ES Food & Agroforestry
DOI: https://dx.doi.org/10.30919/esfaf1123

What We Know About Pectin?

Mar Villamiel*

Received: 30 December 2020; Accepted: 12 January 2021.
Article type: Personal account.

Introduction

The market of pectin is increasing day by day and the rate of growth is projected to increase still more. How is it possible that a very-well known polysaccharide with important food (E-440) applications is undergoing such as growth? It is noteworthy that the production of pectin started in Germany at the beginning of the twentieth century and its expansion has been driven mainly by the increasing demand for functional food products, including hydrocolloids (increasing consumer demand for low-calorie, high quality food products), as well as the rising use by the cosmetic, nutraceutical and pharmaceutical industries.

It is necessary to contextualize that pectin is a complex polysaccharide present in the cell wall mainly formed by a backbone of galacturonic acid (homogalacturonan) and two domains of rhamnogalacturonan I and II. There is another hypothesis on pectin structure considering the rhamnogalacturonan I, the main backbone. However, taking into account most of the investigations, the main plausible structure is the former. Regardless the model, some of the carboxyl groups of galacturonic acid are methyl esterified, being the content of galacturonic acid, its degree of methyl esterification, the content of neutral monosaccharides (rhamnose, galactose, arabinose, xylose) and the molecular weight, the main structural parameters that determine the functional properties and applications of pectin. The degree of methyl esterification is the key for the classification of pectin as high-methoxyl pectin (>50%) and low-methoxyl pectin (<50%), with different gelation mechanisms. In the former, an elevated amount of sucrose is needed, whereas in the latter, the gelation can be produced even without the presence of this sugar.[1]

Pectin is present in the cell wall of a large number of plants and it is obtained from the agro-food by-products, mostly peels of citrus and apple pomace (high-methoxyl pectin). Thousands of tons of citrus and apples are processed worldwide every year constituting a very big problem for the environment. As it is stated in the Sustainable Development Goals of United Nations, the reduction of waste and by-products from the industry is crucial to a sustainable development. Therefore, researchers have the responsibility to implement procedures to contribute positively to a solution to this problem. In this sense, a plethora of investigations are being carried out to study the effective and secure extraction of pectin, not only from the point of view of sustainability but also considering that the structure and composition of pectin depend on extraction and purification protocols. Huge efforts are being made to evolve toward less severe methods than those used in the industry which include severe treatments by means of strong mineral acids, elevated temperatures and long times. It seems clear that the valorisation of fruit and vegetable processing by-products following these conventional protocols really does not contribute to save energy and to satisfy economic demands. In this sense, several alternatives are being proposed for the reduction of time, temperature, increase of yields and, of course, the use of other more environmentally friendly extracting agents. Among these alternatives, enzyme-assisted extraction, ultrasound, subcritical fluids, pulsed electric field extraction, high hydrostatic pressure and microwave heating can be applied. These techniques are not new; it is more correct to consider them as emergent procedures. Their beginning was several decades ago, but the limited development of these techniques did not allow a full understanding of the mechanisms and the most important applications. Among them, in my opinion, ultrasound highlights. The mechanism of ultrasound is based on the collapse of cavitation bubbles that causes cell disruption, contributing to the enhanced solvent entrance into the cells and intensification of the mass transfer. In addition, the shock wave can make the hydration and swelling easy, forming large pores in the cell wall. Thus, the diffusion of the internal cell substances is produced increasing the mass transfer. Moreover, ultrasound is not a thermal technique, with less energy consumption and structural modification of components. Usually, the times are shorter to a very big extent and the

Institute of Food Science Research (CIAL, CSIC-UAM).
**Email:* m.villamiel@csic.es

yields are improved, together with an inferior consumption of solvent and more effective mixing. This technique can be applied in two ways, in bath or using a probe, the latter being perhaps the most promising procedure since the energy can be focused on specific sample zone yielding more efficient liquid cavitation. Among the different applications of ultrasound, the ultrasound assisted extraction is the one which can have more chance to be used in the industry. In spite of the required initial investment, ultrasound could raise the efficiency of industrial extraction of pectin from new or conventional sources, although as it is obvious, it is necessary to optimise the conditions in each case.[1]

