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Gastroretentive Drug Delivery through Natural Mucilage Based Microspheres: A Concise Review

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Abstract: The use of novel drug delivery systems for efficient delivery of drug is recently explored area. Several novel drug delivery systems have been proved to be effective in delivery of drug. Many scientific experts have showed efficacy of novel drug delivery systems in animal models. The carrier mediated drug delivery involves use of various drug loaded carriers like nanoparticles, microparticles, microspheres, microsphere, liposomes, ethosomes, transfersomes, phytosomes and glycosomes. The microspheres are micron sized drug loaded spherical particles. The use of natural gums and mucilage for fabrication of drug loaded microspheres is recently explored area for gastroretentive drug delivery. Thus, present review highlights use of these natural mucilage based microspheres for fabrication of drug loaded microsphere.

Keywords: Natural gums, Mucilage, Microspheres, Gelation of mucilage

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Introduction

The oral route is most common, safe and convenient route of drug administration. The solid oral dosage form like tablet is most popular oral dosage form because of ease of handling, large scale production and stability (Natarajan *et al.*, 2011). About 80% oral dosage forms are available in the form of tablet. However, these dosage forms suffer with number of limitations

like:

1. The daily administration of dosage form is required which is difficult to monitor and greater chance of missing dose.
2. The dosage form like tablet is available with fixed strength thus careful calculation is required to prevent overdosing. It is difficult to

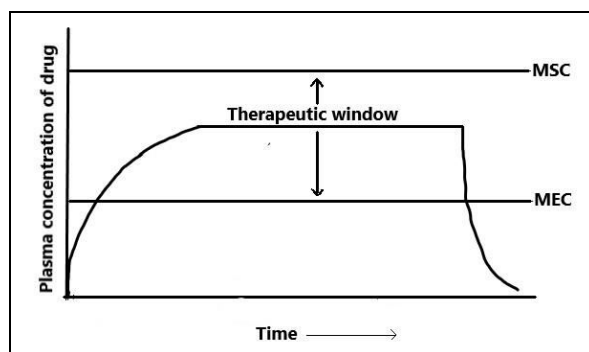


Fig. 1: Typical plasma level - time profile of controlled release system.

calculate exact dose of drug required for a child and geriatric patients.

3. After oral administration the drug enters the systemic circulation and undergoes non-specific distribution at target site, as well as off target site. Thus, majority of administered drug undergoes wastage and more amount of drug need to be administered to produce desired pharmacological effect, which may precipitate dose dependent side effects.

After oral administration of a drug, the drug is absorbed in systemic circulation and concentration of drug in blood plasma increases gradually with time as represented in Figure 1. This phase is known as absorption phase where rate of drug absorption is more than rate of elimination. The therapeutic action of drug starts when concentration of drug in blood plasma reaches in therapeutic window. Once the concentration reaches up to peak level, the descending phase begin. In this phase, the concentration decreased due to metabolism and excretion thus generally known as elimination phase. During this phase the rate of drug elimination is more than its rate of absorption. The therapeutic action of drug is observed until the concentration remains in therapeutic window. The time period during which concentration of drug remains above the MEC is known as duration of action. Once concentration of drug fall below the MEC, the second dose of drug need to be administered to produce desired

pharmacological effect. Thus, fluctuations in plasma drug concentration are observed with conventional drug delivery systems. Extensive researches have been conducted to minimize the limitations associated with conventional drug delivery systems. The fruitful outcome of these researches is developed modified drug release systems.

Rationale:

As mentioned earlier, controlled release drug delivery system was investigated to minimize limitations associated with conventional systems. The controlled release system is defined as the system which releases an encapsulated drug at a predetermined rate so that a constant plasma drug concentration is maintained for extended period of time with minimum side effects. The basic concept behind formulation of controlled release formulations is to alter pharmacokinetics and pharmacodynamics of drugs either by modifying molecular structure or using novel drug delivery principles and physiological parameters. Thus, in depth understanding of pharmacokinetics and pharmacodynamics parameters of drugs is necessary before designing of system. The desirable characteristic of such system is the duration of drug action. The controlled release system should provide therapeutic drug concentration for prolonged period of time. This can be achieved by controlled release of drug from system. The controlled release is possibly achieved by combining drug

with the release modifying polymer. The polymer is used to control release of drug from system. This could possibly prolong the duration of drug action. The objective behind formulation of such system is to improve patient compliance by ensuring safety and enhanced efficacy of drug. This could be ensured by controlling plasma drug concentration and reducing dosing frequency.

