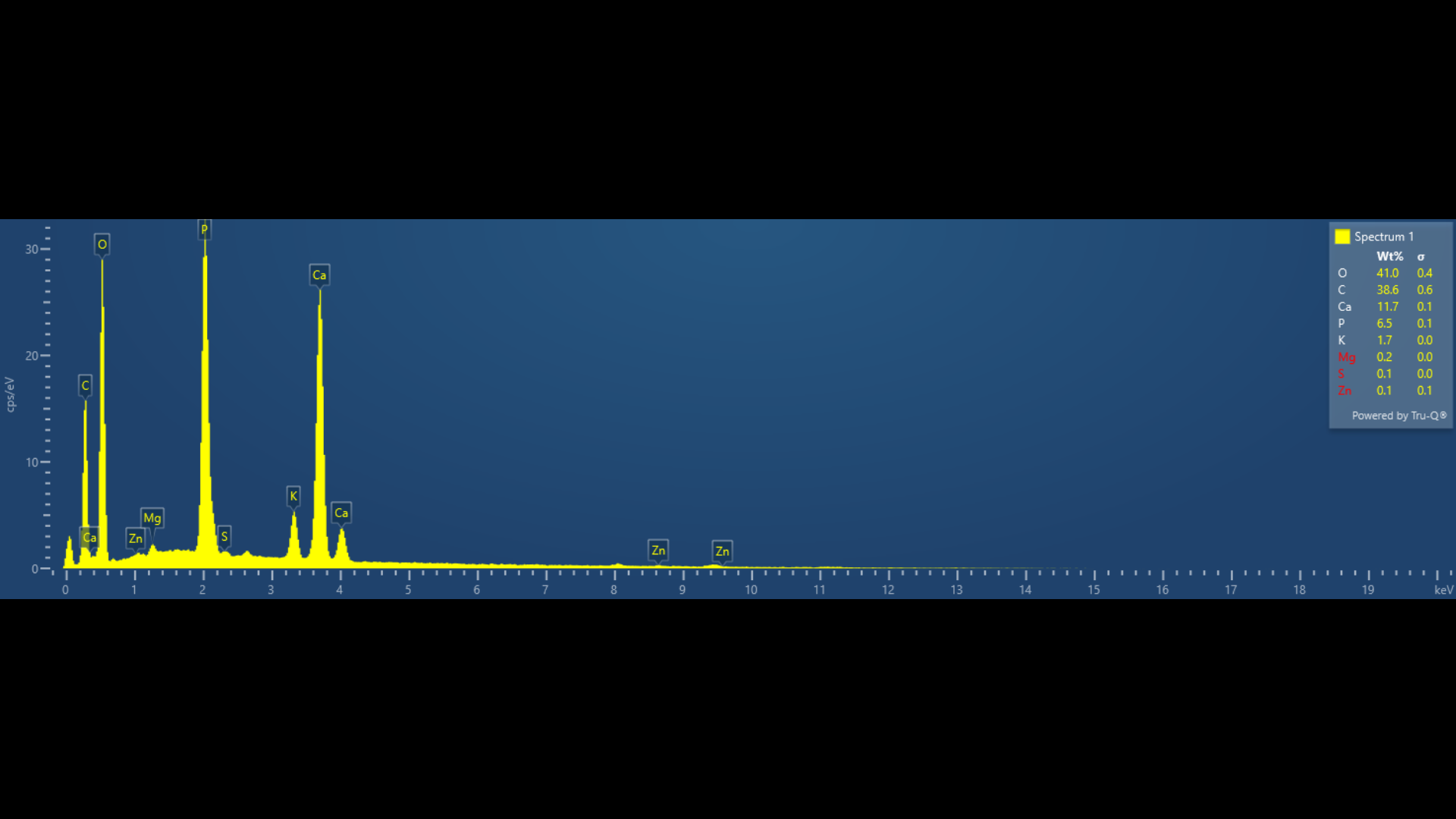
FTIR analysis of the *Morinda citrifolia*-coupled hydroxyapatite nanoparticles revealed characteristic peaks associated with O-H, C-H, and C=O stretching, confirming the presence of *Morinda citrifolia* components. The spectrum also showed peaks indicative of hydroxyapatite, suggesting successful coupling of the two materials. The absence of any new, prominent peaks in the fingerprint region indicates that *Morinda citrifolia* and hydroxyapatite interaction is primarily physical rather than chemical (Figure 1).

From FTIR results, there is strong adhesion between *Morinda citrifolia* and hydroxyapatite nanoparticle (Saadh et al., 2024).

