

Pectin: Properties and utilization in meat products

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ABSTRACT

In recent years, there is increased awareness of conscious consumers about the fact that foods they eat are related directly to their health. In meat industry research and development, studies have accelerated to formulate healthier meat products formulations using plant sources as additive which are also expected to improve the functional properties of the product. Pectin is a water soluble fiber with a structural complexity that occurs naturally in the cell walls of fruits and vegetables, contributes to reducing the risk of cancer, and has some health benefits. Gelation is the most unique property of pectin; it forms a gel in the presence of Ca^{2+} ions or sugar and acid. Pectin presents good water and fat binding property. Therefore, it can be used as a gelling agent, film/coating, and emulsifier and in low-calorie meat products as fat and /or sugar substitution (dietary fiber), as a natural component contributes to phosphate substitution and medical delivery systems in meat products. In this paper, it was aimed to discuss the physico-chemical properties, health implications of pectin and its potential applications in meat products.

Keywords: Pectin, Meat products, Gelling agent, Restructured meat, Low-fat products



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Introduction

Pectin is a type of structural fiber found in the primary cell wall and intracellular layer of plant cells mainly in fruits, such as apples, oranges, lemons, and so on (Mudgil, 2017).

Pectin contains a polysaccharide backbone with an α -(1 \rightarrow 4)-linked D-galacturonic acid. The acid groups along the chain are largely esterified with methoxy groups in the natural product. There can also be acetyl groups present on the free hydroxy groups. As shown in Figure 1, esterification is the reaction between carboxylic acid and alcohol or compounds containing the hydroxyl group (usually methanol) to form ester and water (Parkinson, 2014).

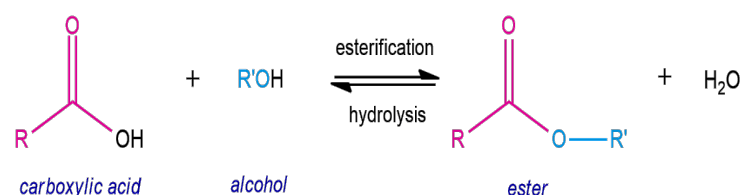


Figure 1. Esterification mechanism of pectin (Parkinson, 2014).

Degree of methyl esterification ranges between 0-100% and on the basis of esterification, there are two different types of pectin; high methoxy (HMP) and low methoxy pectin (LMP) (Ramirez-Suarez et al., 2017).

Table 1 shows pectin content of various plants. Apple pomace and citrus fruit peels are commercially acceptable sources of pectin (Thakur et al., 1997). However, it has been extracted from different plants such as sunflower head, mango peel, soybean hull, sugar beet pulp, chickpea husk, etc. (Fajardo et al., 2016). Pectin from apple forms a more elastic-viscous gel however, citrus pectin displays a more elastic-brittle gel (Masuelli, 2019).

Utilization of pectin has been allowed in all countries, FAO/WHO committee recommended acceptable daily intake of pectin has no limitation and it is as a safe additive except where specified by good manufacturing practice. Pectin is used as a thickening agent, gelling agent, texturizer, emulsifier, stabilizer, and fat or sugar replacer in food industry, the major application of pectin is based on its gelling properties (Thakur et al., 1997). The source and the method of extraction have an influence on the structure and properties of pectin such as viscosity and gelling ability and thus their application in food industry (Gawkowska et al., 2018).

In the present review, it was aimed to investigate the functional properties of pectin and its usages in meat product formulations.

Table 2. Pectin content of various plants

Plants	Pectin	Reference
Sugar beet and sunflower head	10-20%	Yancheva et al., 2016
Cocoa husks	about 9%	Yancheva et al., 2016
Beet and potato pulp and Soy hull	26-28%	Yancheva et al., 2016
Apple pomace	10-17%	Sharma et al., 2014; Fajardo et al., 2016
Citrus peels	20-30%	Panchami & Gunasekaran, 2017; Fajardo et al., 2016
Plants of <i>Lupinus</i> genus	1.5%-7%	Valdés et al., 2015
Burdock from the <i>Arctium</i> genus	Higher than 21%	Valdés et al., 2015
Peach	up to 10%	Valdés et al., 2015
Orange peel/ pomace and seed	30-50 %	Begum et al., 2017
Pineapple	54%	Begum et al., 2017

