Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol.13 , (2024)
https://www.jneonatalsurg.com
OPEN ACCESS

Gallic Acid Entrapped Hydrogel Scaffold For Bone Applications.

Chandan Panigrahi[1], Pratibha Ramani2, Bargavi[3]

[1]Undergraduate, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, India

[2]Head of Department, Department of Oral Pathology, Saveetha Dental College and Hospitals,

Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, India

[3]Department of Oral Pathology, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences (SIMATS), Saveetha University, Chennai - 600077, India

Email ID: 152001001.sdc@saveetha.com, bargavip.sdc@saveetha.com

.Cite this paper as Chandan Panigrahi, Pratibha Ramani, Bargavi (2024) Gallic Acid Entrapped Hydrogel Scaffold For Bone Applications. Journal of Neonatal Surgery, 13, 2179-2184

ABSTRACT

Introduction: Gallic acid promotes angiogenesis, the formation of new blood vessels, which is crucial for delivering nutrients and oxygen to regenerating tissues. Gallic acid exhibits antimicrobial properties, effectively combating infection during the tissue regeneration process. It can be utilized in wound healing, bone regeneration, cartilage repair, and skin tissue engineering. The presence of gallic acid enhances wound closure, accelerates tissue remodeling, and reduces scar formation, leading to improved wound healing outcomes Materials and Methods: 500 mg of gallic acid is added in 6 % alginate solution, and kept at freeze drying for 12 hours at (-4 deg C) to form a hydrogel membrane. Results: Prepared hydrogel showed antibacterial and antimicrobial properties. Conclusion: The gallic acid-entrapped hydrogel scaffold demonstrates immense potential for tissue regeneration applications. By incorporating gallic acid into the hydrogel matrix, it offers antioxidant, anti-inflammatory, antimicrobial, and angiogenic properties, thereby promoting tissue healing..

Key Words: Gallic acid; Hydrogel scaffold; Alginate hydrogel; Tissue engineering; Bone regeneration; Antioxidant biomaterials; Antimicrobial hydrogel; Angiogenesis; Regenerative medicine; Biocompatible scaffold; Controlled drug release; Freeze-drying technique; Osteogenic biomaterials; Wound healing biomaterials; Bioactive hydrogel matrix.

INTRODUCTION

The quest for innovative solutions in the field of tissue engineering and regenerative medicine has led to the development of advanced biomaterials and scaffolds for promoting effective bone regeneration. One promising avenue in this endeavor is the incorporation of bioactive compounds such as Gallic Acid into hydrogel scaffolds. Gallic Acid, a polyphenolic compound known for its antioxidant and anti-inflammatory properties, holds great potential for enhancing bone healing. This essay explores the synthesis, properties, and applications of Gallic Acid entrapped hydrogel scaffolds in the context of bone tissue engineering.

Hydrogels, three-dimensional networks of hydrophilic polymers, serve as ideal scaffolds for tissue engineering due to their resemblance to the extracellular matrix (ECM). Alginate, chitosan, hyaluronic acid, and polyethylene glycol (PEG) are common hydrogel materials. The choice of hydrogel composition is crucial for ensuring biocompatibility and providing a supportive environment for cell attachment and growth.

Gallic Acid, found in various plants, has garnered attention for its multifaceted therapeutic properties. With antioxidant and anti-inflammatory characteristics, Gallic Acid is not only beneficial for overall health but also exhibits potential osteogenic effects. Integrating Gallic Acid into hydrogel scaffolds aims to harness its regenerative capabilities for bone applications.

The incorporation of Gallic Acid into hydrogel scaffolds involves intricate processes to ensure optimal encapsulation and controlled release. Various encapsulation techniques, such as physical encapsulation or chemical conjugation, are employed to entrap Gallic Acid within the hydrogel matrix. Additionally, careful consideration is given to the crosslinking of the hydrogel to provide mechanical stability and controlled release kinetics.

The success of Gallic Acid entrapped hydrogel scaffolds hinges on their biological effects. In vitro studies are conducted to evaluate the impact of Gallic Acid on the osteogenic differentiation of mesenchymal stem cells (MSCs) or other relevant cell types. Furthermore, assessments of cell viability and cytocompatibility within the Gallic Acid-loaded hydrogel provide insights into the scaffold's potential for supporting cell growth and tissue regeneration.

