Carbohydrate Polymers 92 (2013) 1685–1699

Contents lists available at SciVerse ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Review

Pharmaceutical applications of various natural gums, mucilages and their modified forms

Vipul D. Prajapati*, Girish K. Jani, Naresh G. Moradiya, Narayan P. Randeria

Department of Pharmaceutics and Pharmaceutical Technology, SSR College of Pharmacy, Sayli-Silvassa Road, U.T. of Dadra and Nagar Haveli, Sayli, Silvassa 396 230, India

ARTICLE INFO

Article history:
Received 8 October 2012
Accepted 2 November 2012
Available online 15 November 2012

Keywords:
Gums
Mucilages
Pharmaceutical excipients
Pharmaceutical applications

ABSTRACT

A large number of plant based pharmaceutical excipients are available today. Gums and mucilages are the most commonly available plant ingredients with a wide range of applications in pharmaceutical and cosmetic industries. They are being used due to their abundance in nature, safety and economy. They have been extensively explored as pharmaceutical excipients. They are biocompatible, cheap and easily available. Natural materials have advantages over synthetic ones since they are chemically inert, nontoxic, less expensive, biodegradable and widely available. They can also be modified in different ways to obtain tailor-made materials for drug delivery systems and thus can compete with the available synthetic excipients. Recent trend toward the use of plant based and natural products demands the replacement of synthetic additives with natural ones. In this review, we describe the pharmaceutical applications of various natural gums, mucilages and their modified forms for the development of various drug delivery systems.

Contents

1. Introduction

In recent years, plant derived polymers have evoked tremendous interest due to their diverse pharmaceutical applications such as diluents, binders, disintegrants in tablets, thickeners in oral liquids, protective colloids in suspensions, gelling agents in gels and bases in suppository (Zatz & Kushla, 1989); they are also used in cosmetics, textiles, paints and paper-making (Jani, Shah, Prajapati, & Jain, 2009). The plant based polymers have been studied for their application in different pharmaceutical dosage forms like matrix controlled system, film coating agents, buccal films, microspheres, nanoparticles, viscous liquid formulations like ophthalmic solutions, suspensions, implants and their applicability and efficacy has been proven (Alonso-Sande, Teijeiro, Remuñán-López, & Alonso, 2009; Chamarthy & Pinal, 2008; Pandey & Khuller, 2004). These have also been utilized as viscosity enhancers, stabilizers, disintegrants, solubilizers, emulsifiers, suspending agents, gelling agents and bioadhesives, binders in the

* Corresponding author. Tel.: +91 09824284159; fax: +91 0260 2681104.
E-mail address: vippra2000@yahoo.com (V.D. Prajapati).

0144-8617/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.carbpol.2012.11.021

above mentioned dosage forms (Guo, Skinner, Harcum, & Barnum, 1998).

Many natural polymeric materials have been successfully used in sustained-release tablets. These materials include: guar gum, isapghula husk, galactomannon from *Mimosa scabrella*, *Gleditsia triacanthos* Linn (honey locust gum), *Sesbania* gum, mucilage from the pods of *Hibiscus esculenta*, tamarind seed gum, gum copal and gum dammar, agar, konjac, chitosan, etc. (Efentakis & Kouttis, 2001). Industrial gums and mucilages, which, for the most part, are water-soluble polysaccharides, have enormously large and broad applications in both food and non-food industries. Their use depends in the unique physicochemical properties that they provide, often at costs below those of synthetic polymers. The gums and mucilages are frequently used as thickening, binding, emulsifying, suspending and stabilizing agents in pharmaceutical industries. They have also been used as matrices for sustained release of drugs. Gums and mucilages are interesting polymer for the preparation of pharmaceutical formulations, because of their high water-swellability, non-toxicity, low cost and free availability. Gums and mucilages are polysaccharides or complex carbohydrate containing one or more monosaccharides or their derivatives linked in bewildering variety of linkages and structures. They are condensation polymers. The term gum refers to polysaccharide hydrocolloids, which do not form a part of cell wall, but are exudates or slims and are pathological products. Mucilages are part of cell and physiological products (Kulkarni, Gowthamarajan, Rao, & Suresh, 2002; Kulkarni, Gowthamarajan, Satish, & Suresh, 2002).

Robbins has stated, "in spite of the problems which have beset the gums market in recent years, the fact remains that in many cases the gums provide a valuable source of income for many poor smallholders or itinerant laborers, either in very poor countries or in the poorest regions rather than more developed countries as such they are important commodities. . ." (Robbins, 1988). This remains true today. Tens of thousands of people worldwide, living in regions ranging from semiarid deserts to rainforests, depend on the collection of gums, resins and latexes in order to provide them with an income. Equally, many millions of people around the world make use of these products in their everyday life (Jani et al., 2009).

Polysaccharide hydrocolloids including mucilages, gums and glucans are abundant in nature and commonly found in many higher plants. These polysaccharides constitute a structurally diverse class of biological macromolecules with a broad range of physicochemical properties which are widely used for various applications in pharmacy and medicine. Although mucilages can occur in high concentrations in different plant organs, their physiological function in most cases is unclear. Mucilages found in rhizomes, roots and seed endosperms may act primarily as energy reserves whereas foliar mucilages appear not to serve as storage carbohydrates (Clifford, Arndt, Popp, & Jones, 2002). Due to the high concentration of hydroxyl groups in the polysaccharide, mucilages generally have a high water-binding capacity and this has led to studies of their role in plant water relations. It has been suggested that the ability of mucilage to hydrate may offer a mechanism for plants to resist drought (Clarke, Andreson, & Stone, 1979). By the term "mucilage in plants" is meant those substances which are soluble or at least swell very perceptibly in water and which, upon the addition of alcohol, are precipitated in a more or less amorphous or granular mass. Mucilage originates in the plant either as a part of the contents of the cell or as a part of the wall thereof.

The fact for increase in importance of natural plant based material is that plant resources are renewable and if cultivated or harvested in a sustainable manner, they can provide a constant supply of raw materials. However, substances from plant origin also pose several potential challenges such as being synthesized in small quantities and in mixtures that are structurally complex, which may differ according to the location of the plants as well as other variables such as the season. This may result in slow and expensive isolation and purification process. This review gives an insight of applications of natural gums and mucilages in pharmaceutical science as an excipient. Specific references are also made to the use of natural gums, mucilages and their modified form in the design of novel dosage form.

2. Chemical nature of gums and mucilages

Gums and mucilage, because of their polysaccharide nature, produce an indefinite number of monosaccharides on hydrolysis. Depending on the type of hydrolysis products obtained, they can be further classified into pentosans (e.g. xylan) and hexosans (e.g. starch and cellulose).

Gums are pathological products consisting of calcium, potassium and magnesium salts of complex substances known as 'polyuronides'. Mucilages are physiological products related to gums, but they are generally sulfuric acid esters, the ester group being a complex polysaccharide. Both gums and mucilages are closely related to hemicelluloses in composition, except that the sugars produced by hemicelluloses are glucose, mannose and xylose, whereas those produced by gums and mucilages are galactose and arabinose.

Identification of constituent sugar units in a polysaccharide is done by hydrolysis using dilute mineral acids, followed by separation of liberated monosaccharides using different chromatographic techniques. Estimation of total carbohydrate content of a polysaccharide and also the content of monosaccharides can be done by phenol–sulfuric acid method.

The mode of linkage between the monosaccharides can be determined by methylation, periodate and lead tetra-acetate oxidation. Graded hydrolysis technique can be used to get a spectrum of oligosaccharides, which can be further analyzed to get information on sequence of different sugar residues. NMR and mass spectroscopy techniques can also be used for structural elucidation of gums and mucilages.

3. Classification of gums and mucilages

Gums and mucilages are present in high quantities in verities of plants, animals, seaweeds, fungi and other microbial sources, where they perform a number of structural and metabolic functions; plant sources provide the largest amounts. The different available gums are classified in Table 1 (Jani et al., 2009; Vikas et al., 2011).

The different available mucilages are classified in Table 2 (Rishabh, Pranati, & Kulkarni, 2011).

4. Pharmaceutical applications of gums and mucilages

Gums and mucilages possess a complex, branched polymeric structure because of which they exhibit high cohesive and adhesive properties. Such properties are highly useful in pharmaceutical preparations. Hence, gums and mucilages find diverse applications in pharmacy. They are ingredients in dental and other adhesives and as bulk laxatives. These hydrophilic polymers are useful as tablet binders, disintegrants, emulsifiers, suspending agents, gelling agents, stabilizing agents, thickening agents, protective colloids in suspension and sustaining agents in tablets (Deore & Khadabadi, 2008). Pharmaceutical applications of some gums and mucilages that are used commercially as adjuvants in pharmaceutical formulations are summarized in Tables 3–5.

Table 1
Classification of gums.

S. no.	Basis	Class	Example
1	Charge	Non-ionic gums	Guar gum, locust bean gum, tamarind gum, xanthan gum
		Anionic gums	Gum arabic, karaya gum, gellan gum, carrageenans
2	Shape	Short branch	Xanthan gum, guar gum
		Branch on branch	Gum arabic, tragacanth gum
3	Origin	Seed gums	Guar gum, karaya gum, ipomoea, fenugreek, locust bean gum, premcem gum, lesquerella fendleri gum
		Plant exudates	Chicle gum, konjac, gum arabic, gum ghatti, gum karaya, acacia gum, tragacanth
		Microbial exudates	Dextran, gellan gum, xanthan gum, tara gum, spruce gum
		See weed	Sodium alginate, alginic acid, carrageenans, agar–agar
4	Gelation behavior	Cold set gels	Gellan gum, flaxseed gum, gelatin
		Heat set gels	Konjac
		Re-entrant gels	Xyloglucan
5	Chemical structure	Galactomannans	Fenugreek gum, guar gum, locust bean gum, tara gum, dhaincha gum, cassia gum
		Glucomannans	Konjac
		Uronic acid containing gums	Xanthan gum
		Tri-heteroglycans	Gellan gum
		Tetra-heteroglycans	Gum arabic, psyllium seed gum
		Penta-heteroglycans	Gum ghatti, tragacanth

4.1. Applications in tablet formulations

Gums and mucilages find applications in tablet formulation as binders because of their adhesive nature. They impart cohesiveness to the powder mass and convert them into granules, which are further compressed into tablets. They can also be used as disintegrants in tablets (Jani et al., 2005). The disintegrant property of gums and mucilages is due to their ability to absorb water and swell. They can swell up to 5 times their original volume and this swelling leads to breakage of tablets into smaller pieces, which in turn improves the dissolution rate.

Different mucilages have been used as binding agent in pharmaceutical formulations. Mucilage has good binding properties as compared to many synthetic compounds (Rishabh et al., 2011). Binding property of mucilage was used to determine the ability of mucilage as pharmaceutical excipient in different research papers.

Table 2
Classification of mucilages.

S. no.	Basis	Source	Part
1	Intra cell mucilage	Orchids sp.	Corn
		Agropyrum repens L., Beauvois.	Rhizome
		Urginea maritime L., Baker (Squill)	Bulb
		Allium sp. (onion, garlic)	Bulb
		Viola tricolor L.	Stem, leaf, flower, stamens
		Hagenia abyssinica, Bruce, Gmelin	Flower-stalks
		Musa paradisiacal	Pulp
		Aloe	Succulent plant
2	Cell membrane mucilage	*Althaea officinalis* L.	Root
		Cinnamomum sp.	Bark
		Rhamnus frangula L.	Bark
		Sassafras variifolium, Salisbury	Bark of root
		Ulmus fulva	Inner bark
		Barosma betulina, Thunberg	Leaves
		Linum usitatissimum L.	Seed-coat
		S. nigra L., *Sinapis alba* L.	Seed-coat
		Cydonia vulgaris L.	Seed-coat
3	Secreting hairs	*Viola tricolor* L.	Leaf and calyx
		Coffea arabica L.	Leaf
		Prunus avium	Leaf

4.2. Applications as emulsifying and suspending agents

Gums and mucilages can act as emulsifying and suspending agents. They can effectively stabilize the emulsion via interfacial absorption and the subsequent formulation of condensed films of high tensile strength that resist coalescence of droplets. They stabilize oil/water emulsions by forming a strong multimolecular film around each oil globule and thus retard the coalescence by the presence of a hydrophilic barrier between the oil and water phases.

Natural gums and mucilages increase the tensile strength of the hydration layer formed around the suspended particles, through hydrogen bonding, and molecular interactions. Since these agents do not reduce the surface and interfacial tension, they function best in the presence of wetting agents. Gums and mucilages are also frequently used as protective colloids or thickeners. Natural gums and mucilages are hydrophilic colloids, which form dispersion with water and increase the viscosity of continuous phase, so that the solid particles remain suspended in it for a sufficient long time to measure a uniform dose.