Pectin Extraction Methods

According to the previous studies, some parameters mainly pH, time and temperature influence pectin extraction (Yapo et al., 2007; Fathi et al., 2012). Pectin can be extracted by various methods from the cell-wall material in laboratory-scale such as cold/hot water or buffer solutions, cold diluted sodium hydroxide, cold/hot solutions of chelating agents and hot diluted acids (Levigne et al., 2002). Figure 2 shows an optimized method of pectin extraction. Pectin can have physical harm in structure when extracted fully by acidic extraction and acid extraction of pectin has no environmental safety. Therefore, the combination of acid extraction and other methods is used. In recent years, searching for alternative methods that have fewer disadvantages is continued such as using microbial enzymes or enzyme complexes and ultrasound-assisted, ohmic-assisted, microwave-assisted, etc. extractions (Ptichkina et al., 2008; Gavahian et al., 2019). As an example, sonication of pectin leads to increased antioxidant capacity, 200 W and 400 W sonicated pectin have higher oxygen radical absorbance capacity and FRAP values than native pectin. Therefore, ultrasound offers an effective and green process for pectin transformation and creation of antioxidant potent pectin products (Ogutu and Mu, 2017).

Characteristics of Pectin

Solubility and Dispersibility

There are two types of pectin depending on the solubility: water-soluble and water-insoluble pectin. This property is determined by the number and distribution of methoxy groups and the degree of polymerization. It means that a decrease in molecular weight and an increase the (degree of esterification) DE cause to increase solubility increases. Other parameters that have an impact on solubility are pH, temperature, and the nature and concentration of the solute present (Axelos and Thibault, 1991).

Dispersibility means the ease of solubilization of pectin, which is more important than solubility. When dry powdered of pectin added to water, attends to hydrate rapidly and forming clumps (Kachare et al., 2020). Formation of the clump can be prevented by using water-soluble carrier material with dry powdered pectin or improving the dispersibility of pectin by mixing (5/10 parts by weight) fine-powdered sugar or D-glucose (the common dispersing agents) and pectin (Axelos and Thibault, 1991).

Gelation

Gelation is the most unique property of pectin, pectin forms gels in the presence of Ca^{2+} ions or sugar and acid also traps the liquid by forming a three-dimensional network due to the

merging or cross-linking of long polymer chains (Narasimman and Sethuraman, 2016). Two different pectin types form gels under completely different conditions. The ester group is less hydrophilic than the carboxyl group; therefore, HMP makes gel at a higher temperature than the LMP. Low methoxy pectin forms gel in pH (2-6) and presence of divalent ions such as calcium, high methoxy pectin forms a gel in the presence of sugar (>50%) and acid (pH: 3.1-3.6) (Narasimman and Sethuraman, 2016).

