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ARTICLE

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Characterization of Banana Peel Pectin (*Musa acuminata* Colla) as a Potential Halal Pharmaceutical Excipient

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Abstract: *Indonesian Halal Product Assurance Law No. 33 of 2014 states all products circulating in Indonesia must be halal-certified, including pharmaceuticals. Banana peel waste has the potential to produce pectin compounds as pharmaceutical excipients. This study is aimed at determining the characteristics of banana peel pectin as a potential halal pharmaceutical excipient. It has involved qualitative tests and established characteristics of extract pectin by organoleptic test, acidity (pH) test, solubility, equivalent weight, methoxyl concentration, galacturonic acid concentration, esterification degree, moisture content, and ash content. The yield of pectin produced was 17.19%. The qualitative test showed positive pectin, the characteristics of a white powder that is slightly ash, odorless, has a pH of 6.02, is soluble in water, insoluble in ethanol 96%, has an equivalent weight of 5,000 mg, methoxyl concentration of 2.6%, galacturonic acid concentration of 73.92%, esterification degree of 20.19%, moisture content of 7.139% and ash content of 1.6%. Based on the characterization results, banana peel pectin is, by pectin quality standards, a pharmaceutical excipient, especially as a raw material for manufacturing capsule shells, thickeners, and coating and gelling agents.*
Keywords: *banana peel, excipients, halal, pectin, pharmaceuticals*

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1. Introduction

The largest Muslim population in the world is in Indonesia. In 2020, according to the Ministry of Religion of the Republic of Indonesia, the population of Indonesia was 270 million people, of which about 232 million were Muslims. The Muslim population makes up 30% of the total population. In 2025, the Muslim population is predicted to increase to 35% (Esfahani, 2013). Therefore, the consumption of halal products will increase along with the demand. The halal status of pharmaceutical products is a concern due to the implementation of the *Halal Product Guarantee Act*. However, problems arise because not all medicines meet the requirements for halal status. According to the Assessment Institute for Foods, Drugs, and Cosmetics, using the Indonesian Council of Ulama (LPPOM MUI) data, out of 30,000 medicines products registered to the Agency of Drug and Food Control of the Republic of Indonesia (BPOM), only 34 medicines have halal certificates (Hijriawati et al., 2018). Halal status in the pharmaceutical industry can be affected by raw materials. Natural resources in Indonesia can be alternative sources of raw materials, like the banana.

The banana is a fruit grown locally in Indonesia and available year-round in the market. Throughout 2021, Indonesia produced 8.74 tons of bananas. Production increased by 6.28% from the previous year of 8.18 tons. In 2021, consumption reached 2.39 million tons, up 33.81% from 2020. The domestic sector contributes 47.7% to the domestic consumption of bananas (Bayu, 2022). The banana processing industry produces several waste products in the form of peels, which can impact the environment (Achinas et al., 2019; Arshad et al., 2022; Rivadeneira et al., 2022). Banana peel is a potential source of starch, cellulose, and pectin that has yet to be optimally used (Carrion et al., 2021; Doan et al., 2021; Padam et al., 2014; Tibolla et al., 2017). Pectin includes water-soluble polysaccharide compounds and is a pectinic acid containing methoxyl groups. The macromolecules and structural properties of pectin are diverse due to its sources and extraction methods. Statistical data shows the need for pectin in the Asian region, including Indonesia, increases yearly. However, Indonesia depends on imported pectin because its pectin manufacturing industry is not yet developed even though raw materials are abundant (Aisyah et al., 2020) until commercial pectin has a sufficiently high price (Picauly & Gilian, 2020). Commercially, pectin is extracted from orange and apple peels and widely used in industry as stabilizers, emulsifiers, thickeners, encapsulants, or gelling agents (Chandel et al., 2022; Cui et al., 2021; Eghbaljoo et al., 2022; Picot-Allain et al., 2022).

