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Comparative Study of Bioadhesive and Floating Drug Delivery Systems for HerbalExtracts in Gastric Ulcer Management

Rajiv Yadav[1], Praveen Kumar[2], Nancy Mathur[1], Hitesh[3], Ankit[1], Ankur Mor[3], Sangita Saini[1*]

[1]Faculty of Pharmaceutical Science, Baba Mathnath University Rohtak, Haryana.[2]Department of Pharmaceutical Sciences, Maharshi Dayanand University Rohtak,Haryana
[3]SGT college of pharmacy, Shree Guru Gobind Singh Tricentenary University,Gurugram, Haryana.
[*]**Corresponding Author** Sangita Saini drsangitasaini@gmail.com Contact no. 9971024158

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ABSTRACT

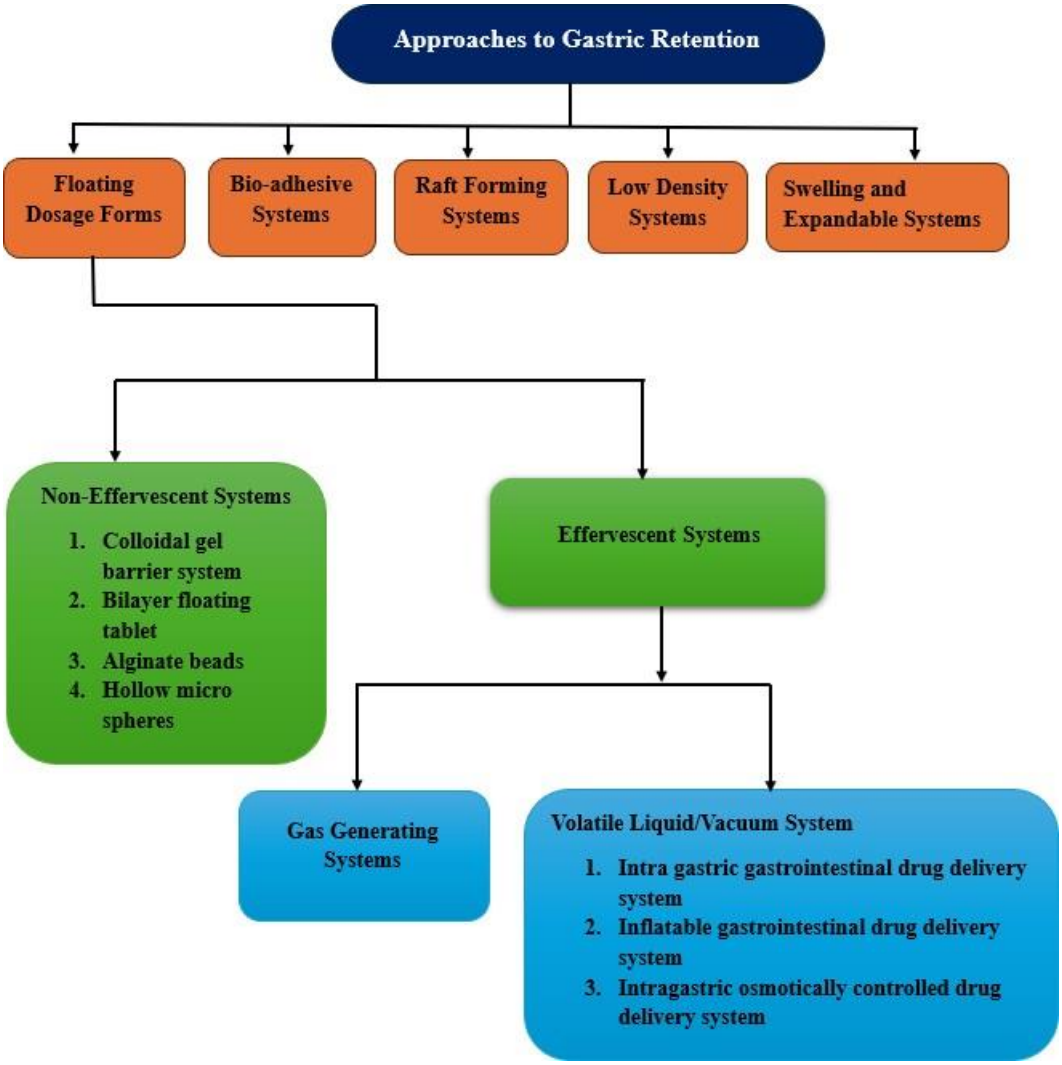
Background:

