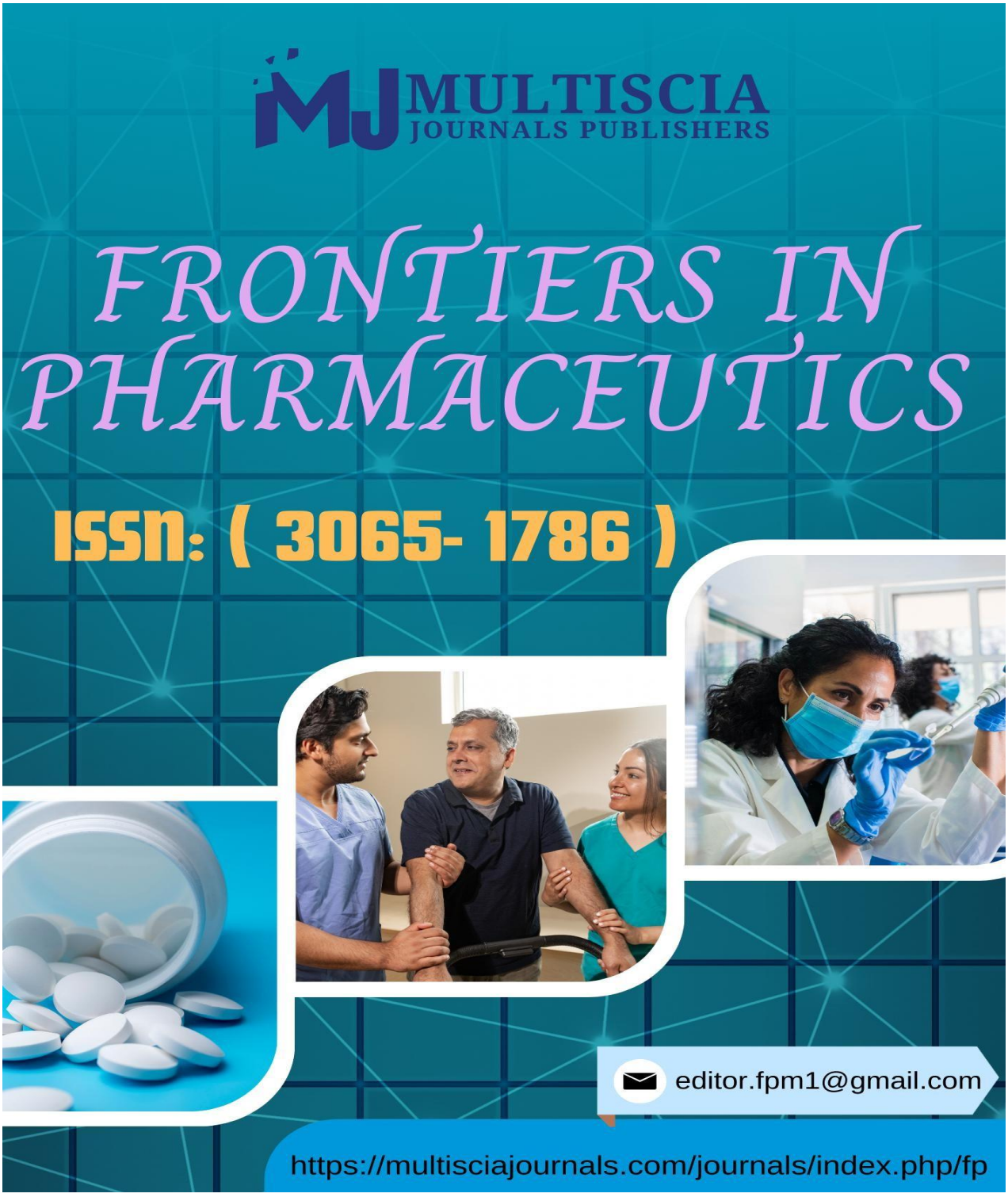
MULTISCIA
JOURNALS PUBLISHERS
FRONTIERS IN PHARMACEUTICS
ISSN: ( 3065- 1786 )
editor.fpm1@gmail.com
https://multisciajournals.com/journals/index.php/fp

**Frontiers in Pharmaceutics**
**Volume 2 Issue 2 2026**

# A Review of Pectin's Chemistry and Medicinal Applications

Kano
Department of **Pharmaceutics**

## Article Info

**Received: 5-01-2026 Revised:12-2-2026 Accepted:15-3-2026 Published:20-4-2026**

**Abstract**

The significance of pectin, a naturally occurring polysaccharide, has grown in recent years. Because natural pectin is biodegradable, scientists and consumers are beginning to recognize its advantages. The dimethyl ester of polygalacturonic acid is called pectin. Under somewhat acidic circumstances, it is commercially produced from apple pomace and citrus peels. Based on the degree of esterification, pectins are classified into two main classes. The creation of three-dimensional networks, or gel formation, is caused by the connection of pectin chains. Pectin was used in the pharmaceutical sector as well as in health promotion and treatment, either by itself or because of its gelling qualities. Matrix tablets, gel beads, and film-coated dosage forms have all been utilized as possible drug delivery vehicles to the gastrointestinal tract. The key chemistry, general characteristics, and gel forming mechanism of pectin will all be covered in this review. We'll give an example of how pectin is used in medicine.

**Introduction**

A naturally occurring biopolymer, pectin is increasingly being used in the biotechnology and pharmaceutical industries. It has been effectively employed as a thickening agent, gelling agent, and colloidal stabilizer in the food and beverage sector for many years. Additionally, pectin possesses a number of special qualities that allow it to be utilized as a matrix for the delivery and/or trapping of various medications, proteins, and cells. The source, manufacture, chemical makeup, and general characteristics of pectin will all be covered in this review. Next, we'll talk about the gels' characteristics and formation processes. Lastly, a few instances of pectin's medicinal applications will be provided.