The rationales of controlled release system are highlighted below:

1. To provide controlled release of medicament for prolonged duration of drug action.
2. To increase the bioavailability of drug.
3. To provide a location-specific action of drug within the GIT.
4. To reduce dosing frequency and to improve patient compliance.

Advantages:

The desirable therapeutic advantages can be achieved by prescribing controlled release formulation:

1. The controlled release dosage form releases the drug in controlled manner, thus frequency of drug administration can be reduced which improve patient compliance and convenience.
2. The concentration of drug in blood plasma is maintained in therapeutic window for prolonged period of time and fluctuations in plasma drug concentration due to repeated administration can be minimized.
3. The total amount of drug administration can be reduced by utilizing controlled release concept thus availability of drug can be maximizing with a minimum dose.
4. The release of drug from dosage form is controlled which eventually control absorption of drug in systemic circulation.
5. As fluctuations in plasma drug concentration is minimize, the safety margin of highly potent drugs can be increased, and the incidence of both local and systemic adverse effects can be

reduced.

Disadvantages:

1. Administration of sustained/ controlled release formulation does not permit prompt termination of therapy. Immediate changes in dose strength during therapy are not possible.
2. Unpredictable *in vitro-in vivo* correlation is observed with controlled release formulations.
3. In controlled release systems, the polymers are included to control the drug release. Thus, accidental release of drug (dose dumping) may be observed; specially with reservoir system, where defects/rupture in polymeric coat is responsible for dose dumping.
4. The cost of these systems is high due to use of expensive equipment and processes are involved in manufacturing of such systems.
5. The controlled release approach is not applicable to all drug candidates. The characteristics of drugs need to be study while selection of suitable drug candidate.

Approaches to design controlled release system:

Basically, controlled release of drug from system is achieved by either modification of drug molecule or by modification of dosage form or by utilizing novel nanocarriers (Musthaba *et al.*, 2009). The various approaches were investigated for controlled release of drug. The modification of existing conventional oral dosage with drug release retarding polymer is widely investigated technique for controlled delivery of drug (Bisht *et al.*, 2007). The use of nanocarriers involves encapsulation of drug in nanocarriers like liposomes (González-ortega *et al.*, 2020), nanoparticles (Zhang *et al.*, 2016), niosomes (Khan and Irchhaiya, 2016) and solid lipid nanoparticles (Bhatt, 2018), and nanostructured lipid carriers (Seyfoddin and Al-kassas, 2013). The encapsulated drug in nanocarriers releases in controlled manner. The use of nanocarriers for controlled delivery through various routes have been investigated widely for effective management of various disease conditions

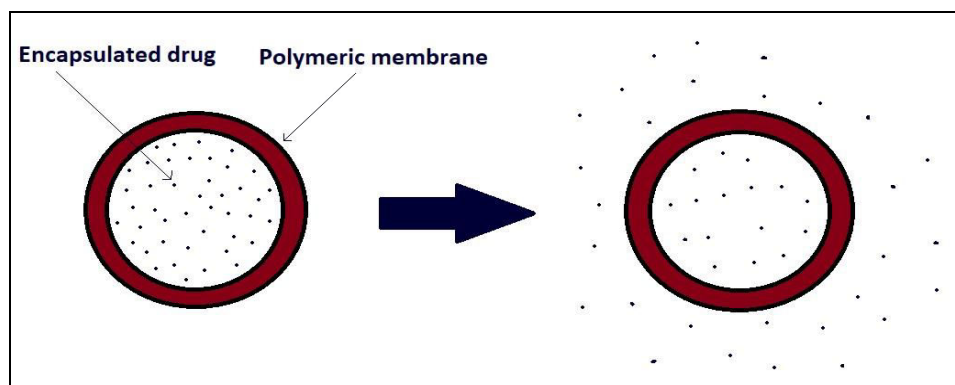


Fig. 2: Reservoir type controlled drug delivery system.

