Pectin Extract from Banana Peel (*Musa Cavendish*) and Its Application as an Emulsifier for Melorin Ice Cream

Rahayu Lestari[1], Ismiyati[1], Yustinah
Master Program of Chemical Engineering Department, Universitas Muhammadiyah Jakarta
Cempaka Putih Tengah Street, Central Jakarta, 10510
Email Address of corresponding author: ismiyati@umj.ac.id

ABSTRACT

The food industry has expanded to diversify products for improved food security, introducing alternatives like melorin, a dessert akin to ice cream but with dairy fat substituted by low-fat vegetable fat. Melorin requires at least 6% fat to follows ice cream's formulation and production processes. Emulsifiers are crucial for melorin quality, in terms of enhancing texture, viscosity, and stability. Pectin which can be extracted from banana peel waste emerges as a potential emulsifier, lecithin in its properties as it contains proteins, or non-polar groups in its carbohydrate chain. This research aims to develop melorin and utilize banana peel waste for emulsifier production. Banana peels undergo ultrasonic extraction with 5% citric acid solvent at various times (10-30 minutes) and temperatures (30-80ºC). This study explores optimal extraction conditions and varying melorin formulations by pectin ratios, evaluated through consumer preference tests. The optimal extraction conditions for banana peel pectin involve a 30-minute process at 61.07°C, resulting in 45.46% pectin yield meeting IPPA's High Methoxyl Pectin standards. Increasing pectin concentration in melorin ice cream boosts water and fat content while reducing ash content due to structural alterations. Despite meeting SNI criteria, melorin's protein content falls short due to low levels in bananas and vegetable milk. Nonetheless, it's a healthier alternative to dairy ice cream, well-received for its lower fat content and improved texture with added pectin as an emulsifier, enhancing consumer satisfaction.

Keywords: Banana peel waste, Ice cream, Melorin, Pectin, Ultrasonic extraction

1. Introduction

The food industry is progressing swiftly, particularly for diversifying products to enhance food security. Ice cream stands out as a favorite among consumers, yet the high milk fat content prompts them to be more discerning in their choices. Melorin emerges as an intriguing alternative in the realm of ice cream products. Melorin is a dessert such as ice cream where some or all of the milk fat is replaced with vegetable fat with a low fat content. Typical issues encountered during the production of melorin ice cream include rapid melting and a less smooth texture compared to ice cream made from animal milk. Emulsifiers serve to enhance the thickness of the ice cream mixture, particularly prior to freezing, and prolong its shelf life by inhibiting crystallization during storage.

The peel of bananas presents a promising alternative source of pectin. Banana peel waste holds significant potential as a raw material due to its high pectin content, ranging from 1.92 3.25%[4]. The pectin extraction process employing ultrasonic methods, which, while

not extensively utilized, offer the advantage of expediting extraction time while maintaining high-quality pectin and minimizing solvent usage.

2. Material and Methods

2.1 Material

Materials used for pectin extraction are banana peel, 5% citric acid, distilled water, 96% ethanol, PP indicator, and NaOH solution.
Materials used for melorin formulation are banana, evaporated milk (vegetable fat), water sugar, and pectin extract (0%; 0.2%; and 0.4 % w/v).

2.2 Methods

a) Pectin Extraction Assisted by Ultrasonic Wave

Extraction involves transferring a substance or solute from its original solution or solid state into a specific solvent. It is a separation method that relies on variations in solubility among the components within the mixture. Ultrasonic extraction offers several advantages, such as eliminating the need for chemical additives, a rapid and cost-effective process, and minimal alteration to the chemical structure, particles, and compounds of the materials involved[4].
Pectin Extraction process involved preparing banana peel powder by separating the peel from the flesh, cleaning it, sun-drying for 2-4 days, and then oven-drying at 50°C until a constant weight is achieved. The dried peel was blended and sifted to increase its surface area for better interaction with the solvent during solvent extraction.

The extraction employed varying times (10, 20, and 30 minutes), and temperatures (30, 60, 80°C). Ultrasonic waves in a bath assisted the extraction. The equipment used is as shown in Figure 1.

