Review Article

An Updated Review on Gastro Retentive Drug Delivery System

Anand Goswami[1]*, Dr. Neetesh Kumar Jain[1], Dr. Manoj Goyal[2]

1. University of Pharmacy, Oriental University, Indore, Madhya Pradesh, India.
2. Jai Institute of Pharmaceutical Sciences & Research, Gwalior, Madhya Pradesh, India.

***Corresponding author's E-mail:** anandgoswami2@gmail.com

Received: 11-09-2020; **Revised:** 22-10-2020; **Accepted:** 30-10-2020; **Published on:** 15-11-2020.

ABSTRACT

The very effective and approved method for applying drug has been oral route. Owing to the great curative advantages of oral controlled release dosage types, improved therapeutic advantages are favored as the interesting subject in the pharmaceutical field. One such innovative advance to prolonging gastric residence time is the gastroretentive drug delivery system, which objects site-specific medicine free in the abdomen for systemic or local effect. This technique is especially helpful for the medicine in the upper part of the gastrointestinal tract which have narrow absorption window. The article aims to summarize the various approaches to gastroretentive behavior. We also summarized important factors affecting gastric retention to consider increasing physiological difficulties in achieving gastric retention. Recently implemented gastrointestinal innovations such as expandable, super porous hydrogel; bio / mucoadhesive, elastic, ion-exchange resin; and low- and high-density systems with their merits and demerits have also been studied. Eventually, the criteria of assessment of the gastroretentive drug delivery systems are addressed.

Keywords: Gastro retentive system, Floating Delivery, Gastric Residence Time, (GRT), Physiology of Stomach

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DOI: 10.47583/ijpsrr.2020.v65i01.006

DOI link: http://dx.doi.org/10.47583/ijpsrr.2020.v65i01.006

INTRODUCTION

Due to the tremendous curative advantages of the orally controlled release dosage types, the important research subject over the past 3 decades is preferred[1]. Around 50% of on-the-market drug delivery systems are oral delivery systems with greater benefits due to consumer acceptance and ease of administration[2]. Due to short gastric retention time (GRT), i.e. the time taken to reach small intestine by the abdomen content[3], oral absorption of drugs is also impeded. Drugs that are readily absorbed from GIT & have a short shelf-life are rapidly eliminated from circulation in the blood, and they need repeated dosing. To overcome this restriction, production of oral sustained-controlled release dosage form is an effort to gradually free the medication into the gastrointestinal tract (GIT) and long-term retain an appropriate concentration of the medication in the general circulation. Such a drug delivery should be maintained in the abdomen after oral administration and released in a controlled manner, so that the medication may possibly consistently distributed to its gastrointestinal tract incorporation sites (GIT) [4].

Consequently, the "gastro-retentive drug delivery system" is beneficial for these medications by enhancing their bioavailability, therapeutic effectiveness & potential dose decrease. Drug absorption in the "gastrointestinal tract" is a highly variable process which depends on factors such as gastric emptying, the "gastrointestinal transit time of dosage forms", the release of drugs from the dosage form and the location of drug absorption [4,5,6]

Need for "Gastroretentive drug delivery system":[7]

- Within the pharmaceutical sector traditional oral delivery is commonly used to treat diseases. However, traditional distribution has many inconveniences and main disadvantages are non-site specificity.
- "Gastro-retentive drug delivery" is one of the site-specific routes for drug delivery either in the abdomen or in the intestine. It is administered by maintaining the dosage type in the stomach & the drug is distributed to various locations in the stomach, duodenum and intestine in a controlled manner

Stomach

The stomach is situated just under the diaphragm in the upper left part of the abdomen [14]. It occupies a section of the hydrochondriazone and epigastric. The principal purpose of the stomach is to temporarily store the food, grind it and then gradually release it into the duodenum. Too little leakage from the stomach occurs because of its low surface area [15].