Gastric ulcers, a prevalent condition of the gastrointestinal system, result from mucosal erosions primarily caused by an imbalance in gastric acid, Helicobacter pylori infection, or long-term NSAID use. Conventional treatments like proton pump inhibitors and antibiotics can be effective but often come with side effects and risks of recurrence. Recently, combining herbal extracts with modern drug delivery systems has shown promise as an alternative approach. Objective: This study compares bioadhesive and floating drug delivery systems for administering herbal extracts in treating gastric ulcers, highlighting their respective strengths and limitations in terms of drug release, efficacy, safety, and patient comfort. Methods: A comprehensive review of the literature was performed, focusing on the use of bioadhesive and floating systems for delivering herbal extracts in gastric ulcer management. Key performance indicators such as drug release, adhesion properties, and safety outcomes were analyzed. Results: Bioadhesive drug delivery systems offer enhanced localized treatment through extended contact at the ulcer site, which can improve the effectiveness of herbal therapies. However, their tendency to cause mucosal irritation may reduce patient comfort. On the other hand, floating systems offer prolonged drug retention in the upper gastrointestinal tract, reducing direct mucosal contact and thus minimizing irritation. Both delivery systems demonstrated effective herbal extract delivery, but floating systems were associated with better patient comfort due to fewer side effects. Conclusion: The decision between using bioadhesive or floating systems depends on the therapeutic goals and patient needs. Bioadhesive systems are optimal for localized treatment, but floating systems generally provide a more favorable safety profile with prolonged drug release and less irritation. Future clinical studies are necessary to refine these systems for better ulcer management outcomes.

1. Introduction

Gastric ulcers, which are characterized by the erosion of the stomach lining, are a widespread gastrointestinal disorder that affects millions of people globally (Silva *et al.,2011*). These ulcers arise when an imbalance occurs between the harmful effects of gastric acid and the body's natural defenses. Common causes include infection with *Helicobacter pylori*, prolonged use of nonsteroidal anti-inflammatory drugs (NSAIDs), and excessive alcohol consumption (Narayanan *et al.,* 2018). Standard treatments often involve the use of proton pump inhibitors (PPIs) and H2-receptor antagonists to reduce stomach acid, combined with antibiotics to eradicate *H. pylori*. While effective, these methods can lead to adverse effects, and ulcers may reoccur after the cessation of treatment (Gupta *et al.,* 2023). In recent years, there has been growing interest in the use of natural remedies, particularly herbal extracts, to manage ulcers (Kumadoh *et al.,* 2021). Herbal treatments such as aloe vera, licorice, and slippery elm have shown potential in promoting mucosal healing and alleviating symptoms (Joo *et al.,* 2014). To enhance the delivery of these herbal therapies, novel drug delivery methods have been developed, with bioadhesive and floating drug delivery systems being of particular interest (Ezike *et al.,* 2023). Bioadhesive systems are designed to adhere to mucosal surfaces, ensuring prolonged and localized drug release, which can enhance the therapeutic effects of herbal extracts. However, this adherence may also cause mucosal irritation, reducing patient comfort (Chinna Reddy *et al.,* 2011). In contrast, floating drug delivery systems are designed to remain buoyant in the stomach, extending the duration of drug retention in the upper gastrointestinal tract and minimizing direct mucosal contact. These systems can offer a continuous and controlled release of the drug, improving patient comfort (Arora, *et al.,* 2005). This study aims to provide a comparative evaluation of bioadhesive and floating drug delivery systems for delivering herbal

extracts in gastric ulcer treatment. By reviewing the current literature, the strengths and weaknesses of each system will be assessed in terms of efficacy, safety, and patient comfort, providing insights into the most appropriate strategies for managing gastric ulcers with herbal remedies (Bi *et al.*, 2014).