4.3. Application as sustaining materials in dosage form

Among various dosage forms, matrix tablets are widely accepted for oral sustained release as they are simple and easy to formulate. Matrix system is the specific type of release system, which prolongs and controls the release of drug that is dissolved or dispersed. Making drug-embedded matrix tablets through the direct compression of a blend of drug, retardant material and additives is one of the simplest formulation approaches. The inclusion of polymeric materials in a matrix system is a common method of modulating drug release. Various natural gums and mucilages have been examined as polymer for sustained release formulations. The use of natural polymers and their semi-synthetic derivative in drug delivery continues to be an area of active research. Drug-release retarding polymers are the key performers in matrix systems. Various polymers have been investigated as drug retarding agents, each presenting a different approach to the matrix system. Based on the features of the retarding polymer, matrix systems are usually classified into three main groups: hydrophilic, hydrophobic and plastic. Hydrophilic polymers are the most suitable for retarding drug release and there is growing interest in using these polymers in sustained drug delivery (Bravo, Lamas, & Salomon, 2004; Genc, Bilac, & Guler, 1999; Khan & Jiabi, 1998). These polymers when come in contact with water, get hydrated and form a gel. The drug release from this gel will be usually diffusion controlled and hence the release will be sustained

Table 3
Pharmaceutical applications of natural gums.

S. no.	Common name	Botanical name	Family	Pharmaceutical applications	References
1	Agar	*Gelidium amansii*	Gelidaceae	Suspending agent, emulsifying agent, gelling agent in suppositories, surgical lubricant, tablet disintegrants, medium for bacterial culture, laxative	John, Declan, and James (2006)
2	Albizia gum	*Albizia zygia*	Leguminoseae	Tablet binder	Oluwatoyin (2005)
3	Carrageenan	*Chondrus cryspus*	Gigarginaceae	Gelling agent, stabilizer in emulsions and suspensions, in toothpaste, demulcent and laxative	Ahmed and Mutasim (2005) and Bonferoni, Rossi, and Tamayo (1993, 1994)
4	Cashew gum	*Anacardium occidentale*	Anacardiaceae	Suspending agent	Pontes (1971) and Zakaria and Zainiah (1996)
5	Cassia tora	*Cassia tora* Linn	Leguminosae	Binding agent	Pawar and D'mello (2004)
6	Guar gum	*Cyamompsis tetraganolobus*	Leguminoseae	Binder, disintegrant, thickening agent, emulsifier, laxative, sustained release agent, colon targeted drug delivery, cross-linked microspheres	Saleh, Yellela, Srinivas, and Vemulapalli (2005), Krishnaiah (2003), Krishnaiah (2001) and Chourasia and Jain (2004a)
7	Gum acacia	*Acacia arabica* and *Acacia senegal*	Leguminoseae	Suspending agent, emulsifying agent, binder in tablets, demulcent and emollient in cosmetics, osmotic drug delivery	Lu, Jiang, and Zhang (2003) and Beneke, Viljoen, and Hamman (2009)
8	Gum ghatti	*Anogeissus latifolia*	Combretaceae	Binder, emulsifier, suspending agent	Jain and Dixit (1988)
9	Gum tragacanth	*Astragalus gummifer*	Leguminoseae	Suspending agent, emulsifying agent, demulcent, emollient in cosmetics and sustained release agent	Owen (2003)
10	Karaya gum	*Sterculia urens*	Sterculiaceae	Suspending agent, emulsifying agent, dental adhesive, sustaining agent in tablets, bulk laxative, mucoadhesive	Sreenivasa, Prasanna, and Mary (2000), Munday and Philip (2000) and Park and Munday (2004)
11	Khaya gum	*Khaya grandifolia*	Meliaceae	Binding agent	Odeku and Itiola (2003)
12	Leucaena seed gum	*Leucaena leucocephata*	Fabaceae	Emulsifying agent, suspending agent, binder in tablets, disintegrating agent in tablets	Verma and Razdan (2001, 2002a, 2002b, 2003a, 2003b)
13	Pectin	*Citrus aurantium*	Rutaceae	Thickening agent, suspending agent, protective agent, beads, floating beads, colon drug delivery, microparticulate drug delivery, transdermal drug delivery, iontophoresis, hydrogels	Pornsak (1998), Pornsak, Srisagul, and Satit (2007), Vandamme, Lenourry, and Charrueau (2002), Sungthongjeen, Pitaksuteepong, and Somsiri (1999), Tho, Sande, and Kleinebudde (2002), Giunchedi, Conte, and Chetoni (1999), Musabayane, Munjeri, and Matavire (2003) and Cheng and Lim (2004)
14	Sodium alginate	*Macrocytis pyrifera*	Lessoniaceae	Suspending agent, gelation for dental films, stabilizer, sustained release agent, tablet coating, mucoadhesive microspheres	Alison, John, and Martyn (1995), Howard and Timmins (1988), Seiyaku (1989) and Viernstein (1988)
15	Tamarind seed polysaccharide	*Tamarindus indica*	Leguminoseae	Binding agent, emulsifier, suspending agent, sustaining agent, hydrogels, mucoadhesive agent and nasal drug delivery	Kulkarni, Dwivedi, and Sarin (1997), Kulkarni, Gowthamarajan, and Dhobe (2005) and Datta and Bandyopadhyay (2006)
16	Xanthan gum	*Xanthomonas campestris*	Xanthomonadaceae	Suspending agent, emulsifier, stabilizer in toothpaste and ointments, sustained release agent, buccal drug delivery system	Ganesh et al. (2011), Dhopeshwarkar and Zatz (1993), Santos, Veiga, Pina, and Sousa (2005) and Vendruscolo, Andreazza, and Ganter (2005)
17	Gellan gum	*Pseudomonas elodea*	–	Disintegrating agent, floating drug delivery system, ophthalmic drug delivery, sustaining agent, hydrogels	Rajinikanth and Mishra (2007), Rozier, Mazuel, Grove, and Plazonnet (1997), Miyazaki, Kawasaki, Kubo, Endo, and Attwood (2001), Kedzierewicz, Lombry, and Rios (1999), Coviello, Dentini, and Rambone (1998), Rajnikanth, Balasubramaniam, and Mishra (2007) and Agnihotri, Jawalkar, and Aminabhavi (2006)
18	Locust bean gum	*Ceratonia siliqua*	Fabaceae	Thickener, stabilizer and controlled release agent	Deshmukh, Sakarkar, and Wakade (2009) and Xiaohong, Michae, and John (2003)
19	Neem gum	*Azadirachta indica* A. Juss.	Meliaceae	Suspending agent, binder and transdermal film forming agent	Kulkarni, Gowthamarajan, Rao, et al. (2002) and Kulkarni, Gowthamarajan, Satish, et al. (2002)

Table 3 (*Continued*)

S. no.	Common name	Botanical name	Family	Pharmaceutical applications	References
20	Badam gum	*Prunus amygdalus*	Rosaceae	Binding, sustaining and transdermal film forming agent	Kulkarni, Gowthamarajan, Rao, et al. (2002) and Kulkarni, Gowthamarajan, Satish, et al. (2002)
21	–	*Caesalpinia pulcherrima*	Fabaceae	Mucoadhesive agent	Sudarshan, Sangeeta, Bothra, and Roshan (2010)
22	–	*Leucaena leucocephala*	Fabaceae	Mucoadhesive agent, emulsifier and binder	Sudarshan et al. (2010), Verma and Razdan (2003b) and Deodhar, Paradkar, and Purohit (1998)
23	–	*Cissus populnea*	Amplidaceae	Binding agent	Eichie and Amalime (2001)
24	–	*Acassia senegal*	Leguminosae	Binder, Disintegrant	Eichie and Amalime (2001)
25	Okra gum	*Hibiscus esculentus*	Malvaceae	Binder and hydrophilic matrix for controlled release drug delivery	Kalu, Odeniyi, and Jaiyeoba (2007) and Amelia, Rakesh, and Shilpa (2011)
26	–	*Sterculia foetida*	Malvaceae	Controlled release preparation	Amelia et al. (2011)
27	Honey locust gum	*Gleditsia triacanthos*	Fabaceae	Matrix tablet, sustained release formulation	Amelia et al. (2011)
28	Tara gum	*Caesalpinia spinosa*	Leguminosae	Thickener, stabilizer	Amelia et al. (2011)
29	Hakea gum	*Hakea gibbosa*	Proteaceae	Sustained release formulation, mucoadhesive agent	Hemant, Indiran, Ashim, and Thomas (1999), Alur, Beal, and Pather (2000), Alur, Pather, and Mitra (1999) and Amelia et al. (2011)
30	Konjac	*Amorphophallus konjac*	Araceae	Controlled release formulation, gelling agent	Amelia et al. (2011)
31	–	*Mimosa scabrella*	Mimosaceae	Release controlling agent	Amelia et al. (2011)
32	–	*Mimosa pudica*	Mimosaceae	Sustained release material	Amelia et al. (2011)
33	Hupu gum (gum kondagogu)	*Cochlospermum gossypium*	Cochlospermaceae	Gastric floating drug delivery	Amelia et al. (2011)
34	–	*Lepidium sativum*	Cruciferae	Controlled release formulation	Amelia et al. (2011)
35	Gum copal	*Bursera bipinnata*	Burseraceae	Film forming agent, Coating material for sustained release and colon targeted drug delivery	Amelia et al. (2011)
36	Gum damar	*Shorea wiesneri*	Dipterocarpaceae	Water resistant coating material, sustained release formulation	Amelia et al. (2011)
37	Moi gum	*Lannea coromandelica* (Houtt.) Merrill	Anacardiaceae	Microencapsulating agent, release rate controlling material	Amelia et al. (2011)
38	*Moringa oleifera* gum	*Moringa oleifera*	Moringaceae	Mucoadhesive agent, disintegrant and binder	Mitul et al. (2012)
39	–	*Abelmoschus esculentus*	Malvaceae	Sustained release formulation and binder	Ofoefule and Chukwu (2001) and Ofoefule, Chukwu, Anyakoha, and Ebebe (2001)
40	Mucuna gum	*Mucuna flagillepes*	Papillionaceae	Microencapsulating agent	Anthony and Obichukwu (2007)
41	Grewia gum	*Grewia mollis*	Malvaceae	Suspending agent, binder	Elijah and Barbara (2010)
42	Myrrh oleo gum	*Commiphora myrrha*	Burseraceae	Mucoadhesive agent	Gurpreet et al. (2011)
43	Gum cordia	*Cordia Obliqua*	Boraginaecae	Enteric Resistant and Sustained release material	Subas and Biswajit (2009) and Mukherjee, Dinda, and Barik (2008)
44	Sesbania gum	*Sesbania grandiflora*	Leguminosae	Gelling agent	Gayatri and Madhabhai (2009)
45	Katira gum	*Cochlospermum religiosum*	Bixaceae	Colon drug delivery	Bharanirajaa, Jayaram, Prasada, and Sen (2011)
46	Malva nut gum	*Scaphium scaphigerum*	Sterculiaceae	Stabilizer, thickening agent	Somboonpanyakul, Wang, Cui, Barbut, and Jantawat (2006)
47	Welan gum	Produced by fermentation using *Alcaligenes* species CGMCC2428	Alcaligenaceae	Thickening agent	Hui, Hong, Sha, Xiaohai, and Pingkai (2012)
48	Bhara gum	*Terminalia bellerica*	Combretaceae	Microencapsulation	Nayak, Nayak, and Patro (2008)

Table 4
Pharmaceutical applications of mucilages.