The pharmaceutical excipients obtained from pectin can be developed into halal products. Halal pharmaceutical excipients refer to the process of developing halal products, which begins with planning, selecting raw materials, halal production, and guaranteeing halal products based on halal management, known as the concept of halal by design (Hijriawati et al., 2014). Therefore, in pectin production, it is necessary to select appropriate raw materials, use extraction solvents that meet halal criteria, and ensure the pre-treatment process for pectin extraction follows the halal management system. Pectin can be a substitute for gelatin in the pharmaceutical industry and as an excipient for halal pharmaceuticals. Pharmaceutical manufacturers usually use animal gelatin as a raw material or excipient for gelling, thickening, stabilizing, and manufacturing capsule shells. However, gelatin raw materials still need to be tested for their halal status. In addition, the use of animal gelatin raises concerns about contamination with bovine spongiform encephalopathy (BSE) (Giménez et al., 2005). Gelatin used in the Indonesia pharmaceutical industry is an imported material. According to data from Gelatin Manufacturers in Europe, in 2005, the world's most significant gelatin production (44.5% –136,000 tons) comes from pig skin raw materials (Faridah & Susanti, 2018). This data shows that gelatin derived from pigs still dominates the global market.

The use of banana peel waste as a raw material for making pectin is an opportunity to develop halal pharmaceutical excipients as an alternative to gelatin, which is used widely in the pharmaceutical and non-pharmaceutical industries. Recently, research on pectin from various sources continues to be developed (Chandel et al., 2022) with various pre-treatments and extraction methods (Ling et al., 2023). Research on pectin from banana peels has been widely reported by Arshad et al. (2022), Padam et al. (2014), Putra et al. (2022), and Rivadeneira et al. (2022). Likewise, pectin can be obtained from waste jackfruit (*Artocarpus heterophyllus*) (Begum et al., 2014), oranges and lemons (Twinomuhwezi et al., 2020), cashew nuts (Yapo & Koffi, 2014) and mango peels (Paper & Dur, 2021). However, to the best of our knowledge, we have yet to research the extraction and characterization of banana peel pectin as a raw material for encapsulation and manufacturing capsule shells. The main objective of this study is to extract and characterize banana peel pectin, which meets the pectin quality standards as an alternative to animal gelatin for use as a halal pharmaceutical excipient.

2. Materials and Methods

2.1. Sample preparation

Banana peel waste was obtained from banana chips from micro, small, and medium enterprises. Banana raw materials were determined first. The banana peel waste was washed with fresh water. After the banana peel was cleaned, chopped, and dried in sunlight, then dry smoothed using a blender. The banana peel powder was then sieved through 100 mesh to prepare it for extraction (Azis et al., 2020).

2.2. Pectin Extraction

2.2.1. Pectin Extraction Process

After preparation, 650 g of the simplicial powder was dissolved in a 5% citric acid solution (powder and solvent ratio is 1:20). The extraction process was carried out using a hot plate stirrer at a 90°C controlled temperature for 40 minutes. After the heating process, the filtrate was filtered. The filtrate was then cooled to room temperature and 96% alcohol was added with a volume ratio of 1:1, then precipitated for 24 hours. The filtrate was filtered (Aziz et al., 2018) and washed using 96% ethanol. This washing process involved adding 96% ethanol until the pectin precipitate was submerged, then stirred and filtered. This process was repeated ten times until the pectin was neutral. The pectin was then dried using an oven at 50°C temperature for 24 hours (Azis et al., 2020). The dried pectin was mashed, sieved through 100 mesh, and weighed for characterization (Kesuma et al., 2018).

2.2.2. Pectin Rendemen

The rendemen calculation is done by weighing the dry pectin and dividing it by the weight of the dried raw material (Picauly & Tetelepta, 2020).

$$\text{Rendemen (\%)} = \frac{\text{Dry Pectin Weight (g)}}{\text{Dry Raw Material Weight (g)}} \times 100 \qquad (1)$$

2.3. Pectin Qualitative Test

2.3.1. Pectin Test Using Ethanol

0.05 g of pectin was dissolved in 5 ml water and then 1 ml pectin solution was added with 1 ml 96% ethanol (Daniarsari & Hidajati, 2005).