**Chemistry of pectin**

**Source and production**

About one-third of the dry material in higher plants' cell walls is composed of pectin, a complex mixture of polysaccharides. The cell walls of grasses contain much lesser amounts of these compounds. The middle lamella of the cell wall contains the largest quantities of pectin, which

gradually diminish as one moves through the primary wall and into the plasma membrane (Kertesz, 1951). Despite the fact that pectin is frequently found in the majority of plant tissues, there are very few sources from which pectins can be produced commercially. The degree of esterification (DE) and molecular size of pectins determine their capacity to form gel, hence changes in these parameters allow pectins from different sources to have variable gelling abilities.
Therefore, a fruit cannot be considered a source of commercial pectin only because a significant amount of pectin is found in it (Thakur et al., 1997). Currently, the majority of commercial pectins come from apple pomace or citrus peel, which are both leftovers from the production of juice (or cider).
Ten to fifteen percent of the dry matter in apple pomace is made up of pectin. 20–30% is found in citrus peel (May, 1990). Citrus and apple pectins are essentially the same from an application perspective. Apple pectins are frequently darker, while citrus pectins typically light cream or light tan in color. Other sources include mango trash, sunflower heads (seeds used for edible oil), and sugarbeet waste from the production of sugar (Rolin, 1993).

Pectin is extracted commercially by subjecting the source material to hot, diluted mineral acid at a pH of around 2. The exact amount of time needed for extraction varies depending on the raw material, the desired type of pectin, and the producer. The solid residue is effectively removed from the heated pectin extract. Since the liquid phase is viscous and the solids are already soft, this is difficult. Pectin concentration and molecular weight both increase viscosity. Operating costs and effective extraction and solids separation are compromised. Filtration using a filter assist can further clarify the pectin extract. After the extract has been purified, it is concentrated under vacuum. The concentrated juice from an apple or citrus can be combined with an alcohol (often isopropanol) to create powdered pectin. After being separated as a stringy gelatinous mass, the pectin is squeezed, cleaned to get rid of the mother liquor, dried, and powdered.

Pectin with around 70% esterification (or methoxylation) is produced by this technique. Some of the ester groups need to be hydrolyzed in order to create different kinds. Acid is typically used to do this, either prior to or during an extended extraction, in the concentrated liquid, or in an alcoholic slurry prior to separation and drying. A variety of calcium reactive low methoxyl pectins can be made using this method. Some of the ester groups are changed into amide groups during hydrolysis with ammonia, resulting in "amidated low methoxyl pectins" (May, 1990).

## Chemical structure

In essence, pectin is a linear carbohydrate. It is both polydisperse and polymolecular, like the majority of other plant polysaccharides, and its composition changes depending on the source and the isolation circumstances. Molecular weight and specific subunit content are examples of characteristics that vary from molecule to molecule in any pectin sample.

Even though pectin was discovered more than 200 years ago, its composition and structure are still not fully understood. Because pectin can alter during plant isolation, storage, and processing, it is exceedingly challenging to establish its structure (Novosel'skaya et al., 2000). Furthermore, the primary components may be accompanied by contaminants. According to Mukhiddinov et al. (2000), pectin is currently believed to be primarily composed of D-galacturonic acid (GalA) units connected in chains by α-(1-4) glycosidic linkage. Some of the carboxyl groups in these uronic acids

are found naturally as methyl esters, while others are commercially processed with ammonia to create carboxamide groups (Fig. 1).

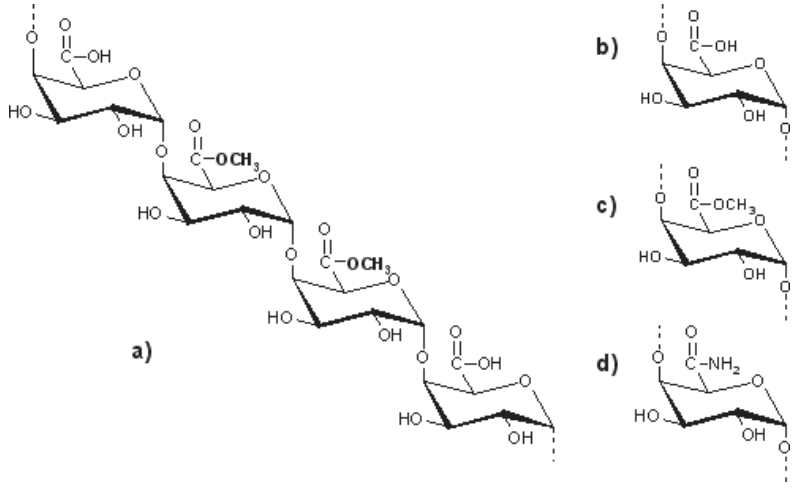


**Fig. 1** (a) A repeating segment of pectin molecule and functional groups: (b) carboxyl; (c) ester; (d) amide in pectin chain.

Pectin has an average molecular weight of between 50,000 and 150,000 daltons, which is equivalent to a few hundred to roughly 1000 saccharide units arranged in a chain. Estimates may vary between measuring techniques, and there may be significant variations between samples and between molecules within a sample.

Neutral sugars are present in addition to the galacturonan segments depicted in Fig. 1. Other neutral sugars such arabinose, galactose, and xylose are found in the side chains, whereas rhamnose (Rha), a small part of the pectin backbone, causes a kink in the straight chain (Fig. 2) (Oakenful, 1991). A typical fragment is a chain of several hundred α-(1-4)-bonded GalA units with a variable DE.

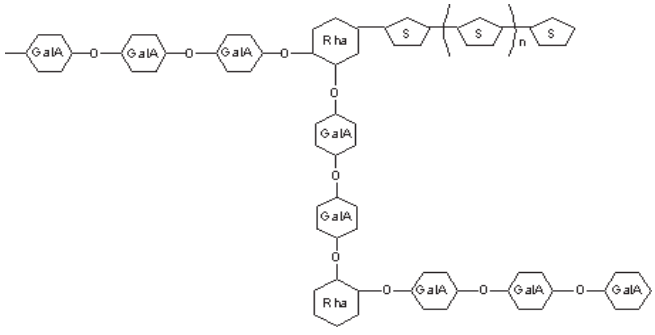


**Fig. 2** Schematic diagram showing how rhamnose (Rha) insertions cause kinking of galacturonic acid (GalA) chain; S = neutral

sugars (adapted from Sriamornsak, 2002).