## EDX

EDX analysis of the *Morinda citrifolia*-coupled hydroxyapatite nanoparticles confirmed the presence of the expected elements, including calcium, oxygen, carbon, nitrogen, and magnesium(Figure 2). The high intensity of the calcium peak indicates the predominance of hydroxyapatite in the composite. The detection of organic elements suggests successful coupling of *Morinda citrifolia* components. No significant impurities or contaminants were identified.

From this EDX result it provides the chemical composition of your *Morinda citrifolia*-coupled hydroxyapatite nanoparticles.

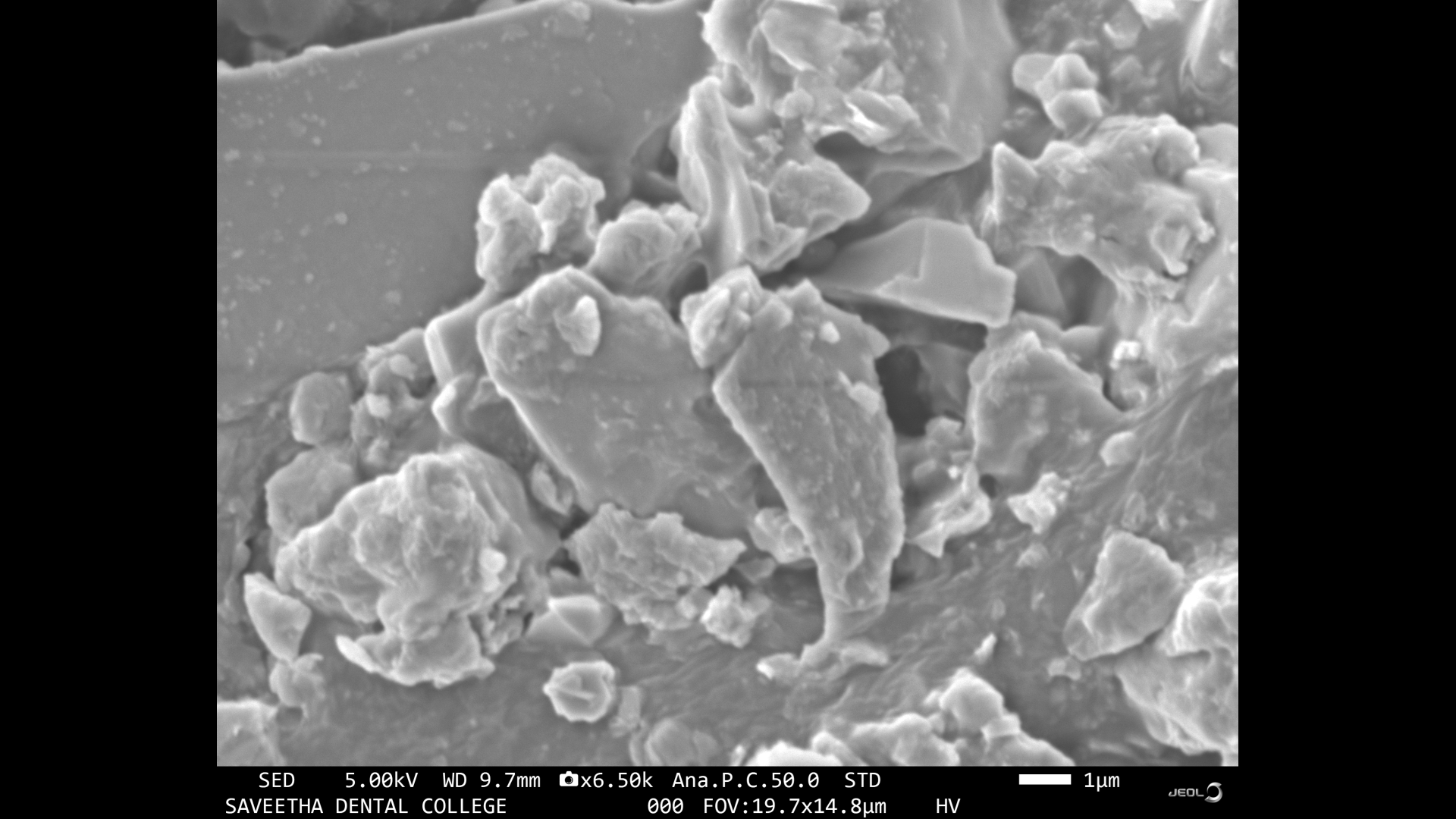


**FIGURE 2:** EDX analysis of the *Morinda citrifolia*-coupled hydroxyapatite nanoparticle

## SEM

SEM analysis revealed a heterogeneous distribution of *Morinda citrifolia*-coupled hydroxyapatite nanoparticles with varying sizes and irregular shapes.(Figure 3) The particles exhibited a rough surface morphology and were prone to agglomeration. The presence of both crystalline and amorphous features suggests a complex interaction between the organic and inorganic components."

