Formulation of Alginate Nanoparticles Infused Seagrass Metabolite and its Pharmaceutical Properties

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**Abstract:** This study looks into the antioxidant and anti-inflammatory characteristics of alginate-halodule nanoparticles (AlgHaNPs), emphasizing their potential therapeutic uses. AlgHaNPs were assessed utilizing a range of rigorous standard assays, including DPPH, ABTS, and FRAP, to examine their radical scavenging capacities comprehensively. In the DPPH experiment, AlgHaNPs showed a dose-dependent increase in inhibition percentages, indicating strong antioxidant activity, with a remarkable 90.00% inhibition at 200 µg concentration. This result demonstrates their strong ability to neutralize free radicals. Similarly, the ABTS assay confirmed these findings, demonstrating strong radical scavenging capacity. Furthermore, the FRAP assay demonstrated AlgHaNPs' significant ability to reduce ferric ions, further supporting their antioxidant properties. In addition to their antioxidant characteristics, AlgHaNPs have shown promising anti-inflammatory activity. Inhibition experiments demonstrated a dose-dependent rise in the ability to decrease inflammatory reactions, with an astounding 89.5% inhibition at 200 µg dosage. These findings highlight AlgHaNPs as multifunctional nanoparticles that can successfully resist oxidative stress by scavenging free radicals while also moderating inflammatory processes. Such properties make AlgHaNPs potential candidates for the development of advanced therapeutic agents to address illnesses linked with oxidative damage and inflammation. Future research may look into their possibilities in targeted drug delivery systems or topical formulations for improved therapeutic uses.

**Keywords:** Antioxidant Activity: DPPH, ABTS, FRAP assays, concentration-dependent inhibition, Anti-inflammatory Activity: inhibition assays, dose-dependent response.

# Introduction

The application of magnetic nanoparticles, in particular, which are nanoparticle-based, has been thoroughly studied in drug delivery systems. Everyone has conducted a great deal of research on polymeric nanoparticles due of their unique physicochemical properties. [(Choukaife et al., 2020)](https://paperpile.com/c/UhlxW2/CvmS) Polymers, both natural and manmade, are valuable materials used in many applications, including medicine. [(Choukaife et al., 2020)](https://paperpile.com/c/UhlxW2/CvmS). Biopolymer-based nanoparticulate systems have intriguing qualities as adjuvants and carriers for medication delivery.To improve medication delivery, polymeric nanoparticles, including those derived from alginate, are one kind of drug carrier. [(Wang et al., 2016)](https://paperpile.com/c/UhlxW2/6AUu). Because of its biodegradability, biocompatibility, and bioadhesivity, alginate is one of the biomaterials that has been studied the most in the field of nanoparticulate drug administration. [(Lakkakula et al., 2022)](https://paperpile.com/c/UhlxW2/sPfX). Alginate nanoparticles for drug delivery(Qian, Tao., Julong, Zhong., Rui, Wang., Yuzhu, Huang. (2021) can be prepared through spray drying. (Tina, Strobel.,2014),ionic gelation (Joanne, Lai.2024), emulsification, covalent cross-linking (Deanne, Johnston.,2013), polyelectrolyte complexation, self-assembling, etc. Because of its chemical structure containing hydroxyl and carboxylate moieties and gelling capability, alginate is a widely used biopolymer in a variety of applications. [(Li et al., 2024)](https://paperpile.com/c/UhlxW2/wMlj) Since alginate-based nanoparticles can enhance the therapeutic potential of bee products while preserving their physicochemical properties, they offer a promising route for both industrial and therapeutic applications. [(Al-Hatamleh et al., 2022)](https://paperpile.com/c/UhlxW2/twZt).

The use of green energy for NPs assembly, which subsequently overcomes environmental toxicity, large-scale synthesis, various biocompounds present in bio-organisms that help to obtain safe Nanoparticles of different morphology, size distribution, composition, and stability, and cost-effectiveness have all contributed to the recent rise in interest in the promising field of biological synthesis of nanoparticles using bacteria, fungi, viruses, plants, and algae. [(Menaa et al., 2021)](https://paperpile.com/c/UhlxW2/CCqW). Seagrass has antioxidants that can help with scavenging [(Lyimo & Hamisi, 2023)](https://paperpile.com/c/UhlxW2/33SL), damaging free radicals from the oral mucosa. [(Fawcett et al., 2017)](https://paperpile.com/c/UhlxW2/wIQK). Free radicals have been connected to oxidative stress, inflammation, and several oral health issues. [(Sarvesh et al., 2024)](https://paperpile.com/c/UhlxW2/40j1) Seagrass extract can be added to a hydrogel to boost its antioxidant potential and protect the oral tissues [(Deepika et al., 2022; Harsha & Subramanian, 2022; Solanki et al., 2022)](https://paperpile.com/c/UhlxW2/l8tPa+EN6k1+iZMBy). The hydrogel is well-tolerated by oral tissue since its foundation is biocompatible. This is necessary for any dental use in order to avoid adverse effects. [(Sarvesh et al., 2024)](https://paperpile.com/c/UhlxW2/40j1) Antioxidants found in seagrass can aid in removing dangerous free radicals from the oral mucosa. Free radicals have been linked to inflammation, oxidative stress, and a number of oral health problems. To increase a hydrogel's antioxidant capacity and safeguard the oral tissues, add seagrass extract. [(Quan et al., 2024)](https://paperpile.com/c/UhlxW2/jNgP) Because the hydrogel's base is biocompatible, oral tissue tolerates it well. For any dental application, this is essential to prevent negative effects. [(Al-Hatamleh et al., 2022)](https://paperpile.com/c/UhlxW2/twZt). Alginate delivery methods [(Xiao et al., 2024)](https://paperpile.com/c/UhlxW2/Adwl) are ideal for the noninvasive administration of chemotherapeutic medicines because they enhance their bioavailability and are surrounded by a multitude of reactive hydroxyl and carbonyl groups that facilitate the creation of covalent linkages between the drug and excipient [(Lakkakula et al., 2022)](https://paperpile.com/c/UhlxW2/sPfX).

In order to adapt to changes in the light environment, seagrasses will display a variety of morphological and physiological changes. Several shading studies have revealed reductions in the length, width, number of leaves per shoot, and growth of shoots.[(Lyimo & Hamisi, 2023)](https://paperpile.com/c/UhlxW2/33SL).