Table 1: Suitable Drug Candidates for Gastroretentive Drug Delivery System [8]

S. No.	Suitable Drug Candidates	Example
1	Medicines which are absorbed mainly in the abdomen	Amoxicillin
2	Medications which are freely soluble in basic pH	Diazepam, Furosemide
3	Medicines which degrade in the colon	Metformin HCl, Ranitidine
4	Drugs with narrow absorption window	Levodopa, Methotrexate
5	Medicines which were quickly absorbed from the GI tract	Tetracycline
6	Medicines which agitate common colonic microbes	Antibiotics against *Helicobacter Pylori*
7	Medicines which work in the abdomen locally	Amoxicillin, Clarithromycin, Misoprostol

Table 2: Unsuitable drug for Gastroretentive drug delivery system [9]

S. No.	Suitable Drug candidates	Example
1	Drugs which have a very small solubility in acid	Phenytoin
2	Drugs which suffer from gastric instability	Erythromycin
3	Medicines targeted for specific release in the colon	5-amino salicylic acid and corticosteroids

Table 3: Advantages and Disadvantages of "Gastroretentive Drug Delivery System [10-13]

S. No.	Advantages	Disadvantages
1	It improves patient observance by raising the regularity of dosing	The limitation of floating systems is so as to they need high levels of stomach fluids for efficient floating. And with such dosage type more water consumption is recommended.
2	Buoyancy increases the time spent in gastric residence	In supine posture (like sleeping), contractile waves can sweep away the floating dosage type (if not of greater size). Therefore, patient must not take floating formulation just before bedtime.
3	Better therapeutic efficacy of short-lived drugs	Drugs with problems of stability in a high acidic medium, with very low solubility in acidic medium, and medicine that cause impatience of gastric mucosa cannot be absorbed into the GRDDS.
4	Site-specific delivery of medication to the stomach	Bio / mucoadhesive systems have problems with high takings of mucus layer, thick mucus layer and related limitations of soluble mucus.
5	Sustained release can prevent gastric irritation.[10]	Swellable formulations have to able of swelling rapidly before leaving the abdomen and attaining a size greater than pylorus aperture. It has to able of resisting MMC phase III housekeeper waves.
6	By making particular floating unit such as microspheres release medicine equivalently, no possibility of dumping.	Gastric retention is partial by a number of factors, including gastric motility, pH and food presence. Such variables are never constant and thus we cannot predict the buoyancy.
7	Delivery of drugs in small intestine region, with narrow absorption window.	The big challenge for a bio-adhesive method is the high rate of gastric mucus turnover.
8	Longer stomach residence time might be beneficial for local action in upper part of small intestine	Oesophageal binding to bioadhesive drug delivery systems is also possible.

Structure and Function

Stomach is classified by human anatomy into three main parts: fundus, neck, and antrum (pylorus). The proximal part called the fundus, and the body acts as storage for undigested food. The antrum provides the central mixing site, and serves as a gastric emptying pump by propeller actions

The stomach also develops endogenous factor in its parietal cells, in addition to HCl. The intrinsic factor developed at this digestive stage allows the subsequent absorption of vitamin B_{12} (cobalamin) into the small intestine. The production of the intrinsic factor is crucial because vitamin B_{12} plays a significant role in the development of red blood cells and neurological functions. Many of these products include dehydration-

setting water, some medicines, including aspirin, amino acids, ethanol, caffeine, and certain water-soluble vitamins. In fact, acidic stomach condition can be lethal to several forms of bacteria and other micro-organisms entering the body through ingestion, potentially shielding the body from infection and disease [16-19].

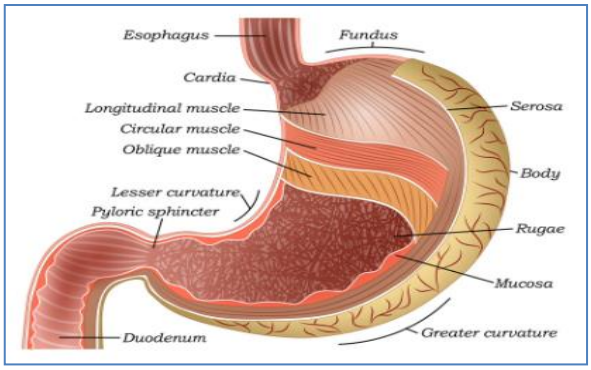

Figure 1: Structure of stomach

Physiology

The primary function of the stomach is food preparation and transport. The stomach allows for reservation of short-term food and fast intake of fairly large meals. The main important enzyme metabolism is encouraged in proteins stomach. Stomach peristalsis mix up and grind eaten food with stomach secretions, transforming it into a diluted liquid shape. The liquefied bulk is transported to the small intestine for further digestion [20-22].