2.3.2. Pectin Test Using NaOH

1 ml of pectin solution was added to 1 ml Sodium Hydroxide (NaOH) 2N, then left at room temperature for 15 minutes (Daniarsari & Hidajati, 2005)

2.3.3. Color Test

Two drops of iodine were added to 1 ml pectin solution added two drops of iodine and then observed for color change (Nurniswati et al., 2016).

2.4. Pectin Characterization

Pectin characterization included organoleptic, solubility, acidity (pH), equivalent weight, methoxyl concentration, galacturonic acid concentration, esterification degrees, ash content, and moisture content (Picauly & Tetelepta, 2020).

2.4.1. Organoleptic Test

An organoleptic test was carried out by directly observing the pectin powder, including color, texture, smell, and taste observations. Based on the Handbook of Pharmaceutical Excipients (HOPE) 2009, pectin has the appearance of a coarse or fine powder, is yellowish-white, is almost odorless, and has a mucilage taste (Husni et al., 2021). Meanwhile, based on the Food Chemical Codex, pectin appears as a coarse to fine powder that is yellowish-white, gray, or brown.

2.4.2. Solubility Test

0.1 g of pectin was dissolved in 2 ml of water and 2 ml of 96% ethanol, then the solubility was observed (Husni et al., 2021). Pectin is soluble in water and insoluble in 96% ethanol and other organic solvents.

2.4.3. pH Test

Based on the HOPE 2009, 1 g of pectin powder was dispersed in 10 ml aquadest and the pH was determined using a pH meter. Pectin has a pH of 6.0–7.2.

2.4.4. Equivalent Weight

0.1 g of pectin was moistened with 1 ml of 96% ethanol, then dissolved in 20 ml of carbonate-free distilled water at 40°C and stirred for one hour. After that, 0.2 g NaCl was added, then three drops of phenolphthalein indicator. This was titrated slowly with standardized 0.1 N NaOH until the color

changed to pink (pH 7.5) for 30 seconds (Devianti et al., 2020).

$$\text{Equivalent Weight (mg)} = \frac{\text{Sample Weight (g)} \times 100}{\text{NaOH Volume (ml)} \times \text{N NaOH}} \quad (2)$$

2.4.5. Methoxyl Concentration

10 ml of NaOH 0.25 N was added to the titrated solution, then stirred for one hour at room temperature in a closed Erlenmeyer flask. After that, 10 ml of 0.25 N HCl was added, then titrated with 0.1 N NaOH until it reached the end point of the titration, which was marked by a change in color to pink (Devianti et al., 2020).

$$\text{Methoxyl Concentration (\%)} = \frac{\text{NaOH Volume} \times \text{N NaOH} \times 31}{\text{Sample Weight (mg)}} \times 100 \quad (3)$$

Description : 31 molecular weight from methoxyl group

2.4.6. Galacturonic Acid Concentration

The galacturonic concentration was calculated from the mEq (milliequivalents) of NaOH obtained by determining the equivalent weight and methoxyl concentration (Picauly & Tetelepta, 2020).

$$\text{Galacturonic Acid Concentration} = \frac{\text{mEq (BE + KM)} \times 176 \times 100}{\text{Sample Weight (mg)}} \quad (4)$$

BE = Equivalent weight
KM = Methoxyl concentration
176 Lowest equivalent weight from pectate acid

2.4.7. Esterification Degree

The esterification degree was calculated using methoxyl and galacturonic concentrations (Picauly & Tetelepta, 2020).

$$\text{Esterification Degree (\%)} = \frac{\text{Methoxyl Concentrartion} \times 176 \times 100}{\text{Galacturonic Concentration} \times 31} \quad (5)$$

2.4.8. Ash Content

An empty porcelain cup was heated in a furnace at 550°C for 30 minutes and cooled in a desiccator. The cup was weighed. 2 g of the sample was heated in an electric furnace at a maximum temperature of 550°C until completely turned to ash. The cup was cooled in a desiccator and then weighed (Picauly & Tetelepta, 2020).

$$\text{Ash Content (\%)} = \frac{\text{Ash Weight (g)}}{\text{Example Ash (g)}} \times 100 \quad (6)$$

2.4.9. Moisture Content

Measurement of water content in the sample was carried out using a moisture analyzer by heating the sample to 105°C temperature so that the water content in the sample would evaporate and be noted as present water content.