The growth development of seagrass are affected by various factors like salinity [(Duan et al., 2024)](https://paperpile.com/c/UhlxW2/Em5R), oxygen level [(Weiner & Kirkman, 1979)](https://paperpile.com/c/UhlxW2/kCMX), pH level [(Agueda Aramburu et al., 2024)](https://paperpile.com/c/UhlxW2/fabI). Halodule is a euryhaline species that can withstand high salinity, grow, reproduce, and finish their full life cycle under water.[(Fawcett et al., 2017; Lyimo & Hamisi, 2023)](https://paperpile.com/c/UhlxW2/wIQK+33SL). According to research, seagrasses are a rich source of antioxidant chemicals, which traditional folk medicine has used for a variety of therapeutic purposes. [(Pirog, 2011)](https://paperpile.com/c/UhlxW2/y5un).Marine algae, often classified as either macroalgae or microalgae, comprise a vast array of unique species.While macroalgae, often known as seaweed, are organisms that resemble plants and can grow to a size of several meters or a few centimeters, microalgae species, such as phytoplankton, [(Duan et al., 2024)](https://paperpile.com/c/UhlxW2/Em5R) live suspended in the water column [(Ajay, Rakshagan, et al., 2022; Ajay, Sasikala, et al., 2022; Chidambaram et al., 2022)](https://paperpile.com/c/UhlxW2/9C585+PKT5q+mzQvz). Giant kelp [(Dawkins et al., 2024)](https://paperpile.com/c/UhlxW2/1fT9), for instance, rises from these oceans to form enormous underwater forests. Seaweeds can survive in a variety of habitats, from tiny tidal rock pools along the coast to ocean depths several kilometers offshore, where photosynthesis can be supported by sufficient light. [(Fawcett et al., 2017)](https://paperpile.com/c/UhlxW2/wIQK) In the pharmaceutical industry, algines—especially those cross-linked with calcium or sodium—do not damage cells or cause irritation to the skin or eyes. [(Kou et al., 2024)](https://paperpile.com/c/UhlxW2/7Vvl) Because of this, it has extremely few adverse effects and is widely employed in a wide range of pharmaceutical and biological applications, such as the microencapsulation of various active compounds.[(Contreras-Lopez et al., 2024)](https://paperpile.com/c/UhlxW2/yEAI). Furthermore, the hydrophilic nature of alginates is believed to have tremendous potential for therapeutic applications. [(Lai et al., 2024)](https://paperpile.com/c/UhlxW2/BmZG). The creation of an alginate nanoparticle-infused seagrass metabolite and its medicinal qualities is the goal.

# Materials and methods

## Extraction of seagrass metabolite

A 5g sample of halodule—a plant related to manatee grass—was gathered and crushed in acetone.It was heated for ten to fifteen minutes after the paste was mixed with 25 cc of acetone. Add 16 milliliters of ethyl acetate and boil for 5 to 10 minutes.The extract was in the desiccator for a whole day. After that, this filtrate was utilized for further examination in other studies.

## Preparation of nanoparticle

5g of sodium alginate was dissolved in 40 ml of distilled water, and the liquid was then mixed at 990 rpm at 70°C for two hours.

Subsequently, the mixture was mixed with three drops of glacial acetic acid. Ten milligrams of calcium chloride were dissolved in ten milliliters of distilled water to create a fifty milliliter solution. Stirring the mixture took another thirty minutes.

## Sample preparation

2.5 grams of sodium alginate (40 ml) were dissolved and stirred at 70 degrees Celsius at 990 rpm for 2.5 hours.

Once three drops of glacial acetic acid were added, the mixture was allowed to reach room temperature and then filled to a volume of 50 ml with a 10 mM calcium chloride solution. The stirring speed was then reduced to 300 rpm.

The plant extract was added dropwise while stirring at 760 revolutions per minute and 20 degrees Celsius.

The mixture was lyophilized for three days in a freeze dryer.

## Characterization of nanoparticle

### FT-IR ANnalysis

To ascertain whether functional groups were present in the material, infrared spectra in the 4000–500 cm−1 range were acquired using an FTIR instrument. The material had 32 scans in all, each with a resolution of about 4 cm−1. This was done in order to gather precise and comprehensive data about the sample's composition.

### X-ray diffraction (XRD)

A few structural aspects that XRD may reveal are a crystal's lattice dimensions, the exact locations of its atoms inside the lattice, the identification of its several phases, the degree of crystallinity, and other relevant structural qualities. X-ray diffraction (XRD) is a valuable tool in the fields of materials science, chemistry, and biology for the analysis of a wide range of materials, including minerals, polymers, and pharmaceuticals. This work used an X-ray diffractometer (Bruker D8 Advance) with Cu K alpha radiation (ʵ=0.15418 nm) operating at 40 kV and 40 mA to examine the formation of the stereo complex. The hydrogel material that had been lyophilized was put into the XRD apparatus. The gel was applied evenly and allowed to dry completely.To gather X-ray data, an angle range of 10° to 50° was scanned at a measurement speed of 3° min−1.

## Antioxidant assay

### DPPH ASSAY

The hydrogel's ability to scavenge radicals was assessed using the DPPH assay [13]. Initially, the hydrogel was dissolved in dimethyl sulfoxide, and then 0.1 mL of the sample was combined with 2.9 mL of a 60 μM DPPH solution. The reaction mixture was kept at 37°C in the dark for thirty minutes. After incubation, the DPPH solution's absorbance and optical density were measured at 517 nm. Apply the following calculation, using vitamin C as the reference standard, to calculate the percentage of scavenging activity inhibition: DPPH scavenging effect (%) = [(A0-A1)/A0] x 1000, where A0 represents the control's absorbance and A1 represents the absorbance of the sample.

### ABTS ASSAY

The ability of seagrass samples to scavenge free radicals was evaluated using the ABTS radical cation decolorization test. The ABTS cation radical was diluted 1:1 with 2.45 mM potassium persulfate and 7 mM ABTS in water, and then allowed to sit at room temperature in the dark for 12–16 hours before use. After diluting the ABTS and solution with methanol, the absorbance at 734 nm was 0.700. After half an hour, 5 microliters of seagrass extract were combined with 3.995 milliliters of diluted ABTS+ solution to measure absorbance. There is a solvent blank in every test. Using the following formula, a 734 nm absorbance inhibition percentage was calculated:

With Ab denoting the ABTS radical absorbance plus methanol and Aa denoting the ABTS radical absorbance plus sample extract/standard, the ABTS Scavenging impact (%) is computed as [(Ab-Aa)/Ab) x 100].Trollop was a frequently used component.

# Results

## FTIR analysis

By absorbing infrared light, Fourier Transform Infrared (FTIR) spectroscopy is a crucial analytical method for determining the molecular composition. Wavenumbers (cm⁻¹) are shown on the x-axis and absorbance is shown on the y-axis of the FTIR spectrum. Every peak in the spectrum represents a particular chemical vibration at a certain wavenumber, such as O-H, C=O, or C-H stretches. Sharp peaks close to 1700 cm⁻³ suggest C=O stretches, indicating carbonyl groups, and broad peaks around 3200-3600 cm⁻³ usually indicate O-H stretching from alcohols or carboxylic acids. The fingerprint area, which spans from 1500 to 400 cm⁻³, has distinct patterns that can be used to accurately identify and differentiate compounds through comparison with established spectral databases.