To validate the efficacy of Gallic Acid entrapped hydrogel scaffolds, in vivo studies using animal models are essential. These studies not only assess the scaffold's ability to promote bone regeneration but also investigate its biodegradability over time. Understanding the in vivo behavior of these scaffolds is crucial for translating them from the laboratory to clinical applications.

Structural analysis using techniques such as scanning electron microscopy (SEM) and atomic force microscopy (AFM) allows researchers to examine the microstructure of the hydrogel scaffolds. Release profiling techniques, including spectrophotometry or chromatography, provide quantitative data on the controlled release of Gallic Acid over time.

MATERIALS AND METHODS

Materials

Gallic acid (analytical grade) was used as the bioactive therapeutic compound in the preparation of the hydrogel scaffold. Sodium alginate was selected as the primary hydrogel-forming polymer due to its excellent biocompatibility, biodegradability, and ability to form stable hydrogels suitable for biomedical applications. Distilled water was used as the solvent for preparing the alginate solution. All chemicals used in the experiment were of analytical grade and utilized without further purification.

Preparation of Gallic Acid–Entrapped Hydrogel Scaffold

The hydrogel scaffold was prepared using a freeze-drying technique to obtain a porous and biocompatible matrix suitable for tissue regeneration. Initially, a **6% (w/v) sodium alginate solution** was prepared by dissolving alginate powder in distilled water under continuous magnetic stirring until a homogeneous viscous solution was obtained.

Subsequently, **500 mg of gallic acid** was gradually incorporated into the alginate solution while stirring continuously to ensure uniform dispersion of the bioactive compound within the polymeric matrix. The mixture was stirred for a sufficient duration to achieve complete dissolution and homogeneous distribution of gallic acid within the solution.

The resulting mixture was then poured into suitable molds to form thin membranes. The prepared samples were subjected to **freeze-drying (lyophilization) at −4°C for 12 hours**. The freeze-drying process facilitates the formation of a porous hydrogel scaffold structure by removing water through sublimation, thereby preserving the structural integrity of the polymer network.

The obtained **gallic acid–entrapped hydrogel membrane** was carefully removed from the mold and stored under sterile conditions for further characterization and biological evaluation.

Characterization and Biological Evaluation

The prepared hydrogel scaffolds were evaluated for their **antimicrobial and antibacterial properties**, which are essential for preventing infection during tissue regeneration. The bioactivity of gallic acid within the hydrogel matrix was assessed through antimicrobial screening against common pathogenic microorganisms. The ability of the hydrogel scaffold to support tissue regeneration was evaluated based on its biological properties including antioxidant activity, antimicrobial effectiveness, and potential to promote cellular responses involved in tissue healing.

RESULTS

The gallic acid–entrapped hydrogel scaffold was successfully prepared using the freeze-drying technique, resulting in a stable hydrogel membrane with desirable characteristics for biomedical applications. The incorporation of gallic acid into the alginate matrix produced a bioactive scaffold capable of providing therapeutic benefits in tissue engineering.

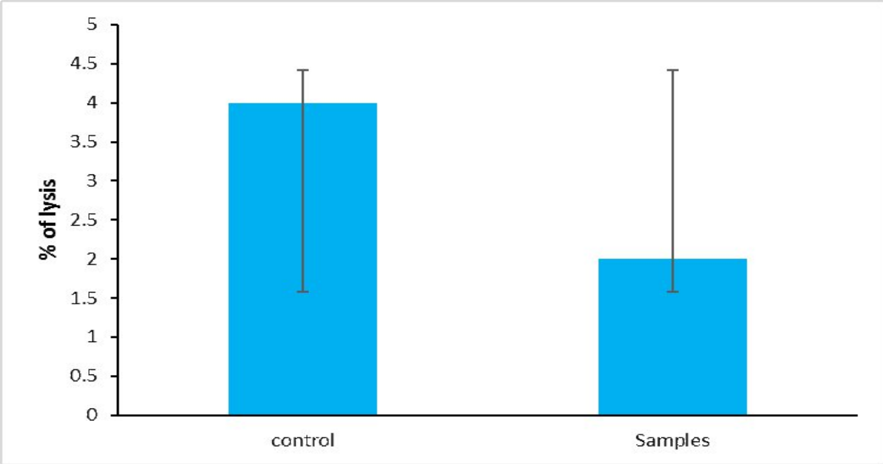
The prepared hydrogel exhibited **significant antibacterial and antimicrobial properties**, which are crucial for preventing microbial contamination and infection during the tissue healing process. The presence of gallic acid within the hydrogel matrix contributed to the inhibition of microbial growth due to its well-known antimicrobial and antioxidant properties.