S. no.	Common name	Botanical name	Family	Pharmaceutical applications	References
1	Abelmoschus mucilage	*Abelmoschus esculentus*	Malvaceae	Binder in tablets, sustained release	Kumar et al. (2009), Ofoefule et al. (2001) and Ofoefule and Chukwu (2001)
2	Aloe mucilage	*Aloe species*	Liliaceae	Gelling agent, sustained release agent	Ahad, Kumar, et al. (2010), Ahad, Reddy, Md, Kumar, and Chitta (2010), Jani, Goswami, et al. (2007) and Jani, Shah, and Jain (2007)
3	Asario mucilage	*Lepidum sativum*	Cruciferae	Suspending agent, emulsifying agent, controlled release tablet	Mehta, Patel, Patel, Vora, and Patel (2010) and Patel, Chauhan, and Patel (1987)
4	Bavchi mucilage	*Ocimum canum*	Labiatae	Suspending agent, emulsifying agent	Patel et al. (1987)
5	Fenugreek mucilage	*Trigonella foenum graecum*	Leguminoseae	Gelling agent, disintegrant, tablet binder, sustaining agent, emollient and demulcent	Kulkarni, Gowthamarajan, Rao, et al. (2002), Kulkarni, Gowthamarajan, Satish, et al. (2002), Data and Bandyopadhyay (2005) and Gowthamarajan et al. (2002)
6	Hibiscus mucilage	*Hibiscus esculentus* Linn	Malvaceae	Emulsifying agent, sustained release agent, suspending agent	Wahi, Sharma, and Jain (1985a, 1985b)
7	Hibiscus mucilage	*Hibiscus rosa sinensis* Linn	Malvaceae	Suspending agent, sustained release agent	Edwin, Edwin, and Dosi (2007) and Jani and Shah (2008a, 2008b)
8	Ispagol mucilage	*Plantago psyllium* and *Plantago ovata*	Plantaginaceae	Cathartic, lubricant, demulcent, laxative, sustaining agent, hydrogels, gastro retentive drug delivery system, binder, emulsifying and suspending agent	Desai, Shidhaye, and Kadam (2007), Prajapati, Prajapati, and Acharya (2006), Srinivas, Prakash, Kiran, Prasad, and Rao (2003), Mithal and Kasid (1964, 1965), Singh, Chauhan, and Kumar (2007a), Singh, Chauhan, and Sharma (2007), Chourasia and Jain (2003, 2004b) and Chavanpatil, Jain, and Chaudhari (2006)
9	Ocimum seed mucilage	*Ocimum gratissimum* Linn	Labiatae	Suspending agent, binding agent	Anroop, Bhatnagar, and Ghosh (2005), Anroop, Ghosh, and Parcha (2006) and Kumar et al. (2007)
10	Satavari mucilage	*Asparagus racemosus*	Aapocynaceae	Binding agent and sustaining agent in tablets	Kulkarni, Gowthamarajan, Rao, et al. (2002) and Kulkarni, Gowthamarajan, Satish, et al. (2002)
11	Cactus mucilage	*Opuntia ficus-indica*	Cactaceae	Gelling agent in sustained drug delivery	Cárdenas, Higuera-Ciapara, and Goycoolea (1997)
12	–	*Anacardium occidentale*	Anacardiaceae	Gelling agent	Kumar et al. (2009)
13	–	*Cassia sophera*	Fabaceae	Binder	Kulkarni, Gowthamarajan, Rao, et al. (2002) and Kulkarni, Gowthamarajan, Satish, et al. (2002)
14	–	*Chlorophytum borivilianum*	Asparagaceae	Suspending agent, binder	Deore and Khadabadi (2008)
15	–	*Delonix regia*	Fabaceae	Binder	Kale, Joshi, Ambhore, and Sitaphale (2009)
16	–	*Vigna mungo*	Fabaceae	Binder	Yadav, Jaiswal, Singh, Chandra, and Jain (2009)
17	–	*Cissus populnea*	Vitaceae	Binder	Eichie and Amalime (2001)
18	–	*Caesalpinia pulcherrima*	Fabaceae	Granulating agent, binder	Selvi, Gopalakrishanan, Ramajayam, and Soman (2010)
19	–	*Cassia angustifolia*	Fabaceae	Granulating agent, binder	Singh and Singh (2010b)
20	–	*Zizyphus jujuba lamk*	Rhamnaceae	Binder	Singh, Gendle, Sheth, Roshan, and Singh (2010)
21	–	*Prosopis juliflora*	Mimosaceae	Binder	Selvi, Gopalakrishanan, Ramajayam, and Soman (2010a)
22	–	*Cassia auriculata*	Fabaceae	Binder	Singh et al. (2009)
23	–	*Cassia fistula*	Cassia fistula	Binder	Singh and Singh (2010a)
24	–	*Dillenia indica*	Dilleniaceae	Gelling agent	Ketousetuo and Bandyopadhyay (2007)
25	–	*Alyssum halocarpus*	Brassicaceae	Thickening agent	Koocheki, Mortazavi, Shahidi, Razavi, and Taherian (2009)
26	–	*Coriolus hirsutus*	Polyporaceae	Base for gel preparation	Rao, Gnanaprakash, Badarinath, Chetty, and Alagusundaram (2010)
27	–	*Chlorophytum borivilianum*	Asparagaceae	Suspending agent	Naglschmid, Kull, and Jeremias (1982)
28	–	*Hibiscus rosa sinensis*	Malvaceae	Superdisintegrant	Shah and Patel (2010)
29	–	*Mimosa pudica*	Fabaceae	Bioadhesive polymer	Ahuja, Kumar, and Yadav (2010)

Table 5
Pharmaceutical applications of gums and mucilages in drug delivery.

S. no.	Natural gum or mucilage	Model drug	Dosage form	References
1	Guar gum (97.3%)	Dexamethasone	Tablets	Kenyon et al. (1997)
2	Guar gum (77.19%)	Indomethacin	Matrix tablets	Prasad, Krishnaia, and Satyanarayana (1998)
3	Guar gum (125%)	Indomethacin	Tablets	Krishnaiah, Satyanarayana, Rama Prasad, and Narasimha Rao (1998)
4	Guar gum (20%)	Albendazole	Matrix tablets	Krishnaiah, Dinesh Kumar, Bhaskar, and Satyanarayana (2001)
5	Guar gum (20%)	Mebendazole	Matrix tablets	Krishnaiah, Dinesh Kumar, Bhaskar, and Satyanarayana (2001)
6	Guar gum (75%)	Diltiazem	Matrix tablets	Ravi, Mishra, and Kumar (2008)
7	Guar gum (65%)	Ornidazole	Matrix tablets	Krishnaiah, Bhaskar, Satyanarayana, and Latha (2003)
8	Guar gum (80%)	5 FU	Tablets	Krishnaiah, Satyanarayana, Dinesh Kumar, Karthikeyan, and Bhaskar (2003)
9	Guar gum	Tinidazole	Tablets	Krishnaiah, Bhaskar, Satyanarayana, and Latha (2003)
10	Guar gum	Calcium sennosides	Matrix tablets	Momin (2004)
11	Guar gum	Mesalazine	Tablets	Demiröz, Acartürk, Sevgi, and Oznur (2004)
12	Guar gum	Rofecoxib	Matrix tablets	Al-Saidan, Krishnaiah, Satyanarayana, and Rao (2005)
13	Guar gum	Albendazole-β-cyclodextrin	Matrix tablets	Shyale, Chowdary, Krishnaiah, and Bhat (2006)
14	Guar gum	Ondansetron	Matrix tablets	Demiroz and Takka (2006)
15	Guar gum (44%)	Indomethacin	Pellets (coated with Eudragit FS 30D)	Ji, Xu, and Wu (2007)
16	Methacrylic acid-g-guar gum (MAA-g-GG)	Metronidazole	Tablets	Mundargi, Patil, Agnihotri, and Aminabhavi (2007)
17	Guar gum–alginate combination cross-linked with glutaraldehyde	BSA	Hydrogels	George and Abraham (2007)
18	Xanthan gum	Caffeine, indomethacin, s odium indomethacin	Matrix tablets	Talukdar and Kinget (1995)
19	Xantan gum:guar gum (10:20)	5-FU	Matrix tablets	Sinha, Mittal, Bhutani, and Kumaria (2004)
20	Xanthum gum:boswellia gum (3:1)	5-FU	Compressed coated tablets	Sinha, Singh, Singh, and Binge (2007)
21	Khaya gum (300 mg) and Albizia gum (400 mg)	Paracetamol and indomethacin	Tablets	Odeku and Fell (2005)
22	Deacylated gellam gum cross-linked with calcium	Azathiopurine	Beads (coated with Eudragit S 100)	Singh, Trombetta, and Kim (2004)
23	Locust bean gum:chitosan (4:1)	Mesalazine	Compression coated tablets	Raghavan, Muthulingam, Josephine, Jenita, and Ravi (2002)
24	Caesalpinia pulcherrima mucilage	Diclofenac sodium	Tablet	Selvi et al. (2010b)
25	Cassia angustifolia seed mucilage	Diltiazem HCl	Tablet	Singh and Singh (2010b)
26	Prosopis juliflora mucilage	Diclofenac sodium	Tablet	Selvi et al. (2010a)
27	*Plantago Psyllium* seed mucilage	Paracetamol	Tablet	Saeedi, Morteza-Semnani, Ansoroudi, Fallah, and Amin (2010)
28	*Cassia fistula* seed mucilage	Diltiazem HCl	Tablet	Singh and Singh (2010a)
29	*Dellinia indica* mucilage	Oxytocin	Nasal gel	Ketousetuo and Bandyopadhyay (2007)

Table 5 (*Continued*)

S. no.	Natural gum or mucilage	Model drug	Dosage form	References
30	*Trigonella foenum graceum* mucilage	Diazepam	Nasal gel	Data and Bandyopadhyay (2005)
31	*Anacardium occidentale* mucilage	Aceclofenac	Topical gel	Kumar et al. (2009)
32	*Cocculus hirsutus* leaf mucilage	Flubiprofen	Gel	Rao et al. (2010)
33	*Chlorophytum borivilianum* mucilage	Zinc oxide	Suspension	Naglschmid et al. (1982)
34	*Abelmoschus esculentus* mucilage	Paracetamol	Suspension	Kumar et al. (2009)
35	*Mimosa pudica* seed mucilage	Fluconazole	Buccal disc	Ahuja et al. (2010)
36	*Ficus reticuleta* fruit mucilage	Diltiazem HCl	Transdermal patch	Ahad, Kumar, et al. (2010) and Ahad, Reddy, et al. (2010)
37	*Moringa oleifera* gum	Paracetamol	Tablet	Mitul et al. (2012)
38	Cissus populnea and Acassia senegal mucilage	Paracetamol	Tablet	Eichie and Amalime (2001)
39	*Plantago ovata* and *Trigonella foenum graceum mucilage*	Paracetamol	Tablet	Kulkarni, Gowthamarajan, Rao, et al. (2002) and Kulkarni, Gowthamarajan, Satish, et al. (2002)
40	*Hibiscus esculentus*	Diclofenac sodium	Matrix tablet	Rishabh (2011)
41	Tamarind seed mucilage	Diazepam	Nasal gel	Rimi and Bandyopadhyay (2006)
42	Gum karaya	Nimesulide	Dispersible tablet	Jani, Goswami, et al. (2007) and Jani, Shah, et al. (2007)
43	Leucaena leucocephala seed gum	Liquid paraffin	Emulsion	Murli, Himasankar, Janki, Seshasayana, and Ramana (2002)
44	Gum karaya	Theophyline	Tablet	Murli et al. (2002)
45	Tragacanth	Albendazole	Tablet	Gohel, Patel, Shah, and Jani (1996)
46	Asparagus racemosus and Cassia sophera mucilages	Paracetamol	Tablet	Kulkarni, Gowthamrajan, and Rao (2002a)
47	*Abelmoschus esculentus* gum	Furosemide and diclofenac sodium	Matrix tablet	Ofoefule and Chukwu (2001)
48	Khaya gum	Paracetamol	Tablet	Odeku and Itiola (2003)
49	*Ocimum basilicum* and *Plantago ovata*	Ibuprofen	Dispersible tablet	Srinivas et al. (2003)
50	Mucuna gum	Glibenclamide	Microspheres	Anthony and Obichukwu (2007)
51	Fenugreek mucilage	Diclofena diethylammonium	Gel	Gowthamarajan et al. (2002)
52	Leucaena leucocephala seed gum	Paracetamol	Tablet	Deodhar et al. (1998)
53	Gum karaya	Flubiprofen and diclofenac sodium	Tablet	Murli, Prasad, Ravi, and Ramana (2000)
54	*Abelmoschus esculentus* gum	Sulphaguanidine	Tablet	Ofoefule et al. (2001)
55	Locust bean gum	Diclofenac sodium	Microspheres	Deshmukh et al. (2009)
56	Gum copal and gum damar	Diclofenac sodium	Matrix tablet	Morkhade, Fulzele, Satturwar, and Joshi (2006)
57	Carrageenan gum	Theophylline	Tablet	Nery and Evone (2002)
58	Eulophia campestris mucilage	Paracetamol	Tablet	Ghule, Darwhekar, Jain, and Yeole (2006)
59	*Moringa oleifera* gum	Diclofenac sodium	Gel	Panda, Swain, Kanungo, and Gupta (2006)
60	*Aegle marmelos* fruit mucilage	Paracetamol	Tablet	Gaikar and Sandhya (2012)
61	*Cassia roxburghii* mucilage	Sulphamethaoxazole	Suspension	Arul, Christopher, Vimalson, Palanisamy, and Jagadeesan (2010)
62	*Ocimum americanumnum* mucilage	Paracetamol	Tablet	Sheth, Shah, and Shah (2010)
63	Flax seed mucilage	Ranitidine HCl	Mucoadhesive tablet	Mahant, Khurana, Dua, Thakar, and Bakshi (2011)
64	*Artocarpus heterophyllus* mucilage	Paracetamol	Tablet	Narkhede, Vidyasagar, Jadhav, Bendale, and Patel (2010)
65	*Hibuscus rosasinensis* mucialge	Aceclofenac	Mouth dissolving tablet	Viral and Rucha (2010)
66	Xanthan gum	Labetalol HCl	Mucoadhesive buccal tablets	Ganesh et al. (2011)
67	Moringa gum	Propranolol HCl	Mucoadhesive buccal tablets	Arun et al. (2011)
68	Myrrh oleo gum	Domperidone	Mucoadhesive matrix tablets	Gurpreet et al. (2011)
69	Gum cordia	Diclofenac sodium	Microencapsulated matrix tablet	Subas and Biswajit (2009)
70	Gum karaya	Metformin HCL	Mucoadhesive microcapsules	Ashok et al. (2011)
71	Gum kondagogu, gum guar and xanthan gum	Gliclazide	Mucoadhesive Microcapsules	Santhosh, Nishanth, Ramakrishna, and Rajyalaxmi (2011)
72	Guar gum	Itraconazole	Mucoadhesive tablet	Shaikh, Pawar, and Kumbhar (2012)

Table 6
Preliminary confirmative tests for dried mucilage powder.

S. no.	Test	Procedure	Observation	Inference
1	Molisch's test	100 mg dried mucilage powder + Molisch's reagent + conc. H_2SO_4 on the side of a test tube	Violet green color observed at the junction of the two layers	Carbohydrate present
2	Ruthenium test	Take a small quantity of dried mucilage powder, mount it on a slide with ruthenium red solution, and observe it under microscope	Pink color develops	Mucilage present
3	Iodine test	100 mg dried mucilage powder + 1 ml 0.2 N iodine solution	No color observed in solution	Polysaccharides present (starch is absent)
4	Enzyme test	Dissolve 100 mg dried mucilage powder in 20 ml-distilled water; add 0.5 ml of benzidine in alcohol (90%). Shake and allow to stand for few minutes	No blue color produced	Enzyme absent (distinction between dried mucilage and acacia)

over a prolonged time (Kulkarni, Gowthamarajan, Rao, et al., 2002; Kulkarni, Gowthamarajan, Satish, et al., 2002).