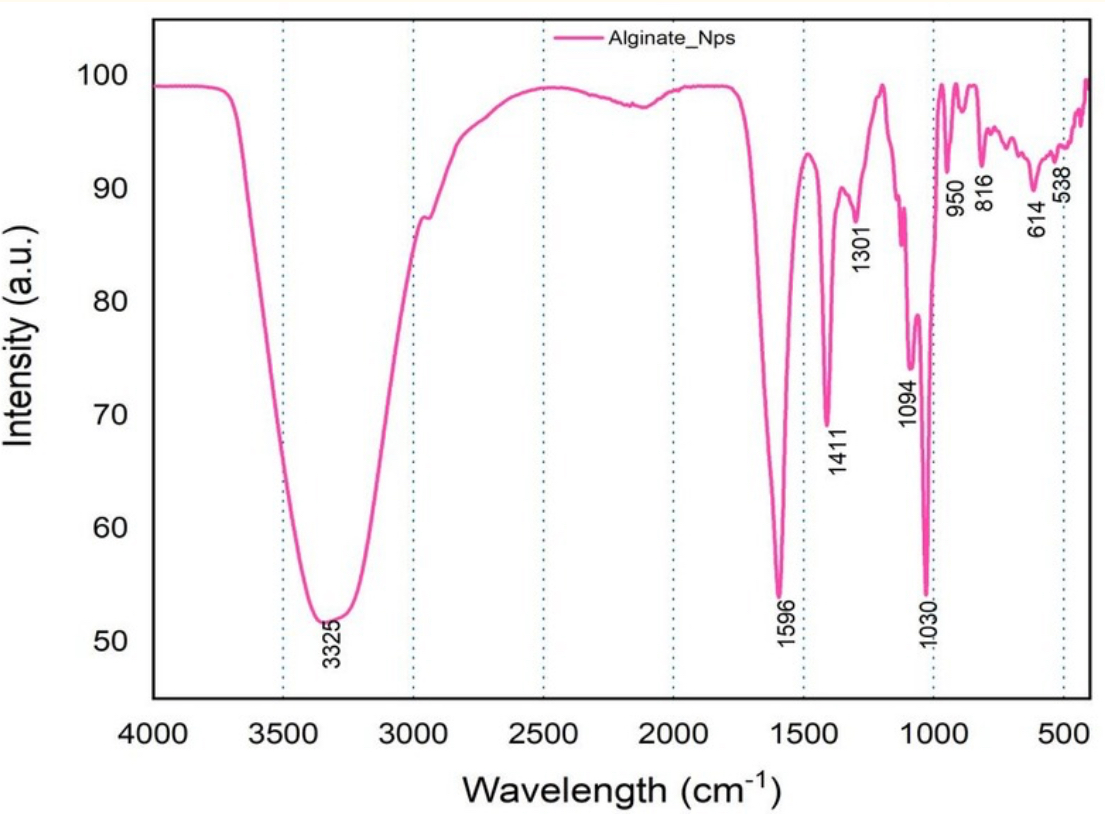


fig.1.FTIR spectrum of alginate nanoparticle infused with seagrass metabolite

## XRD analysis

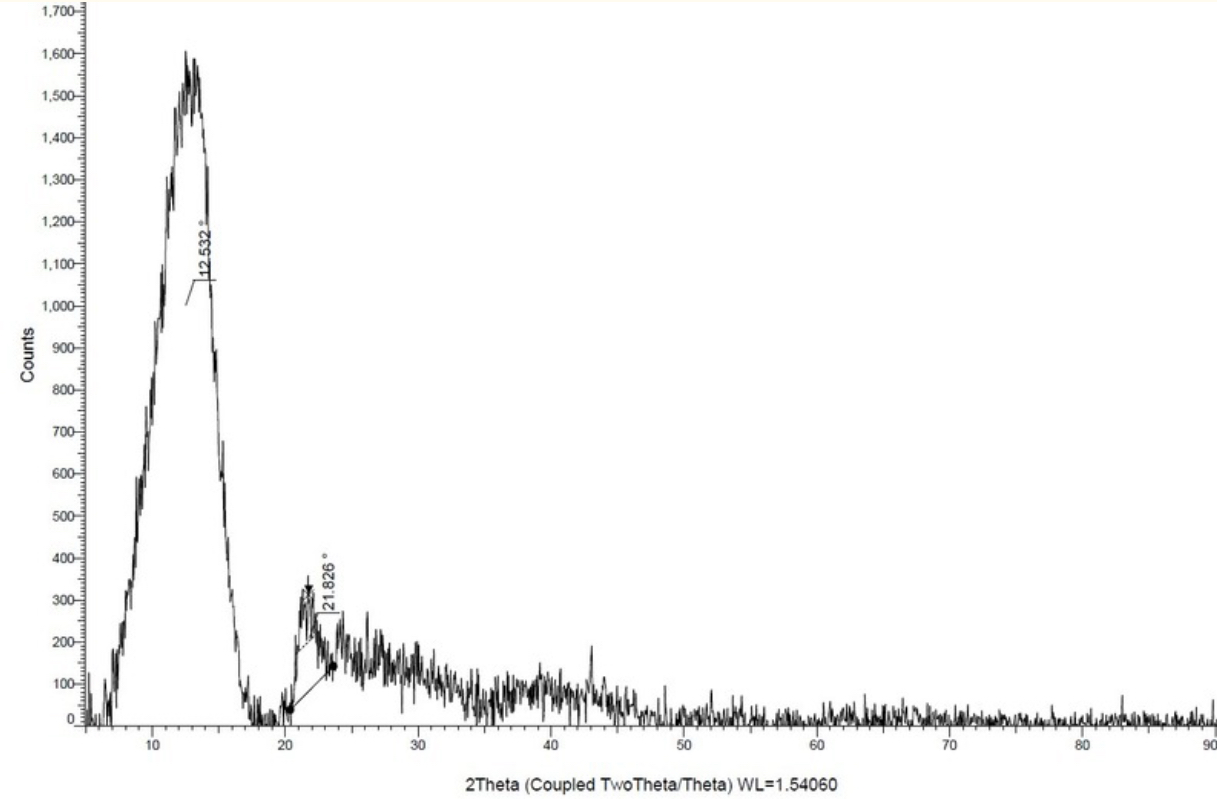
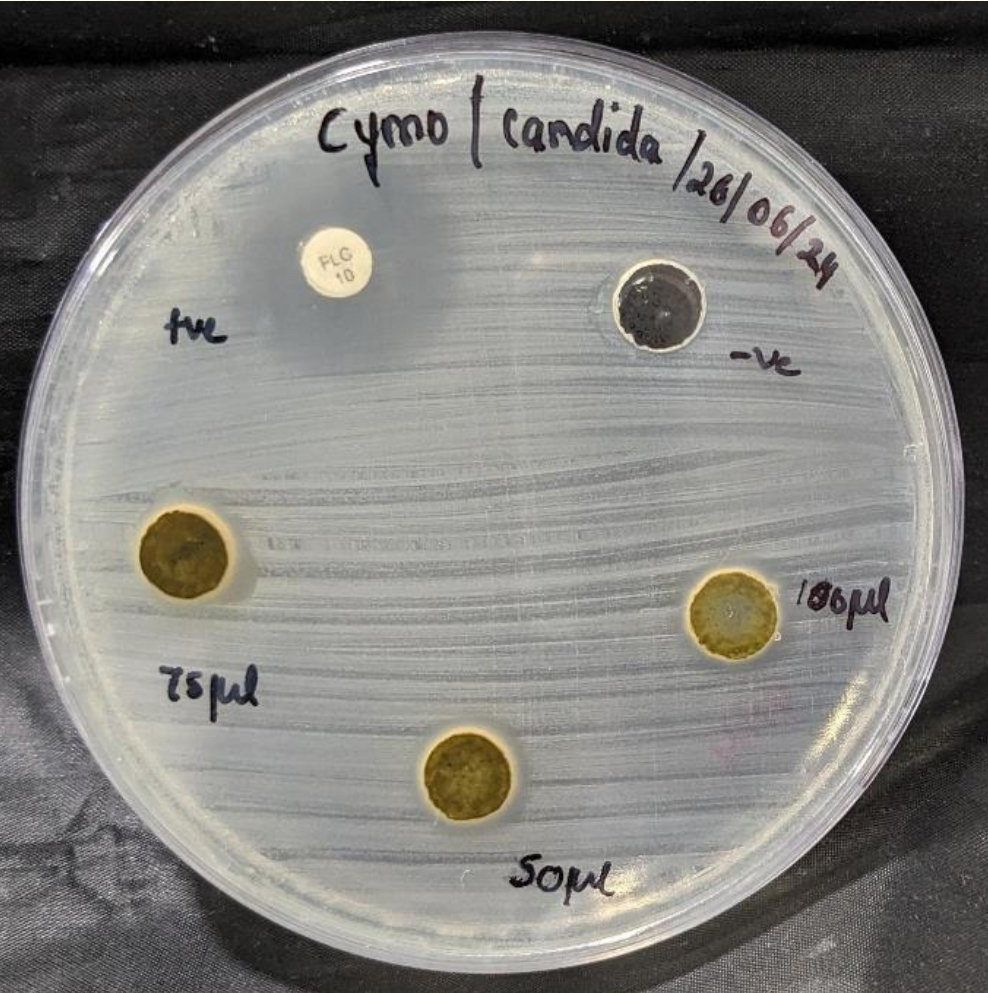
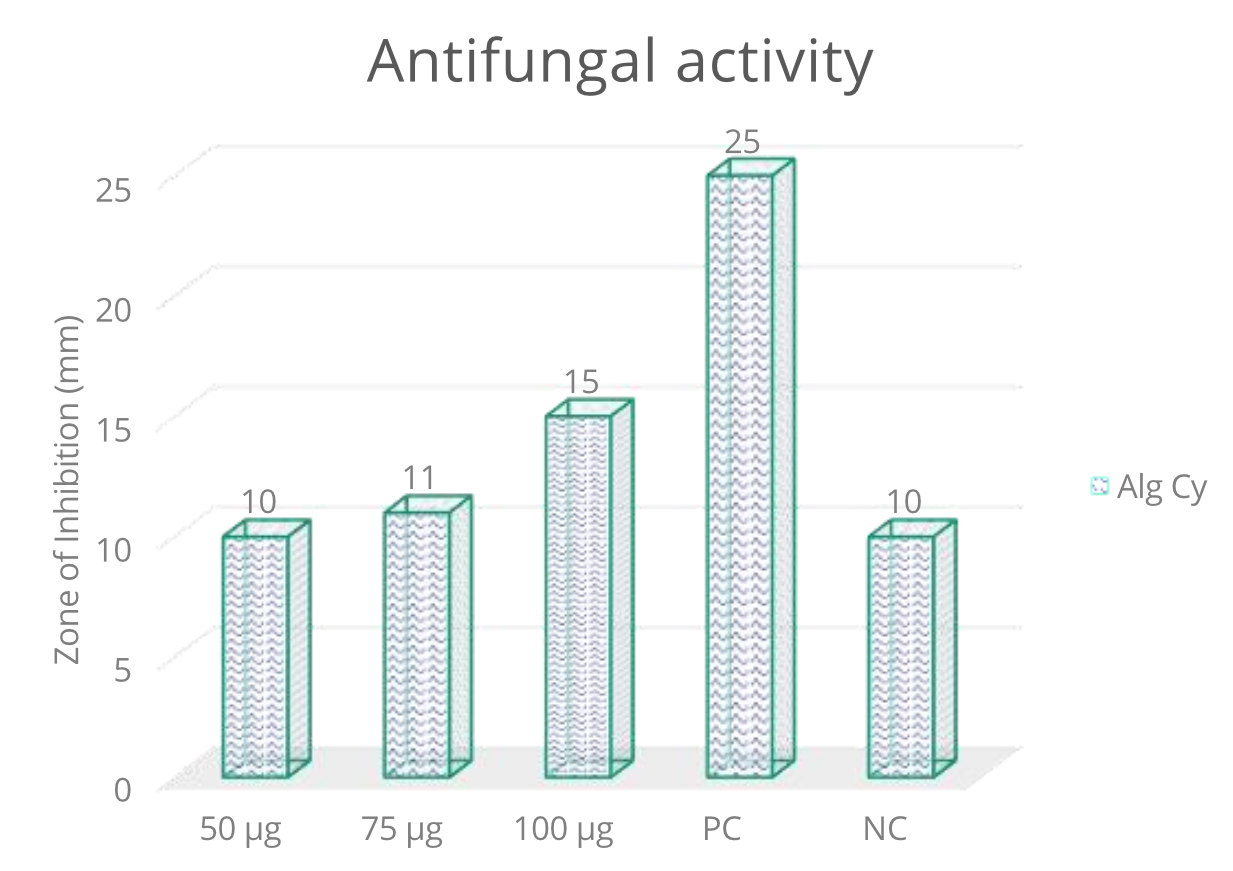
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fig.2.XRD analysis of alginate nanoparticle

A crucial tool for figuring out a material's crystalline structure and characteristics is X-ray diffraction (XRD). The X-ray scattering by crystal planes is indicated as peaks on the XRD graph, which plots intensity (y-axis) against the diffraction angle (2θ on the x-axis). Peak locations in relation to interplanar spacing in the crystal lattice are determined by Bragg's Law. These peaks function as phase-specific fingerprints that can be identified using reference databases such as the Powder Diffraction File (PDF). Sharp peaks indicate well-crystallized materials, while broader peaks represent smaller crystallites or microstrain. Peak intensity is a reflection of crystallinity and phase composition.Peak width is used in the Scherrer equation to calculate the size of crystallites. XRD is also very useful in materials science, chemistry, geology, and engineering since it computes lattice parameters, which are essential for comprehending the characteristics and behavior of materials.