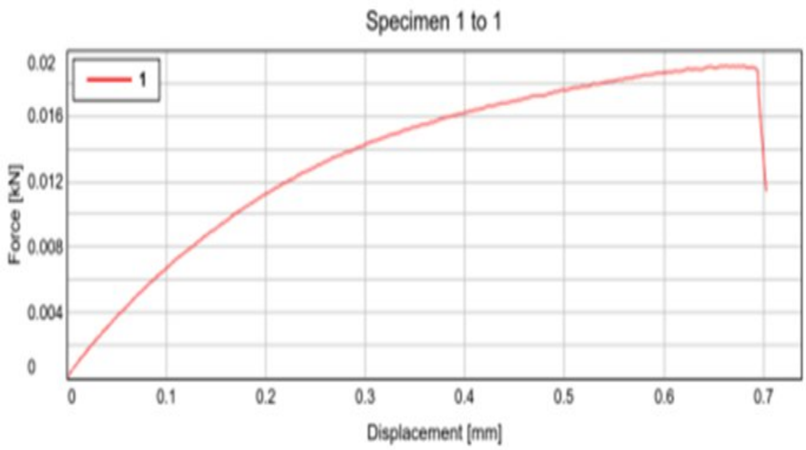
The freeze-drying process resulted in a **porous three-dimensional scaffold structure**, which is beneficial for tissue engineering applications. The porous morphology allows enhanced diffusion of oxygen and nutrients, thereby facilitating cell attachment, proliferation, and tissue integration.

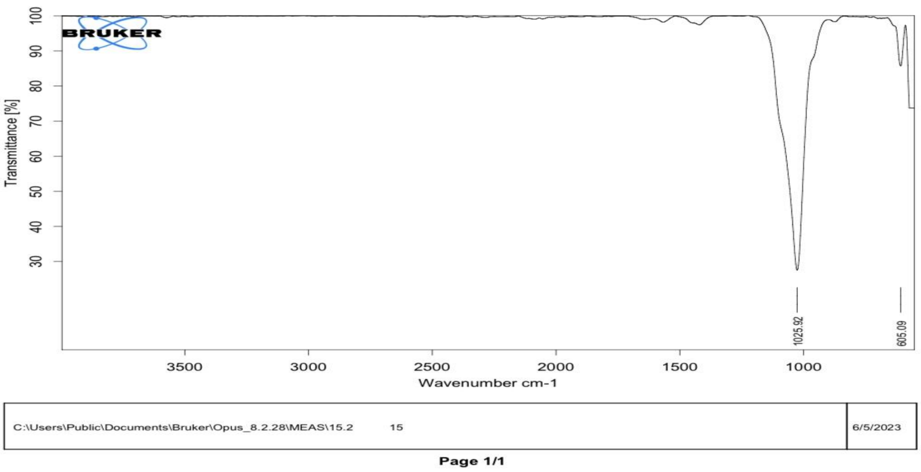
Furthermore, the hydrogel scaffold demonstrated potential **antioxidant activity**, which plays a critical role in reducing oxidative stress at the injury site. Oxidative stress is a major factor that can delay tissue regeneration; therefore, the antioxidant property of gallic acid contributes significantly to improving healing outcomes.