An inter digestive myloelectric cycle or migratory myloelectric cycle (MMC) phenomenon occurs, which is divided into 4 phases as Wilson and Washington have provided. The 4 phases are enumerated below and also shown in Figure 1.

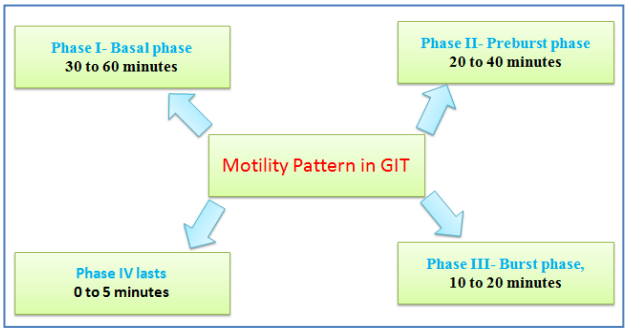

Figure 2: Motility Pattern in Gastrointestinal Tract

Factors Controlling GRDDS

Some of the factors are enumerated below:

Density

Dosage type with lesser density in the stomach substance can float to the outside, while greater density sinks to stomach underneath. The proper density necessary for floating properties is lower than 1 gm/cm^3.

Size

Size must to be higher than 7.5 mm in thickness.

Shape

Either in circles or sphere-shaped formulation exhibit improved property associated to other shapes.

Multiple Unit Formulation

Multiple units are advantageous due to foretell release profile.

Nature of Meal

High concentrations of fatty acid and other indigestible polymers slow down the stomach processing time due to gastric motility variations.

Frequency of Feed

Low frequency of myoelectric complex migration (MMC) contributes up to 400 times to GRT, which in turn depends on the level of food intake.

Age

GRT is more common in geriatric patients, and less common in neonates and infants. Age over 70 (> 70) shows GRT for longer.

Concomitant Intake of Drug

mixture of some drugs along with gastric motility enhancers or depressants, affect "Gastro retention time"[23, 24, 25].

Gastroretentive Techniques

Various strategies have been investigated, including floating, swelling, contraction and adhesion, to improve the gastro-retention of dosage types [26].

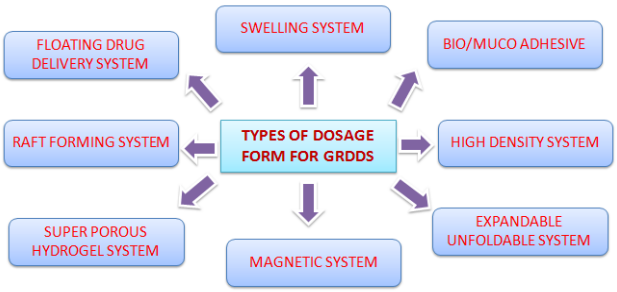

Figure 3: Gastroretentive Techniques

Types of Gastroretentive Dosage Form

Floating Systems

In these systems are devices of low density which have ample buoyancy to float over the gastric content and stay in belly for an extended period of time. As the device floats above the gastric material, the drug is released gradually at the target rate resulting in improved GRT and decreases changeability in the concentration of plasma drugs. The floating drug delivery system and the delivery of bioadhesive drugs are commonly used methods for gastro retention, and floating systems in particular have been thoroughly studied, primarily because the floating mechanism does not adversely affect GI tract motility.

Effervescent and non-effervescent systems may also be listed as floating systems[27, 28].