Figure 1. Series of extraction equipment assisted by ultrasonic waves

b) The extracted mixture was filtered, cooled, and mixed with ethanol, resulting in precipitate formation. This precipitate was then filtered and dried.
c) Pectin Characterization

Following extraction, the pectin is assessed according to standards set by the International Pectin Producers Association (IPPA) before being utilized as an emulsifier in the production of melorin ice cream.
Characterization for pectin properties included water content, equivalent weight, methoxyl content, galacturonic acid content, degree of esterification, and FTIR testing. Pectin yield was calculated as follows:

$$yield\ (\%) = \frac{pectin\ weight\ after\ drying}{initial\ weight\ of\ pectin} \times 100\%$$

Determination of ash and moisture content

The water content of pectin is determined by drying it in an oven at a temperature of 40°C for 8 hours, a method chosen to minimize pectin degradation. The water content typically ranges from 8-12%.

The analysis of pectin ash content aims to determine its compliance with standards. One

gram of pectin is weighed in a porcelain cup of known weight. Ashing is conducted in a furnace at 600°C for 3-4 hours, followed by cooling the obtained ash in a desiccator until a constant weight is achieved.

Determination of equivalent weight, methoxyl content, galacturonic acid and degree of esterification

The equivalent weight was used to calculate both the anhydrouronic acid content and esterification degree of pectin, determined through titration with sodium hydroxide at a pH of 7.5, using either red or black indicator. In this procedure, 0.5 grams of pectin wasdissolved in a solution containing 5 ml ethanol and 100 ml distilled water with 1 gram of NaCl. The resulting mixture was titrated slowly with 0.1 N NaOH, employing phenol red indicator until a red color persists for at least 30 seconds.

$$Equivalent\ weight = \frac{weight\ of\ sample}{ml\ of\ alkaline \times alkaline\ normality}$$

The analysis of methoxyl content in pectin serves to classify pectin standards as either high or low methoxyl, as well as to determine the level of galacturonic acid in pectin. 5 mg of pectin powder was supplemented with 25 ml of 0.25 N NaOH solution, shaken, and left for 30 minutes at room temperature in a closed condition. Subsequently, titrated with 0.1 N NaOH solution using phenol red indicator until it changed to a rust-red color, which persists for at least 30 seconds.

$$Methoxyl = \frac{ml\ of\ alkaline \times normality}{of\ alkaline} \times 31 \frac{}{weight\ of\ sample\ (g)} \times 1000 \times 100$$

The galacturonic acid content was calculated from μeq (milli equivalents) of NaOH obtained from determining the equivalent weight and methoxyl content.

$$Galacturonic\ Acid = \frac{ml\ equivalent + methoxyl \times alkaline\ normalit}{} y \times \frac{}{weight\ of\ pectin} 176 \times 100 \times 100$$

The degree of esterification was calculated from the methoxyl and galacturonate acid content obtained.

$$Degree\ of\ Esterification = \frac{}{metoxhyl\ content \times 176}\ galacturonic\ acid\ content\ \times 31 \times 100\%$$

d) Adding pectin as an emulsifier in mrelorin formulation

Washed bananas were split, cut into pieces, and frozen at -5°C for one hour. Frozen banana pieces were blended with added water. Meanwhile, the pectin samples from each treatment wash heated with 50 ml of water until they boiled. Water and sugar were heated together according to the specified ratio until the sugar dissolved evaporated milk and pectin emulsifier were then added and stirred with the fruit mixture for 10 minutes. The combined mixtures were left at 4°C for 24 hours. Afterwards, the combined ingredients (banana, evaporated milk with vegetable fat, and emulsifier) were stirred and homogenized for 15 minutes. The homogenized melorin was then pack ed into cups. Finally, the melorin was frozen in a freezer at -20°C for approximately 24 hours.

Determination of physical characteristics of melorin

The physical analysis included analysis of total dissolved solids, viscosity, overrun, melting time, and emulsion stability.

Total dissolved solid in melorin was measured using a refractometer. A sample of melorin was dropped on the refractometer prism. The value read on the scale between the dark and light limits indicates the total amount of dissolved solids in the product, measured in units of ^{o}Brix.