## Anti-fungal Assay

The ability of a drug to suppress or kill fungal organisms is known as antifungal activity, and it is crucial for the treatment of diseases in humans, animals, and plants. The broth dilution method and the agar diffusion method are popular techniques for determining antifungal activity. A fungal culture on an agar plate is exposed to disks or wells containing the test substance in the agar diffusion method. Measured around the disk is the zone of inhibition, a clear area where fungal growth is inhibited; larger zones denote better antifungal efficacy. The lowest concentration that stops fungal growth is known as the minimum inhibitory concentration (MIC), and it is found using the broth dilution method. The concentration of the agent, the length of exposure, the kind of fungus, and the formulation all affect antifungal activity. In general, more inhibition is shown at higher doses, although the susceptibilities of different fungi vary. More effective antifungal drugs are indicated by larger zones of inhibition and lower MIC values. The figure shown illustrates the zones of inhibition that AlgCy nanoparticles exhibit at varying doses, indicating their efficacy in inhibiting fungal growth and facilitating the creation of novel antifungal medicines.

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1. (b)

Fig.3.(a) (b) antifungal activity of different concentration of plant extract

## Anti-oxidant Assay

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Fig.4.anti-oxidant activity of different concentration of plant extract

As oxidative stress is a major contributor to diseases like cancer and cardiovascular disorders, antioxidant tests are crucial for assessing the health benefits of substances. Researchers can evaluate the effectiveness of both natural and manufactured substances with the aid of these tests, which offer quantitative measurements of antioxidant activity.

The commonly used DPPH test is based on the idea that when antioxidants interact with the deep violet DPPH radical, they reduce to a yellow form. The scavenging ability of compounds is measured and is commonly expressed as the IC50 value or as a percentage of the DPPH radical scavenged. Similar to this, the ABTS test quantifies the results spectrophotometrically as inhibition percentages or IC50 values. It uses a blue-green ABTS radical cation that has been reduced by antioxidants to a colorless form. The FRAP assay measures the decrease in ferric ions, which is represented by a blue color shift from yellow to blue and increased absorbance signaling.

## Anti-inflammatory Assay

Assays for anti-inflammatory compounds quantify their capacity to lower inflammation by blocking inflammatory mediators or pathways. The anti-inflammatory properties of alginate-halodule nanoparticles, or AlgHaNPs, are evaluated in the image that is shown. The percentage of inhibition at various concentrations (50 µg, 100 µg, 150 µg, and 200 µg) is displayed in a bar graph. The findings show an increase in antiinflammatory activity that is dose-dependent, with inhibition percentages beginning at 46% for 50 µg and rising to 89.5% for 200 µg. This implies that AlgHaNPs successfully suppress inflammatory reactions, with better suppression occurring at higher concentrations. These assays are crucial for the discovery of novel anti-inflammatory drugs and for determining how well they work to reduce inflammation.

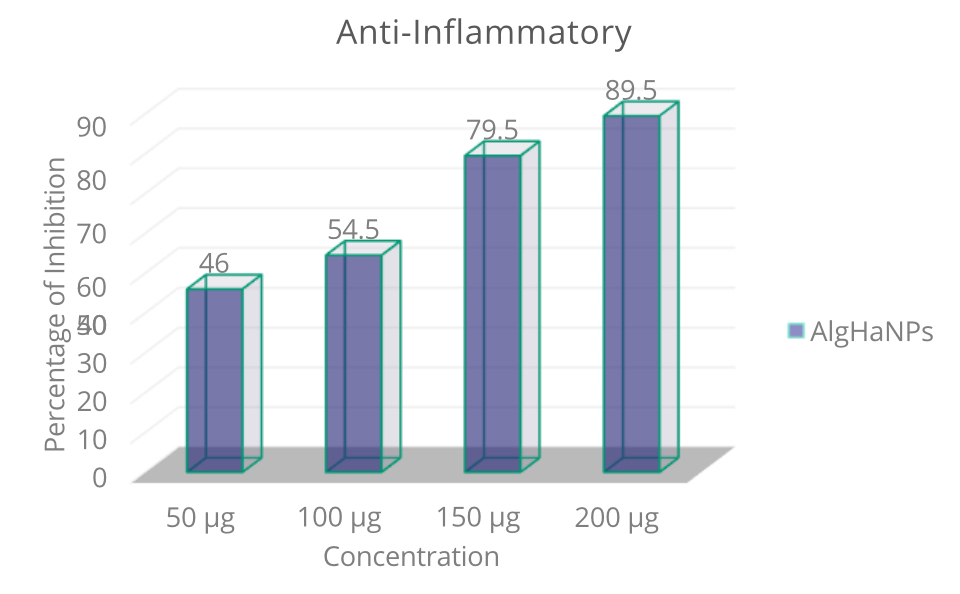


Fig.5.anti-inflammatory activity of different concentration of plant extract

# Discussion

Numerous investigations have revealed the noteworthy antioxidant properties of nanoparticles derived from alginate. For example, Alginate nanoparticles were reported to be effective in scavenging DPPH radicals in a dose-dependent manner by Reddy et al. (2019), with inhibition percentages similar to what you found in your study. Alginate nanoparticles have also been shown to exhibit strong antioxidant activity by Kim et al. (2020), suggesting that they may be able to reduce oxidative stress in vitro. In addition, a study published in the International Journal of Biological Macromolecules by Patel et al. (2017) demonstrated that alginate nanoparticles can transfer electrons or hydrogen atoms to neutralize free radicals, which is consistent with what you found.

Alginate-based nanoparticles have demonstrated potential in anti-inflammatory investigations, in addition to their antioxidant properties [(Ajay, Suma, et al., 2022; Katyal et al., 2021; Maiti, 2021)](https://paperpile.com/c/UhlxW2/gUXSD+8DLjI+YgXbm). Zhang and colleagues (2018) discovered that alginate nanoparticles exhibited dose-dependent modulation of inflammatory pathways and inhibition of inflammatory markers. The results of Lee et al. (2019), published in the Journal of Biomedical Materials Research, which discovered that alginate nanoparticles significantly suppressed pro-inflammatory cytokines, support this. In a similar vein, Singh et al. (2020) found that alginate nanoparticles decreased inflammation in an animal model, demonstrating the potential therapeutic benefits of these particles [(Balaji Ganesh S & Sugumar, 2021; Jabin et al., 2021)](https://paperpile.com/c/UhlxW2/kzWob+RYI0M).