Classification of Floating Drug Delivery System

Effervescent system

The creation of gas bubbles helps bring about floatability. The polymers which are swellable viz. Methyl cellulose, chitosan, as well as various effervescent compounds, such as sodium bicarbonate, citric acid, help to build matrix-type structures of this type[23].They are produced in such a way that CO_2 is eventually released into swollen hydrocolloids when it comes to contact with gastric material, rendering dosage forms buoyant [29]. Such structures are additionally known as:

1. Volatile Liquid Containing System

2. Matrix Tablets Systems

3.Gas Generating Systems

Non- Effervescent System

The non-effervescent floating dosage forms include swellable hydrocolloid, polysaccharide, and matrix forming polymers such as polycarbonate, polyacrylate, and polystyrene[25].The formation has a simple approach, i.e. mixing of medicine and gel, followed by swelling by contracting with gastric fluid after oral administration, thus preserving a relative integrity of the form and retaining a bulk density of less than one (< 1)[25, 26]. Owing to air trapped in the swelled up matrix the dosage type achieves its buoyancy. This swollen up matrix reserves drug and maintains sustained drug release via gelatinous mass [25]. The most widely used excipients are hydroxylpropyl methyl cellulose (HPMC), polyacrylate, and polycarbonates [30].

1. Hydrodynamically balanced systems 2. Alginate beads

3. Microballoons /Hollow Microsphere 4. Layered Tablet

A. Single Layered Floating Tablet B. Double Layered Floating Tablet

Table 4: Commonly Used Drugs in Formulation of GRDDS[31,49]

S. No.	Formulation	Drug
1	Tablet	Aceraminophen, Acetylsalicyclic acid, Amoxicillin trihydrate, Atenolol, Ampicillin, Captopril, Cephalexin, Ciprofloxacin, Cinnarazine, Cholrpheniramine maleate, Dilitiazem, Florouracil, Furosemide, Isosorbide mononitrate, Isosorbide dinitrate, Losartan, Metformin hydrochloride, Nimodipine, P-Aminobenzoic acid (PABA), Pentaoxyfillin, Prednisolone, Piretanide, Riboflabin-5'phosphate, Sotalol, Theophyllin, Verapamil HCl, Ziduvudine
2	Capsule	Chlordizepoxide HCl, Celiprolol HCl, Diazepam, Furosemide, L-Dopa and Benserazide, Misoprostal, Nicardipine, Pepstatin, Propranol, Urodeoxycholic acid
3	Films	Albendazole, Cinnarizine, P-Aminobenzoic acid (PABA), Piretanide, Prednisolone, Quinidine gluconate
4	Microspheres	Aspirin, Cholestyramine, Dipyridamol, Flurbiprofen, Griseofulvin, Iboprufen, Ketoprofen, Nicardipine, Nifedipine, Orlistat, P-nitroanilline, Piroxicam, Rosiglitazone maleate, Terfenadine, Theophylline, Tranilast, Verapamil, amoxicillin
5	Powders	Several basic drugs-Riboflavin, Sotalol, Theophylline.
6	Granules	Cinnarizine, Diclofenac sodium, Diltiazem, Fluorourocil, Indomethacin, Isosorbide dinitrate, Prednisolone, Ranitidine HCl
7	Beads	Beta-cyclodextrin, Curcumin, Diltiazem HCl, Loratidine, Ranitidine HCl

Non-floating System

These "Gastro-Retentive Drug Delivery Systems" do not float in the belly but are maintained by different mechanisms.

Bioadhesive System

Such types of systems adhere to the stomach's biological membrane (mucosa) and sustain a longer duration of intimate interaction with the membrane, while maintaining their prolonged release in the stomach. Such systems are formulated using polymers with bio adhesives. [32]

Magnetic Systems

This approach to improving gastric retention time (GRT) is based on the basic premise that the dosage type comprises a small internal magnet and a magnet over the stomach location mounted on the abdomen. While the magnetic device tends to wobble, the external magnet needs to be placed with a degree of accuracy that could impede patient compliance [33].

High-density Systems

These devices, which have a density of ~3 g/cm^3, are held in the stomach rugae and are able to withstand the peristaltic movements. These systems may be maintained in the lower part of the stomach above a threshold density of 2.4–2.8 g / cm^3.Diluents such as barium sulphate (density = 4.9), zinc oxide, titanium dioxide, and iron powder can be used to manufacture formulations of this high density[34, 35].

