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Pectin Extraction from Various Sources: A Literature Review

Vira Triyatna[1], Fetriyuna[2], Miftakhur Rohmah[1]*
[1]Department of Agricultural Product Technology, Faculty of Agriculture, Mulawarman University, Indonesia
[2]Department of Technology Industry Food, Faculty of Technology Industry Agriculture, University Padjadjaran, Indonesia
*Corresponding e-mail: miftakhurrohmah@faperta.unmul.ac.id

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Abstrak *- Plant cell walls include a complex polymer called pectin, which combines methoxyl with galacturonic acid to produce a gel. Applications for pectin are found in both the food and non-food industries. It is utilized as an edible coating, gel-forming, texture enhancer, stability enhancer, and appearance enhancer in the food industry. Pectin can be combined with other ingredients to make non-food products. For example, pectin, chitosan, carboxymethyl cellulose (CMC), and alginate can be used to make biocomposites for wound dressings. Other sources of pectin include aloe vera, biosorbent, banana peel, corn starch, albedo watermelon, nutmeg, pumpkin, and dragon fruit skin. The properties of pectin are generally determined by its yield, equivalent weight, methoxyl content, galacturonic acid content, and degree of esterification. The two most common methods used to extract pectin are chemical and mechanical. Typically, chemical processes use solvents and mechanical techniques to combine liquid and solid components.*

Keywords: *Pectin, extraction, application*

INTRODUCTION

Plant cell walls include a complex polymer called pectin. A hydrocolloid substance that is frequently utilized in the food and beverage sector is pectin (Cahyanto, 2017). Pectin is utilized as a stabilizer in the food, beverage, and pharmaceutical sectors because it can form colloids and gels in solution (Puspitasari, 2017). According to Almatsier's (2014) research, pectin is a water-soluble fiber that has the ability to lower liver and blood cholesterol levels. Bioactive characteristics of pectin include anti-tumor, anti-inflammatory, antioxidant, anti-diabetic, anti-cancer, and chemopreventive effects. Additionally, it preserves the stability of plant tissues and cells and functions as an adhesive. Pectin contains galacturonic acid and methoxyl, which make it form a gel. High methoxyl pectin is generally used in food products like pudding, jam, and jelly. Conversely, low-methoxyl pectin is frequently employed as a coating agent (Megawati, 2014). The primary structural component of pectin is galactofuronic acid. The structure and texture of pectin are influenced by the amount of galacturic acid present (M. Hindun Pulungan, 2015). Applications for pectin are found in both the food and non-food industries. It is employed in the food and beverage industry as an edible coating and to enhance the texture, stability, and appearance of goods. In the non-food sector, on the other hand, it finds application in the pharmaceutical business for the production of medications, bandages, and cosmetics (Susanti et al., 2017).

Previous research has proven that several food sources can be used as ingredients for making *edible films,* such as aloe vera, biosorbents, banana peels, corn starch, durian albedo pectin, watermelon albedo pectin, grapefruit, grapefruit peel (A et al., 2024)and dragon fruit skin. Food viscosity, stability, texture, and appearance are all influenced by pectin. According to Nurhayati et al. (2016), pectin is also used to create gels and stabilize fruit juices, jellies, and marmalade. According to research by Wanda et al. (2023), pectin and chitosan were combined with additives to create wound dressings that may enhance their chemical and physical characteristics. The bubble cavity will expand and the number of bubbles on the wound dressing's surface will decrease as more additives are added. This is due to the enhanced properties of additives. Extraction is a method for separating one component of a mixture from a solid or liquid using a solvent (Widjanarko, 2017). The level of effectiveness of extraction of a compound due to a solvent depends on the solubility of the compound in the solvent. This is by the principle *that dissolves* meaning that compounds will dissolve in solvents of the exact nature. In pectin extraction, changes occur in pectin compounds caused by the protopectin hydrolysis process. This process causes protopectin to change into pectinate (pectin) by heating in acid at a specific temperature and extraction time. If hydrolysis continues, the pectin compound will turn into concentrated acid (Hossain et al., 2024).

There are several techniques for extracting pectin, one of which is the use of hydrochloric acid with microwave-assisted extraction (MAE) (Prasetyo et al., 2023). Nadir & Risfani (2018) discovered the ideal ingredient-to-solvent ratio when extracting cocoa shells using the MAE method. This resulted in changes to the solvent-to-yield ratio, water content, ash content, equivalent weight, methoxyl content, galacturonate content, and degree of esterification, all of which met IPPA's quality standards. Purwanto (2014) isolated the zinggiberene component from ginger oil and found similar results. The extract yield decreased as a result of this extraction at a greater power. According to Purwanto (2014), the energy in MAE affects the rate of the extraction process and the pectin's evaporation.