3. Results and Discussion

3.1. Sample Preparation

The banana peel waste used as raw material was still raw and green. It is known that the highest pectin yield can be obtained from banana peels with a low level of maturity. When reaching the yellow maturity level, the pectin yield decreases due to the enzymes' process of pectin degradation (Akili et al., 2012).

Table 1. Amount of Raw Materials

Raw material	Results (Weight) (g)
Banana peel	6,525
Banana peel simplicia	855

Table 1 shows the amount of banana peel simplicia produced was as much as 855 g from 6,525 g of banana peel. Based on organoleptic observations, banana peel simplicia had the form of fine powder after being blended and is brown and odorless.

3.2. Pectin Extraction

Pectin extraction was done using a conventional method with a hot plate stirrer and automatic stirring at 600 rpm (Devianti et al., 2020). The yield of pectin produced was 17.19%. The weight of pectin obtained was 111.768 g from the weight of banana peel simplicial of 650 g. The yield of apple pomace

pectins extracted using citric acid is 23.3% (Dranca et al., 2020) and the yield of citrus peel pectins extracted using hydrochloric acid ranges from 11.1% to 21.3% (Cui et al., 2021). Thus, the yield of banana peel pectin and commercial pectin is similar. In the process, using acidic materials such as citric acid is included in halal materials because it is a synthetic material, in contrast to the pectin extraction process using an enzymatic process because it includes a critical halal point. The pectin extraction process can also affect its rheology and viscosity, which act as a thickener and stabilizer. Thickeners and stabilizers in the pharmaceutical industry usually use xanthan gum, which has an unclear status of doubt (*syubhat*) because it is produced by pure culture fermentation techniques from carbohydrates with *Xanthomonas campestris* microbes, by following the Indonesian Ulema Council fatwa regarding the use of microbial materials. In addition, thickeners and stabilizers can be derived from cellulose gum, such as ethyl cellulose, with halal status because it comes from the same plant cell walls as pectin (Jaswir et al., 2020). Factors that affect the value of pectin yield include extraction time, physical form of raw materials, extraction temperature, amount of solvent, ethanol concentration, precipitation time, acid type, and acid ratio. The longer the extraction time, the higher the pectin yield (Picauly & Tetelepta, 2020).

The resulting pectin precipitate was white. To clean the remaining acid residue from the pectin, 96% ethanol was used on the precipitate. The results of several pieces of washing stated the acidity (pH) of the pectin showed the number 6. Washing with 96% ethanol produced a whiter pectin color than washing without alcohol (Febriyanti et al., 2018). This is in line with research conducted by Susilowati et al. (2014), regarding the extraction of pectin from cocoa fruit peel with citric acid solvent. Maximizing the washing process can increase the brightness of the pectin produced (Rahmanda et al., 2021).

From the washing process, wet white pectin was produced. The wet pectin was dried at 50°C for 24 hours. Subsequently, the pectin was ground into powder. After the pectin powder was formed, it was sieved through 100 mesh to obtain a homogeneous grain size (Sitorus et al., 2020). The resulting pectin is shown in Figure 1.

Figure 1. Banana peel pectin.

The resulting banana peel pectin can be used as a halal pharmaceutical excipient. Even though the washing and precipitation processes use ethanol, the ethanol used does not come from the khamr industry according to the Certificate of Analysis (CoA) received from the supplier. So, it does not include halal critical point materials. The final product of this extraction process is in the form of dry pectin. If the final product is produced in a solid state, it can be categorized as halal because, to become a solid state, it must go through several stages, including heating. This process will evaporate ethanol (Norazmi & Lim, 2015).