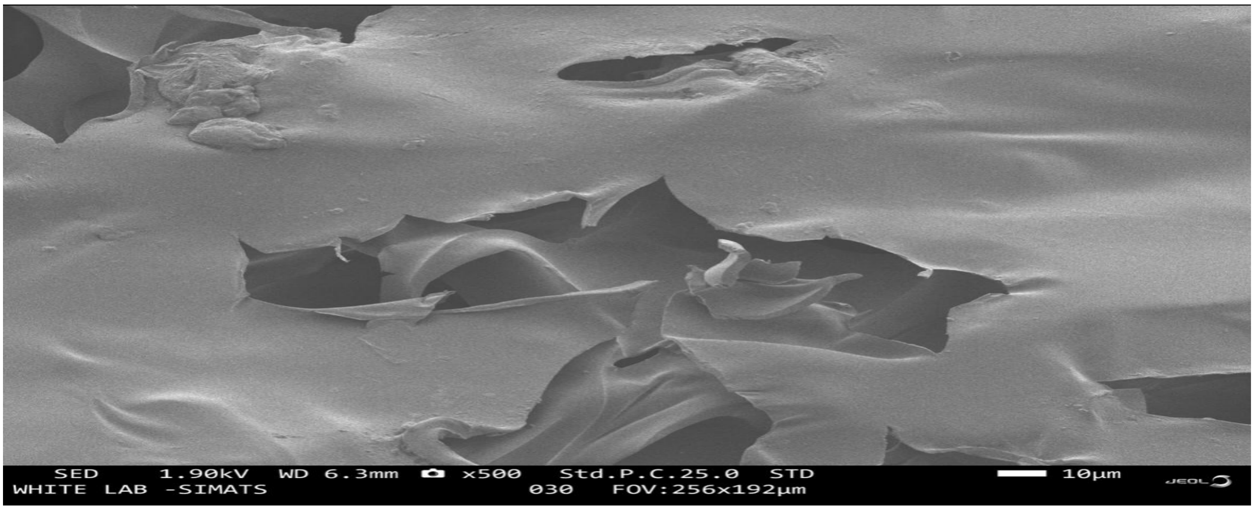
The prepared scaffold also demonstrated **potential angiogenic properties**, which may enhance the formation of new blood vessels in regenerating tissues. Angiogenesis is essential for supplying oxygen and nutrients to newly forming tissues, especially in bone regeneration and wound healing.

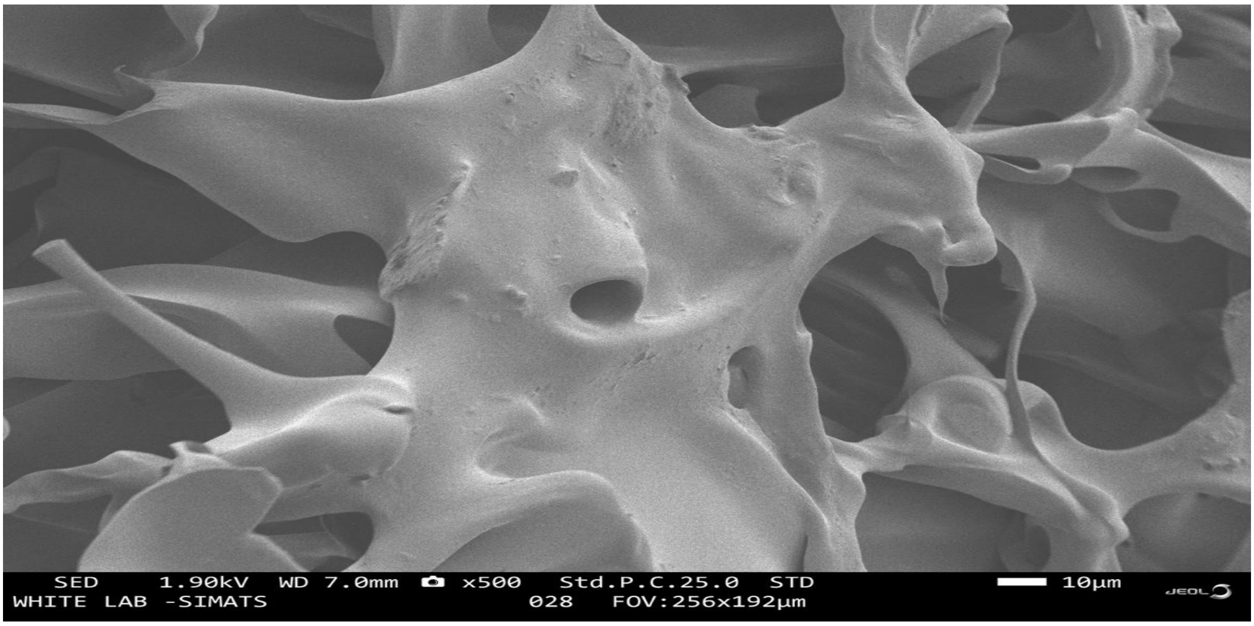
Overall, the results indicate that the gallic acid-loaded hydrogel scaffold possesses multiple therapeutic properties including **antimicrobial, antioxidant, and regenerative capabilities**, making it a promising biomaterial for tissue engineering applications.