(Gupta *et al.*, 2022).

Based on the mechanism of drug release control the controlled release system can be classified into following;

- (1) Diffusion controlled systems
- (2) Dissolution controlled systems

(1) Diffusion controlled systems:

In these systems, the drug release rate from drug delivery systems has been preprogrammed at specific rate. As name suggests, the drug release rate is controlled by diffusion of drug from system. The controlled diffusion of drug from system has been accomplished by system design i.e. by effective use of polymeric drug releasing barrier. These systems have divided into reservoir system, and matrix system.

(a) Reservoir system:

In this type of controlled drug delivery systems, a drug formulation/drug is totally/partially encapsulated with thin polymeric membrane (Fig. 2). The encapsulated drug is released in surrounding environment by diffusion through polymeric membrane. The diffusion of drug through polymeric membrane is rate controlling/slow step. The drug reservoir consists of either solid drug, suspension of drug in viscous polymer or concentrated drug solution. The polymeric membrane may be porous, nonporous or microporous designed for specific release rate

of drug. The encapsulation of drug in polymeric membrane is accomplished by spray coating, air suspension, microencapsulation, capsulation or injection molding. This system can be fabricated in different shape or size i.e. for suitability of administration. Since, the thickness of polymeric coating is uniform, the rate of drug diffusion is constant throughout the lifetime of product. The drug release rate from this system is controlled by controlling partition coefficient and diffusivity of drug and thickness of polymeric membrane.

(b) Matrix system:

The drug reservoir in this system consists of homogeneous dispersion of drug in polymer matrix (Fig. 3). The polymer matrix is formed by crosslinking of either lipophilic or hydrophilic polymer. The dispersion of drug of drug in polymer matrix is accomplished by two methods:

- (i) Mixing of therapeutic dose of fine drug particles with liquid/viscous polymer, followed by crosslinking of polymer chains.
- (ii) Mixing of powdered drug particles with rubbery polymer at elevated temperature.

The resulting medicated polymer matrix is then molded/ extruded to desired shape device for specific application. Another simple technique for fabrication of this system is dissolution of drug and polymer in common volatile organic solvent, followed by evaporation of organic solvent (Dokoumetzidis and Macheras, 2008).

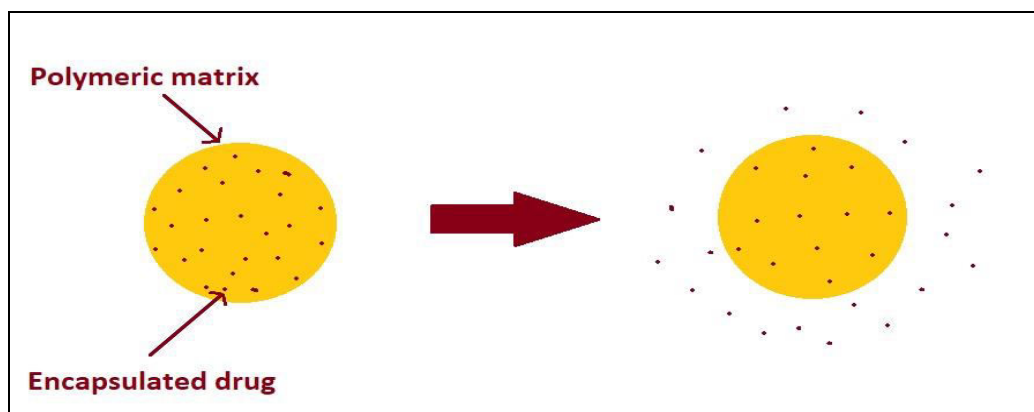


Fig. 3: Matrix type controlled drug delivery system.