Viscosity was assessed with a Brookfield Viscometer, where 100 ml of the sample was poured into a 100 ml beaker. This measurement principle involved gauging the resistance encountered by a rotating cylinder or disk within the measured fluid.

$$Viscosity\ (cP) = dial\ reading \times factor$$

Melorin volume development was measured as overrun, which was calculated based on the volume difference between ice cream and dough at the same mass, or the mass difference between ice cream and dough at the same volume. The overrun value was calculated by comparing the weights of the two measurements.

$$Overrun\ (\%) = \frac{ice\ cream\ mixture\ weight - ice\ cream\ weight}{ice\ cream\ weight} \times 100\%$$

Melting time measurements were conducted at room temperature (approximately 27-30°C). The melorin samples analyzed had been stored in a freezer at -18°C for 24-48 hours. The obtained data is expressed in minutes.

The stability of the emulsion was assessed by subjecting 5 g of sample to a series of temperature changes. First, the sample was placed in an oven at 45°C for 1 hour, then cooled in a cooler at a temperature below 0°C for 1 hour. Subsequently, the sample was returned to the oven at 45°C for 1 hour and left until its weight stabilized.

$$Stability\ of\ the\ emulsion = \frac{Remaining\ samples\ weight}{Total\ weight\ of\ emulsion\ material} \times 100\%$$

3. Results and Discussions

3.1 Yield, ash content, and moisture content

An optimum yield in a central composite design was achieved at a temperature of 61.06°C with an extraction time of 30 minutes, resulting in a yield of 45.46% with a desirability value close to 1. A desirability value approaching 1 indicates the anticipated optimum point[6]. The highest yield observed in the experiment occurred at an extraction temperature of 60°C and an extraction time of 30 minutes, yielding 46.41%. The findings suggest that as the extraction time of pectin from banana peels increases, the yield tends to rise. However, once the optimum temperature is reached, the yield tends to decline. This trend is evident in the temperature-yield graph, where the yield initially increases up to a specific optimum temperature, but then decreases with further increases in temperature and extraction time. The pectin yield tends to increase until it reaches a maximum state, indicating complete hydrolysis of protopectin. This hydrolysis process is facilitated by an acidic solvent during pectin extraction, which helps to separate bivalent ions, break bonds between pectinic acid and cellulose, and hydrolyze protopectin into water-soluble pectin[7].

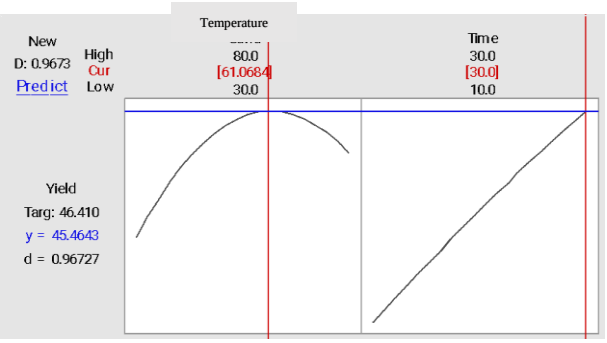


Figure 2. Comparative Curves of yield Pectin Yield against Extraction Temperature and Time

Based on the IPPA standards, pectin must not exceed a maximum water content of 12%. It was observed that the quality of pectin generally enhanced with a reduction in water content [8]. The analysis of research outcomes demonstrates a clear inverse correlation between the duration and temperature of pectin extraction from banana peels and the resultant pectin's water content, as evidenced by the graphical representationin Figure 3.

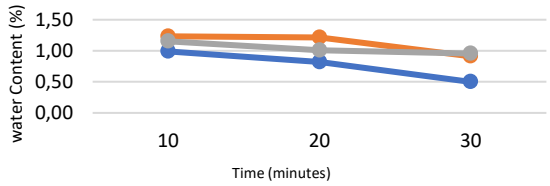


Figure 3. Graph of Water Content Pectin

The purity of pectin is inversely related to its ash content, with higher purity resulting in lower ash content[9]. In this study, the ash content of the produced pectin falls within the range of 3-8% (see Figure 4), adhering to the IPPA quality standards, which stipulates a maximum ash content of 10%. It is observed that prolonged extraction time lead to an increase in ash content. This result can be attributed to the extended contact time between the material and the solvent during the extraction process, facilitating a greater opportunity for the hydrolysis reaction of protopectin to occur.