From the SEM results, we can see the strong physical characteristics of your *Morinda citrifolia*-coupled hydroxyapatite nanoparticles and even the crystallization of this compound is valid from the analysis and exhibiting the remineralising capability

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**FIGURE 3:** *Morinda citrifolia*-coupled hydroxyapatite nanoparticles with varying sizes and irregular shapes SEM Analysis

## PCR ANALYSIS

Fresh LB broth was used for subculture, bacteria cultured overnight at 37°C, was used for total RNA isolation using a total RNA isolation reagent (TRIR) (Ab gene house, United Kingdom). Briefly, 2µg of RNA was transcribed using the reverse transcriptase RT kit from Eurogentec (Seraing, Belgium). 16s r-RNA was used as a housekeeping gene. Genes were amplified using SYBR green mastermix (Takara, Japan) in a qRT-PCR system (CFX96 Touch Real-Time PCR Detection System (Bio-Rad, USA). The PCR protocol was as follows: initial denaturation at 95°C for 5 min followed by 40 cycles of 95°C for 30s, 59-60°C for 30 s and 72°C for 30s.

Relative quantification was calculated from the melt and amplification curves analysis(Figure 4 and 5). The relative expression was determined using the 2-ΔΔCT method. The expression level of each gene was calculated using the fold change relative to the transcriptional level of the corresponding untreated group.

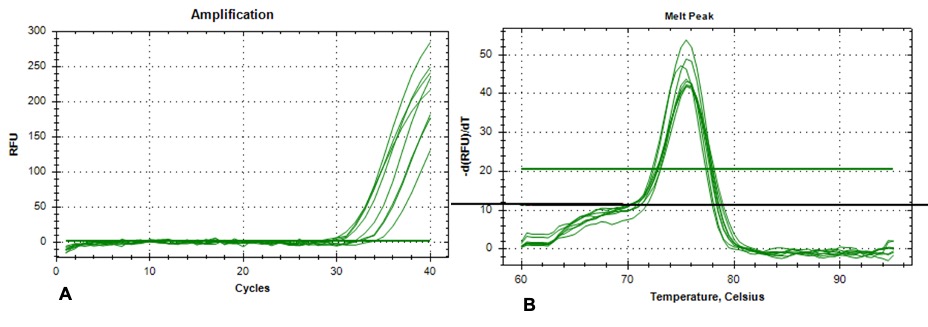
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FIGURE 4: The real time PCR amplification cycle for A:the Lactobacillus untreated with nanoparticle ,B: the Lactobacillus treated with nanoparticle

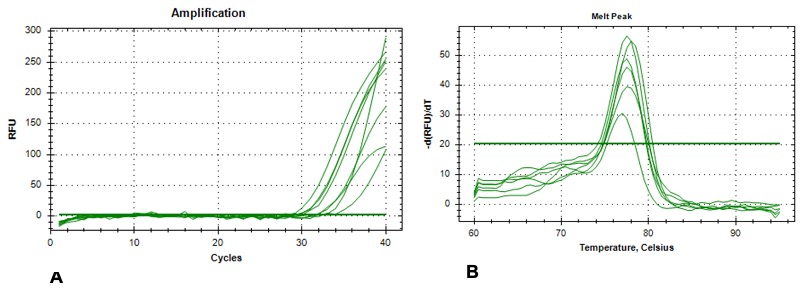


FIGURE 5: The real time PCR amplification cycle of A:S.mutans untreated with nanoparticle, B:S.mutans treated with nanoparticle

# DISCUSSION

The development of novel anticariogenic agents has been a significant focus in dental research. This study explores the potential of *Morinda citrifolia*-coupled hydroxyapatite nanoparticles as a promising candidate[(Imran et al., 2023)](https://paperpile.com/c/aHCPcX/XOCQ7),15[(Desai, 2012)](https://paperpile.com/c/aHCPcX/56nK2). By comparing the findings of this research with existing literature, we can gain a deeper understanding of the potential benefits and challenges associated with these nanoparticles [(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/aHCPcX/XOWiq+EGQVF+PCuWO)[(Solanki et al., 2023)](https://paperpile.com/c/aHCPcX/IURC3). The characterization of the *Morinda citrifolia*-coupled hydroxyapatite nanoparticles in this study aligns with previous research [(Wadhwani et al., 2022)](https://paperpile.com/c/aHCPcX/9Y2zs). FTIR and EDX analysis confirmed the successful coupling of the organic and inorganic components, while SEM analysis revealed a heterogeneous distribution of nanoparticles[(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)](https://paperpile.com/c/aHCPcX/XOWiq+EGQVF+PCuWO). These findings are consistent with studies that have explored the synthesis and characterization of hydroxyapatite-based nanoparticles for dental applications[(Orilisi et al., 2021)](https://paperpile.com/c/aHCPcX/P7aU2).

