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# Chitosan-Based Nanocomposite Hydrogels Reinforced with Nanoparticles: Multifunctional Nanomaterials for Biomedical Applications

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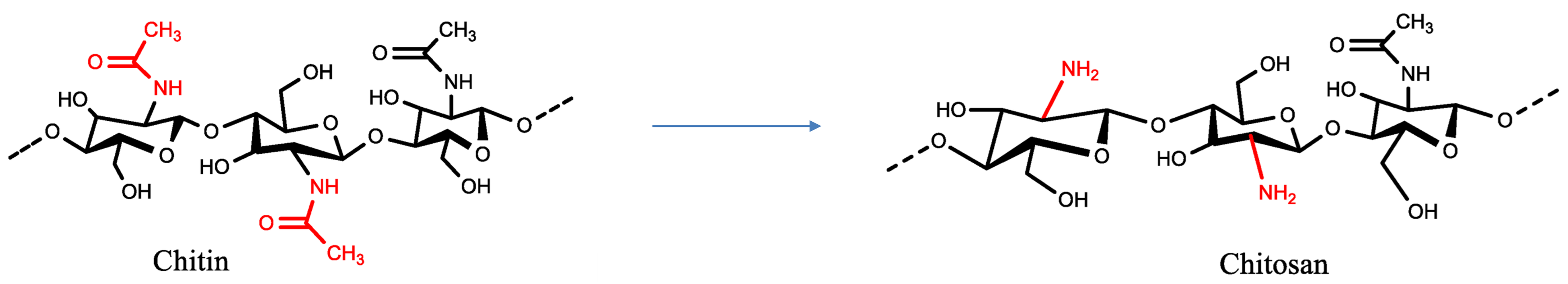
## INTRODUCTION & AIM

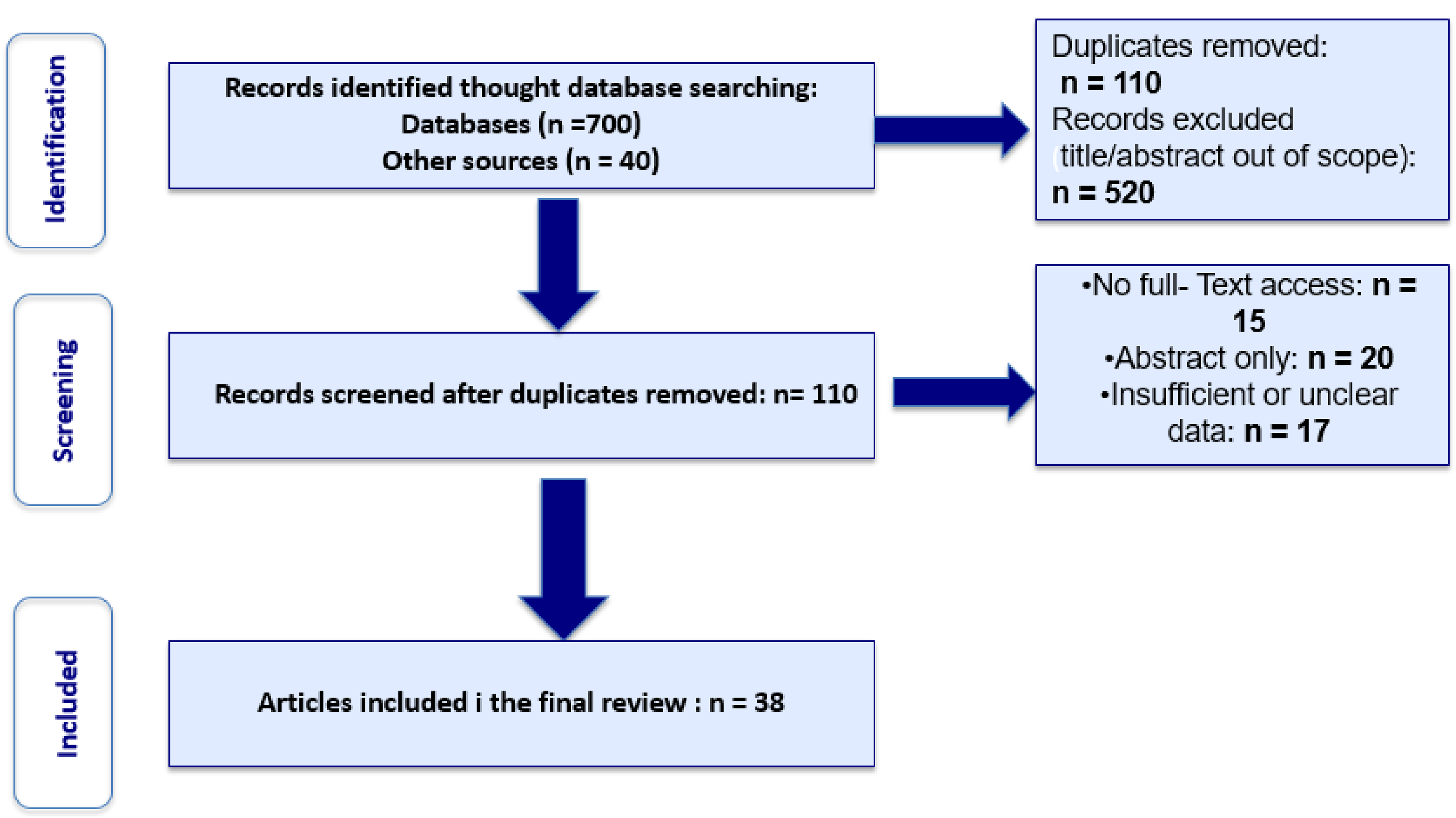
- Chitosan (CS) is a natural cationic polysaccharide obtained by partial deacetylation of chitin, mainly sourced from crustacean shells [1].