4.4. Applications as coating agents

Many gums and mucilages act as good coating agents, which can sustain the drug release, or can protect the drug from degradation in stomach. The mucilage from drumstick polysaccharide (*Moringa oleifera* Lam. Syn. *M. pterygosperma* Gaertn.) has been reported to be a good film-coating polymer for paracetamol granules, which retarded the drug release form the granules when used at 2% concentration (Mitul, Jitendra, & Umesh, 2012). As the number of coatings increased, the drug release was found to reduce.

4.5. Applications as gelling agents

The utilization of natural gums and mucilages as base for pharmaceutical gels is a new concept. Gums and mucilages can form gels either alone or in combinations with others. Gelling is a results of numerous inter and intra molecular associations to produce a three-dimensional network, within which the water molecules are entrapped. Such associations are brought about by either physical (pH change, altering temperature) or chemical (addition of suitable reagents) treatments. The mechanism of gelation in acidic polysaccharides such as pectin is different. In this case, the macromolecular chains are widely hydrogen bonded and as a result, junction zones are formed between hydrogen bonded segments of chains. In alginic acid, the gel formation occurs as a result of interaction with calcium ions. Galactomannans interact synergistically with Xanthan gum or carrageenans to form elastic gels.

Mucilage of various plants has been used as gelling agent due to its non-toxicity, low cost, free availability, emollient and non-irritating nature (Kumar, Patil, Patil, & Paschapur, 2009).

4.6. Applications as mucoadhesive agents

Naturally occurring polymers, being biocompatible and biodegradable, are currently extensively researched for the development of novel drug delivery systems. Mucoadhesive drug delivery techniques are primarily controlled release drug delivery systems, which gets retained in the stomach for longer period of time, thus helping in absorption of drug for the intended duration of time. It helps to improves bioavailability, reduces drug wastage, improve solubility of drugs that are less soluble at high pH environment (e.g. weakly basic drugs like domperidone and papaverine) (Gurpreet, Karan, & Inderbir, 2011; Gurpreet, Karan, Inderbir, & Sandeep, 2011).

Bioadhesion may be defined as the state in which two materials, at least one of which is biological in nature, are held together for extended periods by interfacial forces. When the adhesive attachment is to mucus or a mucous membrane, the phenomenon is referred to as mucoadhesion (Smart, Kellaway, & Worthington, 1984). The most widely investigated group of mucoadhesive is hydrophilic macromolecules containing numerous hydrogen bonds forming groups. Once the dosage form firmly sticks to the mucosal surface, its gastric residence time is prolonging until it is remove by turnover of mucins or by some other means (Harding, Davis, Deacon, & Fiebrig, 1999).

Mucoadhesive behavior could be extremely useful in nasal delivery applications. Mucoadhesive agents in their molecular form make intimate contact with mucin of mucosa and then make adhesion with the nasal membrane and finally the mucoadhesive carriers allow the release of drug through nasal membrane in a continuous fashion (Data & Bandyopadhyay, 2005).

5. Characterization of gums and mucilages

The extraction and characterization of polysaccharide gums is an essential step in establishing their suitability as pharmaceutical excipients (Elijah & Barbara, 2010). The prospects of natural polymers are brighter but even here extensive testing will be required. A suitable strategy is required to save money and time. Over-characterization is not desirable, because excessive use of time and resources could actually delay the launch of innovative excipients. The characterization of gums and mucilages is initially achieved by only a multiple-technique approach. For excipients analysis, analytical techniques can be classified according to the type of information generated.

Structural—Gums and mucilages are polysaccharides and contain sugars. So, confirmation of the different sugars is carried out by chromatography and structure elucidation can be carried out by NMR and mass spectroscopy.
Purity—To determine the purity of the selected gum and mucilage, tests for alkaloids, glycosides, carbohydrates, flavanoids, steroids, amino acids, terpenes, saponins, oils and fats, and tannins and phenols are carried out.
Impurity profile—Testing for impurities must be carried out using suitable analytical techniques.
Physico-chemical properties—Color, odor, shape, taste, touch, texture, solubility, pH, swelling index, loss on drying, hygroscopic nature, angle of repose, bulk and true densities, porosity and surface tension. Different ash values are also estimated. The microbial load and presence of specific pathogens are also determined. In vitro cytotoxicity is also determined. Gums and mucilages are highly viscous in nature. So, the rheological properties of excipients are important criteria for deciding their commercial use. The flow behavior of the samples is determined. Table 6 shows different preliminary confirmative tests for dried mucilage powder.
Toxicity—The acute toxicity of gums and mucilages are determined by the followings fixed-dose method as per OECD guideline No. 425. A sub-acute toxicity study, determination of the LD50, etc., is carried out in rats and guinea pigs of both sexes.

Table 7
Examples of modified gums with their applications.

S. no.	Gums and mucilage	Modification technique	Applications	References
1	Karaya gum	Heat treatment at various temperatures in a hot air oven	Disintegrating agent	Murli et al. (2000) and Murli et al. (2002)
2	Agar and guar gum	Heat treatment at various temperatures in a hot air oven along with co-grinding of both materials	Disintegrating agent	Jani, Goswami, et al. (2007) and Jani, Shah, et al. (2007)
3	Hypochlorite potato starch	Chemical modification of potato starch carried out in presence of hypochloride.	Disintegrating agent	Rama and Rao (2000)
4	Tragacanth	Chemical modification of tragacanth using epichlorhydrine	Disintegrating agent	Gohel et al. (1996)
5	Acacia gum	Chemical modification of acacia gum using epichlorhydrine	Disintegrating agent	Trivedi, Patel, and Patel (1986)
6	Guar gum	Chemical modification of guar gum	Disintegrating agent	Baveja and Misra (1997)
7	Cross-linked amylose	Chemical modification of amylase by substituting it in a one step reaction	Disintegrating and binding agent	Cartilier et al. (1997)
8	Cross-linked cellulse	Chemical modification of cellulose by epichlorhydrine.	Disintegrating and binding agent	Cartilier and Chebli (1999)
9	Polyalkylamine	Chemical modification of polyalkylamine.	Disintegrating agent	Rong-Kun, Mirwais, and Michael (1998)
10	Cyclodextrin	Physical modification – co-drying of micro crystalline cellulose with cyclodextrin	Disintegrating agent	Fenyvest, Antal, Zsadon, and Szejtli (1984)
11	Starch	Physico-chemical treatment of to starch for modification	Disintegrating and binding agent	Okafor, Ofoefule, and Udeala (2001)
12	Sesbania gum	Chemical modification of *Sesbania* gum with tartaric acid for a sustained release formulation and chemical modification of gum with acetone:chloroform mixture for gelling agent	Sustained release formulation, gelling agent	Bharadia, Patel, and Patel (2004) and Gayatri and Madhabhai (2009)
13	Guar gum	Chemical modification of guar gum with glutaraldehyde for colonic delivery, chemical modification using isopropanol as a filmcoating material	Colonic delivery, film coating, hydrogel	Chaurasia, Chourasia, and Jain (2006), Toti and Aminabhavi (2004), Gliko-Kabir, Yagen, Penhasi, and Rubinstein (2000), Rane and Kale (2009) and Sandolo, Coviello, and Matricardi (2007)
14	Tamarind powder	Chemical modification of tamarind powder using epichlorohydrin for a sustained release formulation and partial degradation of β galactosidase for rectal drug delivery	Sustainedrelease formulation, rectal drug delivery	Sumathi and Ray (2002) and Miyazaki, Suisha, and Kawasaki (1998)
15	Psyllium	Chemical modification of psyllium was carried out to form *N*-hydroxy-methylacrylamide based hydrogels, chemical modification with tartaric acid	N-hydroxy-methylacrylamide based hydrogels, oral insulin drug delivery	Singh, Chauhan, and Sharma (2006), Singh, Chauhan, and Kumar (2007), Singh, Chauhan, and Sharma (2007), Singh and Chauhan (2009) and Gohel, Patel, and Amin (2003)
16	Okra fruits (pods) of *Hibiscus esculentus*	Chemical modification with acrylamide synthesis	Controlled drug delivery	Mishra, Clark, and Pal (2008)
17	Ipomoea dasysperma, Ipomoea hederacea, and Ipomoea palmata	Chemical modification of ipomoea with poly(acrylonitrile) grafted drug delivery	Poly(acrylonitrile) grafted drug delivery	Singh, Tiwari, and Tripathi (2005)
18	Pectins	Chemical modification of pectin with acetyl chloride in ethanol for modified drug delivery, chemical modification with ethanolamine for hydrogels and chemical modification of pectin for colonic drug delivery	Modified drug delivery. Hydrogels, colonic drug delivery	Bhatia, Deshmukh, and Choudhari (2008), Mishra et al. (2008) and Liu, Fishman, and Kost (2003)
19	Sterculia gum	Cross-linking with methacrylic acid	Hydrogels, anti ulcer drug delivery	Baljit and Nisha (2008)
20	Konjac glucomannan	Carboxymethylation/carbomoylethylation of gums	Polymeric carrier for site specific bioactive drug delivery	Jiangyang, Wang, Liu, and He (2008)
21	Cashew gum	Carboxymethylation by monochloroacetic acid (MCA)	Controlled drug delivery	Silva et al. (2004)
22	Cassia tora gum	Carbamoylethylation with acrylamide in the presence of sodium hydroxide	Controlled drug delivery	Sharma, Kumar, and Soni (2003) and Sharma, Kumar, and Soni (2004)
23	Tamarind kernel powder (TKP)	Graft copolymerization of acrylamide onto TKP	Colon specific drug delivery	Goyal, Kumar, and Sharma (2008)
24	Cassia tora gum	Graft copolymerization of acrylamide using ceric ammonium nitrate–nitric acid as redox initiator	Controlled drug delivery	Sharma, Kumar, and Soni (2002)
25	Guar gum	Cross-linking with glutaraldehyde	Colon specific drug delivery	George and Abraham (2007)
26	Cashew gum	Cross-linking of with epichlorohydrin	Controlled drug delivery	Silva, Feitosa, Maciel, Paula, and Paula (2006)
27	Arabic gum	Chemically modified with glycidyl methacrylate (GMA)	pH-responsive hydrogel	Reis, Guilherme, Cavalcanti, Rubira, and Muniz (2006)

Once analysis is complete, determination of the structure, composition and impurity profile enables a scientific dossier to be prepared describing the excipients. This information is of value for the regulatory dossier of the final pharmaceutical product that would contain the given excipients.

Finally, gums and mucilages are added to pharmaceutical formulations. So a compatibility study is important. The compatibility studies of gum or mucilage or drugs can be evaluated or studied by spectrophotometry/FTIR/DSC.

6. Modification of existing gum and mucilages

Natural gum polysaccharides are promising biodegradable materials for use in drug delivery systems. However, these materials have certain drawbacks, like uncontrolled rate of hydration, thickening, drop in viscosity on storage, microbial contamination and require some modification to overcome these problems (Baljit & Nisha, 2008). These modifications can be carried out by carboxymethylation/carbomoylethylation, grafting or cross-linking of vinyl monomers onto polysaccharides which produce a tailor-made material for drug delivery systems. Certain modifications like carboxymethylation and carbomoylethylation by replacement of few free-OH groups increase the aqueous solubility of gums (Vikas et al., 2011). It should be noted that many "old" materials compete successfully today after almost a century of efforts to replace them. It is the usual balance of economics and performance that determines the commercial realities.

Carboxymethylation of gums increases their hydrophilicity and solution clarity and makes them more soluble in aqueous systems. Modification of tamarind kernel powder, cassia tora gum and guar gum were investigated by Goyal, Kumar, and Sharma (2007). Various methods are available to modify the state of molecular interaction between polymers. Basically, two methods are available as the physical method and chemical method.

Physical method—A molecular interaction between polymers can be achieved by exposure to dry heat, saturated steam, microwave technology, UV (Khan, Bhattacharia, & Kader, 2006; Vatanasuchart, Naivikul, & Charoenrein, 2005) and gamma radiation (Desai & Park, 2006).

Chemical method—Polymers are treated with chemicals like aldehydes, epichlorhydrin, borax or glutaraldehyde. Temperature is one of the most favorable methods of cross-linking because it avoids both the application of harsh chemical materials for large-scale production and the diversity of equipment and methods used in their application (Micard, Belamri, Morel, & Guilbert, 2000). Table 7 shows examples of modified gums and mucilages.

Grafting of acrylic acid or its derivatives on gums has been used for modifying the swelling characteristics, film forming properties and drug release properties of the later. Chemical modification of tamarind kernel powder (TKP) and cassia tora gum through grafting has received considerable attention for imparting new functional groups for different applications (Goyal et al., 2008). Grafting of gums with other polymers or ions requires availability of –COO– and/or $–CH_2OH$ groups in the gum. The main advantage of these grafted gums is that the resultant molecule can be designed to yield a compound with the desired drug release profile. The grafted molecule could be selected in a way that it does not solubilize while the gum solubilizes at a particular pH. In this way, a predetermined drug release profile could be obtained.