3.3. Pectin Qualitative Test Result

Table 2. Qualitative Identification of Pectin

No.	Treatment	Results
1.	1 mL of pectin + 1 mL of 96% ethanol	A clear precipitate like gelatin is formed
2.	1 mL of pectin + 1 mL of NaOH 2 N left at room temperature for 15 minutes	Formed semi-gel
3.	1 mL of pectin + 2 drops of iodine	Formed a reddish-purple color

Table 2 shows the results of the first pectin identification test were positive and characterized by forming a clear gelatin-like precipitate that distinguishes pectin from most gums. Gelatin has the same precise precipitate identification results as pectin. Gelatin is often used in the pharmaceutical industry, primarily

to manufacture capsule shells. However, the halal status of gelatin is still in doubt (*syubhat*) because 44.5% of its raw material comes from pork (Faridah & Susanti, 2018). So, pectin can be an alternative to gelatin

The second identification of pectin had positive results and was characterized by forming a gel or semi-gel that differentiated pectin from tragacanth. The results showed positive results that formed a semi-gel when the two reacted. This was due to neutralization between two colloids with opposite charges. Pectin colloids have a negative charge and will agglomerate when added cations such as Na^+ (Devianti et al., 2020).

In the color reaction identification test using iodine solution, banana peel pectin gave a positive result in the form of a color change to reddish-violet. This color change was the result of a reaction between iodine and pectin.

3.4. Pectin Characterization

3.4.1. Pectin Organoleptic Results

Table 3. Pectin Organoleptic

Organoleptic Testing	Standard	Banana Peel Pectin
	HOPE 2009	
Form	Coarse or fine powder	Fine powder
Color	Yellowish white	White; a little gray
Smell	Almost odorless	No Smell

Based on Table 3, the results of organoleptic tests were carried out by observing the shape, color, and smell of banana peel pectin (Hanifah et al., 2021). Based on the HOPE 2009, the description of pectin is a coarse or fine powder, yellowish-white, almost odorless, and has a mucilage taste. The organoleptic test results for banana peel pectin in terms of shape, color, and smell almost match the pectin quality standards in HOPE 2009. The resulting pectin has the same organoleptic properties as commercial pectin, which is known to have a brighter color – white, yellowish, gray, or brown (Nurhayati et al., 2016).

3.4.2. Pectin Solubility Results

Table 4. Pectin Solubility Test

No.	Substance	Solvent	Results
1.	Pectin	Water	Soluble in water to form a slightly viscous liquid
2.	Pectin	Ethanol 96%	Insoluble in ethanol and forms clear lumps

Based on Table 4, the solubility test shows, when 0.1 g of pectin was dissolved in water, pectin was obtained, which dissolved in water, forming a slightly viscous liquid. Then, when 0.1 g of pectin was dissolved in 96% ethanol, the pectin was found to be insoluble and clear lumps formed. According to the HOPE 2009 specification, pectin is soluble in water and insoluble in ethanol (95%) and other organic solvents.

Pectin is soluble in water by forming colloids. When pectin dissolves in water, some of its carboxyl groups will be ionized to form carboxylate ions (Daniarsari & Hidajati, 2005). Pectin solubility will also increase along with the increasing degree of esterification and decreasing molecular weight (Aziz et al., 2018). The methoxyl pectin content affected the solubility of pectin in water because this methoxyl group prevented precipitation of the polygalacturonic chain formula, the more methoxyl groups, the more soluble pectin produced in water.

Pectin precipitated when ethanol was added. This follows pectin's nature, which is insoluble in organic solvents such as alcohol. Alcohol acted as a dehydrator to take moisture from the hydrophilic pectin colloid solution and caused clots to form. These clumps were indicated by forming a clear gel in the pectin solution (Timang et al., 2019). Based on this description, it is known that the solubility of banana peel pectin follows the specifications required in HOPE 2009.