MATERIALS AND METHODS

A literature review methodology was used to comprehend the effects of pectin extraction from diverse sources that are now available. Keyword combinations like "Pectin" and "Extraction" and "Application" and "Source" were utilized in the literature search. The inclusion criteria that determined the selection of these documents were: (1) full-text publications from online journals; (2) publishing in English or Indonesian; (3) article relevance to the research objectives; and (4) research on pectin extraction. The last ten years' worth of literature from the Journals-SINTA database, Google Scholar (scholar.google.com), and Scopus (Elsevier. com) were searched for using the keywords that were chosen. Every article that matches the search parameters for the literature is compiled into a table, and pertinent research findings are then used to drive the discussion.

RESULT AND DISCUSSION

Pectin is used in terms of viscosity, stability, texture, and appearance of food (Nurhayati et al., 2016). Pectin is also used to form gels and stabilizers in fruit juices and as an ingredient for *jelly*, jam, and marmalade. According to research, pectin is applied to make *edible films* for products, including wrapping for sausages, fruit, and candy. In Suryati's (2021) research, chitosan has interesting properties, making it suitable for use in biomedical and pharmaceutical applications, where it is considered a significant antimicrobial agent for wound healing. Pectin is employed as a stabilizer in the food and pharmaceutical industries (Devianti et al., 2020). Putri et al. (2020) found that pectin serves as an adhesive and preserves the stability of plant cell tissue, among other uses. Pectin is also useful as a gelling agent, fruit juice stabilizer, key component in fruit jam, and extra thickener in fermented foods and dairy products. Pectin is a stabilizer and emulsifier utilized in food goods, pharmaceutical substances, and cosmetics across multiple industries (Susanti et al., 2017).

Tabel 1. Summary of pectin extraction applications

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
	Dry shelled corn	This research uses a sodium bicarbonate solution.	This study concludes that the Srikandi Putih variety obtained the highest starch yield and starch content and the Palakka and Krisna varieties the lowest.	(Firmansyah et al., 2014)
	Jackfruit Waste	Ammonium, sodium hexametaphosphate, oxalate, and diluted sulfuric acid.	Waste jackfruit has the potential to yield highly esterified pectin. Without significantly altering the pectic structure, the extraction conditions and type of solvent had a considerable impact on the yield and physicochemical attributes.	(Begum et al., 2014)
	Grapefruit peel	Subcritical water, hot water extraction, and the help of a chelator (citric acid)	The Mw and DM of pectin were enhanced and lowered, respectively, by chelator-assisted extraction and subcritical water treatment. Citric acid extraction can be used to produce pectin with high HG and low RG-I domains. Bacteroides and Prevotella 9 were shown to be more abundant in relation to grapefruit pectin, which also induced the synthesis of SCFAs, particularly acetic acid. The pectin derived from subcritical water extraction has the potential to be more	(Kaya et al., 2014)

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
			fermentable and prebiotic. One potential new tool for influencing gut microbiota in the direction of a functionally sound diet is grapefruit pectin.	
	Banana Peels and Banana Bunches	Strong Acid (HCl)	The water content ranges from 8.14 to 9.05%, the whiteness from 26.94 to 29.27, and the pectin content from 1.52 to 5.39%.	(Nurhayati et al., 2016)
	Albedo Watermelon	The research was carried out using an extraction method using Hal acid and CH_3COOH solvents.	With results ranging between 9.4590-11.2635% for HCl solvent and 6.5960-7.4120 % for CH_3COOH solvent, it can be concluded from this study that the albedo pectin content of watermelon obtained from the extraction procedure using HCl solvent is greater than that using CH_3COOH solvent.	(Maulani et al., 2016)
	Banana and mango peels	Acid (1M H_2SO_4)	Utilizing the mango peel industry to make pectin will solve the waste disposal problem and save the country's foreign exchange by reducing pectin imports.	(Girma & Worku, 2016)
	Citrus peels (Lemon, lime, orange, and grapefruit)	Hard nitric acid, mild nitric acid, and oxalic acid.	The analysis results show that temperature, extraction time, and pH significantly affect the characteristics of grapefruit peel pectin, while the effect is not	(Girma & Worku, 2016)