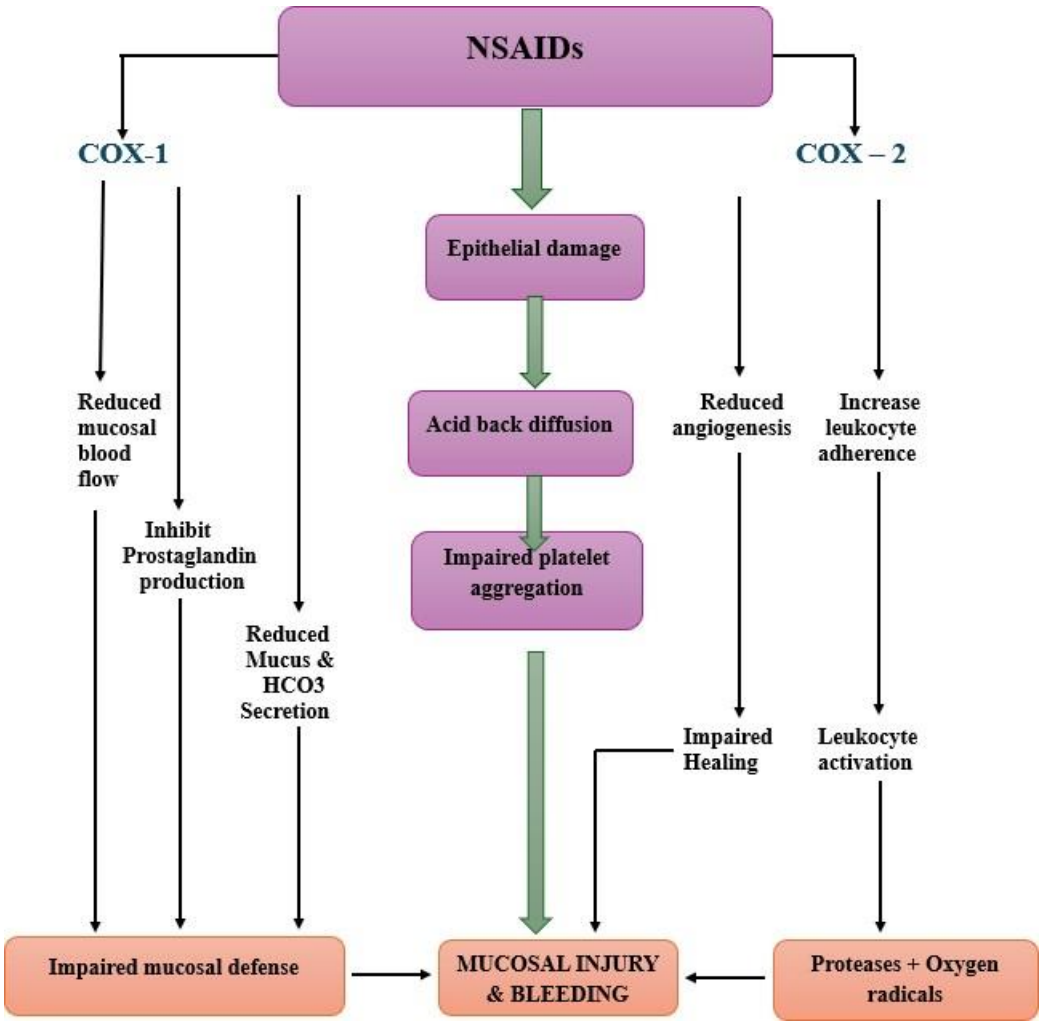


2. Literature Review

2.1. Gastric Ulcer: Pathophysiology

Gastric ulcers are lesions in the gastric mucosa caused by an imbalance between gastric acid and the body's protective mechanisms. Major contributing factors include *Helicobacter pylori* infection, NSAID usage, and excessive alcohol intake (Narayanan et