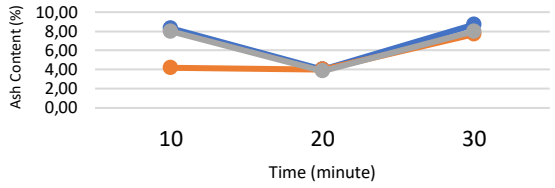


Figure 4. Graph of Ash Content Pectin

3.2 Characterization of Pectins

The acceptable equivalent weights results according to IPPA quality standards range from 500-800mg. In comparison to this standard, theis research reveals compliant equivalent weight values. The data correlation shown in Table 1 indicates a decrease in equivalent weight with higher temperatures and longer durations of extraction. Elevated temperatures and prolonged extraction periods induce depolymerization and demethylation processes. Additionally, high temperatures promote the deesterification of pectin into pectic acid, which leads to an increase in the number of free acid groups. Consequently, the increased number of free acid groups results in a reduction in equivalent weight[10].

Tabel 1. Result of Pectin Characterziation

Tempe-rature (°C)	Time (mi-nute)	Equivalent Weight (mg)	Methoxyl Content (%)	Galactu-ronic Acid (%)	Degree Of Esteri-fication
30	10	694	9.3	78%	67.69
	20	575	10.478	90%	66.10
	30	556	11.036	94%	66.66
60	10	641	11.718	94%	70.77
	20	617	12.338	99%	70.76
	30	562	12.524	102%	69.71
80	10	694	13.206	100%	74.98
	20	568	13.454	107%	71.39
	30	556	13.578	109%	70.72

The methoxyl content indicates the amount of alcohol present in pectin. Pectin is classified into two types based on its methoxyl content: high methoxyl pectin and low methoxyl pectin. Based on this research findings, the extracted pectin from banana peel has a high methoxyl content exceeding 7%. The quality of pectin is assessed based on the effectiveness of extraction process and its ability to form a gel upon rehydration. Pectin demonstrates an efficient gel-forming properties when it possesses high molecular weight, methoxyl content, and polygalacturonate content. Conversely, pectin with low methoxyl content requires polyvalent ions for gel formation[11].

Galacturonic acid serves as the foundational structure of pectin molecules, reflecting the pectin 's purity. The results of this research indicate that the produced pectin meets IPPA quality standards, with a minimum galacturonic acid content of 35%. Higher extraction temperatures and longer extraction times lead to increased galacturonic acid content due to the hydrolysis of protopectin into pectin, primarily composed of D-galacturonic acid. Hydrolysis of the glycosidic bonds in pectin's methyl ester groups contributes to this increase, enhancing the galacturonic acid content[12].

The degree of esterification indicates the percentage of D-galacturonic acid residues esterified by ethanol in pectin[7]. It is determined by comparing the methoxyl content to the galacturonic acid content. This research findings suggest that higher extraction temperatures and longer extraction times result in decreased esterification degrees. This fact aligns with studies indicating that pectin transforms into pectic acid, while methyl esters change to galacturonic acid, leading to a reduction in the degree of esterification[12].

3.3 FT-IR spectroscopy of Pectin

An identification of functional groups in the pectin extract from banana peel was conducted using a Fourier-transform infrared spectrometer (FT-IR) within the wave number range of 4000–500 cm^{-1}. Functional groups in the FTIR spectra can be interpreted into several parts, including Single Bond Stretch (main functional groups), Triple Bonds, Double Bonds, and Fingerprint, as indicated in Figure 5.

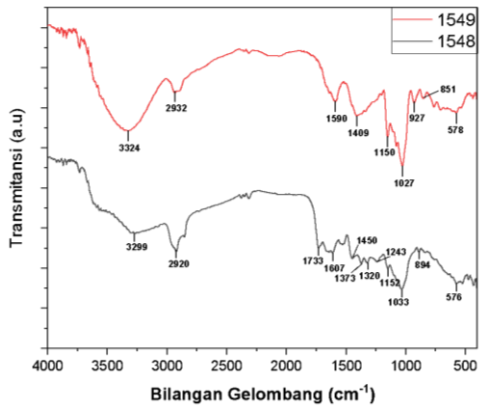
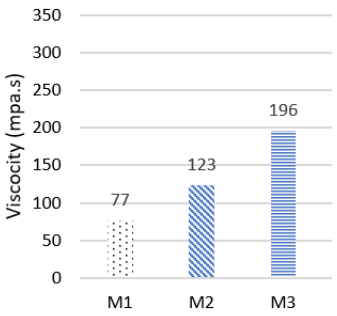