The galacturonan segments in sodium pectate form helices with three subunits per turn and an identical period of 1.31 nm, according to X-ray fiber diffraction investigations. According to NMR spectroscopy, the conformation of GalA units is 4C (Rees & Wright, 1971). The helix is most likely right-handed, according to calculations (Rees & Wright 1971; Walkinshaw & Arnott, 1981a). X-ray fiber diffraction patterns of sodium and calcium pectates, pectic acids, and pectinic acids revealed the same helix structure, according to Walkinshaw & Arnott (1981a,b). However, the arrangements of these helixes in relation to one another in the crystals appeared to be different. They proposed that while pectates pack as corrugated sheets of antiparallel helices, helical pectinic acid molecules pack in a parallel configuration.

## Degree of esterification

Methyl groups partially esterify the polygalacturonic acid chain, and sodium, potassium, or ammonium ions can partially or completely neutralize the free acid groups. The DE is defined as the ratio of esterified GalA groups to total GalA groups. After being incorporated into the cell wall or middle lamella, pectin may undergo some deesterification from its highly esterified original form. Depending on the species, tissue, and age, DEs might vary greatly. Tissue pectins typically contain between 60 and 90% DE. According to DeVries et al. (1986), the distribution of free carboxyl groups along the pectin chains appears to be rather regular, and they are mostly segregated from one another. High methoxyl (HM) and low methoxyl (LM) pectins, which are either amidated or traditionally demethylated molecules, are the pectin types based on the DE. Commercial HM-pectins usually have DEs values between 60 and 75%, while LM-pectins have DEs values between 20 and 40%. These two types of pectin gel through distinct processes. To produce gels, HM-pectin needs a minimum quantity of soluble particles and a pH within a specific range, approximately 3.0. Gels made with HM-pectin can be reversed thermally. To avoid lumping, HM-pectins typically contain a dispersion agent like dextrose and are soluble in hot water. Gels are produced by LM-pectins regardless of the amount of sugar present. Additionally, they are less sensitive to pH than the HM-pectins. For LM-pectins to gel, a specific concentration of calcium or other divalent cations must be present.

## General properties of pectin

Pure water can dissolve pectins. Pectinic and pectic acid monovalent cation (alkali metal) salts are typically soluble in water, whereas di- and trivalent cation salts are either insoluble or poorly soluble. When dry powdered pectin is mixed with water, it tends to hydrate quickly and form clumps. These crumps are made up of semidry pectin packets enclosed in a very moist outer layer. Such crumps take a very long time to dissolve further. Pectin powder can be dry mixed with a water-soluble carrier material to prevent clump formation, or pectin with enhanced dispersibility by a unique manufacturing process (Rolin, 1993; Hercules Incorporated, 1999).

Although diluted pectin solutions are Newtonian, they display non-Newtonian, pseudoplastic behavior at a moderate concentration. Similar to solubility, a pectin solution's viscosity is influenced by its molecular weight, DE, preparation concentration, pH, and counterion content. In general, viscosity, solubility, and gelation are connected. For instance, elements that improve gel strength will also increase viscosity, decrease solubility, and increase the tendency to gel, and vice versa. The structure of pectins, which is a linear polyanion (polycarboxylate), determines these characteristics. Because of coulombic repulsion, the distribution of ionic charges throughout the molecule tends to maintain the extended form of monovalent cation salts of pectins, which are highly ionized in solution (Paoletti, 1986). Moreover, the polymer chains cannot aggregate due to the same coulombic repulsion between the carboxylate anions. (The DE, of course, determines the quantity of negative charges.) Every polysaccharide chain will also be extremely hydrated, particularly every carboxylate group. Because each polymer chain is hydrated, stretched, and independent, solutions of pectin monovalent salts have a steady viscosity.

The carboxylate groups' ionization is inhibited when the pH drops, which causes the carboxylic acid groups' hydration to decrease. Reduced ionization allows the polysaccharide molecules to join and form a gel since they no longer reject one another along their whole length. The DE of the pectin affects apparent pK-values (pH at 50% dissociation); a 65% DE pectin has an apparent pK of 3.55, whereas a 0% DE pectic acid has an apparent pK of 4.10 (Plaschina et al., 1978). However, because they have fewer carboxylate anions at any given pH, pectins with progressively higher levels of methylation will gel at a somewhat higher pH.

Deesterification and depolymerization are two spontaneous processes that break down dissolved pectins; the rate of these processes is influenced by temperature, pH, and water activity. Generally speaking, pH 4 is where maximal stability is found. While higher temperatures accelerate the rate of deterioration, the presence of sugar in the pectin solution has a certain protective effect. Degradation brought on by the hydrolysis of glycosidic bonds is seen at high temperatures and low pH levels. Low pH also promotes deesterification. Deesterification causes an HM-pectin to set more slowly or gradually take on the properties of an LM-pectin. HM-pectin is only stable at room temperature when the pH is close to neutral (5–6). A process known as α-elimination begins when the temperature (or pH) rises, leading to chain cleavage and a very quick loss of viscosity and gelling characteristics. Under these circumstances, LM-pectins exhibit somewhat more stability. Even at ambient temperature, pectin is quickly deesterified and broken down at alkaline pH levels (Rolin, 1993).

While LM-pectins are more durable and should not lose much after a year of storage at room temperature, powdered HM-pectins gradually lose their capacity to produce gels if kept in humid or warm environments (Hercules Incorporated, 1999).