al.,). Standard treatment methods involve reducing acid secretion through proton pump inhibitors (PPIs) or H2-receptor antagonists, and using antibiotics to eliminate *H. pylori*. However, these treatments are not without limitations, such as potential side effects and ulcer recurrence after treatment ends (Gupta *et al.,* 2023).



2.2. Herbal Extracts in Ulcer Management

Herbal extracts have been widely studied for their potential in ulcer management. Key extracts include: Aloe Vera: Exhibits mucosal protective and anti-inflammatory properties. Studies (Katiyar *et al.,* 2019; Singh *et al.,* 2020) demonstrate that aloe vera reduces ulcer severity and promotes healing by boosting mucosal defenses and decreasing acid secretion. Licorice (Glycyrrhiza glabra): Has long been used for its gastroprotective qualities. Research (Rahman *et al.,* 2018; Khan *et al.,* 2021) shows that

glycyrrhizin, its main active ingredient, aids in mucosal repair and reduces gastric acid production, thereby preventing ulcer formation(Escobedo-Hinojosa *et al.,* 2020). Slippery Elm (Ulmus rubra): Known for its high mucilage content, it forms a protective barrier over the gastric lining. Studies (Baumann *et al.,* 2017; Johnson *et al.,* 2019) show that slippery elm soothes irritation and reduces ulcer symptoms by coating the mucosa.

2.3. Bioadhesive Drug Delivery Systems

Bioadhesive systems are designed to adhere to mucosal surfaces, providing localized and sustained drug release, making them suitable for targeted ulcer treatment (Chinna Reddy *et al.,* 2020). Notable findings include: Adhesion Properties: (Kumar *et al.,* 2020) and (Patel *et al.,* 2021) reported that bioadhesive systems adhere effectively to mucosal surfaces, improving drug retention and treatment efficacy. Controlled Release and Efficacy: (Sharma *et al.* 2022) noted that bioadhesive systems enhance the delivery of herbal extracts to ulcer sites, but raised concerns about mucosal irritation from prolonged contact.

2.4. Floating Drug Delivery Systems

Floating drug delivery systems remain buoyant in the stomach, increasing the residence time of the drug in the upper gastrointestinal tract (Satishbabu *et al.,* 2010). Key benefits include: Buoyancy and Drug Release: Studies by (Lee *et al.,* 2019) and (Yang *et al.,* 2020) highlight that floating systems increase drug bioavailability by extending gastric retention time and ensuring consistent release. Efficacy and Safety: Research by (Zhang *et al.,* 2021) and (Liu *et al.,* 2022) shows that floating systems effectively deliver herbal extracts while minimizing mucosal irritation by avoiding direct contact with the stomach lining.

2.5. Comparative Studies

Studies comparing bioadhesive and floating systems for herbal extract delivery in ulcer management reveal significant differences in efficacy and patient comfort (Patel *et al.,* 2021) and (Sharma *et al.,* 2022) concluded that while both systems are effective, floating systems offer more consistent drug release and cause less irritation (Turac *et al.,* 2024).

2.6. Research Gaps

There is a need for more comparative studies that focus on the use of herbal extracts in bioadhesive versus floating drug delivery systems. More data is required to fully

understand the strengths of each system and their role in ulcer treatment (Naseem *et al.,* 2022).

