

ICOPMAP SPECIAL EDITION

REVIEW

# Utilisation of plant-based pectin for halal hard capsule shells as an alternative to pork gelatin

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## Keywords

Capsule shell  
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## Abstract

**Background:** Concerns about halal compliance have arisen with the use of porcine gelatin in capsule shells, particularly among Muslim consumers. Alternative materials are needed as demand for halal products grows in the pharmaceutical and supplement industries. Pectin, a natural plant-derived polysaccharide, can replace porcine gelatin in capsule production. **Objective:** This study aims to conduct a literature review to determine the potential of plant-derived pectin as a material for hard capsule shells. **Method:** The research method employed was a narrative review, which analysed, assessed, and summarised the existing published literature while also seeking innovations not previously discussed. The literature databases used included PubMed, Google Scholar, Scopus, and Elsevier. **Result:** The results showed that pectin has good gelling properties, adequate stability under various storage conditions, and high compatibility with multiple pharmaceutical active ingredients. Pectin also meets halal requirements and can be processed into functional capsule shells. Pectin from multiple plants and fruits can be used for hard capsule shells. **Conclusion:** Plant-based pectin could serve as a halal alternative to gelatin for capsule shells. However, further research is needed to overcome technical challenges for its broader use in the pharmaceutical industry.

## Introduction

The pharmaceutical preparation that is quite popular and favoured by many people is the capsule (Riferty *et al.*, 2017). Capsules are pharmaceutical preparations that contain medicinal substances within a shell, typically made from gelatin (Suparman, 2019). The capsule shell serves as a container used to protect, encase, and cover pharmaceutical drugs, making them easier for the body to swallow and process. Capsule shells are typically made from gelatin; however, with the advancement of science, natural materials can now be utilised as raw materials for producing hard capsule shells (Indonesian Ministry of Health, 2014).

Gelatin is a polymer composed of a mixture of heterogeneous polypeptides obtained from the hydrolysis of collagen in animal connective tissue. The primary sources of gelatin are found in pig and bovine bones, which function as gelling agents in the production of capsule shells. The halal status of medicinal capsules must be identified because they

might be made from non-halal ingredients, ensuring they are safe for consumption by Muslims. Hard capsule shells are typically made from gelatin with a relatively high gel content. In contrast, soft capsule shells are usually made from sugar, gelatin, water, and additional plasticisers such as glycerin, polyhydric alcohols, or sorbitol. The primary source of gelatin is pigs, with 44% derived from pigskin, 28% from bovine hide, 27% from bovine bones, and the remaining 1% from other sources. This results in a total global production of gelatin reaching 326,000 tons (Aris *et al.*, 2020).

Capsules made from pig gelatin represent the most significant proportion of usage, attributed to their accessibility and availability. Although they are not halal, incompatible with hygroscopic materials, prone to brittleness in humid environments, and soften when exposed to high-temperature environments. An alternative material to replace pig gelatin as a capsule shell is to utilise pectin compounds from various plants. Pectin is a chemical compound classified as a

carbohydrate, alongside gum arabic, starch, alginates, and other modified carbohydrates, making it a viable innovative material for producing hard capsule shells (Agustin *et al.*, 2021).

Many plants contain pectin compounds that can be used as raw materials for making capsule shells from seeds, fruit, and fruit peels. Watermelon, cocoa, aloe vera, coffee, jackfruit, konjac tubers, salak seeds, cactus, and seaweed contain pectin compounds that can substitute pig gelatin in halal hard capsule shells (Riferty *et al.*, 2017; Suparman *et al.*, 2019).

Jackfruit is a plant from the Moraceae family that can be easily found in Indonesia. The brown-coloured pectin content in jackfruit peel is 5.74% (Arollado *et al.*, 2018). Besides pectin, jackfruit peel contains polysaccharides and glucomannan, which can form edible film-hard capsule shells (Winarti *et al.*, 2012). The pectin content in jackfruit peel can be efficiently utilised as an edible coating for capsule shells, as jackfruit is abundant (Mukti *et al.*, 2024).

Given the potential of pectin, the researchers conducted a literature review on the utilisation of pectin compounds from plants as raw materials for capsule shells that are safe, effective, halal, environmentally friendly, and have a disintegration time following the standards set by the Indonesian Pharmacopoeia.