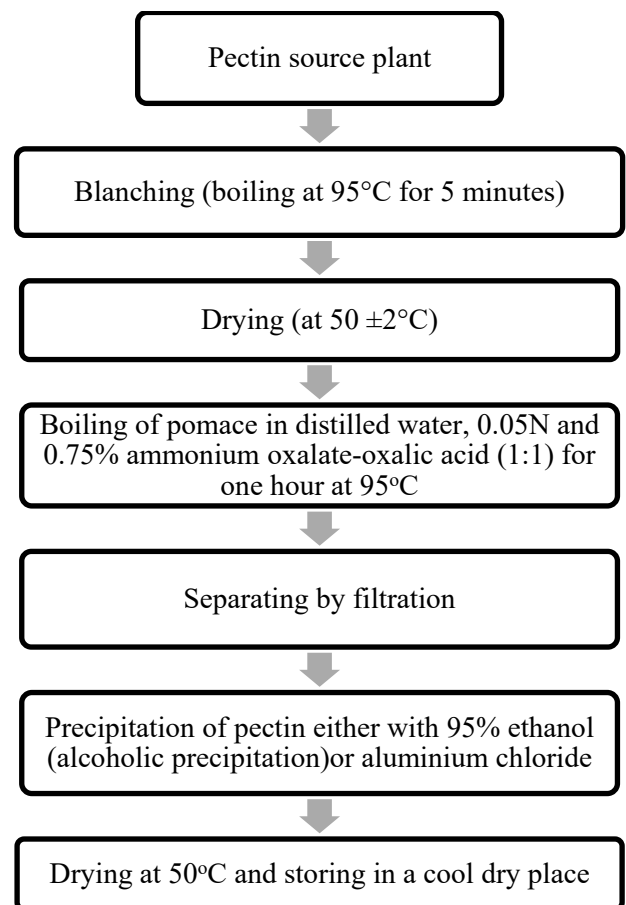


Figure 3. An optimized method for pectin extraction (Sharma et al., 2014)

Table 3. The yield of pectin extraction methods (Vales et al., 2015)

Sources	Methods	Yield
Sugar beet pulp	Citric acid, 99°C	23.95
Watermelon seed	HCl, 85°C	19.75
Tomato peel	Oxalic acid and ammonium oxalate, 90°C (two steps 24 and 12 h)	32.0
Mango peel	Sulfuric acid in the water, 90 °C	>70
Sunflower head	Sodium citrate, 85 °C	16.90

Pectin as Emulsifier

Emulsions assist encapsulation of the bioactive compounds. Depending on the disperse phase, there are two types of liquid emulsion: oil droplet in water (O/W) and water droplet in oil (W/O). Meat emulsion is an example of O/W emulsion, margarine and butter, by contrast are examples of W/O emulsion (Fajardo et al., 2016). A multiple (double) emulsion system defined as ‘emulsion in emulsion’, in which oil-in-water (O/W) and water-in-oil (W/O) are together. For example in W1/O/W2 double emulsion, W1 and W2 are internal and external water phases respectively, there are two different interface layers W1-O (internal water droplets are surrounded by oil) and O-W2 (oil droplets are surrounded by water (Öztürk et al., 2016)).

Emulsifiers are used to mix two liquids that are normally immiscible for manufacturing desirable products. Emulsifiers divided into small-molecular surfactants (lecithin, etc.) and macro-molecular emulsifiers (proteins and plant-based polymers such as soy polysaccharide, pectin, etc.). Good emulsifiers should have low molecular weight, rapidly reduce the interfacial tension and soluble in the external phase. Pectin has been reported to exhibit surface-active property in oil-water interface and thereby stabilizing the oil droplets in emulsion systems (Funami et al., 2007)

O/W emulsion is stabilized by steric and electrostatic interaction of pectin. Pectin improves the stability of emulsion, with the addition of pectin viscosity of the emulsion increased, therefore movement of oil droplets are limited. Molecular weight effects emulsifying capacity of pectin. Small emulsion droplets are efficiently stabilized by low molecular weight pectin. Researches also indicated that pectin increases colloidal binding and coagulation of soluble proteins. The high molecular weight of pectin is an important factor that prevents protein coagulation. Many factors may influence the interactions, such as DE of pectin, pH and processing conditions.

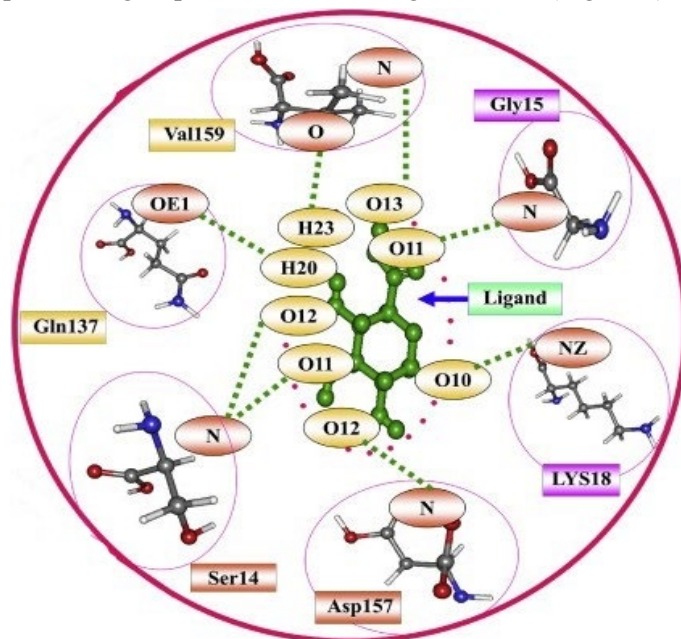
Pectins can stabilize the protein in acidic media through conjugation or complexation. The rate of structure development in pectin gels depends on temperature, pectin concentration and hydration of pectin. (Axelos and Thibault, 1991; Yapo et al., 2007; Fajardo et al., 2016)