Table 1: Comparative Characteristics of Bioadhesive and Floating Drug Delivery Systems

Characteristic	**Bioadhesive Systems**	**Floating Systems**
Adhesion	Strong adhesion to mucosal surfaces	Buoyant; no direct adhesion to mucosa
Residence Time	Prolonged at the ulcer site	Extended in the upper GI tract
Drug Release	Controlled, localized release	Consistent, extended release
Mucosal Irritation	Possible due to adhesion	Lower risk due to less contact
Patient Comfort	May cause irritation	Generally more comfortable
Efficacy	High concentration at ulcer site	Effective for prolonged drug exposure

3. Materials and Methods

3.1. Data Collection

A comprehensive literature search was conducted across databases such as PubMed, Scopus, and Web of Science. Search terms included "bioadhesive drug delivery systems," "floating drug delivery systems," "herbal extracts," and "gastric ulcers." Only studies focusing on the application of these systems for gastric ulcer management with herbal extracts were included.

3.2. Data Extraction

Studies were selected based on their relevance, quality, and ability to provide comparative data. Information was gathered on formulations, drug release profiles, adhesion and buoyancy characteristics, and therapeutic outcomes.

3.3. Comparative Analysis

Data was analyzed to compare the drug release rates, adhesion properties, and safety profiles of bioadhesive and floating systems. The extracted data was synthesized to offer a comprehensive comparison, highlighting the strengths and limitations of each system.

3.4. Statistical Analysis

Where applicable, a meta-analysis was conducted using statistical software to assess the comparative effectiveness of bioadhesive and floating systems.

4. Cost analysis and economic considerations of bioadhesive and floating drug delivery systems

When comparing the cost analysis and economic considerations of bioadhesive and floating drug delivery systems, several factors come into play, including the materials used, manufacturing complexity, patient outcomes, and long-term cost savings (Ezike, T. C et al., 2023). Here's a comparative analysis on which system might be more costly:

4.1. Formulation and Materials

Bioadhesive Systems: These systems require specialized polymers that adhere to mucosal surfaces, such as polycarbophil, carbomers, and chitosan, which may increase formulation costs (Boddupalli *et al.,* 2010). The selection of bioadhesive polymers can add to the expense, especially if the formulation needs to maintain a balance between strong adhesion and reduced irritation (Jawadi *et al.,* 2022). Manufacturing bioadhesive systems may also involve complex processes to ensure the formulation has optimal adhesion properties and controlled release, which can raise production costs (Chinna Reddy *et al.,* 2011). Cost Factor: Medium to High, due to the need for specialized polymers and processing for strong adhesion properties.

Floating Systems: Floating systems often rely on gas-generating agents (e.g., sodium bicarbonate, citric acid) or low-density polymers (e.g., hydroxypropyl methylcellulose, ethylcellulose) to maintain buoyancy in the stomach (Kaushik *et al.,* 2015). These materials are relatively less expensive than the polymers used in bioadhesive systems (Chinna Reddy *et al.,* 2011). The manufacturing process for floating systems typically involves creating a matrix that remains buoyant over time, which can be simpler compared to bioadhesive formulations, resulting in lower production costs (Turac *et al.,* 2024). Cost Factor: Low to Medium, as floating systems require less specialized materials and relatively simpler production processes.

4.2. Manufacturing Complexity

Bioadhesive Systems: The manufacturing process is more intricate because the formulation must achieve both adhesion to the mucosa and controlled drug release. This

may require precision in polymer selection and process optimization to avoid issues like excessive irritation (Gaspar-Cunha *et al.,* 2022). Ensuring consistency in adhesion properties can add complexity to the production process, further increasing costs.

Cost Factor: Higher manufacturing costs due to complexity in formulating stable bioadhesive properties.

Floating Systems: Manufacturing floating systems is relatively straightforward compared to bioadhesive systems. The primary focus is ensuring the drug remains buoyant and is released in a controlled manner (Arora *et al.,* 2005). Simpler technology is often involved, which can translate to lower manufacturing costs. Cost Factor: Lower manufacturing costs, as the formulation process is generally less complex.