## Gel formation properties of pectin

Pectin's capacity to produce gels is its most significant application. Acid and sugar combine with HM-pectin to generate gels. This can be interpreted as the pectin molecule partially dehydrating to the point where it is halfway between completely dissolved and precipitated. Certain limitations are imposed by the unique structure of pectin. In contrast to LM-pectin, HM-pectin lacks enough acid groups to gel or precipitate with calcium ions, yet under some circumstances, precipitation is caused by other ions like copper or aluminum. According to Oakenfull (1991), hydrophobic interactions and hydrogen bonds play a significant role in the aggregation of pectin molecules. Hydrogen bonds between the hydroxyl groups of nearby molecules and the free carboxyl groups on the pectin molecules are what allow gel to develop. Most of the unesterified carboxyl groups are found as partially ionized salts in a neutral or very slightly acidic dispersion of pectin molecules. When combined with the hydroxyl groups, those that are ionized give the molecule a negative charge, which attracts water layers. Because these groups are negatively charged, there may be strong enough repulsive interactions between them to stop a pectin network from forming. The carboxyl ions are transformed into mostly unionized carboxylic acid groups when acid is introduced. Both the repulsive forces between pectin molecules and the attraction between pectin and water molecules are reduced by this reduction in the quantity of negative charges. By competing with the pectin for water, sugar further reduces its hydration. These circumstances reduce pectin's capacity to remain distributed. A gel, a continuous network of pectin that holds the aqueous solution, is created when the unstable dispersion of less hydrated pectin cools. The degree of esterification also influences the rate at which gel formation occurs. Setting happens more quickly when the DE is higher. Additionally, compared to slow-set pectins (i.e., pectin with a DE of 58–65%), rapid-set pectins (i.e., pectin with a DE of above 72%) gel at greater levels and lower soluble solids.

For LM-pectins to properly gel, divalent cations—typically calcium—must be present. The popular "egg-box" hypothesis is the primary basis for the mechanism of LM-pectin gelation (Grant et al., 1973). The mechanism comprises junction zones formed by the ordered, side-by-side associations of galacturonans, wherein particular GalA monomer sequences in parallel or neighboring chains are intermolecularly coupled by ionic and electrostatic bonding of carboxyl groups (Fig. 3).

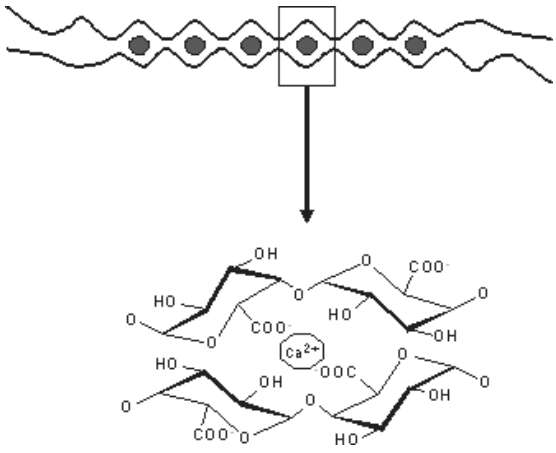


**Fig. 3** Schematic representation of calcium binding to polygalactoronate sequences: 'egg box' dimer and 'egg-box' cavity (adapted from Axelos & Thibault, 1991).

Similar to the 21 model suggested for alginates, it is widely acknowledged that the junctions are composed of dimers in 21 helical symmetry (Axelos & Thibault, 1991). Through their free-electron pairs, the oxygen atoms of the hydroxyl groups, the ring oxygen atoms, and the bridging oxygen atoms of the constituent sugar units take part in the bonding process (Kohn, 1987). The strength of the electrostatic connections determines how long the junction will last. When each participating chain has at least seven consecutive carboxyl groups inside of it, the bonds are stable (Powell et al., 1982). The amount of these junction zones that cause the gel to develop is limited by the presence of methyl ester groups in the main backbone. Other theories for LM-pectin gelation, such as the 32 helical model, have been put out (Walkinshaw & Arnott, 1981a,b), however experiments have not yet verified them. However, it appears that all LM-pectin gels form comparable, if not identical, junction zones (Filippov et al., 1988).

Additionally, amidation enhances LM-pectin's capacity to gel; amidated pectins require less calcium to gel and are less likely to precipitate at high calcium levels (May, 1990). According to Racape and colleagues (1989), the "egg-box" paradigm is insufficient to explain the gelation of amidated pectins because amide group blocks throughout the chain facilitate connection by hydrogen bonding. As would be predicted for any polymer, the gel becomes weaker as the molecular weight decreases. The amidated LM-pectin gelation model was shown in Fig. 4.

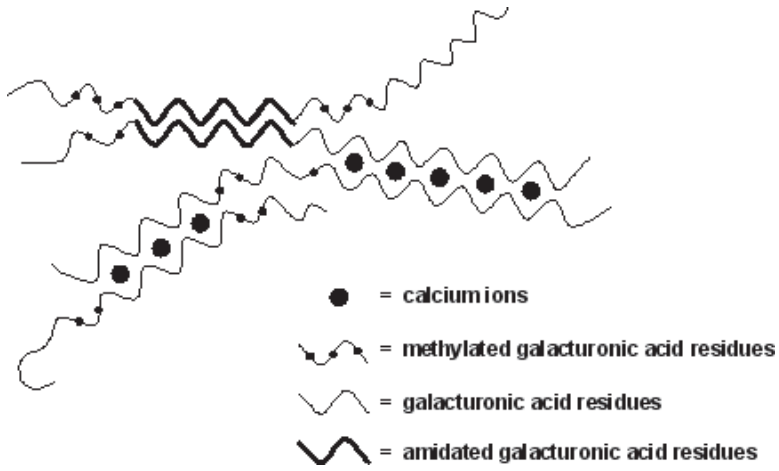


**Fig. 4** Model for the gelation of amidated LM-pectins showing ionic interactions between galacturonic acid residues and hydrogen bonding between amidated galacturonic acid residues (adapted from Sriamornsak, 2002).

