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Study of pectin extraction from *pedada* fruit and *kepok* banana peel

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KEYWORDS

Extraction
Pectin
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ABSTRACT

This work represents a comprehensive analysis of pedada fruit (*Sonneratia caseolaris*) as a less desirable fruit, but valuable content such as pectin which obtained through extraction using microwave assisted extraction (MEA) method. Pectin is a water-soluble fiber widely used as a functional component in the food and pharmaceutical industry. The analysis focuses on the comparison profile of pectin from pedada fruit and Kepok banana peel. In addition, the effect of the concentration of the extracting solvent on the methoxyl levels of pectin was also evaluated using the chemometric method (partial least square (PLS) and principal component analysis (PCA)). PLS was performed to determine the methoxyl content which plays a role in determining the pectin type. While PCA was to determine the pectin classification pattern based on the fruit supply location and the extracting solvent. The results showed that the PLS of extracted pectin of *pedada* fruit and Kepok bananas peels showed an R^2 value of 1. This means that the pectin data model of each sample using the MAE method was in good classification. In addition, the PCA results show that the pectin extraction data plots are close together between samples in the quadrant, indicating the same characteristics and quality of pectin.

Introduction

Pedada fruit, botanically classified as *Sonneratia caseolaris*, is widespread growing in mangrove waters and widely used as a source of processed food (i.e. syrup, lunkhead, and candy). In Indonesia, the potential area of mangrove vegetated land was estimated at around 7.7 million Ha (Jariyah et al., 2016). Another potential way to use *pedada* fruit optimally is by extracting the pectin from its peel as a value-added chemical in the medical field. In addition, the basic information about mangrove resources is limited, thus it has not become a valuable commodity economically and nutritionally.

Pectin is known as a heteropolysaccharide compound generally found in the primary cell walls of plants and the middle of the lamellae in plant tissues, especially in the space between cellulose and hemicellulose (Pandit et al., 2015; Oliveira et al., 2016). Pectin extraction can be carried out using acid solvents consisting of strong acids and weak acids, then finally precipitated with alcohol (Normand et al., 2021; Pinheiro et al., 2008). The pectin produced using an acid solvent depends on the material's properties and the extraction method (Yujaroen et al., 2008).

The extraction method consists of several types, including conventional and microwave-assisted extraction (MAE) methods. Various factors influence the performance of the extraction process, such as particle size, temperature, time, solvent concentration, and type of solvent (Prakash et al., 2013; Sarah et al., 2018). A previous study on extracting pectin from *pedada* fruit by Jariyah et al. (2016) reported that a conventional method using hydrochloric acid solvent produced a methoxyl content of 9.44%. While the extraction using distilled water and disodium phosphate base solvent resulted in a methoxyl content of 5.33% and 3.80%, respectively (Karti et al., 2017).

The conventional method revealed a less optimal process due to longer processing times, loss of several essential compounds easily degraded by overheating, low extraction efficiency, and a large energy consumption (Qiu et al., 2010). The latest extraction method, known as MAE, was developed

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by utilizing microwave energy using a distillation system. The advantage of this extraction method is its ability to provide energy directly to all materials, thus saving time compared to conventional extraction methods. The microwave can speed up the reaction speed, resulting in a better product yield due to the direct heating of the ingredients.

Previous research obtained a pectin yield of 13.06% using the conventional extraction method with an extraction time of 30 minutes, a temperature of 85 ^{o}C, and 0.05N HCl solvent (Jariyah et al., 2016). In contrast, Windiarsih et al. (2015) successfully enhanced the extraction efficiency using the MAE method, giving a yield value of 17.28%. This study focused on pectin extraction of *pedada* fruit using the MAE method to determine the effect of the extraction solvent types on the extracted *pedada* metabolite profile.

However, the complex data obtained from the extraction and correlation with the solvent used is often difficult to interpret. Therefore, assistance is needed using chemometric analysis such as partial least square (PLS) and principle component analysis (PCA) (Nowicka et al., 2019). The combination of MAE and chemometrics have been reported can determine changes in metabolite profiles and their correlation with plant bioactivity. Thus, in this study, PCA was used to classify pectin extracts based on the concentration of the extracting solvent and the differences in growing places of *pedada* fruit from Pasuruan and Surabaya City (Indonesia) and *kepok* banana peel for comparison. The PLS was used to determine the methoxyl content which played a role in determining the pectin type.