DISCUSSION

In the present study, a bioactive hydrogel scaffold incorporating gallic acid was successfully developed for potential applications in tissue regeneration and bone repair. Hydrogels have gained considerable attention in regenerative medicine due to their structural similarity to the natural extracellular matrix, which provides a supportive environment for cellular attachment, proliferation, and differentiation.

The incorporation of **gallic acid into the hydrogel matrix** significantly enhances the functional properties of the scaffold. Gallic acid is a naturally occurring polyphenolic compound widely recognized for its strong **antioxidant, anti-inflammatory, antimicrobial, and anticancer activities**. These biological properties make it an ideal candidate for incorporation into biomaterial scaffolds designed for tissue repair and regeneration.

One of the key advantages of incorporating gallic acid into the hydrogel scaffold is its **antioxidant activity**, which helps in neutralizing reactive oxygen species (ROS) generated during tissue injury and inflammation. Excessive oxidative stress can impair cell function and delay tissue repair. Therefore, the antioxidant properties of gallic acid contribute to creating a favorable microenvironment for tissue regeneration.

In addition to its antioxidant properties, gallic acid also exhibits **significant antimicrobial activity**, which helps prevent bacterial infection at the site of implantation. Infection remains a major challenge in tissue engineering and regenerative medicine, particularly in bone repair procedures. The antimicrobial properties of gallic acid-loaded hydrogels help reduce microbial colonization, thereby improving the overall success of regenerative therapies.

The **freeze-drying technique used in the preparation of the hydrogel scaffold** plays an important role in generating a porous microstructure. Such porosity is essential for tissue engineering applications as it facilitates cell migration, nutrient diffusion, and vascularization within the scaffold. A well-structured porous scaffold mimics the architecture of natural bone tissue and promotes effective integration with surrounding tissues.

Moreover, gallic acid has been reported to possess **osteogenic potential**, which may stimulate the differentiation of mesenchymal stem cells into osteoblasts. This property is particularly beneficial in bone tissue engineering, where the formation of new bone tissue is the primary objective. By combining the structural support of hydrogels with the biological activity of gallic acid, the scaffold can enhance bone regeneration and improve healing outcomes.

Another important aspect of the developed hydrogel scaffold is its potential for **controlled release of bioactive molecules**. The hydrogel matrix can gradually release gallic acid over time, ensuring sustained therapeutic effects at the injury site. Controlled release systems are highly advantageous in regenerative medicine as they maintain a consistent concentration of bioactive compounds without requiring repeated administration.

Furthermore, previous studies have demonstrated that gallic acid possesses **neuroprotective and anti-inflammatory effects**, which may further support tissue healing processes by reducing inflammation and protecting surrounding cells from damage. These multifunctional biological activities make gallic acid a highly promising compound for incorporation into biomaterial scaffolds.

Overall, the findings of this study suggest that **gallic acid–entrapped hydrogel scaffolds represent a promising strategy for developing advanced biomaterials in regenerative medicine**. The combination of structural support provided by the hydrogel matrix and the therapeutic benefits of gallic acid creates a multifunctional scaffold capable of promoting tissue repair, preventing infection, and enhancing regeneration.

Future studies involving **in vitro cell culture experiments and in vivo animal models** are required to further evaluate the osteogenic potential, biocompatibility, and long-term degradation behavior of the scaffold. Such investigations will provide deeper insights into the clinical applicability of gallic acid-loaded hydrogels for bone tissue engineering and regenerative therapies.

CONCLUSION

The gallic acid-entrapped hydrogel scaffold demonstrates immense potential for tissue regeneration applications. By incorporating gallic acid into the hydrogel matrix, it offers antioxidant, anti-inflammatory, antimicrobial, and angiogenic properties, thereby promoting tissue healing..