(2) Dissolution controlled systems:

This system releases the drug in controlled manner where dissolution is rate limiting step in drug release. When drug dissolution rate is high, it is mixed with a carrier having a slow dissolution rate. According to diffusion layer theory, the dissolution process is diffusion layer controlled. In such case, rate of diffusion of drug from solid surface to bulk medium through stagnant layer is rate limiting step.

There are two ways to fabricate dissolution-controlled system i.e. reservoir system and matrix system:

(a) Reservoir system:

In this approach, the drug particles or granules are coated with slowly dissolving polymeric material. The coated particles are then compressed into a tablet or filled in capsules for oral administration.

(b) Matrix system:

In this approach, the solid drug is encapsulated in polymer matrix. The drug solid is homogeneously mixed with polymer and compressed into desired shape for administration. The rate of availability of drug is controlled by permeation of dissolution medium into the polymer matrix. The permeation of medium is controlled by porosity of the matrix, the wettability of the tablet and surface area.

Gastro-retentive drug delivery systems:

Oral route of drug administration is the most preferred convenient and safer route of systemic drug delivery. However, drugs which have short half-lives are eliminated quickly from the systemic circulation, thus frequent dosing of these drugs is required to maintain its concentration within therapeutic window (Khatri and Awasthi, 2016). To avoid these drawbacks, oral sustained-controlled release formulations have been investigated to release the drug slowly into the gastrointestinal tract (GIT) and maintain an effective drug concentration in the systemic circulation for a long time. These modified release oral drug delivery have recently gained interest in pharmaceutical field to achieve improved therapeutic advantages, such as ease of dosing administration, and patient compliance. After oral administration, such a drug delivery systems release the drug in a controlled manner, so that the drug could be supplied continuously to its absorption sites in the GIT. These drug delivery systems suffer from mainly two limitations: the short gastric retention time (GRT) and unpredictable short gastric emptying time (GET), which can result in incomplete drug release at absorption zone (stomach or upper part of small intestine) leading to incomplete drug absorption.

The design of oral modified release dosage form with prolonged gastric retention can possibly overcome these limitations. These dosage forms can possibly retain in stomach for

prolonged period of time and releases the drug in sustained manner. Prolonged gastric retention improves bioavailability, increases the duration of drug release, and reduces drug waste (Garg and Gupta, 2010).

Gastro-retentive drug delivery system is a novel approach to prolong gastric residence time, these dosage forms can retain in the gastric region for long periods and hence significantly prolong the gastric retention time (GRT) of drugs (Boddupalli *et al.*, 2012).

Drug targeting to the stomach can also be attractive for several other reasons:

1. To produce a prolonged local action on to the gastroduodenal wall e.g., drugs used in treatment of *H. pylori* infection e.g., Amoxicillin, Misoprostol.
2. For drugs which have poor stability in the colon e.g., Ranitidine, Metformin HCl.
3. For drugs which have a narrow absorption window e.g., Cyclosporine, Methotrexate, Levodopa.
4. For the drugs which have primarily absorption site as the stomach e.g., Amoxicillin.

Gastrointestinal tract physiology:

The stomach is situated in the left upper part of the abdominal cavity. Anatomically stomach is divided into three parts: fundus, body and antrum (or pylorus). The proximal stomach, made up of fundus and body regions, serves as a reservoir for the ingested materials, while the distal region (antrum) is the major site of mixing motions. Antrum also acts as a pump to force the content from stomach to intestine (Purohit *et al.*, 2018).

Gastric emptying is process, where content in the stomach transfer into small intestine. Gastric emptying occurs in both fasted as well as fed state. The pattern of gastrointestinal motility is different in fasted and fed states. The bioavailability of orally administered drugs will depend on the state of feeding. In the fasted state,

a series of electrical events occur in both stomach and small intestine after every 2–3h. This cyclic event is called the interdigestive myoelectric cycle or Migrating motor complex (MMC). MMC is often divided into four phases: basal (Phase I), pre-burst (Phase II), burst (Phase III), and Phase IV intervals.