Pectin-protein molecules form a network that surrounded oil droplets in emulsion based food products. Nowadays, pectin is used in emulsified low-fat meat products, dairy products, etc. (Masuelli, 2019).

Usage of Pectin in Meat Products

Depending on the functional properties such as gelling ability, water binding ability and acting as an emulsifier pectin is one of the natural ingredients for healthy meat products formulations. Pectin is widely used in meat products to form a gel and/or as a thickener. This property is related to the size, shape, chain length and total negative charge in galacturonic acid structure of pectin molecule.

The interactions between pectin and meat proteins showed in Figure 3, 4 and 5. Actin interacts with pectin through eighteen amino acids; there are eight H-bonds that play an important role in the correct positioning of pectin into the actin surface (Figure 3). Myosin interacts with pectin through thirteen amino acid and twelve H-bonds play an important role in the correct positioning of pectin into the myosin surface (Figure 4). Collagen interacts with pectin through thirteen amino acid and a total of six H-bonds play an important role in the correct positioning of pectin into the collagen surface (Figure 5).

**Figure 3.** Complex structure pectin + actin (Ahmad et al., 2020)

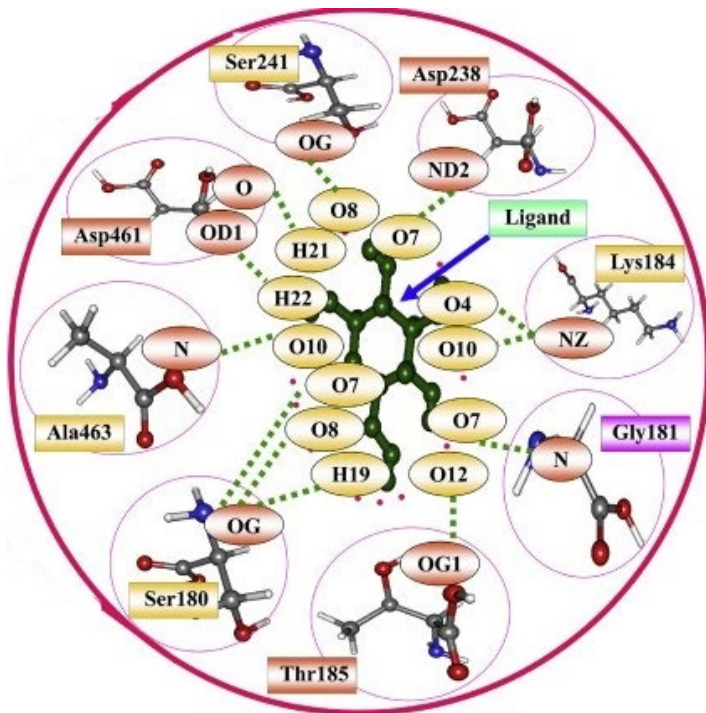


Figure 4. Complex structure pectin + myosin (Ahmad et al., 2020)