Figure 5. Graph FTIR Banana Peel Pectin compared with Comercial Pectin

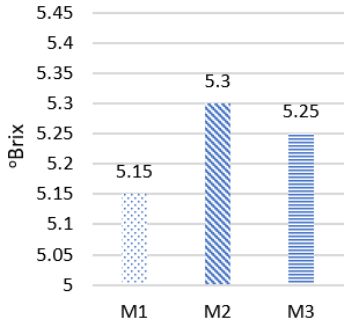
3.4 Figure 5. Shows within the wave number range of 3000-3600 cm^{-1}, with a peak at 3299 cm^{-1} suggesting -OH stretching absorption from intermolecular and intramolecular hydrogen bonds in galacturonic acid. At 2920 cm^{-1}, there's C-H stretching vibrations, while at 1733 cm^{-1}, C=O stretching of carboxylic acid and methyl ester functional groups is observed. Absorption between 800 until 1200 cm^{-1} indicates pectin polysaccharide functional groups. Absorption bands for -$COOCH_3$ and -COOH functional groups were found between 1735 cm-1 to 1320 cm^{-1}. The peak at 1733cm^{-1} indicates C=O stretching vibrations. C-H bending vibrations of pyranose and ester rings appear at 1450, 1373, and 1320 cm^{-1}. C-O stretching vibrations are evident at 1243 cm^{-1} and 1152 cm^{-1}, while C-O-C stretching vibrations at 1033 cm^{-1} imply glycosidic bonds between galacturonic acids at 894 cm^{-1}. Absorption within 720-590 cm^{-1}, peaking at 576 cm^{-1}, indicates O-H (out of plane) bending vibrations. Commercial pectin's FTIR spectrum displays a broad absorption at 3324 cm^{-1}, indicating -OH stretching vibrations. C-H stretching and bending vibrations are noticeable at 2932 cm^{-1} and 1409 cm^{-1}. At 1590 cm-1, and within the range of 1600-1700 cm^{-1}, C=O stretching vibrations from esters and carboxylates of pectin are observed. CH_3 and CH_2 bending vibrations of the ester group are evident at 927 cm^{-1}. Absorption of the polysaccharide functional group is visible within the range of 1200 until 800 cm^{-1}, peaking at 1150 cm^{-1}, 1027 cm^{-1}, and 851 cm^{-1}, indicating stretching vibrations of C-O, C-O-C, and glycosidic bonds. -OH (out of plane) bending vibrations are present at 578 cm^{-1}. Physical and chemical analysis of Melorin Ice Cream

Total dissolved solids (TDS) refers to the amount of minerals or elements dissolved in a solution. In the context of ice cream, TDS represents the total sugar content, as sweetness levels are measured by the amount of sugar dissolved in the ice cream. TDS plays a crucial role in shaping the texture of ice cream and all solid ingredients within it. If the TDS value is too low, the resulting ice cream texture will be coarse, whereas if the TDS value is too high, the ice cream will become soft and sticky[13]. The high TDS content contributes to the low water content in melorin ice cream. Only a small



amount of water forms ice crystals, resulting in ice cream with a smooth texture[14].

Figure 6. Shows the effects of pectin content to the intensity of total sugar as expressed in ^{o}Brix. The increase in pectin content apparently does not significantly change the intensity of Melorin. ^{o}Brix value indicates the concentration of dissolved sugar or salt in the dough, calculated to be equivalent to sucrose. Consequently, a higher total dissolved solids value results in increased sucrose content, enhancing the sweetness of the ice cream.



M1: Control
M2: 0.2% Pectin
M3: 0.4% Pectin

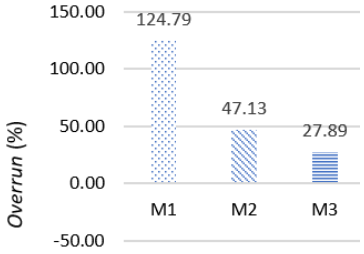
Figure 6. Diagram of ^{o}Brix Melorin

Viscosity plays a significant role in sensory evaluation and overall texture quality of melorin ice cream. Based on measurement results, viscosity values are directly proportional to the pectin concentration in the melorin ice cream formulation (see Figure 7). The optimum viscosity range for ice cream is between 50-300 cps[15]. The viscosity of melorin ice cream is influenced by several factors, including temperature, pressure, solvent material, and solution concentration. The concentration of pectin as an emulsifier results in increased viscosity, and the increasing viscosity causes the resulting melorin ice cream to thicken[16].