- Chitosan is considered a highly attractive biomaterial for biomedical applications due to its unique physicochemical and biological properties [2]:
  - ✓ **Biocompatibility;**
  - ✓ **Biodegradability;**
  - ✓ **Antimicrobial activity;**
  - ✓ **Hemostatic effect .**
- Chitosan has been widely employed in hydrogel systems for biomedical use, and in recent years, particular attention has focused on chitosan-based nanocomposite hydrogels, where nanoparticles further enhance their mechanical, biological, and functional performance [3].

## METHOD

- A systematic literature review was performed following PRISMA guidelines.
- Databases searched: PubMed, Web of Science, Scopus, ScienceDirect, Wiley, Google Scholar.
- Search terms: chitosan hydrogel, nanocomposite hydrogel, chitosan nanoparticles, drug delivery, tissue engineering.
- **Eligibility criteria**:
  - ✓ Original research (2019–2025) on chitosan-based nanocomposite hydrogels.
  - ✓ Duplicates, inaccessible full texts, or irrelevant studies were excluded.
- The selection process is summarized in the **PRISMA flowchart**:




## RESULTS & DISCUSSION

### ❑ Synthesis approaches of chitosan-based hydrogels

- Ionic gelation: electrostatic interactions between chitosan amino groups and multivalent anions; solvent- and initiator-free.
- Covalent crosslinking: stable chemical bonds with crosslinkers; improves mechanical stability and long-term integrity.
- In situ nanoparticle formation: nanoparticles generated within the hydrogel matrix; ensures uniform dispersion and strong polymer–nanoparticle interactions.

### ❑ Roles of incorporated nanoparticles

- Reinforce the hydrogel network.
- Enhance antibacterial activity.
- Impart functionalities (e.g., magnetism, photothermal responsiveness).

### ❑ Key formulation parameters

- Influence mechanical strength, swelling, porosity, and drug release kinetics.

### ❑ Polymer blending strategies

- Chitosan + natural polymers → improved structural versatility.
- Enables injectable, self-healing, and stimuli-responsive nanocomposite systems.

### ❑ Polymer blending strategies

- Incorporating nanoparticles into chitosan hydrogels enhances their stability, extends their functional spectrum, and adapts the material to a wide range of biomedical applications.

| Application | Composition / Nanoparticles | Method | Key Properties | Ref. |
|---|---|---|---|---|
| **Tissue engineering (magnetic scaffold)** | Chitosan + $Fe_3O_4$ + Gelatin + Hyaluronic acid | Freeze-drying & incorporation of magnetic NPs | Magnetic, porous scaffold; improved mechanics; controlled ciprofloxacin release | [4] |
| **Bone defect repair (3D printing)** | Chitosan + Hydroxyapatite + Gelatin + Hyaluronic acid + Magnetic NPs | 3D bioprinting & crosslinking | Bone defect filling, enhanced osteointegration, improved mechanical strength | [5] |
| **Drug delivery & antibacterial** | Chitosan + Agarose + $Fe_3O_4$ + Vancomycin | Double-network hydrogel with in situ NP incorporation | Sustained antibiotic release, antibacterial activity, good swelling behavior | [6] |
| **Multifunctional composite hydrogel** | Chitosan + PNIPAM + Nanoparticles | Physical/chemical crosslinking with NP dispersion | Thermo-responsive, improved cell adhesion and mechanics | [7] |

## REFERENCES

1. F. Hong et al., 2024. https://doi.org/10.1016/j.fochx.2023.101095
2. R. Cassano et al., 2024. https://doi.org/10.3390/polym16131770
3. J. Shah et al., 2025. https://doi.org/10.3390/jfb16020045
4. A. Abou-Okeil et al., 2024. https://doi.org/10.1038/s41598-024-78696-6
5. I. Apăvăloaiei et al., 2025. https://doi.org/10.1016/j.reactfunctpolym.2025.106422
6. A. Viteri et al., 2025. https://doi.org/10.1016/j.cej.2025.164214
7. J. Shan et al., 2024. https://doi.org/10.1016/j.heliyon.2024.e37431

## CONCLUSION

- Chitosan-based nanocomposite hydrogels demonstrate strong potential as next-generation materials in nanomedicine by integrating bioactivity, controlled release, and structural stability.
- Progress in synthesis strategies, nanoparticle design, and polymer integration will further enhance their clinical applicability.
- Optimizing safety, scalability, and translation remains essential for their successful implementation in biomedical practice.