Size Increasing System

Expandable, Unfoldable and Swellable Systems:

If it is larger than the pyloric sphincter, a formulation in the stomach will tolerate gastric movement. The dosage form must, however, be small adequate to be swallowed, and should not cause stomach obstruction either individually or by accumulation. Their configurations [36, 37] are therefore necessary to build an expandable framework for extending GRT:

Gastroretentivity is thus enhanced by the combination of significant dimension with high dosage shape rigidity to withstand peristalsis and mechanical stomach contractility. Unfoldable and swellable devices have been tested, and a successful delivery of gastroretentive drugs has been recently attempted. Unfoldable structures are constructed from biologically degradable polymers. These are available in various geometric types such as tetrahedron, ring or planner membrane (4-mark disk or 4-limbed cross-shape) of compressed bio erodible polymer inside a capsule that extends in the stomach[38-41].

Raft-forming System:

Raft System integrates alginate gels which have a carbonate component and create bubbles in the gel when reacted with gastric acid, allowing floating. Rafting formation devices have provided substantial attention for the delivery of drugs for GI infections and disorders. The process involves the creation of viscous cohesive gel in contact with gastric fluids, in which each portion of the liquid swells into a continuous layer called a raft. This raft is floating on gastric fluids due to low bulk density provided by CO_2 formation. An antacid raft forming floating device involves a gel forming agent (e.g. sodium alginate), sodium bicarbonate, and acid neutralizer forming a foaming sodium alginate gel (raft), which, when in contact with gastric fluids, floats on gastric fluids and prevents the reflux of gastric material (e.g. gastric acid) into the esophagus by serving as a barrier between the stomach and esophagus.[42]

Table 5: Non-Floating Systems

S.No.	Non-floating Systems	Mechanism	Polymer Used
1	Bioadhesive systems	Bioadhesive systems bind to the stomach's biological membrane (mucosa) and sustain a longer period of intimate interaction with the membrane, thereby remaining in the stomach for its prolonged release.	Carbopol, Carboxy methylcellulose, Chitosan, Dextrin, Gliadin, Lectin, Hydroxy methylcellulose, Polyethylene glycol, Polycarbophil, Poly acrylic acid, Sodium alginate, Sucralfate, Tragacanth[43, 44]
2	Magnetic System	This approach to improving gastric retention time is based on the basic premise that the dosage shape includes a small internal magnet and an external magnet above the stomach location.	Magnet [34, 35]
3	High Density Systems	Such systems have a greater density than the gastric fluids, because of which the organ sinks to the bottom and stay in the stomach.	Barium sulphate, Iron, Titanium dioxide, Zinc oxide [45, 46]
4	Swelling Systems	These dosage forms swell to a size after being swallowed which prevents their passage through the pylorus.	Acacia, Agar, Bentonite, Casein, Chitosan, Gellan gum, Hydroxy propyl cellulose, Hydroxy propyl methyl cellulose, Pectin, Sodium carboxy methyl cellulose, Veegum[47, 48]
5	Raft Forming system	This raft is floating on gastric fluids due to low bulk density provided by CO_2 formation.	Alkaline bicarbonates or carbonates [42]

CONCLUSION

"Gastroretentive drug delivery system" has emerged as an effective means of prolonged stomach retention capacity, thereby increasing the gastric residence time of drug and also improving drug bioavailability. Increasing understanding of the effect of gastrointestinal tract physiology on drug delivery will make sure a growing number of drug delivery systems are built to optimize drug delivery of molecules with regional variation of drug absorption. Currently, a lot of work is under way to establish various forms of "gastroretentive delivery systems" of various drugs. These are expected to become increasingly relevant in the future, potentially leading to enhanced efficiencies of various forms of pharmacotherapies.

Acknowledgement: All the resources and facilities were provided by the Oriental University, Indore. The author acknowledges for their essential support.

REFERENCES

1. Garg R and Gupta GD. Progress in controlled gastroretentive delivery systems. Tropical Journal of Pharmaceutical Research 7, 2008,1055-1066.
2. Das PD. Textbook of medicine. Edn 4, Current Book Internationals.2000, pp. 182-95.