Cross-linking of gums require availability of active functional groups in their basic structure. Hence, gums such as guar gum, cashew gum or sterculia gums that possess free alcoholic and/or carboxylic units seem to be a good choice for modification by cross-linking. However, it is essential to investigate the vulnerability of the cross-linking to different pH in order to use the modified molecule for site specific delivery. The high swelling characteristics of natural gums in matrices which leads to burst release does not make them suitable for delivering drugs to distal parts of the gut. Such high swelling can be prevented by phosphate cross-linking (Kabir, Yagen, Penhasi, & Rubinstein, 2000).

7. Conclusion

The use of natural gums for pharmaceutical applications is attractive because they are economical, readily available, non-toxic, and capable of chemical modifications, potentially biodegradable and with few exceptions, also biocompatible. Many studies have been carried out in fields including food technology and pharmaceuticals using gums and mucilages. It is clear that gums and mucilages have many advantages over synthetic materials. Systemic investigations of natural polysaccharides and their derivatives can lead to interesting discoveries in the fields of therapeutic and industrial research. Various applications of gums and mucilages have been established in the fields of pharmaceuticals. Natural gums can also be modified to have tailor-made products for drug delivery systems and thus can compete with the synthetic controlled release excipients available in the market. There are still several plant polysaccharides that are not investigated so far and studies on such sources can make significant contribution in this direction. Therefore, in the years to come, there will be continued interest in natural gums and their modifications aimed at the development of better materials for drug delivery systems.

Acknowledgements

The authors are highly thankful to SSR College of Pharmacy, Silvassa for providing all the necessary support and the essential library information resources.

References

Agnihotri, S. A., Jawalkar, S. S., & Aminabhavi, T. M. (2006). Controlled release of cephalexin through gellan gum beads: Effect of formulation parameters on entrapment efficiency, size, and drug release. *European Journal of Pharmaceutics Biopharmaceutics*, *63*, 249–261.

Ahad, H. A., Kumar, C. S., Ravindra, B. V., Sasidhar, C. G. S., Ramakrishna, G., Venkatnath, L., et al. (2010). Characterization and permeation studies of diltiazem hydrochloride – *Ficus reticuleta* fruit mucilage transdermal patches. *International Journal of Pharmaceutical Sciences Review and Research*, *1*, 32–37.

Ahad, H. A., Reddy, B. K. K., Md, I. B., Kumar, C. H., & Chitta, S. K. (2010). Fabrication and *in vitro* evaluation of glibenclamide *Abelmoschus esculentus* fruit mucilage controlled release matrix tablets. *Journal of Pharmacy Research*, *3*, 943–946.

Ahmed, B., & Mutasim, A. (2005). Sustained release characteristics of tablets prepared with mixed matrix of sodium carragennan and chitosan: Effect of polymer weight ratio, dissolution media and drug type. *Drug Development and Industrial Pharmacy*, *31*(3), 241–247.

Ahuja, M., Kumar, M., & Yadav, M. (2010). Evaluation of mimosa seed mucilage as bucoadhesive polymer. *Yakugaku Zasshi (Journal of the Pharmaceutical Society of Japan)*, *130*(7), 937–944.

Alison, C. H., John, R. M., & Martyn, C. D. (1995). Structure and behavior in hydrophilic matrix sustained release dosage forms: 3. The influence of pH on the sustained-release performance and internal gel structure of sodium alginate matrices. *Journal of Controlled Release*, *33*(1), 143–152.

Alonso-Sande, M., Teijeiro, D., Remuñán-López, C., & Alonso, M. J. (2009). Glucomannan, a promising polysaccharide for biopharmaceutical purposes. *European Journal of Pharmaceutics and Biopharmaceutics*, *72*(2), 453–462.

Al-Saidan, S. M., Krishnaiah, Y. S. R., Satyanarayana, V., & Rao, G. S. (2005). In vitro and in vivo evaluation of guar gum-based matrix tablets of rofecoxib for colonic drug delivery. *Current Drug Delivery*, *2*(2), 155–163.

Alur, H. H., Pather, S. I., & Mitra, A. K. (1999). Evaluation of the gum from *Hakea gibbosa* as a sustained-release and mucoadhesive component in buccal tablets. *Pharmaceutical Development and Technology*, *4*, 347–358.

Alur, H. H., Beal, J. D., & Pather, S. I. (2000). Evaluation of a novel, natural oligosaccharide gum as a sustained-release and mucoadhesive component of calcitonin buccal tablets. *Journal of Pharmaceutical Science*, *88*(12), 1313–1319.

Amelia, M. A., Rakesh, R. D., & Shilpa, N. S. (2011). Recent investigations of plant based natural gums, mucilages and resins in novel drug delivery systems. *Indian Journal of Pharmaceutical Education and Research*, *45*(1), 86–99.

Anroop, B., Bhatnagar, S. P., & Ghosh, B. (2005). Studies on *Ocimum gratissimum* seed mucilage: Evaluation of suspending properties. *Indian Journal of Pharmaceutical Science*, *67*(2), 206–209.

Anroop, B., Ghosh, B., & Parcha, V. (2006). Studies on *Ocimum gratissimum* seed mucilage: Evaluation of binding properties. *International Journal Pharmaceutics*, *325*(1), 191–193.

Anthony, A. A., & Obichukwu, J. N. (2007). Mucuna gum microspheres for oral delivery of glibenclamide: In vitro evaluation. *Acta Pharmaceutica*, *57*, 161–171.

Arul, K. S. G., Christopher, D., Vimalson, Palanisamy, S., & Jagadeesan, M. (2010). Evaluation of suspending properties of *cassia roxburghii* mucilage on sulphamethaoxazole suspension. *International Journal of Pharma and Bio Sciences*, *1*(2), 1–10.

Arun, B. P., Sankaranand, R., Venu, V., Anoosha, M., Sunitha, P., Swetha, T., et al. (2011). Effect of moringa gum in enhancing buccal drug delivery of propranolol hydrochloride. *International Journal of Research in Pharmacy and Chemistry*, *1*(2), 111–116.

Ashok, K., Balakrishna, T., Rajiv, J., Murthy, T. E., Anil, K., & Sudheer, B. (2011). Formulation and evaluation of mucoadhesive microcapsules of metformin hcl with gum karaya. *International Journal of Pharmacy and Pharmaceutical Sciences*, *3*(3), 150–155.

Baljit, S., & Nisha, S. (2008). Modification of sterculia gum with methacrylic acid to prepare a novel drug delivery system. *International Journal of Biological Macromolecules*, *43*, 142–150.

Baveja, J. M., & Misra, A. N. (1997). Modified guar gum as a tablet disintegrant. *Pharmazie*, *52*, 856–859.

Beneke, C. E., Viljoen, A. M., & Hamman, J. H. (2009). Polymeric plant-derived excipients in drug delivery. *Molecules*, *14*, 2602–2620.

Bharadia, P. D., Patel, M. M., & Patel, G. C. (2004). A Preliminary investigation on sesbania gum as a pharmaceutical excipient. *International Journal of Pharmaceutical Excipients*, *4*, 99–102.

Bharanirajaa, B., Jayaram, K. K., Prasada, C. M., & Sen, A. K. (2011). Different approaches of katira gum formulations for colon targeting. *International Journal of Biological Macromolecules*, *49*(3), 305–310.

Bhatia, M. S., Deshmukh, R., & Choudhari, P. (2008). Chemical modification of pectins, characterization and evaluation for drug delivery. *Scientia Pharmaceutica*, *76*, 775–784.

Bonferoni, M. C., Rossi, R., & Tamayo, M. (1993). On the employment of λ-carrageenan in a matrix system. I. Sensitivity to dissolution medium and comparison with Nacarboxymethylcellulose and xanthan gum. *Journal of Controlled Release*, *26*(2), 119–127.

Bonferoni, M. C., Rossi, R., & Tamayo, M. (1994). On the employment of λ-carrageenan in a matrix system. II. λ-Carrageenan and hydroxypropylmethylcellulose mixtures. *Journal of Controlled Release*, *30*(2), 175–182.

Bravo, S. A., Lamas, M. C., & Salomon, C. J. (2004). Swellable matrices for the controlled release of diclofenac sodium: Formulation and in vitro studies. *Pharmaceutical Development and Technology*, *9*(1), 75–83.

Cárdenas, A., Higuera-Ciapara, I., & Goycoolea, F. M. (1997). Rheology and aggregation of Cactus (*Opuntia ficus-indica*) mucilage in solution. *Journal of the Professional Association for Cactus Development*, *2*, 152–159.

Cartilier, L., & Chebli, C. (1999). Cross-linked cellulose as a tablet excipient. US Patent No. 5989589.

Cartilier, L., Mateescu, M. A., & Dumoulin, Y. (1997). Crosslinked amylose as a binder/disintegrant in tablets. US Patent No. 5616343.

Chamarthy, S. P., & Pinal, R. (2008). Plasticizer concentration and the performance of a diffusion-controlled polymeric drug delivery system. *Colloids Surfaces A: Physiochemical Engineering Aspect*, *331*, 25–30.

Chaurasia, M., Chourasia, M. K., & Jain, N. K. (2006). Crosslinked guar gum microspheres: A viable approach for improved delivery of anticancer drugs for the treatment of colorectal cancer. *AAPS PharmSciTech*, *7*, 143–151.

Chavanpatil, M. D., Jain, P., & Chaudhari, S. (2006). Novel sustained release, swellable and bioadhesive gastroretentive drug delivery system for ofloxacin. *International Journal Pharmaceutics*, *316*(1), 86–92.

Cheng, K., & Lim, L. Y. (2004). Insulin-loaded calcium pectinate nanoparticles: Effects of pectin molecular weight and formulation pH. *Drug Development and Industrial Pharmacy*, *30*, 359–367.

Chourasia, M. K., & Jain, S. K. (2003). Pharmaceutical approaches to colon targeted drug delivery systems. *International Journal of Pharmacy and Pharmaceutical Sciences*, *6*(1), 33–66.

Chourasia, M. K., & Jain, S. K. (2004a). Potential of guar gum microspheres for target specific drug release to colon. *Journal of Drug Targeting*, *12*(7), 435–442.

Chourasia, M. K., & Jain, S. K. (2004b). Polysaccharides for colon targeted drug delivery. *Drug Delivery*, *11*, 129–148.

Clarke, A. E., Andreson, R. L., & Stone, B. A. (1979). Form and function of arabinogalactans and arabinogalactan-proteins. *Journal of Phytochemistry*, *18*(4), 521–540.

Clifford, S. C., Arndt, S. K., Popp, M., & Jones, H. G. (2002). Mucilages and polysaccharides in *Ziziphus* species (Rhamnaceae): Localization, composition and physiological roles during drought-stress. *Journal of Experimental Botany*, *53*(366), 131–138.

Coviello, T., Dentini, M., & Rambone, G. (1998). A novel cocross linked polysaccharide: Studies for a controlled delivery matrix. *Journal of Controlled Release*, *55*, 57–66.

Data, R., & Bandyopadhyay, A. K. (2005). Development of a new nasal drug delivery system of diazepam with natural mucoadhesive agent from *Triogenall foenum graecum* L. *Journal of Scientific and Industrial Research*, *64*, 973–977.

Datta, R., & Bandyopadhyay, A. K. (2006). A new nasal drug delivery system for diazepam using natural mucoadhesive polysaccharide obtained from tamarind seeds. *Saudi Pharmaceutical Journal*, *14*, 115–119.

Demiroz, F. T., & Takka, F. A. S. (2006). Investigation of colon-specific dosage forms of ondansetron prepared with natural polymers. *Pharmazie*, *61*, 916–919.

Demiröz, F. T., Acartürk, F., Sevgi, F. T., & Oznur, K. B. (2004). In vitro and in vivo evaluation of mesalazine–guar gum matrix tablets for colonic drug delivery. *Journal of Drug Targeting*, *12*(2), 105–112.

Deodhar, U. P., Paradkar, A. R., & Purohit, A. P. (1998). Preliminary evaluation of *Leucaena leucocephala* seed gum as a tablet binder. *Drug Development and Industrial Pharmacy*, *24*(6), 577–582.

Deore, S. L., & Khadabadi, S. S. (2008). Standardisation and pharmaceutical evaluation of *Chlorophytum borivilianum* mucilage. *Rasayan Journal of Chemistry*, *1*, 887–892.

Desai, K. G., & Park, H. G. (2006). Study of gamma-irradiation: Effects on chitosan microparticles. *Drug Delivery*, *13*, 39–50.

Desai, A., Shidhaye, S., & Kadam, V. J. (2007). Possible use of psyllium husk as a release retardant. *Indian Journal of Pharmaceutical Science*, *69*(2), 206–210.

Deshmukh, V. N., Sakarkar, D. M., & Wakade, R. B. (2009). Formulation and evaluation of controlled release alginate microspheres using locust bean gum. *Journal of Pharmacy Research*, *2*(3), 458–461.

Dhopeshwarkar, V., & Zatz, J. L. (1993). Evaluation of xanthan gum in the preparation of sustained release matrix tablets. *Drug Development and Industrial Pharmacy*, *19*(9), 999–1017.

Edwin, J., Edwin, S., & Dosi, S. (2007). Application of *Hibiscus* leaves mucilage as suspending agent. *Indian Journal of Pharmaceutical Education and Research*, *41*(4), 373–375.