- Phase I (basal phase): lasts from 40–60 min with rare contractions of gastroduodenal walls.
- Phase II (pre-burst phase) lasts for 40–60 min with intermittent contraction action potential. As the phase progresses the intensity and frequency of contraction also increases gradually.
- Phase III (burst phase): lasts for 4–6 min. It includes intense and regular contractions for short periods. Due to this contraction all the undigested material pass from the stomach to the small intestine.
- Phase IV: lasts for 0–5 min and occurs between phases III and I for two consecutive cycles.

In feed state, the gastric emptying rate is slow than in fasting state since the onset of MMC is delayed. To achieve prolonged gastric retention, the dosage form must resist gastric emptying. For this, the dosage form must be able to withstand in the stomach against the force caused by peristaltic waves. Thus, it is necessary to understand the factors affecting gastric retention of dosage form.

Mucoadhesive or bioadhesive gastroretentive systems:

Another important approach to prolonged gastric residence time of drug delivery system is the use of bioadhesive/mucoadhesive polymers (Trickler *et al.*, 2008).

The surface epithelium of stomach constantly exposes to gastric fluid which contains highly concentrated hydrochloric acid (approximately 0.16 N) and protein digesting enzyme, pepsin. Thus, in order to maintain integrity, the surface

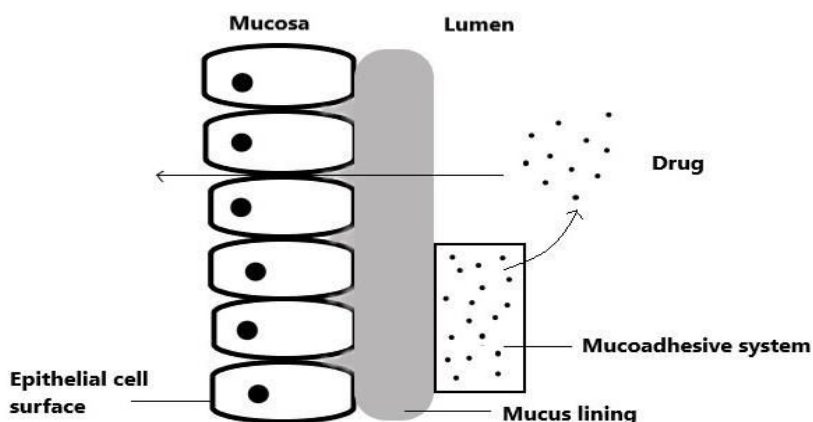


Fig. 4: Mucoadhesive system: Interaction of system with mucus lining of stomach.

epithelium has self-protective mechanism i.e. mucus. Mucus contains mucin i.e. oligosaccharides with sialic acid ($pK_a = 2.6$) and glycoproteins which are capable to neutralize HCl thus protects the epithelium.

The adhesive properties of mucus layer have been recognized and used for development of gastroretentive system. The drug delivery system consists of drug core coated with mucoadhesive polymer as shown in Figure 4. Thus after ingestion of such system, the mucoadhesive polymer hydrates and bind/adhere to mucin molecules in mucus lining of stomach. This enables the device to retain in stomach for extended period of time by resisting gastric emptying. The drug molecules contained in core are constantly released in stomach for absorption. A bio/mucoadhesive polymer is a natural or synthetic polymer capable of adhere to biological membrane, which is then called a bioadhesive polymer or with the mucus lining of the GIT, which is then called a mucoadhesive polymer.

Several approaches have been utilized for incorporation of drug in mucoadhesive polymer for preparation of gastroretentive system. For water soluble polymer it is possible to use polymer to coat the surface of micro-sized capsule shape drug core. The duration of gastric retention

of such system is controlled by dissolution of mucoadhesive polymer.

Natural polysaccharides: A promising carrier for oral drug delivery:

The use of natural excipients as carriers in drug delivery systems is recent trend of oral drug delivery. At present, socio-economic condition of the modern world has elevated the interest of natural polymers. Environmental concerns are also playing considerable role and contributing to the growing interest in natural polymers due to their biocompatibility, biodegradability and low processing cost.