3.4.3. pH Test Results

The pH test was carried out to determine the level of acidity and basicity of pectin. The testing was carried out using a pH meter. The results showed the pH of banana peel pectin was 6.02 or an acidic pH. Based on the standard in HOPE 2009, the pH of pectin is 6–7.2. Therefore, banana peel pectin fits the standard.

The increase and decrease in pectin pH could be influenced by various things, including the acid pectin washing using ethanol. Pectin is a good stabilizer in acidic conditions. Water and components

dissolved in water will be bound to the pectin. These components are organic acids contained in the product. Therefore, these organic acids will be bound to the pectin and these bonds cannot be separated. The higher the addition of pectin, the degree of acidity decreases or the pH value increases. This is because pectin will be hydrolyzed into pectic acid and pectinic acid, so higher acid production and a lower pH.

3.4.4. Equivalent Weight Results

Table 5. Pectin Equivalent Weight

Repetition	Volume of NaOH 0.1 N (ml)	Average (ml)	Equivalent Weight (mg)	International Pectin Producers Association (IPPA) 2003 Standard
Titration 1	0.2	0.2	5,000	600–800 mg
Titration 2	0.2			

The results of the equivalent weight test are shown in Table 5. The principle of the reaction in determining the equivalent weight is based on the occurrence of the saponification reaction of the carboxyl group by NaOH (Husnawati et al., 2019). The volume of NaOH used to react with the carboxyl group is inversely proportional to the equivalent weight value. The larger the volume of NaOH, the smaller the equivalent weight value. The smaller the equivalent weight means the higher the methoxyl pectin content (Aziz et al., 2018).

The extracted pectin was in the form of a powder that coagulates and becomes partially hydrated when in contact with water. Therefore, for the pectin to be wholly dissolved when determining the equivalent weight, the pectin powder was moistened using 96% ethanol so it was completely wetted to the core. Synthetic materials are not included in the critical halal point, but the critical point is the manufacturing process and origin of the raw materials. The ethanol used does not come from the khamr industry following the CoA obtained, so it does not affect the halal product.

The solvent used during the analysis was CO2-free aquadest because the presence of CO2 gas in water could react with NaOH to form carbonate salts, affecting the analysis results. NaCl was added to sharpen the endpoint of the titration (Devianti et al., 2020). The longer the pectin extraction time, the lower the value of the equivalent weight became. The longer extraction time caused pectin's de-esterification process to become pectic acid. This de-esterification process increased the number of free acid groups. This increase in free acid groups reduced the equivalent weight (Picauly & Tetelepta, 2020) —likewise, the higher the temperature, the lower the equivalent weight value.

The lower the pH of the solvent, the lower the equivalent weight produced. Low pH caused the de-esterification of pectin into pectic acid, where the number of free acid groups increased so the equivalent weight decreased. The change in equivalent weight was affected by de-esterification. The increase in the de-esterification process means an increase in the number of free acid groups. This means a decrease in equivalent weight because pectic acid, which has a lower equivalent weight, was increasing (Kesuma et al., 2018).

The stronger and more concentrated the acid used tended to cause polymerization of the pectin chains. This reaction caused the pectin chain formed to be long and the amount of free acid in solution decreased. Decreasing the amount of free acids in the solution causes the equivalent weight value of pectin to increase (Husnawati, 2019). The stronger the acid, the more hydrolyzed protopectin becomes pectinic acid or soluble pectin. Soluble pectin has a high equivalent weight (Kesuma et al., 2018).

3.4.5. Methoxyl Concentration Results

Table 6. Methoxyl Concentration

Repetition	Volume of NaOH 0.1 N (ml)	Average (ml)	Methoxyl Level (%)	IPPA 2003 Standard	Food Chemicals Codex (FCC) 1996 Standard
Titration 1	0.8	0.85	2.6	>7.12% (HMP)	≥7% (HMP)
Titration 2	0.9			2.5-7.12% (LMP)	7% (LMP)

Notes: HMP: High methoxyl pectin; LMP: Low methoxyl pectin

Table 6 shows the results of testing the methoxyl concentration of pectin. Pectin is known to have a high methoxyl level if it has a methoxyl content value equal to 7% or more. If the methoxyl content is less than 7%, the pectin is categorized as having low methoxyl based on the FCC 1996 standard. Based on the IPPA 2003 standard, high methoxyl pectin has >7.12% methoxyl content, while low methoxyl pectin

is 2.5–7.12%. Based on the calculation, the methoxyl pectin content of banana peel is 2.6%, which classifies it as low methoxyl pectin.