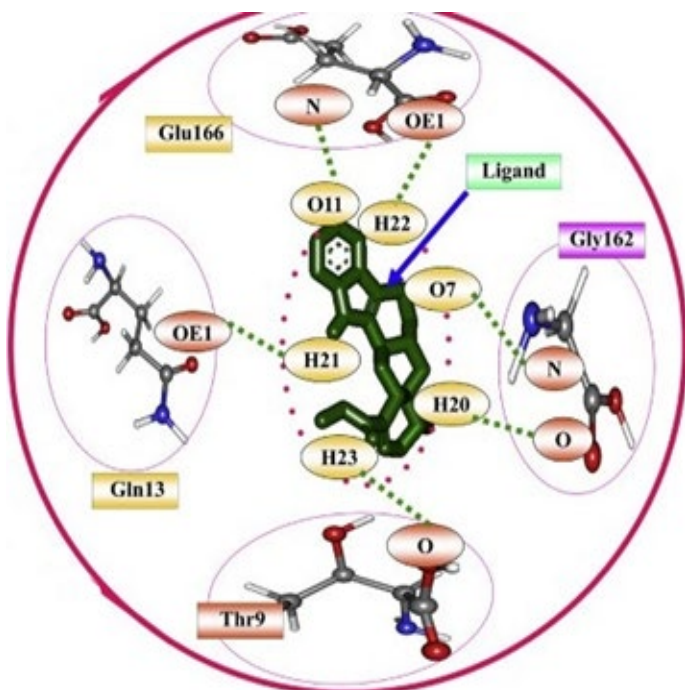


Figure 5. Complex structure pectin + collagen (Ahmad et al., 2020)

Myofibrillar proteins represent the functional part of meat proteins, they are extracted from the muscle tissue, followed by the accumulation around oil droplets and/or participation in the formation of a three-dimensional network gel during meat processing, ultimately contributing to improved emulsion stability, water-holding capacity (WHC), and texture of meat products. The examination of zeta potential and hydrodynamic size has demonstrated that histidine inhibits the aggregation of myosin and increases the solubility of myosin. Recently, it was highlighted that both lysine and arginine improve the water holding capacity and texture. The myosin molecule has an asymmetric structure with two globular heads and a rod-like tail. It associates with insoluble fibers through electrostatic tail-to-tail interaction under physiological conditions. Consequently, pectin has a good interaction with meat proteins based on the H-bond formation and free binding energy (Ahmad et al., 2020).

Film/Coating

Films or coatings are defined as a layer on the food surface or placed between food components (Korkmaz, 2018). Their function is to extend the shelf life of the products and provide a barrier against various hazards. Films should provide mechanical properties and restrict the migration of gas in food wrapping and/or coating. Edible films can represent physical protection, reduction of moisture and lipid transition, limit absorption of oxygen, improve handling features and can be contacted directly with food. Some natural components such as carbohydrates and proteins are used for the manufacturing of films, which have nutritional value, biodegradability, and environmental compatibility (Maftoonzad et al., 2007). Pectin and its derivatives are used in many biodegradable packaging materials that serve as moisture, oil, and aroma barrier, reduce respiration rate and oxidation of food (Ciolacu et al., 2014). Pectin-based edible films and coatings, either alone or enriched with antimicrobial and antioxidant substances, were investigated in meat and meat products (Tural et al., 2017).

Edible films are developed to be used as carrier for additive with specific functions such as anti-browning, antimicrobial agents, texture enhancers, nutrients, probiotics, and flavors (Falguera et al., 2011). As an additional barrier against pathogenic and spoilage microorganisms, antimicrobials are incorporated into edible films to inhibit food surface contamination. Ravishankar et al., (2012) are investigated the incorporation of carvacrol and cinnamaldehyde as antimicrobials into films against *Listeria monocytogenes* on contaminated ham and bologna. The effectivity of pectin films on ham was more than bologna (Ravishankar et al., 2012). Borges et al., (2016) evaluated the effect of free nisin and nisin-loaded pec-

tin nanoparticles on the growth rate of *Listeria innocua* in fermented pork meat model at different temperatures and fermentation conditions during 96 hours. Using both nisin and nisin-loaded pectin nanoparticles had significant inhibition effect on *Listeria innocua* (Borges et al., 2016).

Casings prepared with pectin or combination of gelatin/sodium alginate have been used for sausage production. Sensory analysis of sausages indicated that pectin casings were more preferred to gelatin/sodium alginate casings for sausages (Liu et al., 2007). Kang et al., (2007) studied the physicochemical, microbiological and sensory quality of irradiated cooked pork patties coated with pectin containing green tea leaf extract, found that lipid oxidation and microbial growth decreased in coated samples.