Cross-linked pectin molecules produce the gel structure, which resembles a net. Strong ionic connections between the carboxyls create cross-linkages that are less elastic and more brittle than those created by hydrogen bonds, as in ordinary pectin. With a given amount of calcium, the likelihood of cross-link formation increases with pectins of lower DE. The likelihood that a salt bridge will form increases with the number of reactive carboxyl groups that can do so. Additionally, de-esterified molecules are straighter than esterified ones due to the greater number of charged groups, making them more likely to form calcium connections (Thibault & Rinaudo, 1985).

As the DE increases, less LM-pectin is needed to produce such a gel. The DE has a significant impact on the strengths of these ionic bonded gels. Because they reduce the cross-linking reaction of calcium and increase the solubility of LM-pectin in the presence of calcium, monovalent ions like sodium, which can also react with free carboxyl groups, can have an impact on gel formation (Axelos, 1990). Small doses (10–20%) of sugar appear to reduce syneresis and provide the desired stiffness of these gels, even though sugar is not necessary for gel formation with LM-pectins (Christensen, 1986). The amount of calcium needed to make gel is decreased when sugar is present. High sugar concentrations (60% or more) prevent gel formation because the sugar's dehydration promotes hydrogen bonding and reduces divalent ion forces' ability to cross-link.

**Pharmaceutical uses of pectin**

The pharmaceutical sector uses pectin. Pectin favorably affects blood cholesterol levels. According to a thorough review, it has been shown to lower blood cholesterol in a wide range of subjects and experimental settings (Sriamornsak, 2001). To significantly lower cholesterol, at least 6 g of pectin must be consumed daily. Pectin dosages below 6 g/day are ineffective (Ginter et al., 1979). Within two weeks of treatment, Mietinnen & Tarplia (1977) found a 13% decrease in blood cholesterol.

Pectin acts as a natural prophylactic substance against poisoning with toxic cations. It has been shown to be effective in removing lead and mercury from the gastrointestinal tract and respiratory organs (Kohn, 1982). When injected intravenously, pectin shortens the coagulation time of drawn blood, thus being useful in controlling hemorrhage or local bleeding (Joseph, 1956). Pectin and combinations of pectin with other colloids have been used extensively to treat diarrheal diseases, especially in infants and children. Although a bactericidal action of pectin has been proposed to explain the effectiveness of pectin treating diarrhea, most experimental results do not support this theory. However, some evidence suggests that under certain *in-vitro* conditions, pectin may have a light antimicrobial action toward *Echerichia coli* (Thakur et al., 1997). By immobilizing dietary ingredients in the intestine, pectin slows down the process of digestion. Less food is absorbed as a result. By preventing contact between the intestinal enzyme and the food, the thickness of the pectin layer affects absorption by decreasing the availability of the latter (Wilson & Dietschy, 1974; Dunaif & Schneeman, 1981; Flourie et al., 1984). Pectin provides a sense of fullness due to its high water-binding capability, which lowers food intake. A meal fortified with pectin was found to extend the stomach emptying half-time from 23 to 50 minutes (Holt et al., 1979). These characteristics of pectin are utilized to treat overeating-related illnesses (Di Lorenzo et al., 1988).

Pectin hydrogels have been utilized in controlled-release matrix tablet formulations (Krusteva et al., 1990; Naggar et al., 1992) and as a binding agent in tablet formulations (Slany et al., 1981a,b). HM-pectins have recently been studied by Sungthongjeen et al. (1999) for possible use in controlled-release matrix compositions. Kim & Fassihi (1997a,b,c) investigated the use of a binary polymer system, namely HM-pectin and hydroxypropyl methylcellulose, in drug release rate modification for oral administration. As a sustained release drug administration device, pectin beads made using the ionotropic gelation process (Aydin & Akbuga, 1996) were employed. However, because of their quick in-vitro release, using these beads has several disadvantages. Sriamornsak & Nunthanid (1998) altered the drug release pattern from calcium pectinate gel beads by altering the DE of LM-pectin.

Calcium pectinate has been studied as an insoluble hydrophilic coating for sustained release delivery by interfacial complexation process because pectin can react with calcium ions (Sriamornsak 1996; Sriamornsak et al., 1997a,b). The extrusion-spheronization procedure was used to create the spherical pellets containing calcium acetate, which were subsequently coated in a pectin solution. The pellets were surrounded by a homogeneous, insoluble layer of calcium pectinate gel. Some writers have reported using pectin to create various oral controlled release medication delivery systems (Table 1).

Pectin has a promising pharmaceutical uses and is presently considered as a carrier material in colon-specific drug delivery systems (for systemic action or a topical treatment of diseases such as ulcerative colitis, Crohn's disease, colon carcinomas), as indicated by the large number of studies published over the last few years (Table 2). The potential of pectin or its salt as a carrier for colonic drug delivery was first demonstrated by two studies, i.e. Ashford et al. (1993) and Rubinstein et al. (1993). The rationale for this is that pectin and calcium pectinate will be degraded by colonic pectinolytic enzymes (Englyst et al., 1987), but will retard drug release in the upper gastrointestinal tract due to its insolubility and because it is not degraded by gastric or intestinal enzymes (Sandberg et al., 1983). Rubinstein et al. (1992) demonstrated that pectin-degrading bacteria, *Klebsiella oxytoca,* could adhere to a film casted of low methoxylated pectin. The ability of the bacteria to adhere to the films, however, was not correlated with their ability to degrade pectin. When the dissolution of pectin matrix tablets was analysed with and without *K. oxytoca,* a significant retardation in the dissolution rate was observed in the presence of *K. oxytoca,* suggesting the formation of a biofilm on the matrix or sedimentation of insoluble pectin salts.

Pectin is an interesting candidate for pharmaceutical use, e.g. as a carrier of a variety of drugs for controlled release applications. Many techniques have been used to manufacture the pectin-based delivery systems, especially ionotropic gelation and gel coating. These simple techniques, together with the very safe toxicity profile, make pectin an exciting and promising excipient for the pharmaceutical industry for present and future applications.

