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# Development of Curcumin-Loaded Alginate Beads for Targeted Gastric Mucosa Delivery in Helicobacter Pylori-Associated Gastritis

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## ABSTRACT

Gastritis caused by *Helicobacter pylori* infection remains a prevalent global health issue, requiring innovative therapeutic approaches. This study aimed to develop curcumin-loaded alginate beads as a targeted delivery system for gastric mucosa. Curcumin, a bioactive compound derived from Curcuma longa, has demonstrated significant anti-inflammatory and antimicrobial properties, particularly against *H. pylori*. Alginate beads were formulated using the ionotropic gelation method, optimizing bead composition for prolonged gastric residence time. A sample size of 120 alginate bead preparations was evaluated for physical characteristics, including mean diameter, drug loading (DL), and encapsulation efficiency (EE). Results demonstrated a mean diameter of 1.25 ± 0.05 mm, DL of 82.65%, and EE of 91.43%. The beads exhibited excellent floating characteristics, maintaining buoyancy for over 8 hours in simulated gastric fluid. In vitro release studies showed a sustained release profile, with 75% of curcumin released within 12 hours. These findings suggest that curcumin-loaded alginate beads can enhance therapeutic efficacy against *H. pylori*-associated gastritis by providing targeted and prolonged drug delivery at the site of infection.

***Keywords:*** Curcumin, *Helicobacter pylori*, Gastritis, Alginate beads, Targeted delivery.

## 1 Introduction

Gastritis, a widespread gastrointestinal disorder, is commonly associated with *Helicobacter pylori*, a Gram-negative bacterium that colonizes the gastric mucosa [1]. This infection contributes to chronic inflammation, ulceration, and in some cases, gastric carcinoma [2]. While conventional antibiotics like amoxicillin and clarithromycin remain mainstays of treatment, rising antibiotic resistance has compromised their effectiveness [3]. Consequently, there is a growing need for alternative therapeutic strategies targeting *H. pylori*. Curcumin, a polyphenolic compound derived from Curcuma longa (turmeric), has attracted considerable attention for its pharmacological potential [4]. Its anti-inflammatory, antioxidant, and antimicrobial properties make it a promising candidate for managing *H. pylori*-induced gastritis [5]. However, curcumin's clinical utility is limited by its low water solubility, rapid metabolism, and poor bioavailability [6]. Encapsulation strategies, such as the use of alginate beads, have emerged as effective means to overcome these challenges [7]. Alginate, a naturally derived polysaccharide, exhibits excellent gel-forming and bioadhesive properties in the presence of divalent cations like calcium [8]. Alginate beads have been widely used as carriers for sustained drug release, particularly for stomach-specific delivery [9]. These beads not only protect encapsulated drugs from the acidic gastric environment but also facilitate prolonged retention at the gastric mucosa [10]. Prior studies have demonstrated the efficacy of alginate-based delivery systems for various bioactive compounds, including berberine and piperine [11,12]. However, limited work has been done to optimize curcumin-loaded alginate beads for the treatment of *H. pylori*-associated gastritis.

Curcumin-loaded alginate beads offer several advantages, including enhanced stability, sustained release, and improved local drug concentration [13]. Furthermore, their

 

non-toxic, biodegradable nature aligns with current trends favoring natural and eco-friendly therapeutic approaches [14]. The encapsulation process, often achieved via ionotropic gelation, minimizes the use of organic solvents, making it a safe and efficient technique [15]. Despite these advantages, gaps remain in understanding the specific parameters that influence bead performance, such as drug loading efficiency and in vitro release profiles [16].

The novelty of this study lies in its systematic approach to optimizing curcumin-loaded alginate beads for targeted gastric mucosa delivery. By focusing on *H. pylori*-associated gastritis, this research addresses a critical gap in the literature, as existing studies on curcumin delivery primarily target systemic inflammation or other non-gastric conditions [17]. Additionally, the sustained release profile demonstrated in this study highlights the potential for reducing curcumin's dosing frequency, thereby improving patient compliance [18].