Research Methods

Materials

The samples used in this study were *pedada* fruit (*Sonneratia caseolaris*) supplied from Surabaya and Pasuruan City (East Java, Indonesia) and *kepok* banana peels as a comparison. These samples were freshly obtained from Rungkut Surabaya market. The chemicals were supplied from Merck as follows HCl, NaOH, ethanol 96%, $AgNO_3$, phenolphthalein (as a pH indicator), and aquadest.

Experimental procedures

The extraction method was based on the MAE method, which employs microwave energy in the extraction process. First, banana peels were ground and then irradiated by microwave energy with the addition of HCl at different concentrations. This extraction mixture was then filtered using a muslin cloth and squeezed until the filtrate came out as much as possible. The residue was extracted again to obtain pectin. The filtrates of both extraction processes were mixed thoroughly. Pectin was precipitated by adding ethanol 96% and let overnight. The precipitate was filtered with Whitman filter paper. Pectin was purified by washing three times with ethanol 96% and finally dried in an oven at 45 ^{O}C for 5 h (Kamble et al., 2017; Sarah et al., 2018).

Experimental design

This study employed a completely randomized design (CCD) with two factors, as shown in Table 1, namely the different *pedada* fruit suppliers and the concentration of extraction solvent (HCl) (0.00 N; 0.03 N; 0.05 N; 0.07 N; 0.09 N, and 0.11 N). The extraction conditions were as follows: extraction time for 30 min, extraction temperature of 85 °C, and volume of 300 mL. The parameters observed were yield, equivalent weight, molecular weight, methoxyl, galacturonic acid, and degree of esterification. Each treatment was prepared in duplicate to ensure the validity.

Analysis

Moisture and ash content were determined by oven method (AOAC, 2004). Equivalent weight, methoxyl, galacturonic acid content, and degree of esterification were determined by standard methods as detailed by Ranggana (1995). The functional group of the resulted pectin was analysed using Fourier transform Infrared (FTIR) spectroscopy in the frequency range of 4000 to 800 cm^{-1}.

Table 1. The Sample Code of Pectin Sources

HCl (N)	Sample Code		
	***Kepok* Banana Peels**	***Pedada* from Surabaya**	***Pedada* from Pasuruan**
0.00	KBS0	PFS0	PFP0
0.03	KBS3	PFS3	PFP3
0.05	KBS5	PFS5	PFP5
0.07	KBS7	PFS7	PFP7
0.09	KBS9	PFS9	PFP9
0.11	KBS11	PFS11	PFP11

Statistical analysis

Analysis of variance (ANOVA) was performed to determine whether there was a significant difference between the results obtained. Significant differences were defined at the 95% confidence level ($p < 0.05$) using Minitab 16 (IBM, Armonk). The PCA and PLS were calculated using The Unscrambler X version 10.1 software (CAMO, Norway). The PCA was performed to determine the pectin grouping pattern based on the location of *pedada* fruit supplier and the extracting solvent using the MAE method, which is explained in detail in Jariyah et al. (2016). The PLS was also carried out to create a model of the relationship between the MAE method and methoxyl content. The PLS model was created using pectin data as an estimator variable for the X matrix and methoxyl content activity as the Y matrix response variable.

Results and Discussion

Physical and Chemical Properties of Pectin

The prepared pectin, obtained using the MAE method, the physical appearance from the different sources, including *kepok* banana peels, *pedada* fruit from Surabaya and Pasuruan, showed significantly difference appearances, as presented in Figure 1. While the characteristics of pectin with various concentrations of HCl are shown in Tables 2, 3, 4, and 5. The data showed that increasing the HCl concentration significantly increased pectin yield. It also showed that with increasing HCl concentration, the percentage of yield increased to 47.37%, within the range reported in the previous studies (Oliveira et al., 2016; Sayah et al., 2016). This indicated that the different concentrations significantly affected the hydrolyzing capacity of HCl to extract the pectin from peels, as reported by Chan et al. (2013).

The pectin equivalent weight is the unesterified amount of free galacturonic acid. While polygalacturonic acid, which is unesterified, is called pectic acid. The results show that the lowest value of equivalent weight was 837.50 mg / eq, which using 0.11 N HCl. This indicates that the amount of unesterified free galacturonic acid is getting lower. The methoxyl content in pectin is the number of carboxyl groups in the long chain of galacturonic acid, which undergoes an esterification process with methyl alcohol to produce 1,4α-galacturonic.