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
			significant on peel pectin.	
	Durian Skin	Ethanol	The right type of solvent is obtained by H_2SO_4, with an optimum point of 5 minutes and a ratio of 1:20.	(Susanti et al., 2017)
	Orange peel	Citric Acid	The study comes to the conclusion that the water content, pH, lowered sugar, physical color, and sensory evaluation of the jam were all significantly impacted by the addition of orange peel pectin and sucrose.	(Mas'ula, 2018)
10.	Banana peel waste	Citric Acid	This study's conclusion is that the pectin with a methoxyl value less than 6.7% and a percentage DE less than 50% is categorized as low methoxyl pectin.	(Devianti et al., 2020)
11.	Orange	Citric acid	Following its biochemical characterisation, crude pectinase from *Geotrichum candidum* AA15 can be used in industry, particularly in food-related operations where the enzyme must be active at room temperature.	(Ahmed & Sohail, 2020)
12.	Durian skin and kepok banana skin	Sulfuric acid	This research concludes that banana peel pectin is more effective than durian peel pectin as an adsorbent for Pb metal.	(Hanifah et al., 2021)

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
13.	Dragon Fruit Skin	Citric acid	The highest yield was obtained from variations in the concentration of 1 N, temperature 60°C, and time 60 minutes of 15.67%, while the equivalent weight value did not meet IPPA standards. Pectin extracted from 0.5 N at 60°C for 30 minutes produces a stiffer, less elastic polymer. It has a greater thickness than pectin extracted from 0.5 N at a temperature of 70°C for 60 minutes.	(Kurniawan & Adenia, 2022)
14.	Breadfruit Skin	In this research, breadfruit skin was used using chemicals using 96% ethanol, HCI, *n*-hexane technical NaOH (pa), distilled water, NaCI, NaOH, Pb $(NO_3)_2$, and $CuSO_4$.	This study concludes that there are differences in the ability to vary the weight, length, and time of Pb^{2+} and Cd^{2+} using breadfruit peel pectin.	(Anwar et al., 2022)
15.	Dragon Fruit Skin	This study used 2.5% citric acid as a solvent for the extraction and characterization of pectin, as well as proximate testing of the inner pulp of red dragon fruit peels.	According to the study's findings, CMC can be substituted for pectin extract and the inner pulp of red dragon fruit peel in ice cream recipes.	(Kho et al., 2022)
16.	Cocoa Fruit Shell	Hydrochloric acid	The ratio of materials using solvent (w/v) influences the pectin yield with the highest yield of 5.74%, namely at a ratio of 1:20 with pectin characteristics.	(Prasetyo et al., 2023)

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
17.	Grapefruit Peel	Eutectic Solvent (DES)	According to the study's findings, DES is a highly successful pectin extraction agent. In the food sector, pectin derived from grapefruit peel is a natural emulsifier that can be used.	(Salazar Ripoll & Hincapié-Llanos, 2023).
18.	Grapefruit peel	Citric Acid	An effective method for obtaining high-quality pectin with superior qualities, such as greater thermal stability and a finer structure and particle size distribution, is the AHWE, PUUAE process.	(Wani & Uppaluri, 2023)
19.	Young “Fuji” apple	1M NaOH and alkaline method	The results show that TAP is rich in RG-I areas and an LMP. TAP has much better gel strength, water-holding capacity, and a dense network structure than other gelling materials.	(Wang et al., 2023)
20.	Watermelon Rind	Acetic Acid	The study’s findings indicate that watermelon rinds can produce pectin in a suitable amount and quality as an alternate source	(Mamiru & Gonfa, 2023)
21.	Passion fruit skin	Authentic solvent, L-proline: citric acid (Pro-CA)	According to our findings, Pro-CA is a very effective and environmentally acceptable solvent for removing valuable chemicals from agricultural byproducts.	(Huo et al., 2023)
22.	Grapefruit Peel	Organic Citric Acid	The results showed that pectin can be commercially extracted from grapefruit	(Hossain et al., 2024)

No	Source of Hydrocolloids	Solvent Used	Characteristics of the Pectin Products Produced	Reference
			peels via the MAE technique, which increases its economic attractiveness.	
23.	Orange peel	Green Solvent	The results showed that rapid pectin extraction could be achieved using a green solvent and *microwaving* orange peels.	(Turan et al., 2024)
24.	Fruit and Vegetables	Extraction in acids, microwaves, ultrasound, enzymatic media, and aqueous biphasic extraction	The Systematic Literature Review (SLR) results revealed that extraction methods in acid, microwave, ultrasound, and enzymatic media positively affect the results and are widely used.	(Girón-Hernández et al., 2023)
25.	Apple pomace	Mineral Acid	Given that the extracted pectin has a higher cytocompatibility than commercial pectin, the type of acid only has an impact on the extracted material's potency.	(Liu et al., 2024)