Methoxyl content in pectin has an important role in determining its functional properties, such as the structure and texture of the pectin gel. High methoxyl pectin can form a gel with added sugar and acid. The conditions required for gel formation are 58–75% sugar content with a pH of 2.8–3.5 and a gel formation temperature of around 88°C. Low methoxyl pectin does not require high sugar content for gel formation, so it can be directly used as a thickener with a gel formation temperature of 54°C (Devianti et al., 2019). As a result, it might be used as a gelling agent in medicinal formulations.

The higher the extraction temperature, the higher the methoxyl content produced due to the increasing number of esterified free carboxyl groups (Aziz et al., 2018). However, at 90°C to 100°C specific temperatures, the level of methoxyl pectin could decrease and pectin would experience a decrease in the average level of methoxyl pectin. High temperatures would cause de-esterification of the methoxyl pectin group so it would reduce the level of methoxyl pectin obtained. In acid treatment at high temperatures during heating, there was bond breaking between protopectin and its bonds to other plant tissues. It also broke several methoxyl groups (-OCH3), which would form pectin. If the extraction temperature were too high, all the methoxyl groups would be completely hydrolyzed, resulting in a product that is insoluble in water and no longer easy to form a gel called pectic acid (Daniarsari & Hidajati, 2005).

3.4.6. Galacturonic Acid Level Results

Table 7. Galacturonic Levels

mEq		Galacturonic Acid Level (%)	HOPE 2009	IPPA 2003 & FCC 1996 Standards
mEq NaOH on BE determination	0.08	73.92	≤74%	>35%
mEq NaOH on methoxyl content determination	0.34			

Table 7 shows the test results for galacturonic levels. Galacturonic acid levels strongly influence the functional properties of pectin. The structure and texture of the pectin gel depend on the galacturonic acid content. The higher the galacturonic value, the higher the pectin quality (Febriyanti et al., 2018). According to the IPPA 2003 standard, galacturonic levels are set at a minimum of 35%. Meanwhile, based on the HOPE 2009, the galacturonic concentration is determined to be 74%. Analysis of galacturonic acid levels in banana peel pectin resulted in 73.92%. Therefore, the pectin produced in this study met the standard values.

The high content of polygalacturonic acid also affected gel formation because, the more galacturonic acid content, the stronger the three-dimensional network was formed. Therefore, it could trap all the liquid in it, forming a stronger gel (Widyaningrum et al., 2014). This means the purity of the pectin was sufficient to form a good gel. The results of the galacturonic acid test meet the standards so banana peel pectin has the potential to form gels in pharmaceutical preparations. It can also be applied as an encapsulating agent and coating film (Chandel et al., 2022). Pectin can also be used for alpha-tocopherol microencapsulation (Singh et al., 2018).

3.4.7. Esterification Degree Results

Table 8. Degree of Esterification

Methoxyl (%)	Galacturonic (%)	Esterification degree (%)	IPPA 2003 & FCC 1996 Standards
2.6	73.92	20.23	>50% for high ester pectin <50% for low ester pectin

Table 8 shows the esterification degree is as much as 20.23%. Banana peel pectin has a low ester, <50% according to the IPPA 2003 standard. Factors that affected the esterification degree included extraction time, solvent concentration, temperature, pH, and acid type. The longer the extraction time, the higher the esterification degree. The degree of esterification tended to increase with time because the glycosidic bond of the methyl ester group of pectin tended to hydrolyze to produce galacturonic acid. If the extraction was carried out for too long, the pectin would turn into pectic acid, of which galacturonic acid was free from the methyl ester group. The number of methyl ester groups indicated the number of unesterified carboxyl groups or degree of esterification (Picauly & Tetelepta, 2020).