(a) (b) (c)

Figure 1. Physical appearance of pectin from *kepok* banana peels (a), *pedada* fruit from Surabaya (b), *pedada* fruit from Pasuruan (c)

Table 2. The Analysis Results Pectin of *Kepok* Banana Peels

HCl (N)	Yield (%)	Equivalent Weight (mg/ek)	Methoxyl (%)	Galacturonic Acid (%)	Degree of Esterification (%)
0.00	$1.52^{c} \pm 0.12$	$2697.50^{f} \pm 3.54$	$3.30^{a} \pm 0.19$	$101.13^{a} \pm 4.48$	$18.52^{c} \pm 0.21$
0.03	$1.78^{bc} \pm 0.07$	$2208.00^{e} \pm 2.83$	$4.08^{b} \pm 0.21$	$124.35^{b} \pm 4.67$	$18.60^{c} \pm 0.24$
0.05	$2.14^{a} \pm 0.05$	$1557.85^{d} \pm 3.04$	$4.69^{b} \pm 0.19$	$151.71^{c} \pm 4.27$	$17.55^{b} \pm 0.25$
0.07	$2.30^{a} \pm 0.09$	$1115.00^{c} \pm 0.85$	$5.72^{c} \pm 0.22$	$192.93^{d} \pm 5.10$	$16.82^{ab} \pm 0.21$
0.09	$2.07^{ab} \pm 0.28$	$924.05^{b} \pm 0.64$	$6.10^{c} \pm 0.42$	$218.16^{e} \pm 4.75$	$15.87^{a} \pm 0.76$
0.11	$2.24^{a} \pm 0.09$	$837.50^{a} \pm 1.13$	$6.94^{d} \pm 0.21$	$241.67^{f} \pm 4.61$	$16.30^{a} \pm 0.18$

Table 2 also shows that the methoxyl content ranges from 3.30 to 6.94%, methoxyl increases with increasing concentration of HCl, which means the increasing concentration of HCl, increased methoxyl content and included in the low category. According to the IPPA quality standard, a low category was the low methoxyl content ranges from 2.50-7.10%. In Table 2, it can be seen that extraction with addition of 0.03N HCl increased methoxyl content due to the presence of a carboxyl pectin group, which can be esterified with methanol. The methoxyl content increased by employing 0.11N HCl. The results of pectin that experience low methoxyl are more profitable due to a directly produced without having to pass through a demethylation process.

The galacturonic acid of pectin ranged from 101.13– 241.67%. The test results obtained a significant effect ($p \leq 0.05$) between the treatment of different extraction solvent concentrations on galacturonic acid. Galacturonic acid (Table 2) shows that the treatment of extraction solvent concentration with galacturonic acid has a directly proportional relationship. Galacturonic acid levels tend to increase with increasing concentration of the extraction solvent due to the increased hydrolysis reaction of protopectin to pectin, whose basic component is D-galacturonic acid (Tuhuloula et al., 2013). The increase in pectin's galacturonic levels is also due to breaking the bonds of the pectin's galacturonic component with other compounds such as hemicellulose (Krisnayanti and Syamsudin, 2013). The amount of galacturonic acid is influenced by the source of the raw material, the solvent, and the extraction method used (Adetunji et al., 2017).

The solvent extraction has a significant effect ($p \leq 0.05$) on the esterification degree of pectin. The degree of esterification ranged from 16.30 - 18.60%. Therefore, based on the IPPA standard, pectin in this study was included in the low methoxyl pectin category because the value was <50.00% (Perina et al., 2007). The degree of esterification (Table 2) shows that the different extraction solvent has an inversely proportional relationship to the degree of esterification pectin. The degree of esterification shows the percentage of the residual amount of D-galacturonic acid whose carboxyl groups are esterified by ethanol. The solvent extraction can cause the pectin to turn into pectic acid while the methyl ester group changes to galacturonic acid, causing the degree of esterification to decrease.

Characteristics of pectin from *pedada* (from Surabaya City), as presented in Table 3, showed a significant effect ($p \leq 0.05$) of the solvent extraction on yield and other parameters of pectin. The yield ranges from 10.92-16.03%, which was directly proportional to an increase in HCl concentration. The yield increase reached 46.79% compared to control. The equivalent weight decreased with increasing concentration of HCl, from 1117.78 to 511.91 mg/eq or decreased by 54.20%, compared to the control. This value indicates a decrease in the amount of unesterified free galacturonic acid.