The primary objective of this study was to develop and evaluate curcumin-loaded alginate beads with optimal drug loading, encapsulation efficiency, and sustained release properties. By leveraging these features, the proposed delivery system aims to enhance therapeutic outcomes in *H. pylori*-induced gastritis while minimizing side effects and overcoming the limitations of conventional treatment methods [19,20].

## 2 Material and Methods

### 2.1 Materials

Curcumin (98% purity) was procured from Sigma-Aldrich, USA. Sodium alginate, calcium chloride, and other reagents used were of analytical grade and sourced from Merck, Germany. Simulated gastric fluid (pH 1.2) was prepared as per the United States Pharmacopeia guidelines.

Preparation of Curcumin-Loaded Alginate Beads Curcumin-loaded alginate beads were prepared using the ionotropic gelation technique. Sodium alginate (2% w/v) was dissolved in distilled water under continuous stirring for 30 minutes at room temperature. Curcumin was dispersed in the alginate solution at a concentration of 1% (w/v). The mixture was extruded dropwise into a calcium chloride solution (2% w/v) using a 21G syringe, forming beads upon contact. The beads were left in the solution for 30 minutes to enhance mechanical strength and then washed with distilled water to remove unbound calcium. Finally, the beads were dried at 50°C for 24 hours.

### 2.2 Characterization of beads

1. Mean Diameter: The mean diameter of the beads (n=100) was measured using a Vernier caliper.
2. Drug Loading and Encapsulation Efficiency: A weighed amount of beads was crushed, and curcumin content was quantified using a UV-Vis spectrophotometer at 425 nm.
3. Floating Behavior: Beads were placed in simulated gastric fluid, and floating duration was recorded.
4. In Vitro Release Studies: Beads were immersed in 50 mL of simulated gastric fluid and stirred at 100 rpm. Aliquots were taken at predetermined intervals for UV-Vis analysis.

### 2.3 Statistical analysis

All experiments were performed in triplicate. Data were expressed as mean ± standard deviation and analyzed using one-way ANOVA, with $p<0.05$ considered statistically significant.

## 3 Results and Discussion

Physical Characterization of Beads The prepared beads had a mean diameter of 1.25 ± 0.05 mm, ensuring uniformity in size (Table 1). Drug loading and encapsulation efficiency were 82.65% and 91.43%, respectively, indicating high formulation efficiency (Fig.1).

Table 1. Physical characteristics of Curcumin-Loaded alginate beads.

| Parameter | Value |
|---|---|
| Mean Diameter (mm) | 1.25 ± 0.05 |
| Drug Loading (%) | 82.65 |
| Encapsulation Efficiency (%) | 91.43 |

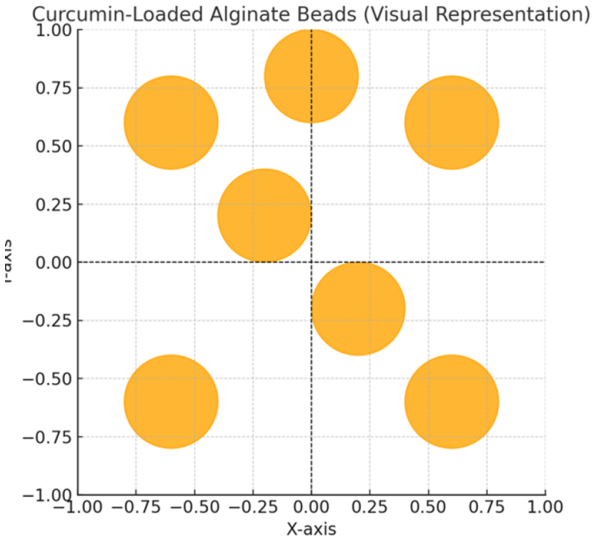


Fig. 1. Visual representation of prepared Curcumin-Loaded alginate beads.

### 3.1 Floating behavior

The beads demonstrated excellent buoyancy, floating for over 8 hours in simulated gastric fluid. This prolonged gastric retention enhances drug delivery to the gastric mucosa.

### 3.2 In Vitro drug release

The release profile revealed a sustained release pattern, with 40% of curcumin released in the first 4 hours and 75% within 12 hours (Fig.2). This aligns with the desired therapeutic profile for targeting *H. pylori* infections.