The higher the value of the equilibrium constant for acid, the higher the degree of esterification. A high K value increases the quantity of acid that dissociates and the number of hydrogen ions, resulting in rapid hydrolysis of protopectin to pectin. (Kesuma et al., 2018).

3.4.8. Moisture Content Results

Table 9. Pectin Moisture Content

Pectin Weight (g)	Moisture Content (%)	HOPE 2009	IPPA 2003 & FCC 1996 Standards
2,073	7.139	≤10%	Maximum 12%

Table 9 shows the result of the moisture content test was less than 10%. This level measurement was carried out to measure the moisture content contained in a sample by taking into account the limits of the moisture content range that had been set. One method to reduce the moisture content was the drying process of the material first to a predetermined moisture content limit. A moisture balance and pectin weight of 2 g were used to determine the moisture content (Hanifah, 2021).

The result of determining the moisture content of banana peel pectin is 7.139%. The quality standard for moisture content set by the IPPA 2003 and FCC 1996 standards is a maximum of 12%. However, the moisture content determined based on the HOPE 2009 is less than or equal to 10%. The results of determining the moisture content carried out in this study met the standard requirements. Moisture content that is too high can be affected by the degree of drying and storage conditions of pectin (Hanifah et al., 2021).

3.4.9. Ash Level Results

Table 10. Pectin Ash Content

Porcelain Crucible Weight (g)	Sample Weight (g)	Weight of Porcelain and Ash (g)	Ash Content (%)	IPPA 2003 Standard
38.6687	2	38.7007	1.6	Maximum 10%

Table 10 shows the result the ash content was 1.6%, which is well below the IPPA 2003 standard, which is 10%. Ash is a residue or residual combustion of organic materials in the form of inorganic materials. Ash content affects the level of pectin purity. The higher the level of pectin purity, the lower the ash content (Hanum et al., 2012).

The ash content of pectin was affected by the residue of inorganic materials contained in the raw material, the extraction method, and pectin isolation. This was due to the acid's ability to dissolve the natural minerals from the extracted material, which increased acid concentration, temperature and reaction time. Dissolved minerals will also precipitate when mixed with pectin during precipitation with alcohol (Aziz et al., 2018; Fajriati et al., 2022).

4. Conclusion

Banana peel pectin has yet to be widely applied in the pharmaceutical industry, even though it has great potential as a pharmaceutical excipient development. In the extraction process, we chose to add acid as a synthetic material compared to the enzymatic process so the pectin produced is included in the positive material list or can be said to be a halal material. The results identified pectin, a colored clear precipitate like gelatin, so it has the potential to be an alternative to gelatin, especially in manufacturing capsule shells. The results of the methoxyl characterization stated that banana peel pectin was included in the low methoxyl pectin category with a percentage of 2.6%, which does not need added sugar and acid but can be directly used as a gelling agent such as cellulose gum and xanthan gum. Xanthan gum comes from the fermentation of pure bacterial cultures, so its status is doubt (*syubhat*) following the Indonesian Ulema Council fatwa regarding microbial materials. The results of the galacturonic acid test indicated the purity of the pectin with a yield of 73.92%, esterification degree of 20.19%, moisture content of 7.139%, and ash content of 1.6%, meeting the HOPE 2009 and IPPA 2003 standards. It can be concluded that pectin has the potential to be applied in the pharmaceutical industry as a thickener or gelling agent and for encapsulation, manufacturing capsule shells, coatings, and films. In this research, characteristic pectin tests have yet to be carried out, such as microscopic tests to complement the qualitative pectin, pectin content, and gel strength tests that can be compared to gelatin and several other types of gelling agents. A recommendation for further research is to add these tests to confirm without a doubt that banana peel pectin can be used as a pharmaceutical excipient.

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