Naturally obtaining polymers are diverse class of macromolecules with a wide range of pharmaceutical applications. Various natural polymers can be classified as proteins-based natural polymers like collagen, gelatin, silk fibroin, fibrin and natural polysaccharides like chitosan, starch, alginate, gellan gum, pectin, gum acacia, gum tragacanth, guar gum. These polysaccharides have some excellent water solubility as well as swelling potential, which eventually are useful for oral controlled drug delivery.

Natural gums:

Natural gums are obtained from different parts of the plant. Chemically, these are polysaccharides containing monosaccharides blocks joined in

linear as well as branched fashion. Thus, hydrolysis of gums results in formation of various sugar units. Gum acacia and tragacanth are most common gums used in pharmaceutical formulations since long period of time. These gums are produced by the plant as part of protection mechanisms on injury to the plant. The process of formation of gum is termed as gummosis, which indicates breakdown of cell walls.

Many scientific experts have investigated use of natural gums in various drug delivery systems. The gums are commonly used as suspending agent, thickening agent, emulsifying agent, binder, drug release retardant, mucoadhesive agent, gelling agent etc. The commonly used gums and their pharmaceutical applications are represented in Table 1.

Plant derived gums in nanomedicine:

The biodegradability, non-toxicity, non-reactivity, adequate availability are few characteristics of natural gums. These characteristics play key role in use of natural gums as excipient in novel drug delivery systems. The study of physical and chemical properties of the gums are essential in selection of suitable gum in development of drug delivery systems. The structural modification of natural gum can result in formation of new class of polymers.

Gums act as stabilizer in many nanocarrier based systems. The nanoparticles like gold and silver nanoparticles can be stabilized using gum. Gums can prevent aggregation of nanoparticles, thus aids in stabilization of nanoparticles. Gums can adsorb over the surface of nanoparticles and forms protective layer around the nanoparticle surface which can possibly prevent aggregation of nanoparticles and enhance stability of nanosystem. Gum can also increase viscosity of dispersion medium which can minimize Brownian motion of nanoparticles.

Plant derived mucilage:

The term mucilage indicates substances which have high water absorbing and swelling

capability on contact with water. Several species of mucilaginous species of plants have been used in traditional system of medicine in the world since last 4000 year. Mucilage is metabolic product of the plant formed by various cells. It plays key role in food storage, germination of seeds as well as serve as important component of water storage in plants. Mucilage found in seed endosperms, roots and rhizomes may act primarily as energy reserves.

Chemically these are high molecular weight (approx. 200,000 Da) compounds consisting of sugar and uronic acid units. These are generally sulphuric acid esters and have a complex structure of polysaccharide. The high-water absorbing capability of mucilage is due to presence of hydroxyl groups in sugar structure of mucilages. However, upon addition of alcohol, mucilages are precipitated in the form of amorphous or granular mass (Fig. 5).

Some important plants and their parts yielding mucilages (Table 2) are presented below:

(i) *Intra cell mucilages*: Rhizome of *Agropyrum repens* L., Bulb of *Urginea maritime* L. (squill); Bulb of *Allium* sp. (onion, garlic), Flower stalks of *Hagenia abyssinica*, Pulp of *Musa paradisiacal*, etc.

(ii) *Cell-membrane mucilages (secondary wall mucilages)*: Bark of *Cinnamomum* species, Bark of *Rhamnus frangula* L., Root bark of *Sassafras variifolium* (Salisbury), Inner bark of *Ulmus fulva*, Seed-coat of *Linium usitatissimum* L., Seed-coat of *Cydonia vulgaris* L., etc.

(iii) *Metamorphosis of cell-wall*: Pith and medullary ray cells: Gum Tragacanth. Parenchyma cells of wood and bark: Cherry gum. Various cells of the bark: Gum Arabic. Primary wall as intercellular substances: Thallus of *Chondrus crispus*.

(iv) *Secreting hairs (Driizenzotten)*: Leaves of *Viola tricolor* L. and *Coffea arabica* L.