This literature review aims to gather information from various reference sources related to innovations in the production of halal capsule shells from plant pectin. The benefits of this literature review include enhancing knowledge and information regarding alternative materials for capsule shells made from pectin, disintegration tests, and their formulations.

## Methods

The literature selection method used in this review article is a narrative review. The following steps were taken in the narrative review method.

### Literature search approach

A specific and clear research topic or question was identified. In this case, the chosen topic is the utilisation of plant-based pectin for hard capsule shells. Literature databases, including PubMed, Google Scholar, Scopus, and ScienceDirect, were utilised for the search. Relevant keywords related to the topic were used to identify reference sources. The keywords used were "alternative plant-based pectin for capsule shells". An evaluation and examination of the reference sources found in the journals was conducted to identify additional relevant sources (manual search or snowballing).

### Inclusion and exclusion criteria for reviewed articles:

Explicit inclusion and exclusion criteria were established in accordance with the research objectives. These criteria include type of publication (peer-reviewed journals, dissertations, theses), year of publication, language, research methods, and availability of full-text access.

### Article selection and evaluation process

An initial screening was conducted based on titles and abstracts to identify journals that met the inclusion criteria. The time limit used was the last 10 years of reviewed articles. The filtered reference sources were read and evaluated according to the inclusion and exclusion criteria. After completing this process, the most relevant, high-quality, and significant articles were selected for inclusion in the literature review.

## Results

The results of the review, based on scientific articles and journals, are presented in Table I.

**Table I: Reviewed articles in hard capsule shells**

Author's name	Title of the Research	Method	Conclusion	Differences/Similarities
Riferty <i>et al.</i> , 2017)	Characterization of albedo pectin powder of watermelon ( <i>Citrullus lanatus</i> (Thunberg) Matsum. & Nakai) as an alternative	Sampling was followed by pectin extraction using the reflux method. Subsequently, precipitation, washing, and drying processes were carried out. The pectin was then	Pectin from watermelon albedo yielded 9.24%, indicating its potential as a pectin source. Therefore, watermelon albedo can be used as a pectin source for hard capsule shells.	<b>Similarity:</b> Pectin from cocoa fruit peels is effective as a base material for hard capsule shells, being cheaper and safer than gelatin. <b>Difference:</b> The type and concentration of solvents used for extraction differ. The procedures

Author's name	Title of the Research	Method	Conclusion	Differences/Similarities
	material in manufacture of hard capsule shell.	characterized, and capsule shell formulation was performed.		for pectin precipitation and washing may vary. The composition and proportion of materials in the capsule shell formulation are different.
Mahardika <i>et al.</i> , 2021	Synthesis and characterization of capsule shells from non-gelatin grass jelly leaves-seaweed as drug delivery system material.	Using an extraction method to obtain the necessary active components.	This study successfully synthesised non-gelatin capsule shells using a combination of green grass jelly leaves and seaweed. The synthesis results showed that the capsule shells could be well-formed and possessed the desired characteristics for drug delivery applications.	<b>Similarity:</b> It emphasises the potential application of capsule shells in drug delivery systems, enhancing therapeutic effectiveness and meeting the needs of consumers who avoid animal-based gelatin. <b>Difference:</b> The resulting capsule shells have different characteristics, such as strength and degree of swelling, depending on the materials and methods used.
Suparman <i>et al.</i> , 2019	Characterization and formulation of capsule shells from cocoa fruit peel pectin flour ( <i>Theobroma cacao L.</i> ).	Utilising extraction, formulation, and moulding methods from cocoa fruit peel pectin.	Pectin from cocoa fruit peels is effective as a base material for hard capsule shells, being cheaper and safer than gelatin.	<b>Similarity:</b> Both pectin and gelatin function as shell-forming materials that protect the contents of the capsule. <b>Difference:</b> Pectin offers a cheaper and safer (halal) alternative. Gelatin is unsuitable for all consumers, particularly those who avoid animal-based products.
Hidayana <i>et al.</i> , 2017	Characterization and production of capsule shell from aloe pectin ( <i>Aloe vera</i> (L.) Burm. F) as an alternative material of capsule shell production.	Using the extraction method from aloe vera leaves with heat and acid solvent (HCl) to convert protopectin into water-soluble pectin for capsule shells.	Pectin from aloe vera leaves can be used as a natural alternative for making capsule shells compared to gelatin.	<b>Similarity:</b> Both are used in the pharmaceutical industry for the production of drug formulations in capsule form. <b>Difference:</b> Aloe vera pectin is derived from the extraction of aloe vera leaves, whereas gelatin is derived from animal collagen.
Rizal <i>et al.</i> , 2023	Capsule shell formulation from jackfruit peel pectin ( <i>Artocarpus heterophyllus lam</i> ) and capsule disintegration time test.	Using the extraction method on a hot plate at 85°C for 120 minutes with a stirring speed of 600 rpm using a magnetic stirrer.	The pectin extracted from jackfruit peel showed good potential as a raw material for capsule shell production.	<b>Similarity:</b> The capsule shell material serves to mask the unpleasant taste of medicine and maintain the stability of pharmaceutical preparations. <b>Difference:</b> Pectin is derived from plant sources, specifically from jackfruit peel and other fruits, while gelatin is obtained from animal sources, usually from collagen extracted from skin and bones.
Amin & Alam, 2020	Characterization and production of hard capsule shells from green grass jelly extract ( <i>Premna oblongifolia</i> ).	Using the extraction method with the assistance of a Shimadzu UV-1800 UV-Vis spectrophotometer.	The pectin extracted from green grass jelly leaves weighed 14 grams and had a greenish-brown colour. The moisture content and ash content of the resulting pectin met the quality standards set by the <i>International Pectin</i>	<b>Similarity:</b> The use of green grass jelly leaves as a source of pectin is a natural alternative that can reduce dependence on synthetic materials, making it more environmentally friendly and safe for health. <b>Difference:</b> The quality of pectin may vary depending on growth