M1: Control
M2: 0.2% Pectin
M3: 0.4% Pectin

Figure 7. Diagram of Viscocity Melorin

Overrun is a parameter used to measure the increase in volume of ice cream caused by trapped air during the agitation process. In Figure 8, it appears that the increasing pectin content lowers the overrun. High viscosity in melorin ice cream results in low overrun because the ice cream mixture struggles to expand, making it difficult for air to penetrate the mixture[17]. According to the Indonesian National Standard (SNI), the ideal overrun value for household-scale ice cream processing is 30-50%, while for industrial-scale ice cream, the ideal overrun value is 60-80%[16].



M1: Control
M2: 0.2% Pectin
M3: 0.4% Pectin

Figure 8. Diagram of Overrun Melorin

Melorin ice cream mixture needs to have a consistency that is not too thick, because it will be difficult to expand and reduce overrun. When developing the volume of ice cream, the role of the mixing process is very significant.

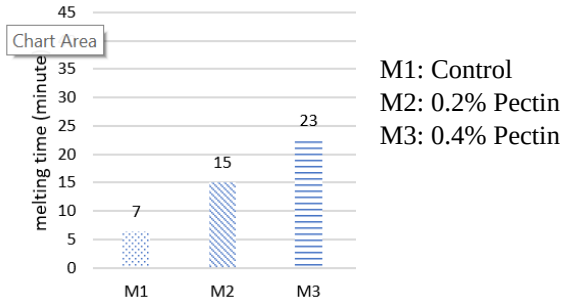


Figure 9. Diagram of Melting Time Melorin

The melting of ice cream occurs because water spreads out through its constituent components by gravity. The melting speed of ice cream is influenced by several factors, such as the amount of air trapped in it, the presence of ice crystals, and the formation of networks by fat globules during the freezing process [16]. In Figure 9, it is observed that the increasing level of pectin increases the melting time, and thus lowering the melting speed. The viscosity and texture of melorin ice cream are correlated with the melting rate. Consistency is related to the rate of increase in ice cream volume (overrun). A decrease in the overrun value affects the melting time from freezing to room temperature, causing the ice cream to melt longer.

Emulsion stability refers to the degree to which liquids remain dispersed without coalescing or uniting. The stability of an emulsion is directly proportional to the addition of pectin concentration (see Figure 10). Smaller and more uniform lipid globule sizes lead to increased stability of the mixture. Increased viscosity also affects the stability of melorin ice cream emulsion. Higher viscosity can be achieved by adding dispersed phase (vegetable milk) or reducing the continuous phase (banana). Pectin can be used to stabilize suspension or emulsion systems. The highest stability achieved with the addition of 0.5% CMC to dragon fruit ice cream is 93.32%[18].

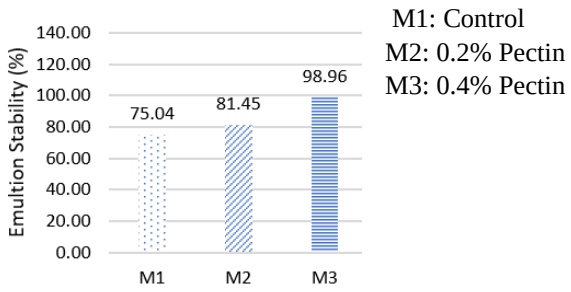


Figure 10. Diagram of Stability Emultion Melorin

A series of chemical characteristics were measured, including water content (wet bulb method), also ash , protein, and fat contents of melorin ice cream. The results of proximate analysis can be seen in Table 2.