**Table 1** Controlled release formulation using pectin.

| Dose form | Types of pectin | Application | References |
|---|---|---|---|
| Tablets | Pure and standardised pectin | Binding agents and delayed drug release | Slany et al.,1981a,b |
| Tablets | HM-pectin | Monolithic bioerodible system | Krusteva et al., 1990 |
| Tablets | HM-pectin | Sustained release properties of direct compression tablets | Naggar et al., 1992 |
| Tablets | HM-pectin (pure and standardised) | Hydrogel matrix system | Sungthongjeen et al., 1999 |
| Tablets | HM-pectin | Direct compression of the mixture of HM-pectin and HPMC | Kim and Fassihi, 1997a,b,c |
| Gel beads | LM-pectin | Pectin beads prepared by ionotropic gelatin | Aydin and Akbuga, 1996 |
| Gel beads | LM-pectin (amidated) | Sustained release drug delivery using calcium pectinate gel beads | Sriamornsak and Nunthanid, 1998, 1999 |
| Gel beads | LM-pectin (amidated) | *In-vitro* and *in-vivo* studies of pectin hydrogel beads | Munjeri et al., 1998; Musabayane et al., 2000 |
| Gel beads | LM-pectin | A crosslinked calcium-alginate-pectinate-cellulose acetophthalate gel spheres. | Pillay et al., 2002 |
| Pellets | LM-pectin | Calcium petinate or calcium alginate-pectinate prepared by ionotropic gelation | Pillay and Fassihi, 1999 |
| Particulates | LM-pectin | Alginate-pectin-polylysine system | Liu and Krisnan, 1999 |
| Microspheres | LM-pectin | Pectin-based microspheres prepared by emulsification technique | Esposito et al., 2001;Wong et al., 2002 |
| Coated pellets | LM-pectin (amidated and non-amidated) | Insoluble calcium pectinate gel coating for sustained release delivery prepared by interfacial complexation | Sriamornsak et al., 1997a,b |

HM-pectin = high methoxy pectin; LM-pectin = low methoxy pectin.

**Table 2** Colon-specific drug delivery using pectin.

| Dose form | Types of pectin | Application | References |
|---|---|---|---|
| Tablets | Calcium pectinate | Compression of calcium pectinate (matrix system) | Rubinstein et al., 1993 |
| Tablets | HM-pectin | Compression coat | Ashford et al., 1993 |
| Tablets | HM-pectin and LM-pectin | Matrix system | Ashford et al., 1994 |
| Tablets | Calcium pectinate | Matrix system and compression coat | Rubinstein and Radai, 1995 |
| Tablets | HM-pectin and LM-pectin | Direct compression of HM-pectin or LM-pectin alone or combined with MCC | Kim et al., 1998 |
| Tablets | HM-pectin | Compression coated with HM-pectin/ethylcellulose mixtures | Semde et al., 1999 |
| Tablets | Amidated LM-pectin and calcium salt of pectin | Direct compression of amidated or calcium of pectin alone or incorporated with ethylcellolose | Ahrabi et al., 2000 |
| Gel beads | LM-pectin (amidated) | Formation of a chitosan polyelectrolyte complex around calcium pectinate beads | Munjeri et al., 1997 |
| Gel beads | LM-pectin (amidated) | Calcium pectinate gel beads for protein delivery Coating | Sriamornsak, 1998, 1999 |
| Film coated tablets | HM-pectin | with mixtures of HM-pectin and ethylcellulose aqueous dispersion | Wakerly et al., 1997; Macleod et al., 1997 |
| Film coated tablets | HM-pectin or LM-pectin | Coating with HM-pectin or LM-pectin combined with commercially aqueous polymer dispersion | Semde et al., 1998, 2000a,b |
| Film coated tablets | HM-pectin | Coating with HM-pectin or HM-pectin/chitosan mixtures | Fernandezhervas and Fell, 1998; Macleod et al., 1999a |
| Film coated tablets | HM-pectin | Coating with mixtures of HM-pectin/chitosan/HPMC | Macleod et al., 1999b |
| Capsule with plug | LM-pectin | Direct compression of pectin/ pectinase-plug | Krogel and Bodmeier, 1999 |

HM-pectin = high methoxy pectin; LM-pectin = low methoxy pectin; HPMC = hydroxypropyl methylcellculose.

**Conclusion**

Pectin is a naturally occurring biopolymer that can be employed in the pharmaceutical business, health promotion, and therapy due to its chemistry and gel-forming properties. Additionally, it has the potential to be employed in pharmaceutical preparation and drug formulation as a carrier of a wide range of biologically active substances, both for sustained release applications and as a carrier to target medications to the colon for systemic action or local treatment. It is possible to create dosage forms with different morphologies and properties by choosing the right kind of pectin, gelation conditions, additional excipients, and coating agents. We anticipate seeing many novel and fascinating applications in the future as pectin-based delivery system research and development progresses.

References

S.F. Ahrabi and associates (2000). creation of pectin matrix tablets to distribute the model medication ropivacaine to the colon. 10, pp. 43-52, European Journal of Pharmaceutical Sciences.
M. Ashford and associates (1993). An assessment of pectin as a medicine delivery system for the colon. Controlled Release Journal, 26,pages 213–220.
M. Ashford and associates (1994). research on pectin-based medication delivery systems for the colon. Controlled Release Journal, 30, pp. 225-232.
M.A.V. Axelos (1990). Ion complexation of biopolymers: gel viscoelastic characteristics and macromolecular structure. Macromolecular Symposia, 39, 323-328.
Thibault, J.F., and M.A.V. Axelos (1991). Low-methoxyl pectin gelation chemistry. In Pectin Chemistry and Technology, ed. Walter, R.H. (New York: Academic Press)
Akbuga, J., and Z. Aydin (1996). Pectin bead preparation and assessment. Pharmaceutics International Journal, 137, 133-136.
S.H. Christensen (1986). Pectins. M. Glicksman, ed., Food Hydrocolloids III (Florida: CRC Press)
J.A. DeVries and associates (1986). Methoxyl group distribution in pectins. 65–176 in Carbohydrate Polymers, 6, 1.
C. Di Lorenzo and associates (1988). In obese patients, pectin increases satiety by delaying stomach emptying. 1211–1213 in Gastroenterology, 95.
Schneeman, B.O., and Dunaif, G. (1981). Dietary fiber's impact on the function of human pancreatic enzymes in vitro. 34, 1034-1035, American Journal of Clinical Nutrition.
H.N. Englyst and associates (1987). Mixed populations of human fecal bacteria break down polysaccharides. 163-171 in FEMS Microbiology and Ecology, 95.
E. Esposito and associates (2001). A preformulation investigation of pectin-based microspheres. New York Academy of Sciences Annuals, 994, pp. 160-179.
Fell, J.T., and Fernandezhervas, M.J. (1998). Pectin/chitosan mixes as coatings for colon-specific medication delivery - an in vitro study. International Journal of Pharmaceutics, 169, 115–119.
M.P. Filippov and associates (1988). Ion exchange on pectic material sheets is investigated using infrared spectroscopy. 131–135 in Carbohydrate Polymers, 8.