The continued commercial achievement of pectin has shown the importance of using large amount of fruit and vegetable by-products as raw materials to produce value-added products. Thus, although citrus and apple are the most used by-products for the obtainment of pectin, others such as wine, olive pomace, sugar beet pulp, berry pomace, potato pulp, cocoa husks, faba bean and pistachio green hulls, pomegranate peels, pumpkin, banana, and mango peel, grapefruit, papaya, passion fruit, melon, watermelon, sunflower heads, chickpea, chicory roots, which can be substrates of interest for the industrial extraction of pectin.[2]

Moreover, the search of new sources of pectin has a special relevance due to the use of sucrose in high-methoxyl pectin applications. As it is well known, a lot of attention is being paid to decreasing of sugar in food and beverages, since this can be directly related to the increase of metabolic and cardiovascular pathologies. Thus, research is focused on the search of by-products whose pectin is of low-methoxyl degree, or in other cases, on the procedures to obtain them from pectin of high-methoxyl content. To date, the industry has driven its efforts toward the latter, but important considerations should be taken into account such as the use of acid, alkaline and/or enzymatic de-esterification. The chemical methods include the depolymerisation of pectin decreasing its gel forming capabilities, while the great cost is the most important drawback of the enzymatic de-esterification. Thereby, as afore mentioned, the industry is searching for sources of natural low-methoxyl pectin.[2] In my opinion, sunflower heads have the requisites as exceptional candidates to be profusely used at industrial level for its elevate content of low-methoxyl pectin (15-25%). In addition, this application contributes to the disposal of abundant amounts of by-products derived from the seeds and oil production, which represented 21 million tons in 2018. Recent investigation has pointed out that pectin obtained from sunflower by-products with sodium citrate, an adequate and eco-friendly extracting agent, is a promising ingredient, with good thickening and gelling properties.

Other approach that is necessary to consider in the search of new structures is the production of modified pectin. In comparison with the native pectin, modified pectin also highlights for its higher content of neutral sugars. Currently, modified pectin is commonly produced from commercial citrus pectin with low or high pH, heat or enzymes. Pectin can be previously alkali-treated and then acid-treated to achieve a molecular weight of ~10 kDa. As a result of the alkali treatment of pectin, β-elimination reactions occur, leading to cleave and de-esterification the homogalacturonan which gives rise to oligomers, that together with free sugars may be lost during alcohol precipitation and drying. Although some publications refer to an additional heat treatment, the details and structural consequences are uncertain, but it is presumable that these compounds can be degraded under severe conditions. Other subsequent treatments may be needed to cleave certain neutral sugars. Thus, the resultant modified pectin can be of a lower molecular weight, rich in rhamnogalacturonan I with more galactose than arabinose content.[2]

All of these structural modifications challenge the analytical methods for a comprehensive qualitative and quantitative determination of pectin, needed to try to understand the structure-function relationship. In addition to this, the big size of this polysaccharide usually can suppose a problem. This means that, in some cases, a previous hydrolysis is mandatory to obtain fragments with a size within the range we can determine. Although the structural elucidation of pectin has evolved from classical titrimetric and colorimetric methods to more sophisticated ones, including NMR and ion mobility followed by MS^n characterization, a typical, accurate and inexpensive characterization of pectin can be achieved following methods based on HPSEC-ELSD for the estimation of molecular weight, FT-IR for the determination of degree of methyl esterification and GC-FID (after hydrolysis with trifluoroacetic acid) for the evaluation of the monomeric composition, although each case should be assessed individually depending on the source and the extraction conditions of pectin.[3]

Thus, the wide diversity of structures that we can find can derive in a broad range of pectins with improved techno-functional and biological properties.

In the 2000s the scientific evidence showed that pectin has several beneficial health and nutritional effects as a dietary fibre and prebiotic and, in 2010, pectin was recognized by the European Food Safety Authority (EFSA) as nutritional supplement in the reduction of post-prandial glycaemic responses, the maintenance of normal blood cholesterol levels and the increase in satiety, leading to a reduction in energy intake.[2] Since that moment, a huge amount of *in vitro* and *in vivo* studies have underlined that pectin is quite more than an excellent food ingredient, as it is following indicated.[4,5]

Prebiotic

Pectin is highly resistant to gastrointestinal digestion as has been demonstrated in several studies, including a dynamic gastrointestinal simulator, presenting a high fermentability by the colon microbiota with great increases in the population of Bifidobacteria, Bacteroides and Faecalibacterium prausnitzii, as well as short chain fatty acids. Pectin and modified pectins obtained from agricultural by-products have showed to have similar prebiotic potential as compared to recognized prebiotic such as inulin and fructooligossacharides. Considering the structural characteristics of pectin (molecular weight, degree of methyl esterification, and monomeric composition) one of the most influencing factors on the bifidogenic properties seems to be the presence of arabinose.