Author's name	Title of the Research	Method	Conclusion	Differences/Similarities
			<i>Producers Association</i> (IPPA), making it suitable for use in preparing hard capsule shells.	conditions, harvest time, and extraction methods, which can affect the consistency of the results.
Khairunnisa et al., 2019	Characterization of pectin from robusta coffee fruit peel ( <i>Coffea canephora</i> Pierre ex A.Froehner) in the manufacture of hard capsule shell.	Using the extraction and reflux method with aquades as the solvent.	Pectin can be used as an alternative to gelatin in the production of hard capsule shells, with good specifications for pharmaceutical applications.	<b>Similarity:</b> Pectin from Robusta coffee fruit peels can serve as an alternative material to gelatin in the production of hard capsule shells, demonstrating flexibility in pharmaceutical industry applications. <b>Difference:</b> Slightly High Equivalent Weight: The equivalent weight of pectin, at 808.27 mg, slightly exceeds the established standard, which may affect the consistency and quality of the final product.
Syihabuddin et al., 2011	Optimization and characterization of pectin from cacao fruit peel ( <i>Theobroma cacao</i> L.) as alternative material for manufacturing of hard capsule shell	The method applied is Microwave-Assisted Extraction (MAE). This method utilizes microwave energy to enhance extraction efficiency and increase the yield of pectin obtained.	The characterization results of the pectin meet the quality standards set by the <i>International Pectin Producers Association</i> (IPPA).	<b>Similarity:</b> Cocoa fruit peels contain pectin that can be utilised as a material for hard capsule shells. <b>Difference:</b> The quality of the pectin produced can vary depending on the source of the cocoa fruit peels used, including factors such as variety, growing conditions, and initial processing methods.
Rosmalasari, 2018	Fabrication of halal hard capsule based on porang tube ( <i>Amorphophallus oncophillus</i> )	The extraction method was used.	The research successfully produced halal capsule shells made from porang tubers by utilizing glucomannan extracted from the tuber. The addition of papaya leaf extract to the glucomannan gel had a positive effect on the thickness of the resulting capsule shells.	<b>Similarity:</b> Capsule shells made from porang tubers meet halal criteria, making them suitable for consumers who prioritise halal aspects in pharmaceutical products. <b>Difference:</b> Capsule shells made from porang tubers tend to be more brittle compared to gelatin-based capsule shells, which can affect the durability and integrity of the capsules.
Abdullah, et al., 2023	The making of hard capsule Shells from salak ( <i>Salacca zalacca</i> ) glucomannan seeds with the addition of moringa fruit $\alpha$ -amylase enzyme	Extraction methods were used. Data were analyzed using FTIR spectroscopy, gel solution viscosity tests, and drug release time in water and acidic solutions. This method aims to evaluate the effect of adding $\alpha$ -amylase enzyme on the quality of the solution and hard capsule shells made from salak seed glucomannan.	The resulting capsule shells showed significant differences; without the $\alpha$ -amylase enzyme, the shells were round and elongated, with blunt ends, thick, rough surfaces, and dark brown in colour. With the addition of the enzyme, the shells became smoother and thinner. The addition of $\alpha$ -amylase enzyme had a positive effect, producing thinner and smoother shells and improving disintegration efficiency in solution.	<b>Similarity:</b> The addition of the enzyme improves the quality of the shells, making them thinner and smoother, and enhances disintegration efficiency. <b>Difference:</b> Additional $\alpha$ -amylase enzyme is required to produce more efficient hard capsule shells.