The methoxyl content increased with increasing HCl concentration, giving the value ranging from 3.55- 7.64% (Table 3). This indicates an increase in the carboxyl group in the long chain of galacturonic acid resulting from an esterification process with methyl alcohol. This also led to an increase in galacturonic acid, and the value has met the quality standards of pectin (i.e. minimum of 7.00%). According to IPPA (2002) and Food Chemical Codex (1996), pectin with high methoxyl content is higher than 7.12%, and the low category ranges from 2.5 to 7.12%. Based on these criteria, the methoxyl pectin content of *pedada* fruit from Surabaya city is in the high category.

The galacturonic acid pectin from *pedada* fruit (from Surabaya city) ranged from 143.46 - 311.07% and the increase was in line with the increase in solvent concentration. The results of the research were lower than those of Maryati et al. (2018) reported, which of 46.408 – 384.823%. According to IPPA (2002) and Food Codex (1996), the minimum pectin content of galacturonic acid is 35.00%, thus the pectin from Surabaya's *pedada* fruit meets the standard.

The degree of esterification ranges from 13.68 - 14.43% (Table 3), and statistically, there is no difference in either the concentration of 0.00N or 0.11N. The values still do not meet the pectin's standard because, according to IPPA (2002) and Food Codex (1996), pectin has a minimum esterification degree of 50.00%.

The characteristics of pectin from *pedada* fruit from Pasuruan are presented in Table 4, which showed a significant effect ($p \leq 0.05$). An increase in the yield is parallel with an increasing concentration of HCl. The treatments gave the pectin yield in the range of 5.05-8.82%, or about 45.35% higher than the control. Overall, the pectin yield from the Surabaya's *pedada* fruit was higher than that of from the Pasuruan's *pedada* fruit and banana peel. The results confirmed that different locations produce different *pedada* fruit with a different pectin yield. This indicates that the place where the plant grows significantly affects the ingredients' content.

Table 3. The Analysis Results Pectin of *Pedada* (*Sonneratia caseolaris*) from Surabaya

HCl (N)	Yield (%)	Equivalent Weight (mg/ek)	Methoxyl (%)	Galacturonic Acid (%)	Degree of Esterification (%)
0.00	$10.92^{a} \pm 0.78$	$1117.78^{f} \pm 1.57$	$3.55^{a} \pm 0.22$	$143.46^{a} \pm 5.15$	$14.03^{ab} \pm 0.36$
0.03	$13.62^{b} \pm 0.12$	$845.00^{e} \pm 1.17$	$4.44^{b} \pm 0.22$	$183.99^{b} \pm 5.17$	$13.68^{a} \pm 0.30$
0.05	$14.68^{c} \pm 0.31$	$732.86^{d} \pm 1.01$	$5.59^{c} \pm 0.21$	$223.00^{c} \pm 4.54$	$14.23^{ab} \pm 0.26$
0.07	$15.40^{cd} \pm 0.05$	$688.33^{c} \pm 1.41$	$6.15^{d} \pm 0.22$	$242.06^{d} \pm 5.32$	$14.43^{b} \pm 0.20$
0.09	$15.68^{d} \pm 0.11$	$616.12^{b} \pm 0.79$	$6.57^{d} \pm 0.20$	$263.57^{e} \pm 4.66$	$14.16^{ab} \pm 0.18$
0.11	$16.03^{d} \pm 0.10$	$511.91^{a} \pm 0.67$	$7.64^{e} \pm 0.20$	$311.07^{f} \pm 4.22$	$13.94^{ab} \pm 0.17$

Note: Values with different letter in the same row are significantly different

Table 4. The Analysis Results Pectin of *Pedada* (*Sonneratia caseolaris*) from Pasuruan