B. Flourie and associates (1984). Pectin's effects on normal man's unstirred layer thickness and jejunal glucose absorption. Gut, 25, 936-937.
E. Ginter and associates (1979). Pectin plus ascorbic acid is a natural hypocholesterolemic agent. 406-408 in the International Journal of Viticulture and Natural Resources, 49.
G.T. Grant and associates (1973). Divalent cations and polysaccharides interact biologically. FEBS Letters, 32, 195-198.
Hercules, Inc. (October 14, 1999). Pectin is described in general terms in food gum products. (Online:
Holt and colleagues (1979). Dietary fiber's impact on paracetamol and glucose absorption and stomach emptying. Lancet, 24, 636-637.
G.H. Joseph (1956). Pectin: Pharmaceutical literature bibliography.
Kertesz, Z.I. (1951) (Ontario: Sunkist Growers). the pectic materials. (Interscience, New York)
Fassihi, R., and Kim, H. (1997a). Drug release rate modification using a binary polymer system: I. Release mechanism characterization. Pharmaceutical Sciences Journal, 86, pp. 316-322.
Fassihi, R., and Kim, H. (1997b). Binary polymer system use in medication release rate modulation: II. Release kinetics are affected by hydrodynamic circumstances and formulation factors. Pharmaceutical Sciences Journal, 86, 323-328.
Fassihi, R., and Kim, H. (1997c). I. Diltiazem hydrochloride is a novel ternary polymeric matrix system for regulated drug delivery of highly soluble medications. Pharmaceutical Research, 14, 1415–1421.
Kim and colleagues (1998). Granular pectin's compactibility is characterized using a compaction simulator for tableting operations. International Journal of Pharmaceutics, 161, 149-159.
R. Kohn (1982). Toxic cations bind to plant tissues, pectin, and its oligomeric fragment. 273-275 in Carbohydrate Polymers, 2.
R. Kohn (1987). Divalent cations bind to the pectin oligomeric fragment. 343-353 in Carbohydrate Research, 160.
Bodmeier, R., and I. Krogel (1999). An enzyme-containing capsular-shaped pulsatile medication delivery device is evaluated. 1424–1429 in Pharmaceutical Research, 16.
S. Krusteva and associates (1990). pharmacological study of a nystatin system that is bioerodible. Pharmazie, 45, 195-197.
Krishnan, T.R., and Liu, P. (1999). A possible formulation for controlled release is alginate-pectin-poly-L-lysine particle. Pharmacy and Pharmacology Journal, 51, 141-149.
G.S. Macleod and associates (1997). research on the physical characteristics of films made of ethylcellulose and pectin that are meant to be used for colonic medication delivery. Pharmaceutics International Journal, 157, pp. 53–60.
G.S. Macleod and associates (1999a). Pectin, chitosan, and HPMC films could be used for bimodal drug release. Controlled Release Journal, 58, pp. 303-310.
G.S. Macleod and associates (1999b). Pectin: chitosan: hydroxypropyl methylcellulose film-coated tablets for selective drug administration to the colon. Pharmaceutics International Journal, 187, 251-257.
C.D. May (1990). Sources, manufacturing, and uses of industrial pectins. 79–99 in Carbohydrate Polymers, 12.

Tarpila, S., and T.A. Miettinen (1977). Pectin's impact on biliary lipids, fecal-bile acid, and serum cholesterol in both hyperlipidemic and non-lipidemic people. Acta Clinica Chimica, 60, pp. 1429-1431.
Z.K. Mukhiddinov and associates (2000). Ramnogalacturonan and pectin homo are isolated and structurally characterized. Talanta, 53, 171-176.
O. Munjeri and associates (1997). Chitosan's function in altering drug release in amidated pectin-based hydrogel beads for colon-specific drug delivery. Controlled Release Journal, 46, pp. 273-278.
O. Munjeri and associates (1998). An analysis of amidated pectin hydrogel beads' potential as a chloroquine delivery matrix.
Pharmaceutical Sciences Journal, 87, pp. 905-908.
C.T. Musabayane and associates (2000). Insulin-loaded amidated pectin hydrogel beads given orally maintain insulin plasma concentrations in rats with streptozotocin-induced diabetes. Endrocrinology Journal, 164, pp. 1-6.
V.F. Naggar and associates (1992). One potential matrix for oral sustained-release formulations of water-soluble medications is pectin. STP Pharma Sciences, 2, 227-234.
I.L. Novosel'skaya et al. (2000). Trends in pectin science and applications. Chemistry of Natural Compounds, 36, pp. 1–10.
D.G. Oakenfull (1991). High-methoxyl pectin chemistry. R.H. Walter, ed., The Chemistry and Technology of Pectin. Paoletti, S. (1986) (New York: Academic Press). Pillay, V., and Fassihi, R. (1999) in Chemistry and function of pectins, eds. M.L. Fishman and J.J. Jen. (Washington, DC: American Chemical Society). In vitro release modulation from crosslinked pellets for site-specific medication delivery to the gastrointestinal system. I. Comparing the kinetics of pH-responsive drug release. Controlled Release Journal, 59, pp. 229-242.
V. Pillay and associates (2002). For lineat drug release, a crisslinked calcium-alginate-pectinate-cellulose acetophthalate gelisphere system is used. Drug Delivery, 9, 77–86.
I.G. Plashchina and associates (1978). investigations of pectin solutions using circular dichroism. Carbohydrate Research, 60, 1–8.
Powell and colleagues (1982). Pectin conformation and interaction: II. The effects of residue sequencing on calcium pectate gel chain attachment. Molecular Biology Journal, 155, pp. 517-531.
E. Racape and associates (1989). characteristics of amidated pectin. II. Amidated pectin and amidated pectic acid polyelectrolyte behavior and calcium binding. Biopolymers, 28, 1435-1439.
Wright, A.W., and D.A. Rees (1971). conformation of polysaccharides. Part VII: Model building calculations for the kinking function of L-rhamnose residues in pectic materials and a-1,4 galacturonan.
Chemical Society Journal, Section B, 2, pp. 1366-1372.
C. Rolin (1993). Pectin. R.L. Whistler and J.N. BeMiller, eds., Industrial Gums.Third edition. (Academic Press, New York)Radai, R., and Rubinstein, A. (1995). Analysis of calcium pectinate formulations' colon specificity in vitro and in vivo. 41, pp. 291-295, European Journal of Pharmaceutics and Biopharmaceutics.
A. Rubinstein and associates (1992). bacterial adhesion to pectin-cast films. Microbios, 70, 284-285.
A. Rubinstein and associates (1993). Calcium pectinate is being evaluated in vitro as a possible colon-specific medication delivery vehicle. Pharmaceutical Research, 10, 258-263.