Plant derived mucilage in nanomedicine:

Some mucilages have been reported to show antihypertensive, antibacterial, antioxidant,

Table 1: Common natural polysaccharides and their use in drug delivery

Name of gum	Scientific name	Constituent	Applications in drug delivery
Gum acacia	<i>Cyamopsis tetragonoloba</i> (Fabaceae)	Galactose, Mannose	Suspending agent, emulsifier, tablet binder, demulcent and emollient
Gum tragacanth	<i>Astragalus brachycalyx</i> (Fabaceae)	Arabino galactans, Pectinaceous	Suspending agent, emulsifier, demulcent and emollient
Almond Gum	<i>Prunus dulcis</i> (Rosaceae)	L-arabinose, L-galactose	Adhesive and suspending agent
Tamarind gum	<i>Tamarindus indica</i> (Fabaceae)	Glucosyl: Xylosyl: Galactosyl	Drug release retardant
Grewia gum	<i>Grewia mollis</i> (Malvaceae)	Galacturonic acid, Rhamnose	Drug release retardant
Khaya gum	<i>Khaya grandifoliola</i> (Meliaceae)	L-arabinose, L-galactose	Drug release retardant
Terminalia catappa gum	<i>Terminalia catappa</i> (Combretaceae)	Cyanidin 3-glucoside, Gallic acid	Drug release retardant
Okra gum	<i>Abelmoschus esculentus</i> (Malvaceae)	Rhamnose, Glucose	Suspending agent, drug release retardant
Albizia gum	<i>Albizia zygia</i> (Fabaceae)	Mannose, Arabinose	Emulsifier
Cashew gum	<i>Anacardium occidentale</i> (Anacardiaceae)	Galactose, Rhamnose	Suspending agent, drug release retardant
Bhara gum	<i>Terminalia bellirica</i> (Combretaceae)	Gallic acid, Ellagic acid	Drug release retardant
Cordia gum	<i>Cordia myxa</i> (Boraginaceae)	Galactose, Mannose, Rhamnose	Drug release retardant
Honey Locust Gum	<i>Gleditsia triacanthos</i> (Fabaceae)	Carbohydrates, Fats, Fibers	Drug release retardant
Tara Gum	<i>Caesalpinia spinosa</i> (Fabaceae)	Galactomannans	Drug release retardant
Neem Gum Azadirachta indica	<i>Azadirachta indica</i> (Meliaceae)	Galactose, Fucose	Binder
<i>Moringa oleifera</i> Gum	<i>Moringa oleifera</i> (Moringaceae)	Glucuronic acid, Galactose	Binder, gelling agent
Gum Damar	<i>Shorea javanica</i> (Dipterocarpaceae)	Resins	Drug release retardant
Hakea Gum	<i>Hakea gibbose</i> (Proteaceae)	Arabinose, Galactose	Binder, drug release retardant
Olibanum Gum	<i>Boswellia serrata</i> (Burseraceae)	Resins, Carbohydrates	Binder, drug release retardant
Alginate	<i>Laminaria species</i> (Laminariaceae)	Alginic acid	Stabilizer, suspending agent, emulsifier, gelling agent, tablet coating, tablet binder, matrix in controlled release, bioadhesive enhancer
Xanthan gum	<i>Xanthomonas campestris</i>	D-mannosyl, D-glucosyl, as well as D-glucosyluronic acid	Stabilizer, suspending agent, emulsifier, gelling agent, tablet binder, matrix in controlled release, bioadhesive enhancer
Guar gum	<i>Cyamopsis tetragonoloba</i> (Leguminosae)	Galactomannans	Suspending agent, emulsifier, gelling agent, thickener, tablet binder, matrix in controlled release, bioadhesive enhancer

Name of gum	Scientific name	Constituent	Applications in drug delivery
Karaya gum	<i>Firmiana simplex</i> (Malvaceae)	α -d-galacturonic	Suspending agent, emulsifier, sustained release agent, bioadhesive enhancer
Gum ghatti	<i>Anogeissus latifolia</i> (Combretaceae)		Binder and emulsifier
Gellan gum	<i>Sphingomonas elodea</i>	Rhamnose, glucuronic acid and glucose	Stabilizer, suspending agent, emulsifier, matrix in controlled release
Locust bean gum	<i>Ceratonia siliqua</i> (Fabaceae)	Galacto-mannopyranosyl amine units	Mucoadhesive, colon targeting of drugs
Konjac	<i>Amorphophallus konjac</i> (Araceae)	Galactose, Mannose	Gelling agent, drug release retardant