Table 2. Chemical Analysis Result of Melorin

Compo-nents	Component Content (%)			SNI
	Control (0%)	Pectin 0. 2%	Pectin 0. 4%	
Water Content (Wb)	74 .91%	76 .04%	76 .17%	-
Ash	8 .49%	7 .92%	6 .51%	≥ 2.7
Protein	1 .63%	2 .055%	0 .308%	≥ 2 .7
Fat	22 .97%	26 .21%	35 .62%	≥ 5

The relatively high water content in melorin ice cream is caused by the hydrolysis of water bonds in the form of pectin gel, which can increase the water content in the product. An ANOVA test conducted on water content showed that different concentrations of pectin significantly influenced melorin ice cream. Based on the Duncan post hoc test results, it was found that the addition of pectin had a significant effect to the water content value. The water content of melorin ice cream meets the requirement of good quality ice cream because, according to a previous research, it should contain a minimum 55% of water [19].

The ash contents of melorin ice cream range from 6.51% to 8.49%. These results fall above the SNI standard of a minimum 2.7%. ANOVA and Duncan post hoc tests conducted

showed that the addition of pectin significantly influences the ash content in melorin ice cream. The reduction in ash content may occur due to the increase in pectin concentration, leading to a decrease in the amount of vegetable milk and banana bound to the dispersing phase[20].

The protein content in melorin does not meet the SNI for ice cream of minimum 2.7%. This result occurs because the protein content in bananas is relatively low, approximately 1.2%, and vegetable milk also has low protein content. The protein in ice cream is part of the non-fat milk solids. An ANOVA analysis showed that the addition of pectin did not significantly affect the protein content of the ice cream.

The melorin fat content meets the SNI for ice cream because it far exceeds the minimum of 5% . The fat in melorin ice cream comes from vegetable milk and bananas. Fat content is an essential element in ice cream, contributing to its smooth texture and providing density. An ANOVA test showed that the addition of pectin in the formulation of melorin ice cream significantly affected its fat content.Melorin is a healthy choice for those seeking ice cream with lower fat content compared to dairy-based ice cream.

3.5 Preference Test of Melorin Ice Cream

Consumer preference test result indicates that all three formulations of melorin ice cream are suitable and well-received. The addition of pectin to melorin ice cream enhances overall consumer satisfaction.

Table 2. Hedonic Test of Melorin

Parameter	Hedonic Test Mean		
	M1	M2	M3
Colour	4.30±1.022[a]	4.30±1.055[a]	4.40±0.968[a]
Flavour	4.10±1.029[a]	4.17±1.117[a]	4.20±1.064[a]
Texture	4.03±1.098[a]	4.10±1.094[a]	4.60±0.770[b]
Aroma	4.47±0.860[a]	4.10±1.062[a]	4.47±0.973[a]
Overall	4.40±0.855[a]	4.33±0.884[a]	4.47±0.947[a]

Keterangan: 5= Like, 4= Like Somewhat, 3= Neutral, 2=Dislike Somewhat, 1=Dislike
a,b = similar letter notation means there is no significat difference at the Mann-Whitney Test Level which has a value of 5%

The organoleptic evaluation of melorin ice cream, incorporating varying concentrations of pectin (M1, M2, and M3), includes assessments of texture, aroma, taste, and overall acceptability. Panelists provided subjective feedback regarding their preferences for each parameter. Analysis involved comparing hedonic scale data with numerical scale results after statistical testing. Kruskal-Wallis Test results for color, taste, aroma, and overall parameters indicated a significance level of $P<0.05$ was accepted, suggesting no significant differences between treatments (M1, M2, and M3) in terms of color, taste, aroma, and overall melorin ice cream with added pectin concentration. However, significant differences were observed in texture parameters across all treatments.

3.6 Conclusion

1. The optimum extraction conditions for pectin from banana peel are 30-minute duration at 61.07°C, as it yields the maximum pectin of 45.46%. The produced pectin meets the IPPA criteria for High Methoxyl Pectin.
2. The increase in concentration of added pectin significantly increases the water and fat content, while reduces the ash content of melorin ice cream. This effect is attributed to the alteration in the structure and formulation of melorin ice cream resulting from the added pectin concentration.
3. Chemical and physical analyses confirm that melorin ice cream meets SNI criteria, except for the protein content parameter, which falls short due to the relatively low protein content in bananas and vegetable milk.
4. Melorin is a healthy choice for those seeking ice cream with lower fat content compared to dairy-based ice cream. It is

suitable and well-received, while the addition of pectin emulsifier enhances consumer satisfaction.

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