3. Shargel L and Andrew BC. Applied Biopharmaceutics and Pharmacokinetics. Edn 4, London: Prentice Hall Int. 1999, 112-25.
4. Streubel A, Siepmann J and Bodmeier R. Gastroretentive drug delivery system. Expert Opin Drug Deliv, 3(2), 2006, 217-33.
5. Bardonnet PL, Faivre V, Pugh WJ, Piffaretti JC &Falson F. Gastroretentive dosage forms: overview and special case of *Helicobacter pylori*. J Control Release,111,2006, 1-18.
6. Nayak AK, Maji R and Das B.Gastroretentive drug delivery system: A review. Asian Journal of Pharmaceutical and Clinical Research, 3, 2010, 1-10.
7. YieWC. Concepts and System Design for Rate Controlled Drug Delivery in Novel Drug Delivery System.Edn2, New York, Marcell Dekker Inc. 1992.
8. Mathur P, Saroha K, Syan N, Verma S and Kumar V. Floating drug delivery system: An innovative acceptable approach in gastro retentive drug delivery. Scholars Research Library, 2, 2010, 257-270.
9. Nayak AK, Maji R and Das B. Gastroretentive drug delivery systems: a review. Asian Journal of Pharmaceutical and Clinical Research, 3(10), 2010, 1-10.
10. Streubel A, Siepmann J, Bodmeier R. Floating matrix tablets based on low density foam powder: effects of formulation and processing parameters on drug release. European Journal of Pharmaceutical Sciences, 18, 2003, 37-45.
11. Khan R. Gastro retentive Drug Delivery System – A Review.Int J Pharm Bio Sci, 4(2), 2013, 630-646.
12. Joseph R. Robinson, Lee V. Controlled Drug Delivery, Fundamentals and Applications. Edn 2, Revised and Expanded, Marcell. Dekker Inc., New York 2009.
13. Sharma S and Pawar A. Low density multiparticulate system for pulsatile release of meloxicam. Int J Pharm. 313, 2006,150-158.
14. Tortora GJ, Grabwoski SR. Principles of anatomy and physiology. New York: John Wiley and Sons publishers, 9, 2000, 866-8.
15. Ross and Wilson. Anatomy and physiology in health and illness. London: Churchill Livingstone Publishers 9, 2001, 295-9.
16. Cheng J, Wu J, Ye Y, Zhang C, Zhang Y and Wang Y. The prognostic significance of extramural venous invasion detected by multiple-row detector computed tomography in stage III gastric cancer. Abdom Radiol (NY). 41(7), 2016,1219-26.
17. Fagoonee S and Pellicano R. Helicobacter pylori: molecular basis for colonization and survival in gastric environment and resistance to antibiotics. A short review. Infect Dis (Lond).51(6), 2019, 399-408.
18. Gonsalves N. Eosinophilic Gastrointestinal Disorders. Clin Rev Allergy Immunol.57(2), 2019,272-285.
19. Pimentel AM, Rocha R, Santana GO. Crohn's disease of esophagus, stomach and duodenum. World J Gastrointest Pharmacol Ther. 10(2), 2019, 35-49.
20. Wilson CG and Washington N: The Stomach: its role in oral drug delivery. In: Rubinstein, M.H., (Ed.). Physiological pharmaceutics: biological barriers to drug absorption. Ellis Harwood. Chechester 1989, pp. 47-70.
21. Desai S: A novel floating controlled release drug delivery system based on a dried gel matrix network [master's thesis]. Jamaica, NY, St John's University,1984.
22. Prajapati S and Dharamsi A: Floating drug delivery for prolonging gastric retention of dosage form. Indian Journal of Novel Drug Delivery 5,2013, 15-27.
23. Sharma N, Agarwal D, Gupta M and Khinchi M: A comprehensive review on floating drug delivery system. International Journal of Research in Pharmaceutical and Biomedical sciences 2,2011, 428-441.
24. Vasa S and Banji D: Approaches for gastrotentive drug delivery systems. International Journal of Applied Biology and Pharmaceutical Technology 1, 2010, 589-601
25. Bhardwaj L, Sharma PK and Malviya R: A short review on gastro retentive formulations for stomach specific drug delivery: special emphasis on floating *in-situ* gel systems. African Journal of Basic and Applied Sciences 3,2011, 300-312.
26. Subramanyam CVS, Setty JT. Laboratory manual of physical pharmaceutics. Vallabh Prakashan 200, pp. 21.
27. Sangekar, S., Evaluation of effect of food and specific gravity of the tablets on gastric retention time. Int.J.Pharm.35, 1985, 34-53.
28. Hardenia SS, Jain A, Patel R and Kaushal A. Floating drug delivery systems: A review. Asian Journal of Pharmacy and Life Science1, 2011, 284-293.
29. Pandey A, Kumar G, Kothiyal P and Barshiliya Y. A Review on current approaches in gastro retentive drug delivery system. Asian Journal of Pharmacy and Medical Science 2, 2012, 60-77.
30. Mishra A and Gupta P. Gastro retentive drug delivery system: A review. International Journal of Drug Development and Research 4,2012, 28-39.
31. Sharma AR and Khan A. Gastroretentive Drug Delivery System: An approach to enhance Gastric retention for prolonged drug release. Int J Pharm Sci Res. 5(4),2014, 1095-06.doi: 10.13040/IJPSR.0975-8232.5(4).1095-06
32. PantS, BadolaA and KothiyalP. A Review on gastroretentive drug delivery system. International Journal of Research and Development in Pharmacy and Life Sciences5(4), 2016, 2178-2187.
33. Huang Y, Leobandung W, Foss A and Peppas NA. Molecular aspects of muco- and bioadhesion: tethered structures and site-specific surfaces. J Control Release 65(1-2), 2000, 63-71.
34. Klusner EA, Lavy E, Stepensley D, Friedman M and Hoffman A. Novel gastroretentive dosage form: evaluation of Gastroretentivity and its effect on riboflavin absorption in dogs. Pharm Res 19,2002, 1516-23.
35. Abubakar O, Nur Jun S and Zhang. Recent progress in sustained: controlled oral delivery of captopril: an overview. Int J Pharm. 2000;139-146.