Efentakis, M., & Kouttis, A. (2001). Release of furosemide from multiple unit and single unit preparations containing different viscosity grade of sodium alginate. *Pharmaceutical Development and Technology*, *6*(1), 91.

Eichie, F. E., & Amalime, A. E. (2001). Evaluation of the binder effects of the gum mucilages of *Cissus populnea* and *Acassia senegal* on the mechanical properties of paracetamol tablets. *African Journal Biotechnology*, *6*(19), 2208–2211.

Elijah, I. N., & Barbara, R. C. (2010). Characterization of grewia gum, a potential pharmaceutical excipient. *Journal of Excipients and Food Chemistry*, *1*(1), 30–40.

Fenyvest, E., Antal, B., Zsadon, B., & Szejtli, J. (1984). Cyclodextrin polymer, a new tablet disintegrating agent. *Pharmazie*, *39*(7), 473–475.

Gaikar, N., & Sandhya, P. (2012). Evaluation of *Aegle marmelos* fruit mucilage for binding properties. *International Journal of Pharmaceutical Science and Research*, *3*(2), 620–622.

Ganesh, G. N. K., Manjusha, P., Gowthamarajan, K., Suresh, K. R., Senthil, V., Jawahar, N., et al. (2011). Design and development of buccal drug delivery system for labetalol using natural polymer. *International Journal of Pharmaceutical Research and Development*, *3*(3), 37–49.

Gayatri, C. P., & Madhabhai, M. P. (2009). Preliminary evaluation of sesbania seed gum mucilage as gelling agent. *International Journal of PharmTech Research*, *1*(3), 840–843.

Genc, L., Bilac, H., & Guler, E. (1999). Studies on controlled release dimenhydrinate from matrix tablet formulations. *Pharmaceutica Acta Helvetiae*, *74*(1), 43–49.

George, M., & Abraham, T. E. (2007). pH sensitive alginate–guar gum hydrogel for the controlled delivery of protein drugs. *International Journal of Pharmaceutics*, *335*(2), 123–129.

Ghule, B. V., Darwhekar, G. D., Jain, D. K., & Yeole, P. G. (2006). Evaluation of binding properties of eulophia campestris wall mucilage. *Indian Journal of Pharmaceutical Science*, *September–October*, 566–569.

Giunchedi, P., Conte, U., & Chetoni, P. (1999). Pectin microspheres as ophthalmic carriers for piroxicam: Evaluation *in vitro* and *in vivo* in albino rabbits. *European Journal of Pharmaceutical Science*, *9*(1), 1–7.

Gliko-Kabir, I., Yagen, B., Penhasi, A., & Rubinstein, A. (2000). Phosphated crosslinked guar for colon-specific drug delivery: I. Preparation and physicochemical characterization. *Journal of Controlled Release*, *63*, 121–127.

Gohel, M. C., Patel, S. D., Shah, N. K., & Jani, G. K. (1996). Evaluation of synthesized cross-linked tragacanth as a potential disintegrant. *Indian Journal of Pharmaceutical Science*, *59*(3), 113–118.

Gohel, M. C., Patel, M. M., & Amin, A. F. (2003). Development of modified release Diltiazem HCl tablets using composite index to identify optimal formulation. *Drug Development and Industrial Pharmacy*, *29*, 565–574.

Gowthamarajan, K., Giriraj, K. T., Muthukumar, A., Mahadevan, N., Samanta, M. K., & Suresh, B. (2002). Evaluation of fenugreek mucilage as gelling agent. *International Journal of Pharmaceutical Excipients*, *January*, 16–19.

Goyal, P., Kumar, V., & Sharma, P. (2007). Carboxymethylation of tamarind kernel powder. *Carbohydrate Polymers*, *69*, 251–255.

Goyal, P., Kumar, V., & Sharma, P. (2008). Graft copolymerization of acrylamide on to tamarind kernel powder in the presence of cerric ion. *Journal of Applied Polymer Science*, *108*, 3696–3701.

Guo, J., Skinner, G. W., Harcum, W. W., & Barnum, P. E. (1998). Pharmaceutical applications of naturally occurring water-soluble polymers. *Pharmaceutical Science and Technology Today*, *1*, 254–261.

Gurpreet, A., Karan, M., & Inderbir, S. (2011). Formulation and evaluation of mucoadhesive matrix tablets of taro gum: Optimization using response surface methodology. *Polimery w Medycynie*, *41*(2), 23–34.

Gurpreet, A., Karan, M., Inderbir, S., & Sandeep, A. (2011). Formulation and evaluation of controlled release mucoadhesive matrix tablets: Assessment of myrrh

oleo gum resin as a natural pharmaceutical excipient. *International Journal of Pharmaceutical Sciences and Drug Research*, *3*(2), 84–88.
Harding, S. E., Davis, S. S., Deacon, M. P., & Fiebrig, I. (1999). Biopolymer bioadhesives. *Biotechnology and Genetic Engineering Reviews*, *16*, 41–85.
Hemant, H. A., Indiran, S., Ashim, K. M., & Thomas, P. J. (1999). Transmucosal sustained-delivery of chlorpheniramine maleate in rabbits using a novel, natural mucoadhesive gum as an excipient in buccal tablets. *International Journal of Pharmaceutics*, *188*(1), 1–10.
Howard, J. R., & Timmins, P. (1988). Controlled release formulations. US Patent, 4792452.
Hui, Li., Hong, X., Sha, Li., Xiaohai, F., & Pingkai, O. (2012). Optimization of exopolysaccharide welan gum production by Alcaligenes sp. CGMCC2428 with Tween-40 using response surface methodology. *Carbohydrate Polymers*, *87*(2), 1363–1368.
Jain, N. K., & Dixit, V. K. (1988). Studies on gums and their derivatives as binding agent. *Indian Journal of Pharmaceutical Science*, *50*, 113–114.
Jani, G. K., & Shah, D. P. (2008a). Evaluation of mucilage of *Hibiscus rosa sinensis* Linn as rate controlling matrix for sustained release of diclofenac. *Drug Development and Industrial Pharmacy*, *34*(8), 807–816.
Jani, G. K., & Shah, D. P. (2008b). Assessing *Hibiscus rosa sinensis* Linn as an excipient in sustained release tablets. *Pharmaceutical Technology*, *32*(1), 62–75.
Jani, G. K., Goswami, J. M., Prajapati, V. D., Zinzuwadia, M. M. m., Joshi, B. R., & Dabhi, A. S. (2005). Studies on formulation and evaluation of new superdisintegrants for dispersible tablets. *International Journal of Pharmaceutical Excipients*, *2*, 37–43.
Jani, G. K., Goswami, J. M., Prajapati, V. D., Zinzuwadia, M. M. m., Joshi, B. R., & Dabhi, A. S. (2007). Studies on formulation and evaluation of new superdisintegrants for dispersible tablets. *International Journal of Pharmaceutical Excipients*, *April–June*, 37–43.
Jani, G. K., Shah, D. P., & Jain, V. C. (2007). Evaluating mucilage from Aloe barbadensis Miller as a pharmaceutical excipient for sustained-release matrix tablets. *Pharmaceutical Technology*, *31*, 90–98.
Jani, G. K., Shah, D. P., Prajapati, V. D., & Jain, V. C. (2009). Gums and mucilages: Versatile excipients for pharmaceutical formulations. *Asian Journal of Pharmaceutical Science*, *4*(5), 309–323.
Ji, C., Xu, H., & Wu, W. (2007). In vitro evaluation and pharmacokinetics in dogs of guar gum and Eudragit FS30D-coated colon-targeted pellets of indomethacin. *Journal of Drug Targeting*, *15*(2), 123–131.
Jiangyang, F., Wang, K., Liu, M., & He, Z. (2008). In vitro evaluations of konjac glucomannan and xanthan gum mixture as the sustained release material of matrix tablet. *Carbohydrate Polymers*, *73*(2), 241–247.
John, G. L., Declan, M. D., & James, E. K. (2006). The use of Agar as a novel filler for monolithic matrices produced using hot melt extrusion. *European Journal of Pharmaceutics and Biopharmaceutics*, *64*(1), 75–81.
Kabir, I. G., Yagen, B., Penhasi, A., & Rubinstein, A. (2000). Phosphated crosslinked guar for colon-specific drug delivery: I. Preparation and physicochemical characterization. *Journal of Controlled Release*, *63*, 121–127.
Kale, R. H., Joshi, U. M., Ambhore, D. P., & Sitaphale, G. R. (2009). Evaluation of *Delonix regia* Raf. endospermic mucilage as tablet binder. *International Journal of ChemTech Research*, *1*, 11–15.
Kalu, V. D., Odeniyi, M. A., & Jaiyeoba, K. T. (2007). Matrix properties of a new plant gum in controlled drug delivery. *Archives of Pharmacal Research*, *30*(7), 884–889.
Kedzierewicz, F., Lombry, C., & Rios, R. (1999). Effect of the formulation on the in vitro release of propranolol from gellan beads. *International Journal of Pharmaceutics*, *178*(1), 129–136.
Kenyon, C. J., Nardi, R. V., Wong, D., Hooper, G., Wilding, I. R., & Friend, D. R. (1997). Colonic delivery of dexamethasone: A pharmacoscintigraphic evaluation. *Alimentary Pharmacology and Therapeutics*, *11*(1), 205–213.
Ketousetuo, K., & Bandyopadhyay, A. K. (2007). Development of oxytocin nasal gel using natural mucoadhesive agent obtained from the fruits of *Dellinia indica*. *Asia Life Sciences*, *33*, 57–60.
Khan, G. M., & Jiabi, Z. (1998). Formulation and in vitro evaluation of ibuprofen-carbopol 974P-NF controlled release matrix tablets III: Influence of coexcipients on release rate of the drug. *Journal of Controlled Release*, *54*(2), 185–190.
Khan, M. A., Bhattacharia, S. K., & Kader, M. A. (2006). Preparation and characterization of ultra violet (UV) radiaton cured bio-degradable films of sago starch/PVA blend. *Carbohydrate Polymer*, *63*, 500–506.
Koocheki, A., Mortazavi, S. A., Shahidi, F., Razavi, S. M. A., & Taherian, A. R. (2009). Rheological properties of mucilage extracted from *Alyssum homolocarpum* seed as a new source of thickening agent. *Journal of Food Engineering*, *91*(3), 490–496.
Krishnaiah, Y. S. R. (2001). Guar gum as a carrier for colon specific delivery; influence of metronidazole and tinidazole on in vitro release of albendazole from guar gum matrix tablets. *Journal of Pharmacy and Pharmaceutical Science*, *4*(3), 235–243.
Krishnaiah, Y. S. R. (2003). Development of colon targeted oral guar gum matrix tablets of Albendazole for the treatment of helminthiasis. *Indian Journal Pharmaceutical Science*, *65*(4), 378–385.
Krishnaiah, Y. S. R., Satyanarayana, S., Rama Prasad, Y., & Narasimha Rao, S. (1998). Evaluation of guar gum as a compression coat for drug targeting to colon. *International Journal of Pharmaceutics*, *171*(2), 137–146.
Krishnaiah, Y. S. R., Dinesh Kumar, P. V. R. B., Bhaskar, P., & Satyanarayana, V. (2001). Development of colon targeted drug delivery systems for mebendazole. *Journal of Controlled Release*, *77*(1–2), 87–95.
Krishnaiah, Y. S. R., Nageswara Rao, L., Bhaskar Reddy, P. R., Karthikeyan, R. S., & Satyanarayana, V. (2001). Guar gum as a carrier for colon specific delivery; influence of metronidazole and tinidazole on in vitro release of albendazole from guar gum matrix tablets. *Journal of Pharmacy and Pharmaceutical Sciences*, *4*(3), 235–243.
Krishnaiah, Y. S. R., Satyanarayana, V., Dinesh Kumar, B., Karthikeyan, R. S., & Bhaskar, P. (2003). In vivo pharmacokinetics inhumanvolunteers: Oral administered guar gum-based colon-targeted 5-fluorouracil tablets. *European Journal of Pharmaceutical Sciences*, *19*(5), 355–362.
Krishnaiah, Y. S. R., Bhaskar, Y. I. M. P., Satyanarayana, V., & Latha, K. (2003). Pharmacokinetic evaluation of guar gum-based colon-targeted drug delivery systems of tinidazole in healthy human volunteers. *Drug Delivery*, *10*(4), 263–268.
Krishnaiah, Y. S. R., Muzib, Y., Indira Rao, G., Srinivasa Bhaskar, P., & Satyanarayana, V. (2003). Studies on the development of colon targeted oral drug delivery systems for ornidazole in the treatment of amoebiasis. *Drug Development and Industrial Pharmacy*, *10*(2), 111–117.
Kulkarni, D., Dwivedi, A. K., & Sarin, J. P. S. (1997). Tamarind seed polyose: A potential polysaccharides for sustained release of verapamil hydrochloride as a model drug. *Indian Journal of Pharmaceutical Science*, *59*(1), 1–7.
Kulkarni, G. T., Gowthamrajan, K., & Rao, G. B. (2002). Evaluation of binding properties of selected natural mucilages. *Journal of Scientific Research and Industrial Research*, *61*, 529–532.
Kulkarni, G. T., Gowthamarajan, K., Rao, G. B., & Suresh, B. (2002). Evaluation of binding properties of *Plantago ovata* and *Trigonella foenum graecum* mucilages. *Indian Drugs*, *39*(8), 422–425.
Kulkarni, G. T., Gowthamarajan, K., Satish, K. M. N., & Suresh, B. (2002). Gums and mucilages: Therapeutic and pharmaceutical applications. *Natural Product Radiance*, 10–17.
Kulkarni, G. T., Gowthamarajan, K., & Dhobe, R. R. (2005). Development of controlled release spheroids using natural polysaccharide as release modifier. *Drug Delivery*, *12*(4), 201–206.
Kumar, R., Shirwaikar, A., Prabu, S., Mahalaxmi, R., Rajendran, K., & Kumar, D. (2007). Studies of disintegrant properties of seed mucilage of *Ocimum gratissimum*. *Indian Journal of Pharmaceutical Sciences*, *69*(6), 753–758.
Kumar, R., Patil, M. B., Patil, R. S., & Paschapur, M. S. (2009). Evaluation of *Abelmoschus esculentus* mucilage as suspending agent in paracetamol suspension. *International Journal Pharmaceutical Technology and Research*, *1*(3), 658–665.
Liu, L. S., Fishman, M. L., & Kost, J. (2003). Pectin-based systems for colon-specific drug delivery via oral route. *Biomaterials*, *24*, 3333–3343.
Lu, E. X., Jiang, Z. Q., & Zhang, Q. Z. (2003). A water-insoluble drug monolithic osmotic tablet system utilizing gum arabic as an osmotic, suspending and expanding agent. *Journal Controlled Release*, *92*, 375–382.
Mahant, S., Khurana, N., Dua, S., Thakar, P., & Bakshi, I. (2011). Formulation and evaluation of mucoadhesive tablets using flaxseed mucilage. *Journal of Pharmaceutical and Biomedical Science*, *6*(18), 1–7.
Mehta, K. K., Patel, H. H., Patel, N. D., Vora, C. N., & Patel, N. J. (2010). Comparative evaluation of natural and synthetic super disintegrant for promoting nimesulide dissolution for fast dissolving technology. *International Journal Pharmacy and Pharmaceutical Science*, *2*(3), 102–108.
Micard, V., Belamri, R., Morel, M., & Guilbert, S. (2000). Properties of chemically and physically treated heat gluten films. *Journal of Agricultural and Food Chemistry*, *48*, 2948–2953.
Mishra, A., Clark, J. H., & Pal, S. (2008). Modification of Okra mucilage with acrylamide: Synthesis, characterization and swelling behavior. *Carbohydrate Polymer*, *72*(4), 608–615.
Mithal, B. M., & Kasid, J. L. (1964). Evaluation of the emulsifying properties of *Plantago ovata* (Ispaghula) seed husk. *Indian Journal of Pharmaceutical Science*, *26*(12), 316–319.
Mithal, B. M., & Kasid, J. L. (1965). Evaluation of the suspending properties of *Plantago ovata* (Ispaghula) seed husk. *Indian Journal of Pharmaceutical Science*, *27*, 331–335.
Mitul, T. P., Jitendra, K. P., & Umesh, M. U. (2012). Assessment of various pharmaceutical excipients properties of natural *Moringa oleifera* gum. *International Journal of Pharmacy and Life Sciences*, *3*(7), 1833–1847.
Miyazaki, S., Suisha, F., & Kawasaki, N. (1998). Thermally reversible xyloglucan gels as vehicles for rectal drug delivery. *Journal of Controlled Release*, *56*, 75–83.
Miyazaki, S., Kawasaki, N., Kubo, W., Endo, K., & Attwood, D. (2001). Comparison of in situ gelling formulations for the oral delivery of cimetidine. *International Journal of Pharmaceutics*, *220*, 161–168.
Momin, M. K. P. (2004). In vitro studies on guar gum based formulation for the colon targeted delivery of sennosides. *Journal of Pharmacy and Pharmceutical Sciences*, *7*(3), 325–331.
Morkhade, D. M., Fulzele, S. V., Satturwar, P. M., & Joshi, S. B. (2006). Gum copal and gum dammar: Novel matrix forming materials for sustained release drug delivery. *Indian Journal of Pharmaceutical Science*, *January–February*, 53–58.
Mukherjee, B., Dinda, S. C., & Barik, B. B. (2008). Gum cordia: A novel matrix forming material for enteric resistant and sustained drug delivery – A Technical Note. *AAPS PharmSciTech*, *9*(1), 330–333.
Mundargi, R. C., Patil, S. A., Agnihotri, S. A., & Aminabhavi, T. M. (2007). Development of polysaccharide-based colon targeted drug delivery systems for the treatment of amoebiasis. *Drug Development and Industrial Pharmacy*, *33*(3), 255–264.
Munday, D. L., & Philip, J. C. (2000). Compressed xanthan and karaya gum matrices: Hydration, erosion and drug release mechanisms. *International Journal of Pharmaceutics*, *203*(1–2), 179–192.
Murli, G. V., Prasad, Ch. D. S., Ravi, K., & Ramana, K. V. (2000). Studies on the modified form of gum karaya and its applicability as tablet disintegrant. *International Journal of Pharmaceutical Excipients*, *April*, 185–191.
Murli, G. V., Himasankar, K., Janki, B., Seshasayana, A., & Ramana, K. V. (2002). Studies on preparation and evaluation of modified form of gum karaya. *Indian Journal of Pharmaceutical Science*, *64*(3), 244–249.

