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A Comprehensive Review: "Buoyant Drug Delivery Systems: A Promising Strategy for Gastroretentive Controlled Release Therapy"

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Abstract- Oral drug delivery remains the most preferred route of administration due to patient compliance and cost effectiveness. However, conventional dosage forms often exhibit poor bioavailability because of rapid gastric emptying and limited absorption window in the upper gastrointestinal tract. Buoyant or Floating Drug Delivery Systems (FDDS) are gastroretentive systems designed to remain buoyant in gastric fluid for prolonged periods, thereby enhancing gastric residence time and improving therapeutic efficacy. This review highlights the principle, classification, formulation strategies, evaluation parameters, advantages, limitations, and future perspectives of buoyant drug delivery systems.

Keywords- Buoyant system, Floating drug delivery, Gastroretentive system, Hydrodynamically balanced system, Controlled release, Microspheres.

I. INTRODUCTION

Buoyant Drug Delivery Systems (FDDS) are advanced oral, low-density gastroretentive systems that float on gastric fluids, extending gastric residence time and allowing for controlled, sustained drug release. They enhance bioavailability, particularly for drugs with narrow absorption windows or instability in the lower gastrointestinal tract, reducing dosing frequency.

Key Aspects of Buoyant Drug Delivery Systems:

- Mechanism: These systems have a bulk density lower than that of gastric fluids (1.004–1.01 g/cm³), allowing them to remain buoyant without affecting gastric emptying rate.
- Formulation Strategies: They are typically prepared using hydrophilic, swellable polymers (like HPMC K4M, K15M) and gas-generating agents (like sodium bicarbonate) that produce to initiate floating.

These systems represent a crucial approach in pharmaceutical technology to enhance the efficacy of drugs that are otherwise poorly absorbed or quickly eliminated from the stomach.

Oral controlled drug delivery systems have gained significant attention in pharmaceutical research. However, drugs with narrow absorption windows, poor stability in alkaline pH, or local action in the stomach require prolonged gastric retention.

Gastroretentive drug delivery systems (GRDDS) were developed to overcome this limitation. Among them, Floating Drug Delivery Systems (FDDS) are most promising due to simplicity and effectiveness.

FDDS are designed to have a density lower than gastric fluid (≈1.004 g/cm³), enabling them to float on stomach contents without affecting gastric emptying rate.

II. PRINCIPLE OF BUOYANCY

The mechanism of FDDS is based on Archimedes' Principle, which states:

A body immersed in fluid experiences an upward force equal to the weight of the fluid displaced.

Mathematical Expression:

Where:

ρ_f = Density of gastric fluid

g = Acceleration due to gravity

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V = Volume of displaced fluid for floating:

III. Mechanism of Floating

Floating occurs through two primary mechanisms:

3.1 Effervescent Systems

Contain:

Sodium bicarbonate →Citric acid / Tartaric acid In acidic stomach pH:

CO_2 is released → Gas is entrapped in polymer matrix

Density decreases → System floats

3.2 Non-Effervescent Systems

Contain swellable polymers:

HPMC, Carbopol, Sodium alginate, Chitosan

Mechanism:

Hydration → Gel formation

Swelling → Reduced density

Sustained drug release

IV. Classification of Floating Drug Delivery Systems

4.1 Single Unit Systems

- Floating tablets
- Floating capsules
- Hydrodynamically balanced systems

Advantages: Simple design

Disadvantages: Risk of dose dumping

4.2 Multiple Unit Systems

- Floating microspheres
- Floating beads
- Floating pellets

Advantages:

✓ Reduced dose dumping

✓ Uniform drug release

✓ Better safety profile

V. Ideal Drug Candidates

Suitable drugs include:

- Drugs absorbed in upper GIT
- Drugs unstable in intestinal pH
- Drugs with short half-life
- Drugs acting locally in stomach

Examples:

Captopril, Metformin, Furosemide, Ranitidine, Amoxicillin

VI. Formulation Components

Component	→	**Role**
Polymers (HPMC, Carbopol)	→	Swelling & gel formation
Gas generating agents	→	CO_2 formation
Fillers	→	Bulk formation
Lubricants	→	Manufacturing aid
Release modifiers	→	Sustained release

VII. Evaluation Parameters

Pre-Compression:

Angle of repose, Bulk density, Compressibility index

Post-Compression:

Hardness, Friability, Weight variation, Drug content

Floating Parameters→ Floating lag time, Total floating time

Swelling index, In-vitro drug release

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Advantages	*Disadvantage*
✓ Prolonged gastric residence time for acid unstable drugs	Not suitable
✓ Improved bioavailability for gastric irritants	Not suitable
✓ Reduced dosing frequency	Dependent on gastric motility
✓ Site-specific delivery	Requires sufficient gastric fluid
✓ Better patient compliance	

VIII. Recent Advances

- Floating nanoparticles
- Floating in-situ gel systems
- Raft forming systems
- 3D printed gastroretentive systems
- Combination of floating + mucoadhesive systems

IX. Future Perspectives

Research is focusing on:

- Personalized gastroretentive systems
- Smart polymers
- Targeted gastric drug delivery
- Nanotechnology-based floating systems

FDDS have significant potential in improving therapeutic outcomes in drugs with narrow absorption window.

X. Conclusion

Floating drug delivery systems represent a major advancement in oral controlled drug delivery. By enhancing gastric retention and improving bioavailability, these systems offer promising therapeutic benefits. Continued innovation in polymers and formulation technologies will further strengthen their clinical relevance.

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