36. Klusner EA, Lavy E, Friedman M and Hoffman A. Expandable gastroretentive dosage forms. J Control Release 90(2),2003, 143-62.
37. Klusner EA, Lavy E, Stepensley D, Friedman M and Hoffman A. Novel gastroretentive dosage form: evaluation of Gastroretentivity and its effect on riboflavin absorption in dogs. Pharm Res 19,2002, 1516-23.
38. Caldwell LJ, Gardner CR and Cargill RC. Drug delivery device which can be retained in the stomach for controlled period of time. US Patent 473 5804. April 5, 1988.
39. Caldwell LJ, Gardner CR, Cargill RC, Higuchi T. Drug delivery device which can be retained in the stomach for a controlled period of time. US Patent 475 8436: July 19,1988.
40. Klusner EA, Lavy E, Barta M, Cserepes E, Friedman M and Hoffman A. Novel gasrtroretentive dosage form: evaluation of Gastroretentivity and its effect on levodopa absorption in humans. Pharm Res 20(9), 2003, 1466-73.
41. Garg S and Sharma S. Gastroretentive drug delivery systems.B usiness Briefing: Pharmatech 2003: 160-66.
42. Chen J, Blevins WE, Park H and Park K. Gastric retention of superporous hydrogel composites. J Control Release 64(1-3), 2000, 39-51.
43. David B. Approaches for gastrotentive drug delivery systems. International Journal of Applied Biology and Pharmaceutical Technology 1, 2010, 589-601.
44. Narang N. An updated review on: Floating drug delivery system (FDDS). International Journal of Applied Pharmaceutics 3, 2011, 1-7.
45. Clarke GM, Newton JM and Short MD. Gastrointestinal transit of pellets of differing size and density. International Journal of Pharmaceutics 100, 1993,81-92.
46. Kumar S, Jamil F, Rajput M and Sharma S: Gastro retentive drug delivery system: Features and facts. International Journal of Research in Pharmaceutical and Biomedical Sciences 3,2012, 125-136
47. Soni RP, Patel AV and Patel RB. Gastroretentive drug delivery systems: A review. International Journal of Pharma World Research 2,2011, 1-24.
48. Shep S, Dodiya S, Lahoti S and Mayee R. Swelling system: A novel approach towards gastroretentive drug delivery system. Indo-Global Journal of Pharmaceutical Sciences 1,2011, 234-242.
49. Goyal MK and Mehta SC "Preparation and evaluation of calcium silicate based floating microspheres of amoxicillin" published in Journal Applied Pharmaceutical Sciences 1(4), 2011), 137-141.

Source of Support: None declared.

Conflict of Interest: None declared.