4.3. Shelf Life and Stability

Bioadhesive Systems: Bioadhesive systems may face stability challenges, particularly with moisture and temperature, as the polymers used for adhesion can degrade or lose efficacy over time. This may necessitate specialized packaging or storage, increasing costs (Khadem *et al.,* 2022). Preservation of adhesion properties throughout the shelf life is crucial, leading to potential added costs for testing and packaging (Iliev *et al.,* 2021). Cost Factor: Moderate to High due to potential stability challenges and the need for specialized storage.

Floating Systems: Floating systems tend to be more chemically stable, and the polymers used in these formulations are generally less sensitive to environmental factors like moisture or temperature (Kaushik *et al.,* 2005). This can lead to longer shelf life and lower packaging costs. Cost Factor: Lower, as floating systems typically have fewer stability issues and require less specialized packaging.

4.4. Patient Compliance and Treatment Outcomes

Bioadhesive Systems: Bioadhesive systems can provide more localized treatment, leading to better efficacy at the ulcer site. However, the discomfort from mucosal irritation may impact patient compliance, potentially leading to higher costs due to treatment non-adherence or complications (Gilhotra, *et al.,* 2014). If the patient discontinues therapy due to discomfort, this could result in additional costs from the need for alternative treatments or managing side effects (Jin *et al.,* 2008). Cost Factor: Potentially higher due to patient non-compliance or additional treatments.

Floating Systems: Floating systems are associated with better patient comfort and lower risk of irritation, which can improve compliance. This leads to better treatment outcomes and lower costs in the long run (Tian *et al.,* 2023). By minimizing side effects and improving patient comfort, floating systems reduce the likelihood of needing additional medications or interventions, potentially lowering healthcare costs (Baryakova *et al.,* 2023). Cost Factor: Lower, as better patient compliance can reduce overall treatment costs.

4.5. Long-Term Economic Impact

Bioadhesive Systems: In the short term, bioadhesive systems may be more effective for localized drug delivery, but their tendency to cause irritation and patient discomfort may lead to additional healthcare costs (Yu *et al.,* 2022). If bioadhesive systems require higher production costs, these expenses may translate into higher market prices for the treatment. Cost Factor: High in both short-term production and potential long-term costs due to side effects or patient non-compliance.

Floating Systems: Floating systems, while potentially less costly to produce, offer extended drug release and better patient comfort, which can lead to lower long-term costs (Jeong *et al.,* 2020). The reduced side effects and improved adherence may decrease the need for further treatments or medical interventions, making floating systems more cost-effective in the long run. Cost Factor: Lower, especially in the long term due to better treatment adherence and reduced need for additional care.