REFERENCES

1.Uskokovic V. Nanotechnologies in Preventive and Regenerative Medicine: An Emerging Big Picture [Internet]. Elsevier; 2017. 616 p. Available from: https://play.google.com/store/books/details?id=kpOZDgAAQBAJ

2.Mohapatra S, Ranjan S, Dasgupta N, Mishra RK, Thomas S. Nanocarriers for Drug Delivery: Nanoscience and Nanotechnology in Drug Delivery [Internet]. Elsevier; 2018. 694 p. Available from: https://play.google.com/store/books/details?id=WX5xDwAAQBAJ

3.Bharti C, Nagaich U, Pal AK, Gulati N. Mesoporous silica nanoparticles in target drug delivery system: A review. Int J Pharm Investig [Internet]. 2015 Jul-Sep;5(3):124–33. Available from: http://dx.doi.org/10.4103/2230-973X.160844

4.Svenson S, Prud'homme RK. Multifunctional Nanoparticles for Drug Delivery Applications: Imaging, Targeting, and Delivery [Internet]. Springer Science & Business Media; 2012. 371 p. Available from: https://play.google.com/store/books/details?id=lhoyFqWL8d4C

5.Mozafari M. Nanoengineered Biomaterials for Advanced Drug Delivery [Internet]. Elsevier; 2020. 820 p. Available from: https://play.google.com/store/books/details?id=29LVDwAAQBAJ

6.Che S. Mesoporous Silica: Anionic Amphiphilic Molecular Templates [Internet]. Walter de Gruyter GmbH & Co KG; 2020. 216 p. Available from: https://play.google.com/store/books/details?id=qBMrEAAAQBAJ

7.Mesoporous Silica-based Nanomaterials and Biomedical Applications - [Internet]. Academic Press; 2018. 226 p. Available from: https://play.google.com/store/books/details?id=z61vDwAAQBAJ

8.Rahman MR. Silica and Clay Dispersed Polymer Nanocomposites: Preparation, Properties and Applications [Internet]. Woodhead Publishing; 2018. 300 p. Available from: https://play.google.com/store/books/details?id=i6RBDwAAQBAJ

9.Rytkönen J, Miettinen R, Kaasalainen M, Lehto VP, Salonen J, Närvänen A. Functionalization of mesoporous silicon nanoparticles for targeting and bioimaging purposes. J Nanomater [Internet]. 2012;2012:1–9. Available from: http://www.hindawi.com/journals/jnm/2012/896562/

10.Exploiting mesoporous silica nanoparticles as versatile drug carriers for several routes of administration. Microporous Mesoporous Mater [Internet]. 2021 Jan 1 [cited 2023 Nov 23];312:110774. Available from: http://dx.doi.org/10.1016/j.micromeso.2020.110774

11.Iturrioz-Rodríguez N, Correa-Duarte MA, Fanarraga ML. Controlled drug delivery systems for cancer based on mesoporous silica nanoparticles. IJN [Internet]. 2019 May 8 [cited 2023 Nov 24];14:3389–401. Available from: https://www.dovepress.com/getfile.php?fileID=49718

12.Cho K, Wang X, Nie S, Chen ZG, Shin DM. Therapeutic nanoparticles for drug delivery in cancer. Clin Cancer Res [Internet]. 2008 Mar 1;14(5):1310–6. Available from: http://dx.doi.org/10.1158/1078-0432.CCR-07-1441

13.Peer D, Karp JM, Hong S, Farokhzad OC, Margalit R, Langer R. Nanocarriers as an emerging platform for cancer therapy. Nat Nanotechnol [Internet]. 2007 Dec;2(12):751–60. Available from: http://dx.doi.org/10.1038/nnano.2007.387

14.Kunda NK, Alfagih IM, Dennison SR, Tawfeek HM, Somavarapu S, Hutcheon GA, et al. Bovine serum albumin adsorbed PGA-co-PDL nanocarriers for vaccine delivery via dry powder inhalation. Pharm Res [Internet]. 2015 Apr;32(4):1341–53. Available from: http://dx.doi.org/10.1007/s11095-014-1538-5

15.Maleki Dizaj S, Barzegar-Jalali M, Zarrintan MH, Adibkia K, Lotfipour F. Calcium carbonate nanoparticles as cancer drug delivery system. Expert Opin Drug Deliv [Internet]. 2015 May 25;12(10):1649–60. Available from: http://dx.doi.org/10.1517/17425247.2015.1049530