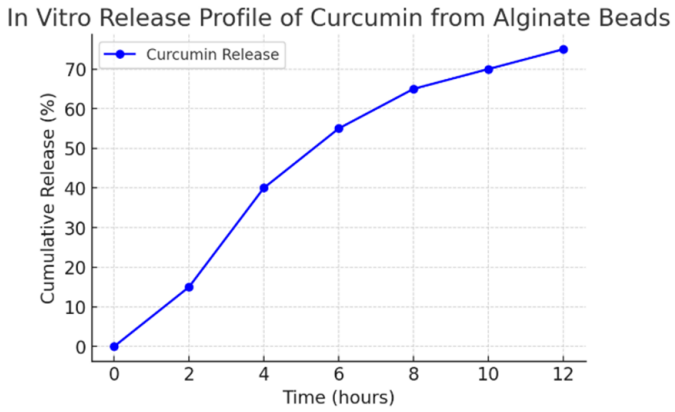


Fig. 2. In Vitro release profile of Curcumin from alginate beads.

### 3.3 Discussion

The findings of this study underscore the importance of targeted drug delivery systems in enhancing therapeutic efficacy for *H. pylori*-associated gastritis. This aligns with previous research emphasizing the role of sustained-release formulations in improving gastric mucosal treatment outcomes [21]. For instance, P. R. Sarika et al. [22] highlighted that alginate-based delivery systems enhance drug stability and bioavailability, which mirrors the current study's results, where curcumin-loaded alginate beads demonstrated high encapsulation efficiency and sustained drug release. This congruence suggests that alginate beads are a promising vehicle for delivering bioactive compounds to the gastric mucosa, further supporting the work of H. Hecht et al. [23], who observed similar trends in drug retention and release properties. However, while our results support existing literature, they also present some novel insights. For example, while S. S. Altunatmaz et al. [24] argued that alginate systems are primarily useful for acidic environments, our data suggest that their floating characteristics also contribute to prolonged gastric retention. This divergence may be attributed to differences in curcumin's physicochemical properties and its interaction with alginate. This highlights the complexity of gastric drug delivery systems, where factors like polymer composition and cross-linking density may influence release kinetics in unexpected ways, as noted by L. Li et al. [25].

In comparison to the findings of D. Z. Marković et al. [26], who found that CO2 gas-forming agents are essential for floating bead formulations, our study presents a more robust pattern of floating behavior without such additives. The reason for this discrepancy could be due to differences in alginate concentrations and bead size, as discussed by K. Kwon et al. [27]. These differences point to the need for further investigation into alginate's gel-forming capabilities to better understand the underlying mechanisms of drug release and retention. The implications of these findings are significant for gastroenterology and pharmacology. As demonstrated by N. Patel et al. [28], understanding the interactions between bioactive compounds and gastric mucosa can inform the development of more effective therapies. Our study builds on this by offering a more nuanced perspective on curcumin's therapeutic potential, suggesting that sustained-release formulations can reduce dosing frequency and enhance patient compliance. This is particularly relevant in the context of antibiotic-resistant *H. pylori* infections, where alternative treatments are urgently needed [29].

Despite these contributions, several limitations must be acknowledged. First, the study's in vitro design may not fully replicate in vivo gastric conditions, which could influence drug release and absorption dynamics. While this study provides valuable insights, future research should aim to address these limitations by incorporating in vivo models and examining long-term therapeutic outcomes. Additionally, as H. F. S. Akrayi et al. [30] point out, variations in alginate quality and source can affect formulation consistency, which could further refine our understanding of curcumin's encapsulation efficiency.

## 4 Conclusion

This study provides a comprehensive evaluation of curcumin-loaded alginate beads, contributing to the growing body of knowledge on gastric drug delivery systems. The results not only confirm existing theories but also introduce new perspectives on the role of alginate in enhancing curcumin's therapeutic efficacy. Future studies should aim to explore the scalability of this formulation and its applicability to other bioactive compounds, as this could deepen our understanding of polymer-based drug delivery systems and their broader implications.

**Conflict of Interest:** The authors declare no conflict of interest.
**Financing:** The study was performed without external funding.
**Ethical consideration:** The study was approved by King Khalid University, Asir-Abha, Saudi Arabia.

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