Pectin as Fat Substitution

Fat has an important role in meat products, including stabilizing meat emulsions, increasing cooking yield and water holding capacity, and improving texture. Fat also has an impact on binding, rheological and structural properties of meat products. However, high-fat diets are related to obesity, high blood pressure, cardiovascular and coronary heart diseases (Choi et al., 2016). Three different techniques can be applied to reduce the fat content in meat product formulations; changing the chemical composition of the carcass, using meat with low-fat content (manipulating animal raw materials or selecting lean meat) and using fat substitutes. Different fat substitutes have been used to ensure the functionality of fat. Substitutes derived from carbohydrates are generally hydrophilic because they have large number of hydrogen bonds with water, which forms an emulsion system on the targeted food tissue (Schmiele et al., 2015; Tufeanu and Tita, 2016).

Using pectin can be considered a feasible way to replace or reduce animal fat in meat products. Méndez-Zamora et al. (2015) studied the effect of substitution of animal fat with different formulations of pectin and inulin on chemical composition, textural, and sensory properties of emulsion type sausages and they recorded combined using of 15% pectin and 15% inulin could be used as animal fat replacer.

Effects of carrageenan and/or pectin gel (20%) were evaluated in low-fat beef frankfurters, frankfurters formulated with either carrageenan or carrageenan/ pectin gel had acceptable sensory scores (Candogan and Kolsarıcı, 2003). In another study, different fat replacers were investigated in low-fat frankfurters. According to the results, the emulsion stability of the batter was affected in different way due to the addition of different hydrocolloids. Samples including 1% pectin concentration had the highest cooking yield and water holding capacity (WHC) similar to control. TBA values decreased by addition of 0.5% pectin. Sensory analysis showed that one of

the closest samples to the control were 0.5% pectin by the consumers (Jafarzadeh Yadegari, 2015). Han and Bertram (2017) evaluated using pectin in fat-reduced pork meat model system; pectin added samples showed similar properties with the normal fat controls.

Replacing pork back fat with 35% olive oil resulted positive scores in sensory characteristics when 0.45% of pectin was added (Pappa et al., 2000).

The substitution of 5% mango peel pectin to fat content in Chinese sausage enhanced color and conserve the physical qualities as well as sensory attribute

Plant sources containing pectin were also used in meat industry. Apple pomace was used in different meat products such as chicken sausages (Yadav et al., 2016), buffalo meat sausage (Younis and Ahmad, 2015) and reduced-fat chicken sausages (Choi et al., 2016). All these studies showed an increment in cooking yield, WHC, emulsion stability. Çoksever (2009) investigated the effects of bitter orange albedo at different concentrations on the quality of naturally fermented Turkish style sausages and results were similar to pectin uses studies. Decreasing in weight loss and increasing in cooking yield were observed by the addition of 1% soy hull pectin in both fresh and frozen/thawed beef patties while TBARS value, statistically not affected and sensory scores were similar to control (Kim et al. 2016).

Pectin Assisted Phosphate-Free Meat Products

Phosphates are multi-functional and low-cost compounds. Phosphates enhance product yield by increasing water holding capacity, flavor, and texture as well as having antioxidant functions as a metal chelating agent. However, researches show that high phosphate intake has several health risks. Therefore, there is a trend for reducing the amount of use in formulations or replacing them with natural components that meet their effects (Tabak et al., 2019). In phosphate free meat products, natural calcium powders are widely used as alkaline ingredients to increase the pH value of products. Since low methoxy pectins form gels through calcium ions, low methoxy pectin is a promising additive for phosphate free meat product formulations. Besides this due to its water-binding property pectin can assist or enhance water-binding properties of phosphate reduced and phosphate free meat products (Ko et al., 2014; Cho et al. 2017; Cho et al. 2018).

Tabak et al., (2019) showed combined using of eggshell powder with pectin or carrageenan enhanced the technological and sensory qualities of phosphate free chicken patties.