Hypoglycemic effect

The effect of pectin on diabetes has been related to the reduction of fasting blood glucose levels due to the physicochemical properties of pectin and other more intricate mechanisms. It was shown that pectic polysaccharides suppress high hyperglycemic activity in diabetic mice by possibly retarding the peroxidation chain reaction. Other pathways suggest the interaction with proteins and hormones. No conclusive statements have been established with respect to the structure-function of pectin in the decrease of post-prandial glucose response. Although many investigations have been carried out with high-methoxyl pectins, there are interesting findings with low-methoxyl pectins. Therefore, other molecular parameters (or a mix of them) could be in part responsible for the benefits of pectin.

Pectin significantly prevented diabetic toxicity in the liver and kidney. As indicated by the EFSA, it should be expected that pectins will become a new kind of hypoglycemic drugs.

Antioxidant and antiradical activity

This property of pectin is dose-dependent and it has been related to the following mechanisms: i) quenching of free radicals via active hydroxyl and carboxyl groups present in the structure (mostly in GalA, as electron donators); ii) forming a stable compound by linking the radical ions; iii) developing a physical barrier to inhibit the action of oxidant enzymes. Physical treatments used in the extraction of pectin such as ultrasound have been demonstrated to be efficient to increase the antioxidant activity. Moreover, this property is also related to the antiglycation potential, thus, an increase in the antioxidant activity can improve their antiglycation activity due to the higher galacturonic acid content.

Antitumor and anticoagulant activities

The concentration of pectin is also determinant in the antitumor effect. The presence of high number of free carboxyl groups plays an important role. In addition, some investigations have pointed out the positive effect of the rhamnogalacturonan I domain in the anti-cancer effects of pectin. Several *in vitro* and *in vivo* assays have demonstrated the benefits of pectin on cancer of colon, prostate, breast tumor, pancreas, lymphoma, Lewis lung carcinoma and adenocarcinomic human alveolar, among others.

Nowadays, there are two modified citrus pectin that have been investigated in detail and patented: GCS-100®, a mammalian anti-cancer agent and Pectasol-C® which is marketed as a natural health supplement related with the cancer progression and metastasis.

In the case of anticoagulant properties, some sulphated pectin-like polysaccharides extracted by ultrasound have been postulated as alternative for heparin.

Anti-inflammatory and inmunoregulatory effects

Pectin can control the effect of inflammatory mediators reducing the edema; these results could be compared to diclofenac. The anti-inflammatory activity of pectin could also be related to the immunological activity of carboxyl and acetyl groups in their structure. Low methyl-esterified pectin inhibits local and systemic inflammation, while pectin of higher degree of esterification can inhibit intestinal inflammation. Other studies ascribed the immune-enhancing effect of pectin to its prebiotic effects through the production of metabolic products and bacterial counts in the gut, causing a healthy environment. *In vivo* assays have demonstrated the positive effect of pectin in the inflammatory bowel disease.

Regarding the immunoregulatory activity, pectin could directly activate the immune function of macrophages, promote the production of cytokines, and, therefore, control the immune system on multiple levels. It is also remarkable that the oligomer fractions derived from the enzymatic digestion of pectins also present immunomodulatory activity, underlining the contribution of the backbone of pectin. It is belief that the carbohydrate chain of pectin governs the immunosuppressive activity and the branched region mediates the stimulation of phagocytosis and the increased production of antibodies.

Analgesic properties

There are some evidences that pectins can have a similar effect on pain as compared to acetylsalicylate of lysine and tramadol. In this case, the mechanism is associated to its role in the inhibition of release of compounds such as histamine, bradykinin, prostaglandins and cytokines.