Table 2: Botanical sources, constituents and pharmaceutical applications of common mucilages

Common name	Botanical name	Constituent	Applications in drug delivery
Mimosa mucilage	<i>Mimosa pudica</i> (Fabaceae)	D-glucuronic acid, D-xylose	Drug release retardant
Hibiscus rosa-sinensis	<i>Hibiscus rosa-sinensis</i> (Malvaceae)	D-glucuronic acid, Rhamnose	Binder and drug release retardant
Asario Mucilage	<i>Lepidium sativum</i> (Brassicaceae)	Galactose, Mannose	Emulsifier and suspending agent
Fenugreek Mucilage	<i>Trigonella foenum-graecum</i> (Fabaceae)	Galactose, Mannose	Drug release retardant
Aloe Mucilage	<i>Aloe vera</i> (Xanthorrhoeaceae)	Galactan, Arabinan, D-glucuronic acid	Drug release retardant
Phoenix Mucilage	<i>Phoenix dactylifera</i> (Arecaceae)	Cellulose, Mannose, Pectin	Binder
Cassia tora Mucilage	<i>Senna tora</i> (Fabaceae)	Tannins, Cinnamaldehyde	Binder and suspending agent
Cocculus Mucilage	<i>Cocculus hirsutus</i> (Menispermaceae)	Carbohydrates	Gelling agent
Cordia Mucilage	<i>Cordia dichotoma</i> (Boraginaceae)	Carbohydrates	Binder and emulsifier
Ocimum Mucilage	<i>Ocimum americanum</i> (Lamiaceae)	Galacturonic acids, Rhamnose	Disintegrating agent



Fig. 5: Overview of preparation and outcomes of natural gum-based microspheres.

Table 3: Overview of natural gum-based microspheres

Gum	Drug	Microcarrier	Outcome
<i>Prunus armeniaca</i>	Tramadol	Microspheres	Sustained drug release and non-toxicity in animal model
<i>Acacia nilotica</i>	Naringin	Microspheres	Sustained drug release
Gellan gum	Metronidazole	Microspheres	Controlled drug release
Okra and gellan gums	Metformin	Microspheres	Better mucoadhesive potential to goat intestinal mucosa
Karaya gum	Penicillamine	Microbeads	Better swelling index and sustained drug release
<i>Acacia nilotica</i>	Famotidine	Microspheres	Controlled drug release
Khaya gum	Metformin	Microspheres	Sustained drug release
Gum Arabic	Bovine serum albumin	Microbeads	Better swelling index
Okra gum	Metformin	Microspheres	Better swelling index
Acacia gum	Diclofenac sodium	Microbeads	Controlled drug release
Locust bean gum	Aceclofenac	Microspheres	Controlled drug release and better reduction of rat hind paw edema induced by carrageenan
Guar gum and xanthan gum	Glipizide	Microspheres	Good mucoadhesive potential
Guar gum	Metronidazole	Microspheres	Sustained drug release

antiasthmatic and hypoglycemic activities. The promising application of mucilage is drug delivery. Mucilages are widely investigated for development of drug delivery systems (Table 3). The less toxicity, biocompatibility and biodegradability are ideal properties of mucilage which are useful in development of drug delivery systems. Many scientific investigators have utilized plant derived mucilage for development of nano and microcarrier based systems.

Gum-alginate based microspheres for controlled drug delivery:

Microspheres are spherical, micron sized biocompatible carriers utilize for controlled delivery of encapsulated drugs. The drug loaded in matrix of microspheres is released in controlled manner. Microspheres can be prepared using polymers, proteins and lipids. Recently, natural gum and alginate combination has been explored for fabrication of biocompatible matrix of microspheres. Numerous scientific experts working in pharmaceutical field have investigated various natural gums for formulation of biocompatible microspheres.

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