Author's name	Title of the Research	Method	Conclusion	Differences/Similarities
Mahardika, et. al, 2022	Synthesis and characterization of non-gelatin capsule shells from aloe vera ( <i>Aloe vera</i> L) carrageenan.	The methods used are extraction and heat-assisted maceration.	This study demonstrates that aloe vera pectin can be used as a base material for non-gelatin capsule shells that meet performance standards.	<b>Similarity:</b> Pectin has properties suitable for pharmaceutical applications. The capsule shells exhibit good disintegration and dissolution times. This opens opportunities for the formulation of drug products based on natural materials. <b>Difference:</b> The pectin production process results in low yields. The research may not cover all evaluation parameters. Not all drugs can be formulated with pectin.
Mahardika, et. al, 2023a	Synthesis and characterization of halal capsule shells from konjac tuber ( <i>Amorphophallus oncophillus</i> ) with variants of papaya leaf extract	The method used is extraction.	Overall, this study shows that konjac tuber can be utilised as an effective base material for producing halal capsule shells, with characteristics meeting pharmaceutical standards.	<b>Similarity:</b> High glucomannan content results in optimal viscosity of the capsule shells. <b>Difference:</b> Physical properties such as mechanical strength and stability of the capsule shells need to be improved for optimal shell performance.
Mahardika, et al. 2023b	Synthesis and characterization of non-gelatinized capsule shells from seaweed ( <i>Euchemma cottonii</i> ) and koboi cactus ( <i>Cereus peruvianus</i> ) for drug delivery systems.	Extraction and drying methods.	Pectin from cactus and seaweed can be used as a halal capsule shell substitute.	<b>Similarity:</b> Can be used in various drug formulations. <b>Difference:</b> Pectin quality varies, affecting consistency. Complex analysis procedures can impact time and cost.

Table II presents the characteristics of pectin and gelatin. Pectin and gelatin differ in their sources, gel

properties, tensile strength, transparency, biodegradability, and availability.

**Table II: Pectin and gelatin characteristics**

Characteristics	Pectin	Gelatin
Source	Plants (skin, fruit, tuber )	Animals (bones, skin)
Gel properties	Formed at low pH, requires sugar	Formed at a low temperature, no need for additional sugar
Tensile strength	More low compared to gelatin	Taller compared to pectin
Solubility	Dissolves in hot water	Dissolves in hot water
Transparency	Lack of transparency compared to gelatin	More transparent compared to pectin
Biodegradability	Tall	Tall
Availability	Easy to obtain, many sources of experience	Availability depends on the source animal
Halal/vegan	Halal and vegan	Not halal and not vegan

## Discussion

### **Comparison of capsule shell characteristics from pectin and gelatin**

In general, both pectin and gelatin have the potential to form films or shells that can be used as capsules. However, both have different characteristics, which will affect the performance and application of the capsules.

Based on Said's research (2014), capsule shells were produced from goat skin gelatin using a formulation that included 10 g of material, 9 g of glycerol, 22.4 mg of MgCO<sub>3</sub>, 5.5 mg of tapioca starch, 72.1 mg of sago starch, and 30 ml of distilled water. The resulting disintegration time was longer (65.41 minutes). The difference in disintegration time could be attributed to the varying components used in the capsule shell composition. The goat skin gelatin capsule shell contained almost 80% filler components, primarily starch (sago and tapioca), which were more dominant than MgCO<sub>3</sub>, significantly affecting the disintegration time of the capsule. This resulted in a longer disintegration time for the goat skin gelatin capsule shell when tested at a temperature of 37±0.5°C.