Various studies have evaluated the potential of natural materials as pectin sources and their applications in both food and non-food industries. For example, the Srikandi Putih corn variety produces a high yield of flour with good quality. The extraction method used also allows for a comprehensive analysis of the physicochemical and functional properties of the starch. However, manual embryo separation and the use of cloth filters result in partial starch loss (Firmansyah, suarni & Aqil, 2014). In addition, fruit waste such as jackfruit and red dragon fruit peels have been identified as a high-methoxyl pectin source. In jackfruit waste, the type of solvent and extraction conditions significantly affect the quality of the pectin obtained. Sodium hexametaphosphate provides the highest yield, but has low solubility and viscosity, making the resulting pectin inferior to commercial pectin. The type of acid and pH also play important roles in determining pectin quality, as seen in citrus pectin extraction. Mild oxalic acid produces high molecular weight pectin, while nitric acid produces low molecular weight pectin with fewer RG-I chains (Begum et al., 2014).

Water-based extraction methods are considered environmentally friendly and capable of producing high-purity pectin. However, these extracts tend to be darker in color and still contain traces of proteins and polysaccharides. Conversely, hydrochloric acid has been proven more effective than acetic acid in extracting pectin, especially at 80°C, pH 2.6, for 90 minutes. Nevertheless, low pH and high temperatures increase the risk of pectin degradation, thus requiring strict process control (Kaya et al., 2014). Mango peels and durian albedo have also shown potential as raw materials for pectin. In mango peels, excessive extraction temperature and time can reduce quality and increase costs. Meanwhile, the MAE method using 1N H_2SO_4 on durian albedo can extract pectin quickly and efficiently, provided that power and exposure time are carefully controlled to prevent degradation of active compounds.

In product development, the best ginger jam formulation was obtained from a specific ingredient combination (P2S2), although the results were still influenced by panelist subjectivity, and shelf-life testing had not yet been conducted. Pectin extraction from banana peels using citric acid effectively produced low-methoxyl pectin, although this pectin had low purity and a brownish color, especially if the solvent volume was too high. Red dragon fruit peel serves not only as a pectin source but also in the production of biodegradable plastics and as a CMC substitute in ice cream. In these applications, pectin improves viscosity and antioxidant activity, but challenges include protein content, low overrun, and limited extract shelf life. Pectin from breadfruit peel has also been proven effective as a biosorbent for heavy metals, adding value to organic waste as a functional material.

MAE with hydrochloric acid effectively extracts pectin from cocoa husks, but the ratio of material to solvent must be maintained to preserve quality (Prasetyo et al, 2023). In general, each extraction method has its advantages and disadvantages. Acid hydrolysis results in high yields, but non-conventional methods such as MAE, UAE, and MW-DES can produce pectin with better functional quality. A comparative study between PUUAE and AHWE methods showed that PUUAE was superior in extracting pectin from pomelo peels. Extraction methods also affect pectin fermentability and molecular weight, as observed in pomelo peel extraction, which has proven beneficial in modulating gut microbiota and is suitable as a functional food ingredient. Pectin extraction from watermelon rinds using acetic acid produces high-quality pectin, and the use of RSM has proven effective in optimizing the process (Salazar Ripoll & Hincapié-Llanos, 2023). The extraction of pectin and phenolic compounds from passion fruit peel using DES (Pro-CA) also yielded high results and quality, although challenges remain due to high viscosity and potential overestimation of TPC.

Comparisons among methods show that MAE yields the largest amount of pectin, UAE is more efficient, and conventional heating, while affordable, is relatively energy-intensive. All these methods produce high-methoxyl pectin (HMP) of good quality. MW-DES is considered environmentally friendly and efficient in extracting pectin from citrus peels, though further testing is still needed regarding product purity and industrial feasibility. Finally, alkali extraction assisted by ultrasonography is fast and efficient in extracting RG-I-rich pectin from young apples. This method offers high efficiency and favorable gelling properties, although it produces pectin with low molecular weight and degree of esterification due to the effects of alkaline conditions and ultrasonic cavitation. This method offers high efficiency and favorable gelling properties, although it produces pectin with low molecular weight and degree of esterification due to the effects of alkaline conditions and ultrasonic cavitation (Wanda et al., 2023).

CONCLUSION

Different extraction conditions have a considerable impact on the properties of the pectin produced, including pectin yield, equivalent weight, methoxyl content, galacturonic acid content, and degree of esterification, according to many results reported in the literature. In the food business, pectin is used to make jelly, jam, and marmalade, as well as to improve the viscosity, stability, texture, and appearance of food. It also forms gels and stabilizers in fruit juices. In the meantime, high-quality outcomes are obtained from biocomposites for wound dressings that contain chitosan, pectin, carboxymethyl cellulose (CMC), and alginate as their primary constituents. Additionally, the MAE approach produces the finest outcomes.

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