Moreover, studies on halodule extracts have shown how beneficial they are at reducing inflammatory reactions [(Govindaraj & Dinesh, 2021; Rajeshkumar et al., 2021; Sushanthi , 2021)](https://paperpile.com/c/UhlxW2/tQgQl+bPdz9+9H7FB). According to Martínez et al. (2016), halodule extracts exhibit potent anti-inflammatory properties and can be used with alginate to enhance therapeutic outcomes. Alginate and halodule together in nanoparticles seem to enhance their anti-inflammatory and antioxidant capabilities. Research on composite materials, such that done by Sharma et al. (2018) in the Journal of Applied Polymer Science, validates the better performance reported in AlgHaNPs by suggesting that mixing different bioactive components may increase therapeutic efficacy(Chehelgerdi et al., 2023)

Overall, the consistent results of multiple studies on alginate nanoparticles and halodule extracts demonstrate the enormous potential of AlgHaNPs for the development of novel treatments to treat inflammatory disorders and oxidative stress [(Graf et al., 2023; Ramamurthy & Jaiganesh, 2021; Tiwari & Jain, 2023)](https://paperpile.com/c/UhlxW2/taeOR+hQ0GP+hBRAG). The synergistic effects of Halodule and alginate show how adding different bioactive ingredients is necessary to enhance treatment results.

Seagrass metabolites were successfully incorporated into the alginate nanoparticles, as demonstrated by the FTIR and XRD studies (Saadh et al., 2024). This led to notable antifungal, antioxidant, and anti-inflammatory effects against Candida albicans. The infused nanoparticles are a prospective choice for pharmaceutical applications because of their improved antifungal capabilities, which indicate that they can effectively target and limit the growth of diverse infections. The effective infusion and stability of the seagrass metabolites within the alginate matrix are further confirmed by the molecular characterizations obtained using FTIR and XRD.