Using Pectin in Restructured Meat Products

Pectin specially amidated low methoxy pectin (ALMP) have certain functionality in gel products. ALMP is an anionic carbohydrate that its anionic groups interact with the cationic groups of protein and hydrogen bonds consequently, increase the functional and mechanical properties of protein systems. Therefore, its addition can affect the gelling process, depending on concentration and raw matter (Ramirez-Suarez et al., 2017). Gel matrix is formed by binding small pieces of meat as a result of solubilizing myofibrillar proteins in restructured meat products. Addition of pectin can improve one or more properties of solid food (patties) such as cohesion, firmness, juiciness, freeze/thaw stability or texture resistance to shrinking during cooking (Deo et al., 2019). Urestia et al., (2003) used different concentrations of ALMP for producing restructured fish to improve the quality properties of surimi. Results observed that 5% of ALMP decreased expressible water content in restructured products. 1% concentration of ALMP recommended to improved texture and gel strength in restructured fish (Urestia et al., 2003). Ramirez-Suarez et al., (2017) evaluated the effects of different concentration ALMP pectin on quality properties of jumbo squid (*Dosidicus gigas*) muscle gels due to the low functionality of muscle proteins and

limited use. Texture was improved by adding ALMP. The highest WHC was shown in samples contain 3% ALMP compared to control (Ramirez-Suarez et al., 2017). As shown in Table 3 besides other properties, pectin has potential as a preservative, carrier of materials, and provides good rheological properties.

Health Benefits of Pectin

Pectin presents cholesterol-lowering, serum glucose-lowering and anti-cancer activities due to the specific structural domains, carrying bioactive properties. Pectin as soluble fiber decreases blood serum total cholesterol and low-density lipoprotein cholesterol, without having any effect on high-density lipoprotein cholesterol. Pectin has a good potential in food delivery, pectic-oligosaccharides obtained in a refined form from apple pomace presented prebiotic effects, which contribute to a healthy environment (Naqash et al., 2017). Pectin reduces blood sugar when consumed with food and studies have shown that pectin reduces the risk of some cancer types. For example, studies showed that extraction of pectin from citrus fruits prevents the formation of spontaneous prostate cancer cells in the body. These studies have also demonstrated the relationship between pectin and decreasing the risk of prostate cancer (Çoksever, 2009).

Table 3. Review of recent researches

Products	Applications	Results	References
Beef, chicken filet, shrimps and whiting (fish)	Edible film containing pectin for freshness	High sensitivity to gaseous amines and good standard degradation markers	Dudnyk et al., 2018
Raw-fermented sausage	Incorporation of 3% pectin	Similar rheological properties as the full-fat control	Zeeb et al., 2018
Emulsion-type sausage	Incorporation of 1.88% pectin	Higher in softening value	Zeeb et al., 2018
Meat batter	15% inulin and 15% pectin as a fat replacer	No effects on physical properties	Silva-Vazquez et al., 2018
Raw beef meat	Edible pectin-fish gelatin films	Improving oxygen barrier and delaying the lipid oxidation	Bermúdez-Oria et al., 2019
Meat sausage	LM pectin(4%)-encapsulated-fat	Preventing fat digestion and absorption/ improving texture	Santiaguín-Padilla et al.,2019
Hamburger patty (semi-finished products)	Alginate-pectin with whey protein concentrate	Inhibiting lipid oxidation, improving tenderness and better quality	Barybina et al., 2019
Fresh pork loin	Nanoemulsion loaded pectin edible coating	The best preservation and stability in 15 days 4°C	Xiong et al.,2020

Conclusion

Pectin is a water-soluble fiber and used in food industry as emulsifier, stabilizer, gelling, and thickening agent. Pectin presents in the cell walls of most plants, apple pomace and citrus peel are the two major sources of commercial pectin. Pectin extraction is a multiple-stage process in which hydrolysis and extraction of the pectin macromolecules from plant tissue and their solubilization takes place under the influence of different factors. Pectin has been used successfully for many years in food industry as a thickening, gelling agent and a stabilizer. Consumers have preferred products with natural additives while having the sensory properties of traditional food. Pectin is one of the promising natural additives for low fat meat products and also can be used in phosphate free formulations and emulsion type products due to the gelling and water binding ability. Pectin edible films incorporated with natural antimicrobials have potential application in preservation as active packaging materials for meat products.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Ethics committee approval: The authors declare that this study does not require ethical permission.

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Disclosure: -

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