Musabayane, C. T., Munjeri, O., & Matavire, T. P. (2003). Transdermal delivery of chloroquine by amidated pectin hydrogel matrix patch in the rat. *Renal Failure*, *25*, 525–534.

Naglschmid, F., Kull, U., & Jeremias, K. (1982). Physiologische Untersuchungen über Blattschleime. Untersuchungen an Verbascum densiflorum. *Biochemie und Physiologie der Pflanzen*, *177*(8), 671–685.

Narkhede, S., Vidyasagar, G., Jadhav, A., Bendale, A., & Patel, K. (2010). Isolation and evaluation of mucilage of *Artocarpus heterophyllus* as a tablet binder. *Journal of Chemical and Pharmaceutical Research*, *2*(6), 161–166.

Nayak, B. S., Nayak, U. K., & Patro, K. B. (2008). Rout. Design and evaluation of controlled release Bhara gum microcapsules of famotidine for oral use. *Research Journal of Pharmacy and Technology*, *1*(4), 433–437.

Nery, L. R., & Evone, S. G. (2002). Matrices of water soluble drug using natural polymer and direct compression method. *Drug Development and Industrial Pharmacy*, *28*(8), 975–988.

Odeku, O. A., & Fell, J. T. (2005). In vitro evaluation of khaya and albizia gums as compression coatings for drug targeting to the colon. *Journal of Pharmacy and Pharmacology*, *57*(2), 163–168.

Odeku, O. A., & Itiola, O. A. (2003). Evaluation of the effect of khaya gum on the mechanical and release properties of paracetamol tablets. *Drug Development and Industrial Pharmacy*, *29*(3), 311–320.

Ofoefule, S. I., & Chukwu, A. (2001). Application of *Abelmoschus esculentus* gum as a mini-matrix for furosemide and diclofenac sodium tablets. *Indian Journal of Pharmaceutical Science*, *November–December*, 532–535.

Ofoefule, S. I., Chukwu, A., Anyakoha, N., & Ebebe, I. M. (2001). Application of *Abelmoschus esculentus* in solid dosage formulation 1: Use as a binder for a poorly water soluble drug. *Indian Journal of Pharmaceutical Science*, *63*(3), 234–238.

Okafor, I. S., Ofoefule, S. I., & Udeala, O. K. (2001). A comparative study of modified starches in direct compression of a poorly water soluble drug (hydrochlorothiazide). *Bollettino Chimico Farmaceutico*, *140*, 36–39.

Oluwatoyin, A. O. (2005). Assessment of *Albizia zygia* gum as a binding agent in tablet formulations. *ACTA Pharmaceutica*, *55*(3), 263–276.

Owen, S. C. (2003). Gum tragacanth. In C. R. Raymond, J. S. Paul, & J. W. Paul (Eds.), *Handbook of pharmaceutical excipients* (pp. 654–656). Washington DC, USA: The Pharmaceutical Press and the American Pharmaceutical Association.

Panda, D., Swain, S. S., Kanungo, S. K., & Gupta, R. (2006). Preparation and evaluation of gels from gum of *Moringa oleifera*. *Indian Journal of Pharmaceutical Science*, *November–December*, 777–780.

Pandey, R., & Khuller, G. K. (2004). Polymer based drug delivery systems for mycobacterial infections. *Current Drug Delivery*, *1*, 195–201.

Park, C. R., & Munday, D. L. (2004). Evaluation of selected polysaccharide excipients in buccoadhesive tablets for sustained release of nicotine. *Drug Development and Industrial Pharmacy*, *30*(6), 609–617.

Patel, M. M., Chauhan, G. M., & Patel, L. D. (1987). Mucilage of lepidium sativum, Linn (Asario) and ocimum canum, sims. (Bavchi) as emulgents. *Indian Journal of Hospital Pharmacy*, *24*, 200–202.

Pawar, H., & D'mello, P. M. (2004). Isolation of seed gum from cassia tora and preliminary studies of its applications as a binder for tablets. *Indian Drugs*, *41*(8), 465–468.

Pontes, U. R. (1971). Determination of HLB of Anacardium gum. *Revista de Farmacia e Bioquimica da Universidade de Sao Paulo*, *2*, 83–91.

Pornsak, S. (1998). Investigation of pectin as a carrier for oral delivery of proteins using calcium pectinate gel beads. *International Journal of Pharmaceutics*, *169*, 213–220.

Pornsak, S., Srisagul, S., & Satit, P. (2007). Use of pectin as a carrier for intragastric floating drug delivery: Carbonate salt contained beads. *Carbohydrate Polymer*, *67*, 436–445.

Prajapati, S. T., Prajapati, V. D., & Acharya, S. R. (2006). Characterization of disintegration properties of *Plantago ovata* mucilage in the formulation of dispersible tablets. *Indian Journal of Pharmaceutical Education and Research*, *40*(3), 208–211.

Prasad, Y. V., Krishnaia, Y. S. R., & Satyanarayana, S. (1998). In vitro evaluation of guar gum as a carrier for colon-specific drug delivery. *Journal of Controlled Release*, *51*(2), 281–287.

Raghavan, C. V., Muthulingam, C., Josephine, J. A., Jenita, L., & Ravi, T. K. (2002). An in vitro and in vivo investigation in to the suitability of bacterially triggered delivery system for colon. *Targeting Chemical and Pharmaceutical Bulletin*, *50*(7), 892–895.

Rajinikanth, P. S., & Mishra, B. (2007). Preparation and in vitro characterization of gellan based floating beads of acetohydroxamic acid for eradication of *H. pylori*. *Acta Pharmaceutica*, *57*(4), 413–427.

Rajnikanth, P. S., Balasubramaniam, J., & Mishra, B. (2007). Development and evaluation of a novel floating in situ gelling system of amoxicillin for eradication of *Helicobacter pylori*. *International Journal of Pharmaceutics*, *335*(1–2), 114–122.

Rama, N. R., & Rao, U. M. (2000). Hypochlorate modified potato starch: A new potato starch derivative as potential tablet disintegrant. *International Journal of Pharmaceutical Excipients*, (3), 216–219.

Rane, S., & Kale, V. (2009). Evaluation of modified guar gum as film coating material. *International Journal of ChemTech Research*, *1*(2), 180–182.

Rao, K. M., Gnanaprakash, K., Badarinath, A. V., Chetty, C. M., & Alagusundaram, M. (2010). Preparation and evaluation of flurbiprofen gel; mucilage of *Cocculus hirsutus* leaf powder as gel base. *International Journal of Pharmaceutical Technology and Research*, *2*(2), 1578–1583.

Ravi, V., Mishra, S. T., & Kumar, P. (2008). Influence of natural polymer coating on novel colon targeting drug delivery system. *Journal of Material Science: Material Medicine*, *19*(5), 2131–2136.

Reis, M. R., Guilherme, O., Cavalcanti, A., Rubira, A. F., & Muniz, E. C. (2006). Synthesis and characterization of pH-responsive hydrogels based on chemically modified Arabic gum polysaccharide. *Polymer*, *47*, 2023–2029.

Rimi, D., & Bandyopadhyay, A. K. (2006). A new nasal drug delivery system for diazepam using natural mucoadhesive polysaccharide obtained from tamarind seeds. *Saudi Pharmaceutical Journal*, *14*(2), 115–119.

Rishabh, M. (2011). Extraction characterization and evaluation of selected mucilage as pharmaceutical excipient. *Polimery w Medycynie*, *41*(3), 39–44.

Rishabh, M., Pranati, S., & Kulkarni, G. T. (2011). Applications of mucilages in drug delivery—A review. *Advances in Biological Research*, *5*(1), 1–7.

Robbins, S. R. J. (1988). Gum arabic. A review of recent trends in selected markets for water-soluble gums. *Overseas Development Natural Resources Institute Bulletin*, *108*, 18–33.

Rong-Kun, C., Mirwais, S., & Michael, L. (1998). Evaluation of the disintegrant properties for an experimental, cross-linked polyalkylammonium polymer. *International Journal of Pharmaceutics*, *173*, 87–92.

Rozier, A., Mazuel, C., Grove, J., & Plazonnet, B. (1997). Functionality testing of gellan gum: A polymeric excipient material for ophthalmic dosage forms. *International Journal of Pharmaceutics*, *153*, 191–198.