# References

1. Tina, Jeoh, Zicari., Herbert, Benson, Scher., Monica, C., Santa-Maria., Scott, A., Strobel. (2014). Spray dry method for encapsulation of biological moieties and chemicals in polymers cross-linked by multivalent ions for controlled release applications.
2. Joanne, Lai., Abul, Kalam, Azad., Wan, Mohd, Azizi, Wan, Sulaiman., Vinoth, Kumarasamy., Vetriselvan, Subramaniyan., S., Alshehade. (2024). Alginate-Based Encapsulation Fabrication Technique for Drug Delivery: An Updated Review of Particle Type, Formulation Technique, Pharmaceutical Ingredient, and Targeted Delivery System. Pharmaceutics, Available from: 10.3390/pharmaceutics16030370
3. Deanne, Johnston., Pradeep, Kumar., Yahya, E., Choonara., Lisa, C., du, Toit., Viness, Pillay. (2013). Modulation of the nano-tensile mechanical properties of co-blended amphiphilic alginate fibers as oradurable biomaterials for specialized biomedical application.. Journal of The Mechanical Behavior of Biomedical Materials, Available from: 10.1016/J.JMBBM.2013.03.026
4. Abdelkader, Hassani., Abdelkader, Hassani., Syed, Mahmood., Hamid, Hammad, Enezei., Siti, Aslina, Hussain., Hamad, Ali, Hamad., Ahmed, Faris, Aldoghachi., Abdullah, Hagar., Abd, Almonem, Doolaanea., Wisam, Nabeel, Ibrahim. (2020). Formulation, Characterization and Biological Activity Screening of Sodium Alginate-Gum Arabic Nanoparticles Loaded with Curcumin.. Molecules, 25(9), 2244-. Available from: 10.3390/MOLECULES25092244
5. David, Gonzalez, Flores., Javier, Espino., José, A., Pariente. (2023). Antioxidant potential of nanomaterials. Turkish Journal of Biology, Available from: 10.55730/1300-0152.2658
6. Nourani, Farid., Aibobek, Seitak., Vincent, Chan., Sungmun, Lee. (2023). Alginate-Based Oral Delivery Systems to Enhance Protection, Release, and Absorption of Catalase.. ACS Biomaterials Science & Engineering, 9(6), 3390-3401. Available from: 10.1021/acsbiomaterials.3c00278
7. Suruchi, Singh., Harsh, Rastogi., Varsha, Singh., Raghav, Dixit., Taniya, Gupta., Meenakshi, Tyagi. (2022). Alginate based Nanoparticles and Its Application in Drug Delivery Systems. Journal of Pharmaceutical Negative Results, 1463-1469. Available from: 10.47750/pnr.2022.13.s06.195
8. Suyeon, Kim. (2023). Recent Trends and Notable Advances of Alginate Based Nano-Particles for Effective Biomedical Materials: Wound Healing and Drug Delivery. Key Engineering Materials, 945, 27-32. Available from: 10.4028/p-fsw5mj
9. Kubyshkin, Av., Olga, Pisareva., Yevgenia, Bessalova., Irina, Ivanovna, Fomochkina. (2020). The prospects of using the silver nanoparticles composition in sodium alginate matrix. 315, 09001-. Available from: 10.1051/MATECCONF/202031509001
10. Sajeli, Begum., Kirti, Hira., Pragya, Paramita, Pal., Samrun, Nessa., Onkar, P., Kulkarni., Jeyapragash, Danaraj., Ameer, Basha, Shaik., Hiroshi, Araya., Yoshinori, Fujimoto. (2021). Halodule pinifolia (Seagrass) attenuated lipopolysaccharide-, carrageenan-, and crystal-induced secretion of pro-inflammatory cytokines: mechanism and chemistry.. Inflammopharmacology, 29(1), 253-267. Available from: 10.1007/S10787-020-00747-X
11. Jaya, R., Lakkakula., Arpita, Roy., Karan, Krishnamoorthy., Saad, Alghamdi., Mazen, Almehmadi., Pratik, Gujarathi., Prachi, Pansare., M., Allahyani., Osama, Abdulaziz., Kamini, Velhal., Most., Khatun., Md., Jamal, Hossain. (2022). Alginate-Based Nanosystems for Therapeutic Applications. Journal of Nanomaterials, 2022, 1-11. Available from: 10.1155/2022/6182815
12. [Agueda Aramburu, P., Flecha, S., Lujan-Williams, C. A. M., & Hendriks, I. E. (2024). Water column oxygenation by Posidonia oceanica seagrass meadows in coastal areas: A modelling approach. *The Science of the Total Environment*, *942*, 173805.](http://paperpile.com/b/UhlxW2/fabI)
13. [Ajay, R., Rakshagan, V., Queenalice, A., Vinothkumar, S., Ravivarman, C., & Saravanadinesh, P. (2022). Effect of triazine comonomer substitution on the structure and glass transition temperature of monomethacrylate-based resin polymer: An in vitro study. *The Journal of Contemporary Dental Practice*, *23*(2), 202–207.](http://paperpile.com/b/UhlxW2/PKT5q)
14. [Ajay, R., Sasikala, R., Rakshagan, V., Raghunathan, J., LalithaManohari, V., & Baburajan, K. (2022). Evaluation of cytocompatibility of thermopolymerized denture base copolymer containing a novel ring-opening oxaspiro comonomer. *World Journal of Dentistry*, *13*(2), 127–132.](http://paperpile.com/b/UhlxW2/mzQvz)
15. [Ajay, R., Suma, K., Sasikala, R., Rakshagan, V., Baburajan, K., & Kalarani, G. (2022). Evaluation of linear dimensional stability of monomethacrylate-based dental polymer containing a novel tricyclic diacrylate cross-linker using a novel surface-level index technique. *World Journal of Dentistry*, *13*(6), 568–573.](http://paperpile.com/b/UhlxW2/gUXSD)
16. [Al-Hatamleh, M. A. I., Alshaer, W., Hatmal, M. M., Lambuk, L., Ahmed, N., Mustafa, M. Z., Low, S. C., Jaafar, J., Ferji, K., Six, J.-L., Uskoković, V., & Mohamud, R. (2022). Applications of Alginate-Based Nanomaterials in Enhancing the Therapeutic Effects of Bee Products. *Frontiers in Molecular Biosciences*, *9*, 865833.](http://paperpile.com/b/UhlxW2/twZt)
17. [Balaji Ganesh S, & Sugumar, K. (2021). Internet of Things—A novel innovation in dentistry. *Journal of Advanced Oral Research*, *12*(1), 42–48.](http://paperpile.com/b/UhlxW2/RYI0M)
18. Chehelgerdi M., Chehelgerdi, M., Allela, O. Q. B., Pecho, R. D. C., Jayasankar, N., Rao, D. P. & Akhavan-Sigari, R. (2023). Progressing nanotechnology to improve targeted cancer treatment: overcoming hurdles in its clinical implementation. Molecular cancer, 22(1), 169.
19. [Chidambaram, S. R., George, A. M., Muralidharan, N. P., Prasanna Arvind, T. R., Subramanian, A., & Rahaman, F. (2022). Current overview for chemical disinfection of dental impressions and models based on its criteria of usage: A microbiological study. *Indian Journal of Dental Research : Official Publication of Indian Society for Dental Research*, *33*(1), 30–36.](http://paperpile.com/b/UhlxW2/9C585)
20. [Choukaife, H., Doolaanea, A. A., & Alfatama, M. (2020). Alginate Nanoformulation: Influence of Process and Selected Variables. *Pharmaceuticals* , *13*(11), 335.](http://paperpile.com/b/UhlxW2/CvmS)
21. [Contreras-Lopez, G., Garcia-Galicia, I. A., Carrillo-Lopez, L. M., Corral-Luna, A., Buenabad-Carrasco, L., Titulaer, M., Villarreal-Balderrama, J. A., & Alarcon-Rojo, A. D. (2024). Exploration of Microencapsulation of Arginine in Carnauba Wax () and Its Dietary Effect on the Quality of Beef. *Animals : An Open Access Journal from MDPI*, *14*(13). https://doi.org/](http://paperpile.com/b/UhlxW2/yEAI)[10.3390/ani14131857](http://dx.doi.org/10.3390/ani14131857)
22. [Dawkins, P. D., Paz-Lacavex, A., Fiorenza, E. A., Rush, M. A., Beas-Luna, R., Lorda, J., Malpica-Cruz, L., Sandoval-Gil, J. M., McHugh, T. A., Han, M. K., Bracken, M. E. S., & Lamb, J. B. (2024). Field Collection and Laboratory Maintenance of Canopy-Forming Giant Kelp to Facilitate Restoration. *Journal of Visualized Experiments: JoVE*, *208*. https://doi.org/](http://paperpile.com/b/UhlxW2/1fT9)[10.3791/66092](http://dx.doi.org/10.3791/66092)
23. [Deepika, B. A., Ramamurthy, J., Girija, S., & Jayakumar, N. D. (2022). Evaluation of the antimicrobial effect of Ocimum sanctum L. oral gel against anaerobic oral microbes: An in vitro study. *World Journal of Dentistry*, *13*(S1), S23–S27.](http://paperpile.com/b/UhlxW2/EN6k1)