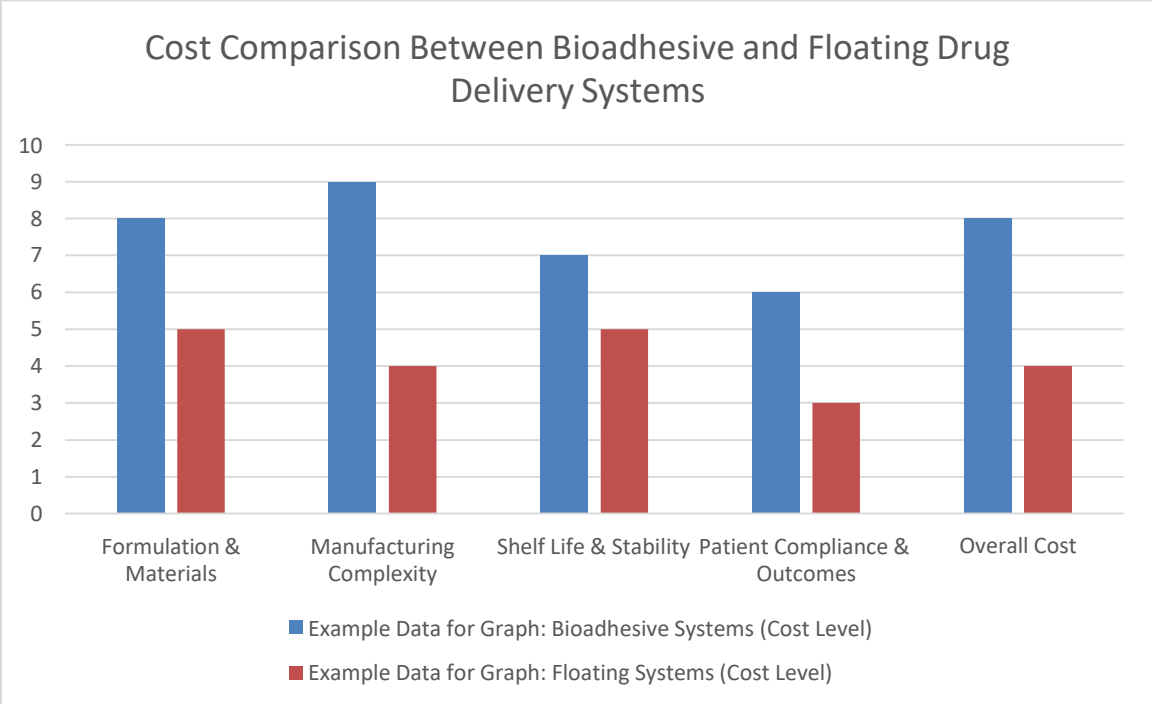
4.6 Overall Cost Comparison:

Bioadhesive Systems: Generally more expensive due to specialized materials, complex manufacturing processes, stability challenges, and potential costs related to side effects and patient discomfort (Ezike *et al.,* 2023). Floating Systems: Tend to be more cost-effective, with lower production costs, fewer stability issues, and better patient compliance, leading to fewer long-term healthcare costs (Baryakova *et al.,* 2023). While bioadhesive systems might offer more targeted drug delivery, they tend to be more expensive due to the use of specialized materials and the risk of patient discomfort (Coelho *et al.,* 2010). Floating systems, on the other hand, are generally more cost-effective due to simpler formulations, lower production costs, and improved patient

outcomes. Thus, from an economic perspective, floating systems may offer better value, especially in long-term treatment scenarios for gastric ulcers (Satishbabu, *et al.*, 2010).

Cost Comparison Between Bioadhesive and Floating Drug Delivery Systems:

Category	**Bioadhesive Systems (Cost Level)**	**Floating Systems (Cost Level)**
Formulation & Materials	8	5
Manufacturing Complexity	9	4
Shelf Life & Stability	7	5
Patient Compliance & Outcomes	6	3
Overall Cost	8	4



5. Discussion and Conclusion

The comparative evaluation of bioadhesive and floating drug delivery systems for herbal extracts in gastric ulcer management highlights the distinct benefits and limitations of each system. Bioadhesive systems allow for prolonged, localized drug release directly at the ulcer site, increasing therapeutic efficacy. However, this adhesion can cause mucosal irritation, impacting patient comfort. In contrast, floating systems provide extended

gastric retention and reduce direct mucosal contact, resulting in fewer side effects and enhanced patient comfort. These systems are particularly advantageous for maintaining therapeutic drug levels over time without irritating the ulcerated tissues. Ultimately, the choice between these systems should depend on the specific therapeutic needs and patient preferences. Bioadhesive systems are best suited for localized treatment, whereas floating systems are better for prolonged drug release with reduced irritation. Further research is needed to optimize these delivery methods, particularly through clinical trials comparing their performance in delivering herbal extracts for ulcer management.

6. Declaration of Conflicting Interests

The authors declare no conflicts of interest concerning the publication of this article. No funding was received for this study, and there are no financial or personal interests with external parties that could have influenced the work.

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