A.S. Sandberg and associates (1983). the impact of citrus pectin on the small intestine's nutrition absorption. Clinical Nutrition in Human Nutrition, 37, pp. 171-183.
R. Semde and associates (1998). Pectin leaching from mixed pectin-insoluble polymer films used for colonic medication administration. International Journal of Pharmaceutics, 174, 233-241.
R. Semde and associates (1999). Pectin HM/ethylcellulose compression-coated formulations for colonic medication administration are evaluated in vitro. 561-565 in STP Pharma Sciences, 9.
R. Semde and associates (2000a). Theophylline release from pellets coated with water-insoluble polymers containing pectin HM or calcium pectinate is affected by pectinolytic enzymes. International Journal of Pharmaceutics, 197, 169–179.
R. Semde and associates (2000b). Pectin HM/Eudragit RL/Eudragit NE film-coating compositions for colonic medication administration are being studied. Pharmaceutics International Journal, 197, 181-192.
J. Slany and associates (1981a). Tablets containing pectin as a binding agent are evaluated. Obzor Farmaceuticky, 50, pp. 491-498.
J. Slany and associates (1981b). investigation of citrus pectins' functional effect in tablets. 195–200 in Ceska a Slovenska Farmacie, 30.
. Sriamornsak (1996). the creation of sustained release theophylline pellets using pectin. Mahidol University MSc thesis.
P. Sriamornsak (1998). Calcium pectinate gel beads are being used to investigate the use of pectin as a carrier for oral protein delivery. Pharmaceutics International Journal, 169, 213-220.
P. Sriamornsak (1999). Oral protein release properties from calcium pectinate gel beads are influenced by calcium content, hardening agent, and drying conditions. 8, 221-227; European Journal of Pharmaceutical Sciences.
P. Sriamornsak (2001-2002). The function of pectin in health. Silpakorn University Journal, 21–22, pp. 60–77.
P. Sriamornsak (2002). examination of specific physicochemical characteristics of alginate and pectin gels used for medication administration. Charles Sturt University PhD thesis.
Nunthanid, J., and Sriamornsak, P. (1998). Gel beads made of calcium pectinate for medication delivery with controlled release: I. In vitro release studies and preparation. Pharmaceutics International Journal, 160, pp. 207-212.
Nunthanid, J., and Sriamornsak, P. (1999). Gel beads made of calcium pectinate for medication delivery with controlled release: II. The impact of processing and formulation factors on drug release. Microencapsulation Journal, 16, pp. 303-313.
P. Sriamornsak and associates (1997a). creation of calcium pectinate-coated theophylline pellets with prolonged release. Controlled Release Journal, 47, pp. 221-232.
P. Sriamornsak and associates (1997b). Pellets covered with calcium pectinate gel serve as a substitute for calcium pectinate beads. International Journal of Pharmaceutics, 156, 189-194.
In 1999, Sungthongjeen et al. research on pectins as possible hydrogel matrices for medication administration with controlled release. Development of Drugs

B.R. Thakur and associates (1997). A review of pectin's chemistry and applications. Food Science and Nutrition Critical Reviews, 37, pp. 47–73.
J.F. Thibault and M. Rinaudo (1985). interactions between alkaline and enzyme-deesterified pectins and mono- and divalent counterions.
Biopolymers, 24, 2131-2144.

Z. Wakerly and associates (1997). Research on pectin/ethylcellulose film-coated tablets as a possible colonic delivery method for medication release.
Pharmaceutics International Journal, 153, 219-224.
Arnott, S., and M.D. Walkinshaw (1981a). Pectin interactions and conformations. I. X-ray diffraction study of neutral and acidified sodium pectate. Molecular Biology Journal, 153, pp. 1055–1073.
Arnott, S., and M.D. Walkinshaw (1981b). Pectin interactions and conformations. I. Junction zone models for calcium pectate and pectinic acid gels. Molecular Biology Journal, 153, pp. 1075-1085.
Dietschy, J., and Wilson, F. (1974). The surface area and impact of the intestine unstirred water layer on the kinetics of active transport. Acta Biochimica et Biophysica, 34, p. 1034.
T.W. Wong and associates (2002). release properties of pectin microspheres made using an emulsification method. Microencapsulation Journal, 19, pp. 511-522.