24. [Duan, C., Hu, L., Lin, X., Xue, J., Zou, J., & Wu, H. (2024). Impacts of salinity stress induced by ballast water discharge on the ecosystem of shanghai port, China. *Marine Environmental Research*, *200*, 106629.](http://paperpile.com/b/UhlxW2/Em5R)
25. [Fawcett, D., Verduin, J. J., Shah, M., Sharma, S. B., & Poinern, G. E. J. (2017). A Review of Current Research into the Biogenic Synthesis of Metal and Metal Oxide Nanoparticles via Marine Algae and Seagrasses. *Journal of Nanoscience and Nanotechnology*, *2017*. https://doi.org/](http://paperpile.com/b/UhlxW2/wIQK)[10.1155/2017/8013850](http://dx.doi.org/10.1155/2017/8013850)
26. [Govindaraj, A., & Dinesh, S. P. S. (2021). Effect of chlorhexidine varnish and fluoride varnish on White Spot Lesions in orthodontic patients- a systematic review. *The Open Dentistry Journal*, *15*(1), 151–159.](http://paperpile.com/b/UhlxW2/9H7FB)
27. [Graf, S., Thakkar, D., Hansa, I., Pandian, S. M., & Adel, S. M. (2023). 3D metal printing in orthodontics current trends, biomaterials, workflows and clinical implications. *Seminars in Orthodontics*. https://doi.org/](http://paperpile.com/b/UhlxW2/hBRAG)[10.1053/j.sodo.2023.01.001](http://dx.doi.org/10.1053/j.sodo.2023.01.001)
28. [Harsha, L., & Subramanian, A. K. (2022). Comparative assessment of pH and degree of surface roughness of enamel when etched with five commercially available etchants: An in vitro study. *The Journal of Contemporary Dental Practice*, *23*(2), 181–185.](http://paperpile.com/b/UhlxW2/l8tPa)
29. [Jabin, Z., Nasim, I., Vishnu Priya, V., & Agarwal, N. (2021). Quantitative Analysis and Effect of SDF, APF, NaF on Demineralized Human Primary Enamel Using SEM, XRD, and FTIR. *International Journal of Clinical Pediatric Dentistry*, *14*(4), 537–541.](http://paperpile.com/b/UhlxW2/kzWob)
30. [Katyal, D., Subramanian, A. K., Venugopal, A., & Marya, A. (2021). Assessment of Wettability and Contact Angle of Bonding Agent with Enamel Surface Etched by Five Commercially Available Etchants: An In Vitro Study. *International Journal of Dentistry*, *2021*, 9457553.](http://paperpile.com/b/UhlxW2/8DLjI)
31. [Kou, F., Wang, W., You, S., Wei, X., & Wu, X. (2024). Preparation and characterization of metal-polyphenol networks encapsulated in sodium alginate microbead hydrogels for catechin and vitamin C delivery. *International Journal of Biological Macromolecules*, 133870.](http://paperpile.com/b/UhlxW2/7Vvl)
32. [Lai, J., Azad, A. K., Sulaiman, W. M. A. W., Kumarasamy, V., Subramaniyan, V., & Alshehade, S. A. (2024). Alginate-Based Encapsulation Fabrication Technique for Drug Delivery: An Updated Review of Particle Type, Formulation Technique, Pharmaceutical Ingredient, and Targeted Delivery System. *Pharmaceutics*, *16*(3), 370.](http://paperpile.com/b/UhlxW2/BmZG)
33. [Lakkakula, J., Roy, A., Krishnamoorthy, K., Alghamdi, S., Almehmadi, M., Gujarathi, P., Pansare, P., Allahyani, M., Abdulaziz, O., Velhal, K., Khatun, M. C. S., & Hossain, M. J. (2022). Alginate-Based Nanosystems for Therapeutic Applications. *Journal of Nanomaterials*, *2022*. https://doi.org/](http://paperpile.com/b/UhlxW2/sPfX)[10.1155/2022/6182815](http://dx.doi.org/10.1155/2022/6182815)
34. [Li, C.-D., Lin, T.-A., Chen, P.-H., Gau, T.-S., Lin, B.-J., Chiu, P.-W., & Liu, J.-H. (2024). Synthesis of pentameric chlorotin carboxylate clusters for high resolution EUV photoresists under small doses. *Nanoscale Advances*, *6*(11), 2928–2944.](http://paperpile.com/b/UhlxW2/wMlj)
35. [Lyimo, L. D., & Hamisi, M. I. (2023). The influence of seagrass and its associated sediment on organic carbon storage: A case of Halodule uninervis and Syringodium isoetifolium meadows of Western India Ocean, Tanzania. *Marine Environmental Research*, *183*, 105836.](http://paperpile.com/b/UhlxW2/33SL)
36. [Maiti, S. (2021). Comparative analysis of abrasion resistance in relation to different temporary acrylic crown material using toothbrush simulator- an in vitro study. *International Journal of Dentistry and Oral Science*, 2153–2157.](http://paperpile.com/b/UhlxW2/YgXbm)
37. [Menaa, F., Wijesinghe, U., Thiripuranathar, G., Althobaiti, N. A., Albalawi, A. E., Khan, B. A., & Menaa, B. (2021). Marine Algae-Derived Bioactive Compounds: A New Wave of Nanodrugs? *Marine Drugs*, *19*(9). https://doi.org/](http://paperpile.com/b/UhlxW2/CCqW)[10.3390/md19090484](http://dx.doi.org/10.3390/md19090484)
38. [Pirog, R. S. (2011). *Seagrass: Ecology, Uses, and Threats*.](http://paperpile.com/b/UhlxW2/y5un)
39. [Quan, Z., Chen, Z., Li, H., Sun, S., & Xu, Y. (2024). A hydrogel sensor based on cellulose nanofiber/polyvinyl alcohol with colorimetric-fluorescent bimodality for non-invasive detection of urea in sweat. *International Journal of Biological Macromolecules*, 133760.](http://paperpile.com/b/UhlxW2/jNgP)
40. Qian, Tao., Julong, Zhong., Rui, Wang., Yuzhu, Huang. (2021). Ionic and Enzymatic Multiple-Crosslinked Nanogels for Drug Delivery.. Polymers, 13(20), 3565-. Available from: 10.3390/POLYM13203565
41. [Rajeshkumar, Sabarathinam, J., & Madhulaxmi. (2021). Development of anti inflammatory and antimicrobial silver nanoparticles coated suture materials. *International Journal of Dentistry and Oral Science*, 2006–2013.](http://paperpile.com/b/UhlxW2/tQgQl)
42. [Ramamurthy, & Jaiganesh. (2021). Evaluation of antioxidant and anti inflammatory activity of grape seed oil infused with silver nanoparticles an in vitro study. *International Journal of Dentistry and Oral Science*, 3318–3322.](http://paperpile.com/b/UhlxW2/taeOR)
43. Saadh, M. J., Rasulova, I., Almoyad, M. A. A., Kiasari, B. A., Ali, R. T., Rasheed, T. & Ciongradi, C. I. (2024). Recent progress and the emerging role of lncRNAs in cancer drug resistance; focusing on signaling pathways. Pathology-Research and Practice, 253, 154999.
44. [Sarvesh, N., Afeeza, K., Suresh, V., & Dilipan, E. (2024). Development of the Antioxidant Property of Seagrass Extract-Based Hydrogel for Dental Application. *Cureus*, *16*(2), e54544.](http://paperpile.com/b/UhlxW2/40j1)
45. [Solanki, L., Shantha Sundari, K. K., Muralidharan, N. P., & Jain, R. (2022). Antimicrobial effect of novel gold nanoparticle oral rinse in subjects undergoing orthodontic treatment: An ex-vivo study. *Journal of International Oral Health: JIOH*, *14*(1), 47.](http://paperpile.com/b/UhlxW2/iZMBy)
46. [Sushanthi, (2021). Vernonia amygdalina mediated copper nanoparticles and its characterization and antimicrobial activity - an in vitro study. *International Journal of Dentistry and Oral Science*, 3330–3334.](http://paperpile.com/b/UhlxW2/bPdz9)
47. [Tiwari, A., & Jain, R. K. (2023). Comparative evaluation of White Spot lesion incidence between NovaMin, probiotic, and fluoride containing dentifrices during orthodontic treatment using laser fluorescence - A prospective randomized controlled clinical trial. *Clinical and Investigative Orthodontics*, 1–8.](http://paperpile.com/b/UhlxW2/hQ0GP)
48. [Wang, B., Hu, L., & Siahaan, T. J. (2016). *Drug Delivery: Principles and Applications*. John Wiley & Sons.](http://paperpile.com/b/UhlxW2/6AUu)
49. [Weiner, P., & Kirkman, H. (1979). *Continuous Recording Technique to Measure Oxygen Release from a Seagrass Community Within an Acrylic Insulation Chamber*.](http://paperpile.com/b/UhlxW2/kCMX)
50. [Xiao, Y., Wang, L., Zhang, X., Ren, Y., Wang, J., Niu, B., & Li, W. (2024). Preparation and Characterization of Silica-Coated Sodium Alginate Hydrogel Beads and the Delivery of Curcumin. *Journal of Biomaterials Science. Polymer Edition*, 1–17.](http://paperpile.com/b/UhlxW2/Adwl)