In research conducted by Syihabuddin and Kurniaty (2019), the formulation of capsule shells from chocolate fruit skin flour (*Theobroma cacao* L.) as a material for making hard capsule shells used 0.78 grams of pectin, 5.00 grams of carrageenan, and distilled water up to 100 ml. The resulting capsule weighed 96.30 mg, with a total length of 22.05 mm, a body diameter of 7.24 mm, and a cap diameter of 7.65 mm. The disintegration time obtained was 21 minutes and 34 seconds.

In Riferty's research (2017), capsule shells were produced from watermelon rind pectin (*Citrullus lanatus*), containing 13% pectin. The best hard capsule shell formula was F6 (2.6% pectin, 10.04% CMC-Na, 0.08% CaCl<sub>2</sub>, and 86.92% distilled water), resulting in brown-coloured capsules with a hard texture, no odour, and cloudy clarity. The specifications of the capsule shell met the standards of PT Kapsulindo Nusantara, with a weight of 89.3 grams, a body diameter of 7.32 mm, and a cap diameter of 7.68 mm. The disintegration time was 20 minutes and 45 seconds. According to the Indonesian Pharmacopoeia, 5th edition, an appropriate disintegration time is 15 minutes or less than 30 minutes.

### **Source natural pectin and its quality**

Several sources naturally rich in pectin, among others:

- Skin fruit: apple, orange, lemon, mango
- Wall cell plants: beets, carrots

- Alga

Pectin from different sources has different characteristics. For example, pectin from the skin of an orange generally has a high methyl ester content, so it requires higher sugar levels to form a gel. Pectin from apples contains more methyl esters and is frequently used in the production of jam.

To determine the source of pectin, one needs to consider several factors:

- Viscosity: Pectin with proper viscosity will produce a strong and flexible capsule.
- Degree of methylesterification: Influences gel strength and interactions with other components.
- Contents sour galacturonic acid: Influence gel properties and stability of the capsule.

### **Specification of shell the ideal capsule**

Shell the ideal capsule should fulfil a number of criteria:

- Strength mechanics: Strong enough to protect the contents capsule during the production and distribution process.
- Resilience to humidity: Prevent the Contents capsule from absorbing moisture and damage.
- Speed disintegration: Dissolve fast inside the body for release of contents from the capsule.
- Biocompatibility: Does not interact negatively with capsule contents or the human body.
- Aesthetics: Has an attractive appearance and is easy to swallow.

### **Testing results of pectin**

Results of a review of various studies indicate that pectin has considerable potential as a material replacement for gelatin in the manufacture of shell capsules. Several studies have successfully produced capsule pectin with good mechanical properties, which is biodegradable and can be customised to meet specific needs.

However, further studies are required to optimise the pectin capsule formulation. Several aspects need to be investigated more thoroughly, which are:

- Influence type pectin on the characteristic physical and chemical capsules.
- Interaction between pectin with fillers and active substances.
- Stability term long capsule pectin.
- In vivo evaluation of drug bioavailability in pectin capsules.

## Conclusion

This literature review comprehensively examines the potential of plant-based pectin as an effective halal alternative to pork gelatin in capsule shell production. Pectin, a natural polysaccharide derived from plants, offers a promising solution to meet this need.

The review suggests that pectin from plants can be used as a substitute for pork gelatin in the production of hard capsule shells. Jackfruit, cocoa, green cincau leaves, coffee, and several other plants contain pectin compounds in varying percentages, making them suitable for hard capsule shells. The resulting capsules exhibit good physicochemical properties, including excellent gelling ability, adequate stability under various conditions, and compatibility with pharmaceutical active ingredients. Additionally, pectin meets halal requirements, making it a viable and ethical alternative for a broader market.

However, despite its significant potential, there are still technical challenges, such as optimising the manufacturing process and improving resistance to extreme environmental conditions. Further research and technological development are needed to ensure that pectin can be widely adopted in the pharmaceutical industry as a more consumer-friendly alternative to gelatin.

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