Saeedi, M., Morteza-Semnani, K., Ansoroudi, F., Fallah, S., & Amin, G. (2010). Evaluation of binding properties of *Plantago psyllium* seed mucilage. *Acta Pharmaceutica*, *60*, 339–348.

Saleh, M. A., Yellela, S. R., Srinivas, S. P., & Vemulapalli, S. (2005). In vitro and in vivo evaluation of guar gum matrix tablets for oral controlled release of water soluble Diltiazem hydrochloride. *AAPS PharmSciTech*, *6*(1), 14–21.

Sandolo, C., Coviello, T., & Matricardi, P. (2007). Characterization of polysaccharide hydrogels for modified drug delivery. *European Biophysics Journal*, *36*(7), 693–700.

Santhosh, K. M., Nishanth, K. N., Ramakrishna, R., & Rajyalaxmi, K. (2011). Preparation and characterization of mucoadhesive microcapsules of gliclazide with natural gums. *Stamford Journal of Pharmaceutical Science*, *4*(1), 38–48.

Santos, H., Veiga, F., Pina, M. E., & Sousa, J. J. (2005). Compaction compression and drug release properties of diclofenac sodium and ibuprofen pellets comprising xanthan gum as a sustained release agent. *International Journal of Pharmaceutics*, *295*(1–2), 15–27.

Seiyaku, F. (1989). Sustained-release dilazep hydrochloride tablets. containing sodium alginate. Japan Patent, 01025721.

Selvi, R. S., Gopalakrishanan, S., Ramajayam, M., & Soman, R. (2010a). Evaluation of mucilage of prosopis juliflora as tablet binder. *International Journal of Pharmacy and Pharmaceutical Science*, *2*, 157–160.

Selvi, R. S., Gopalakrishanan, S., Ramajayam, M., & Soman, R. (2010b). Evaluation of mucilage of *Caesalpinia pulcherrima* as binder for tablets. *International Journal of ChemTech Research*, *2*(1), 436–442.

Shah, V., & Patel, R. (2010). Studies on mucilage from *Hibuscus rosasinensis* Linn as oral disintegrant. *International Journal of Applied Pharmaceutics*, *2*, 18–21.

Shaikh, A. A., Pawar, Y. D., & Kumbhar, S. T. (2012). An *in vitro* study for mucoadhesion and control release properties of guar gum and chitosan in itraconazole mucoadhesive tablets. *International Journal of Pharmaceutical Science and Research*, *3*(5), 1411–1414.

Sharma, B. R., Kumar, V., & Soni, P. L. (2002). Cerric ammonium nitrate-initiated graft copolymerization of acrylamide on to cassia tora gum. *Journal of Applied Polymer Science*, *86*, 3250–3255.

Sharma, B. R., Kumar, V., & Soni, P. L. (2003). Carbamoyl ethylation of cassia tora gum. *Carbohydrate Polymers*, *54*, 143–147.

Sharma, B. R., Kumar, V., & Soni, P. L. (2004). Carbamoyl ethylation of guar gum. *Carbohydrate polymers*, *58*, 449–451.

Sheth, N. S., Shah, N. V., & Shah, N. C. (2010). Extraction of mucilage from *Ocimum americanum* Linn & its role as disintegrant in tablets formulation. *Journal of Global Pharma Technology*, *2*(12), 26–31.

Shyale, S., Chowdary, K. P. R., Krishnaiah, Y. S. R., & Bhat, N. K. (2006). Pharmacokinetic evaluation and studies on the clinical efficacy of guar gum-based oral drug delivery systems of albendazole and albendazole-β-cyclodextrin for colon-targeting in human volunteers. *Drug Development Research*, *67*(2), 154–165.

Silva, D. A., De Paula, R. C. M., Feitosa, J. P. A., De Brito, A. C. F., Maciel, J. S., & Paula, H. C. B. (2004). Carboxymethylation of cashew tree exudate polysaccharide. *Carbohydrate Polymers*, *58*(2), 163–171.

Silva, D. A., Feitosa, J. P. A., Maciel, J. S., Paula, H. C. B., & Paula, R. C. M. (2006). Characterization of crosslinked cashew gum derivatives. *Carbohydrate Polymers*, *66*, 16–26.

Singh, B., & Chauhan, N. (2009). Modification of psyllium polysaccharides for use in oral insulin delivery. *Food Hydrocolloids*, *23*, 928–935.

Singh, S. K., & Singh, S. (2010). Evaluation of *Cassia fistula* Linn seed mucilage in tablet formulations. *International Journal of Pharmaceutical Technology and Research*, *2*(3), 1839–1846.

Singh, S., & Singh, S. (2010). Isolation and evaluation of *Cassia aungostifolia* seed mucilage as granulating agent. *International Journal of Pharmaceutical Sciences and Research*, *1*, 118–125.

Singh, B. N., Trombetta, L. D., & Kim, K. H. (2004). Biodegradation behavior of Gellan gum in simulated colonic media. *Pharmaceutical Development and Technology*, *9*(4), 399–407.

Singh, V., Tiwari, A., & Tripathi, D. N. (2005). Poly(acrylonitrile) grafted Ipomoea seed-gums: A renewable reservoir to industrial gums. *Biomacromolecules*, *6*(1), 453–456.

Singh, B., Chauhan, G. S., & Sharma, D. K. (2006). The release dynamics of model drugs from the psyllium and N-hydrox ymethylacrylamide based hydrogels. *International Journal of Pharmaceutics*, *325*, 15–25.

Singh, B., Chauhan, G. S., & Kumar, S. (2007). Synthesis characterization and swelling responses of pH sensitive psyllium and polyacrylamide based hydrogels for the use in drug delivery (I). *Carbohydrate Polymer*, *67*(2), 190–200.
Singh, B., Chauhan, G. S., & Sharma, D. K. (2007). The release dynamics of salicylic acid and tetracycline hydrochloride from the psyllium and polyacrylamide based hydrogels (II). *Carbohydrate Polymer*, *67*(4), 559–565.
Singh, S. K., Ushir, Y. V., Chidrawar, R. V., Vadalia, K. R., Sheth, N. R., & Singh, S. (2009). Preliminary evaluation of *Cassia auriculata* seed mucilage as binding agent. *Pharmacognosy Journal*, *l*, 251–257.
Singh, S. K., Gendle, R., Sheth, N. R., Roshan, P., & Singh, S. (2010). Isolation and evaluation of binding property of *Zizyphus jujuba lamk* seed mucilage in tablet formulations. *Journal of Global Pharma Technology*, *2*(1), 98–102.
Sinha, V. R., Mittal, B. R., Bhutani, K. K., & Kumaria, R. (2004). Colonic drug delivery of 5-fluorouracil: An in vitro evaluation. *International Journal of Pharmaceutics*, *269*(1), 101–108.
Sinha, V. R., Singh, A., Singh, S., & Binge, J. R. (2007). Compression coated systems for colonic delivery of 5-fluorouracil. *Journal of Pharmacy and Pharmacology*, *59*(3), 359–365.
Smart, J. D., Kellaway, I. W., & Worthington, H. E. (1984). An in vitro investigation of mucosa adhesive materials for use in controlled drug delivery. *Journal of Pharmacy and Pharmacology*, *36*(5), 295–299.
Somboonpanyakul, P., Wang, Q., Cui, W., Barbut, S., & Jantawat, P. (2006). Malva nut gum (Part I): Extraction and physicochemical characterization. *Carbohydrate Polymers*, *64*(2), 247–253.
Sreenivasa, B., Prasanna, R. Y., & Mary, S. (2000). Design and studies of gum karaya matrix tablet. *International Journal of Pharmaceutical Excipients*, 239–242.
Srinivas, K., Prakash, K., Kiran, H. R., Prasad, P. M., & Rao, M. E. B. (2003). Study of ocimum basilicum and *Plantago ovata* as disintegrants in the formulation of dispersible tablets. *Indian Journal of Pharmaceutical Science*, *65*(2), 180–183.
Subas, C. D., & Biswajit, M. (2009). Formulation and evaluation of gum cordia as an enteric resistant and sustained release material in microencapsulated matrix tablet formulations. *International Journal of Pharmaceutical Science and Technology*, *2*(1), 37–41.
Sudarshan, S., Sangeeta, S., Bothra, S. B., & Roshan, P. (2010). Pharmaceutical characterization of some natural excipient as potential mucoadhesive agent. *The Pharma Research Journal*, *4*, 91–104.
Sumathi, S., & Ray, A. R. (2002). Release behaviour of drugs from tamarind seed polysaccharide tablets. *Journal of Pharmacy and Pharmaceutical Science*, *5*(1), 12–18.
Sungthongjeen, S., Pitaksuteepong, T., & Somsiri, A. (1999). Studies on pectins as potential hydrogel matrices for controlled release drug delivery. *Drug Development and Industrial Pharmacy*, *25*(12), 1271–1276.
Talukdar, M. M., & Kinget, R. (1995). Swelling and drug release behaviour of Xanthan gum matrix tablets. *International Journal of Pharmaceutics*, *120*(1), 63–72.
Tho, I., Sande, S., & Kleinebudde, P. (2002). Pectinic acid: A novel excipient for production of pellets by extrusion/spheronisation: Preliminary studies. *European Journal of Pharmaceutics and Biopharmaceutics*, *54*, 95–99.
Toti, U. S., & Aminabhavi, T. M. (2004). Modified guar gum matrix tablet for controlled release of diltiazem hydrochloride. *Journal of Controlled Release*, *95*(3), 567–577.
Trivedi, B. M., Patel, P. M., & Patel, L. D. (1986). Crosslinked gum acacia as a disintegrant. *Indian Journal of Pharmaceutical science*, *48*(6), 188–190.
Vandamme, F., Lenourry, A., & Charrueau, C. (2002). The use of polysaccharides to target drugs to the colon. *Carbohydrate Polymer*, *48*, 219–231.
Vatanasuchart, N., Naivikul, O., & Charoenrein, S. (2005). Molecular properties of cassava starch modified with different UV irradiatons to enhance baking expansion. *Carbohydrate Polymer*, *61*, 80–87.
Vendruscolo, C. W., Andreazza, I. F., & Ganter, J. L. (2005). Xanthan and galactomannan (from M. scabrella) matrix tablets for oral controlled delivery of theophylline. *International Journal of Pharmaceutics*, *296*(1–2), 1–11.
Verma, P. R. P., & Razdan, B. (2001). Studies on *Leucaena leucocephala* seed gum: Evaluation of suspending properties. *STP Pharma Sciences*, *11*, 289–293.
Verma, P. R. P., & Razdan, B. (2002a). Evaluation of *Leucaena leucocephala* seed gum in tabletting. I. Disintegrant properties. *STP Pharma Sciences*, *12*, 109–112.
Verma, P. R. P., & Razdan, B. (2002b). Evaluation of *Leucaena leucocephala* seed gum in tabletting I. Binding properties in granules and tablets. *STP Pharma Sciences*, *12*, 113–119.
Verma, P. R. P., & Razdan, B. (2003a). Evaluation of *Leucaena leucocephala* seed gum as suspending agent in sulphadimidine suspensions. *Indian Journal of Pharmaceutical Science*, *65*, 665–668.
Verma, P. R. P., & Razdan, B. (2003b). Studies on *Leucaena leucocephala* seed gum: Emulsifying properties. *Journal of Scientific & Industrial Research*, *62*, 198–206.
Viernstein, H. (1988). Retarded-release drug tablet with alginic acid-sodium aiginate matrix. Austrian Patent, 385200.
Vikas, R., Parshuram, R., Ashok, K. T., Ram, S. S., John, F. K., & Charles, J. K. (2011). Modified gums: Approaches and applications in drug delivery. *Carbohydrate Polymers*, *83*(3), 1031–1047.
Viral, S., & Rucha, P. (2010). Studies on mucilage from *hibuscus rosasinensis* Linn as oral disintegrant. *International Journal of Applied Pharmaceutics*, *2*(1), 18–21.
Wahi, S. P., Sharma, V. D., & Jain, V. K. (1985a). Studies on suspending property of mucilages of Hygrophila spinosa Tanders and *Hibiscus esculentus* Linn. *Indian Drugs*, *22*, 500–502.
Wahi, S. P., Sharma, V. D., & Jain, V. K. (1985b). Studies on emulsifying property of mucilages of Hygrophila spinosa and *Hibiscus esculentus*. *Indian Journal of Natural Product*, *1*, 3–6.
Xiaohong, M. G., Michae, J. T., & John, N. S. (2003). Influence of physiological variables on the in vitro drug-release behavior of a polysaccharide matrix controlled-release system. *Drug Development and Industrial Pharmacy*, *29*, 19–29.
Yadav, I. K., Jaiswal, D., Singh, H. P., Chandra, D., & Jain, D. A. (2009). Evaluation of seed mucilage of *Vigna mungo* (L.) as a binder in tablet formulations. *Journal of Pharmacy Research*, *2*(7), 1281–1283.
Zakaria, M. B., & Zainiah, A. R. (1996). Rhelological properties of cashew gum. *Carbohydrate Polymer*, *29*(1), 25–27.
Zatz, J. L., & Kushla, G. P. (1989). In M. M. Reiger, & G. S. Banker (Eds.), *Pharmaceutical dosage forms – Disperse systems* (p. 508). New York: Marcel Dekker Inc.