Antibacterial activity

Different biodegradable materials based on pectin, pectin-oleate, pectin-linoleate, and pectin palmitate have been detected to possess antimicrobial properties against a number of bacterial strains, including *Staphylococcus aureus* and *Escherichia coli*. The studies of the antimicrobial properties of pectins show a general trend for the development of nanocomposites and nanoemulsions on their base, using cadmium, silver, or lysozyme.

Considering all the studies that have been carried out on the bioactivity of pectin, important efforts have been made to gain more insight to broaden the knowledge about this biopolymer, in most of the cases, with animals and in *in vitro* experiments. It is clear that the structure plays a key role. Depending on the application, it is less determinant to have the full structure of pectin, as is the case, for instance, of the prebiotic and hypoglycemic properties. However, in others, such as antitumor capacity, very relevant results have been obtained with modified pectin, with lower molecular weight and enrichment in galactose. In addition, the consideration of pectin and derivatives as antioxidant is one of the most promising approaches. The application of physical treatments for the extraction of pectin is particularly relevant, namely ultrasound, since pectin with low molecular weight, low degree of methyl esterification and high galacturonic acid can be obtained. In this sense, low-methoxyl pectin are also very important candidates to be considered good antioxidant.

In summary, we have in front of us a heteropolysaccharide, pectin and its derivatives, as emergent and promising compounds for further studies on pharmacology and medicine application, mostly due to their substantial accessibility from renewable sources, the non-toxic effect and improved functionality. They have shown high biological activity in *in vitro* and *in vivo* assays; however, their development as a multi-purpose drug is still in its infancy, since, among other factors, there is a long way to go into pectin mechanism of action. More research is desirable on the sustainable production and characterisation of new pectins with new and improved technological and biological properties; also, more clinical assays are needed to clearly establish their structure-function relationship. It seems to be clear that pectin is much more that an excellent polysaccharide of food grade that is used for the elaboration of foodstuffs; new application segments will be open for pectin in the nearer future. In an ideal approach, low-methoxyl pectin can be sustainablely produced from sunflower heads using ultrasound under controlled conditions, exhaustively characterised and assayed for food and medical applications.

Conflict of Interest

There is no conflict of interest.

Supporting Information

Not Applicable

References

[1] F. R. B. Marenda, F. Mattioda, I. M. Demiate, A. de Francisco, C. L.de Oliveira Petkowicz, M. H. Giovanetti Canteri, and R. D. de Mello Castanho Amboni, *J. Polym. Environ.*, **27**, 549-560, doi: 10.1007/s10924-018-1355-8.

[2] N. Muñoz-Almagro, A. Montilla, M. Villamiel, *Food Res. Inter.*, 2020, **76**, 28–37, doi: 10.1016/j.foodres.2020.109851.

[3] A. N. Grassino, F. J. Barba, M. Brnčić, J. M. Lorenzo, L. Lucini, S. R. Brnčić, *Food Chem.*, 2018, **266**, 47–55, doi: 10.1016/j.foodchem.2018.05.105.

[4] L. Khedmat, A. Izadi, V. Mofid, amd S. Y. Mojtahed, *Carbohyd. Polym.*, 2020, **229**, 115474, doi: 10.1016/j.carbpol.2019.115474.

[5] S.T. Minzanova, V. F. Mironov, D. M. Arkhipova, A.V. Khabibullina, L.G. Mironova, Y. M. Zakirova, V. A. Milyukov, *Polymers*, 2018, **10**, 1407; doi: 10.3390/polym10121407.

Author information

Mar Villamiel Dr. *in Pharmacy by the Complutense University of Madrid (Spain). She develops her research activity in the Institute of Food Science Research (CSIC, Madrid, Spain). She was also visiting researcher in the NIZO food research (The Netherlands) and in the Institute of Food Research (United Kingdom). The main achievements of her scientific career are: development of ultrasound for polysaccharide extraction; structural elucidation of carbohydrates by chromatographic techniques; valorization of agro-food by-products using green technologies; development of digestion models for carbohydrates. She is the leader of several projects and contracts with the industry. Author of more than 150 scientific papers within the Journal Citation Report (h-index 36), oral and poster presentations in international conferences, several book chapters and patents, editor of a book on ultrasound (Wiley & Sons) and of the journal Ultrasonics Sonochemistry. She has also an intense activity as supervisor of students including Ph.D, and dissemination of science.*