The PCR analysis in our study suggests that the nanoparticles may influence the expression of genes related to cariogenesis in *Lactobacillus* and *Streptococcus mutans* [*(Aparna et al., 2021; Poornima et al., 2021; Verma & Muthuswamy Pandian, 2021)*](https://paperpile.com/c/aHCPcX/XOWiq+EGQVF+PCuWO). This aligns with previous research demonstrating the potential of hydroxyapatite nanoparticles to inhibit the growth and activity of cariogenic bacteria [(“Novel Nanosystems to Enhance Biological Activity of Hydroxyapatite against Dental Caries,” 2021)](https://paperpile.com/c/aHCPcX/ofMSX) [(Chokkattu et al., 2023)](https://paperpile.com/c/aHCPcX/ZaHlc). However, further studies are needed to establish a definitive link between gene expression changes and reduced cariogenic potential [(Merchant et al., 2022; Pandiyan et al., 2022)](https://paperpile.com/c/aHCPcX/f4xdM+hIDyj)

Several studies have investigated the use of hydroxyapatite nanoparticles for caries prevention. For example, (12) demonstrated the ability of hydroxyapatite nanoparticles to reduce biofilm formation and acid production by cariogenic bacteria [(Chokkattu et al., 2022; Ramamurthy et al., 2022)](https://paperpile.com/c/aHCPcX/lkv6W+wxRDL). Similarly, (18) reported that hydroxyapatite nanoparticles can enhance the remineralization of enamel, thereby preventing caries progression(19).

The incorporation of *Morinda citrifolia* into these nanoparticles is a novel aspect of this study. Previous research has highlighted the antimicrobial and anti-inflammatory properties of *Morinda citrifolia[(Tanikawa et al., 2021)](https://paperpile.com/c/aHCPcX/VnWzj)*. The combination of hydroxyapatite and Morinda citrifolia may provide synergistic effects, enhancing the anticariogenic potential of the nanoparticles[(Ganapathy e al., 2021; Merchant et al., 2022; Pandiyan et al., 2022)](https://paperpile.com/c/aHCPcX/f4xdM+hIDyj+otZE6).

The anticariogenic effects of these nanoparticles could be attributed to several mechanisms:

* Antimicrobial activity: *Morinda citrifolia* may directly inhibit the growth of cariogenic bacteria.
* Surface modification: The nanoparticles could alter the surface properties of teeth, making them less susceptible to bacterial adhesion and biofilm formation.
* Mineral release: Hydroxyapatite nanoparticles can release calcium and phosphate ions, which can promote remineralization of demineralized enamel.

While the results of this study are promising, several challenges remain:

* Long-term efficacy: The long-term efficacy of these nanoparticles in preventing caries needs to be evaluated through clinical trials.
* Biocompatibility: Ensuring the biocompatibility of the nanoparticles for oral use is crucial.
* Delivery and retention: Developing effective methods for delivering and retaining the nanoparticles in the oral cavity is essential.

Future research should focus on addressing these challenges and exploring the potential of *Morinda citrifolia*-coupled hydroxyapatite nanoparticles as a promising anticariogenic agent and remineralising agent in in vivo setup[(Muthuswamy Pandian et al., 2022b; Ramakrishnan et al., 2023b)](https://paperpile.com/c/aHCPcX/XoUFj+2weg5).

# CONCLUSION

This study successfully demonstrates the strong adhesion between *Morinda citrifolia* and hydroxyapatite nanoparticles, as confirmed by FTIR analysis. EDX results further reveal the chemical composition of the *Morinda citrifolia*-coupled hydroxyapatite nanoparticles, validating the incorporation of bioactive compounds. Additionally, SEM analysis highlights their well-defined physical characteristics, underscoring their potential as effective biomaterials.

Notably, real-time PCR analysis shows a significant reduction in the nucleic acid expression of *Lactobacillus* and *Streptococcus mutans* following treatment with the *Morinda citrifolia*-coupled hydroxyapatite nanoparticles. This suggests that these nanoparticles not only enhance physical and chemical properties but also exhibit antimicrobial activity, potentially inhibiting the growth of pathogenic bacteria.

Overall, these findings indicate that *Morinda citrifolia*-coupled hydroxyapatite nanoparticles hold significant promise for applications in dental and biomedical fields, particularly in the development of biomaterials that can mitigate microbial activity while ensuring biocompatibility. Further research is warranted to elucidate the underlying mechanisms and evaluate their potential for clinical applications.

# FUTURE SCOPE

Further research on this study endeavors *Morinda citrifolia*-coupled hydroxyapatite nanoparticles from the lab to clinical practice, enhancing their utility in healthcare settings.

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