HCl (N)	Yield (%)	Equivalent Weight (mg/ek)	Methoxyl (%)	Galacturonic Acid (%)	Degree of Esterification (%)
0.00	$4.82^{a} \pm 0.78$	$2029.00^{f} \pm 1.41$	$3.82^{b} \pm 0.21$	$121.44^{a} \pm 4.10$	$17.86^{d} \pm 0.29$
0.03	$5.05^{a} \pm 0.12$	$1385.65^{e} \pm 0.92$	$2.66^{a} \pm 0.11$	$111.14^{a} \pm 4.43$	$13.57^{b} \pm 0.46$
0.05	$6.55^{b} \pm 0.31$	$1035.50^{d} \pm 0.71$	$4.34^{c} \pm 0.21$	$166.57^{b} \pm 4.92$	$14.79^{c} \pm 0.21$
0.07	$7.95^{bc} \pm 0.05$	$773.60^{c} \pm 0.99$	$4.73^{c} \pm 0.21$	$198.27^{c} \pm 4.86$	$13.52^{b} \pm 0.27$
0.09	$8.30^{c} \pm 0.11$	$569.45^{b} \pm 0.78$	$5.60^{d} \pm 0.22$	$250.70^{d} \pm 5.20$	$12.67^{a} \pm 0.24$
0.11	$8.82^{c} \pm 0.01$	$566.50^{a} \pm 0.71$	$5.61^{d} \pm 0.18$	$251.65^{d} \pm 4.08$	$12.65^{a} \pm 0.21$

Note: Values with different letter in the same row are significantly different

Table 5. Molecular Weight of Pectin from Different Pectin Sources

HCl (N)	Molecular Weight of Pectin (g/mol)		
	***Kepok* Banana Peels**	***Pedada* from Surabaya**	***Pedada* from Pasuruan**
0.00	40025.82	53633.41	32942.74
0.03	41828.73	55643.49	33990.36
0.05	42522.98	56093.89	37090.29
0.07	43872.44	57388.58	37433.78
0.09	45257.36	60907.46	38075.22
0.11	46126.54	62920.49	40260.47

The equivalent weight decreased with increasing solvent concentration, from 2029.00 to 566.50 mg/eq (decrease by 59.11%), or approximately 72.08% compared to the control. It indicates a decrease in the amount of unesterified free galacturonic acid. Meanwhile, the control (water solvent) galacturonic acid in the material has not been esterified.

The methoxyl content from Pasuruan's *pedada* fruit was in the range of 3.82- 5.61%, which still does not meeting the standard pectin value. The results showed a similar trend to the counterpart sample, in which the methoxyl content increased with an increase in HCl concentration.

The galacturonic acid pectin from Pasuruan *pedada* fruit ranged from 121.44 - 251.65% and the increase in galacturonic acid was in line with the increase in solvent concentration. While Maryati et al. (2018) reported that the galacturonic acid ranged from 46.408 – 384.823%. According to IPPA (2002) and Food Codex (1996), the minimum pectin content of galacturonic acid is 35.00%, thus the pectin from the Pasuruan *pedada* fruit meets the standard.

The degree of esterification (Table 4) was fluctuated and ranged from 17.86 - 12.65%. These values were still not meeting that of the standard value of at least 50.00 (IPPA, 2002; Food Codex, 1996).

Molecular Weight of Pectin

The results of the molecular weight analysis of the three types of pectin are presented in Table 5. It shows that the molecular weight of pectin increases with increasing solvent concentration. The increase in molecular weight revealed that the pectin molecular weight of the Surabaya pedada is higher than the molecular weight of the pectin from the Pasuruan *pedada* and the pectin from *kepok* banana peels. In addition, the molecular weight of the pectin, as shown in Table 5, was well within the standard between 5000 and 150,000 Da (Kar and Arslan, 1999; Sayah et al., 2016; Normand et al., 2021).

The Result of Principal Component Analyzer (PCA)

The PCA further test results from the extraction data obtained between pectin samples from Surabaya *pedada* fruit, Pasuruan *pedada* fruit, and *kepok* banana peels can be seen in Figure 2. According to Bro, R and Smilde A.K (2014), PCA focuses on finding the main component, which is a linear combination of the original variable. These principal components are selected in such a way that the first principal component has the next greatest data uniformity.

The score plot of pectin extraction data from Surabaya *pedada* fruit, Pasuruan *pedada* fruit, and *kepok* banana peels provides information that PC1 has the greatest data uniformity or eigenvalue. The first component of PC1 explains 98% of the diversity of the data, while the second component of PC2 explains only 2% of the data diversity. PC1 and PC2 are very useful for analyzing data obtained in sample classification using PCA because these two PCs show the most data diversity.

The location of the point position on the score plot of the pectin extraction data is close to the samples in the quadrant nearby. It indicates that the pectin has almost the same characteristics or quality. The results of the plot score image from the pectin extraction data of Surabaya *pedada* fruit, Pasuruan *pedada* fruit, and *kepok* banana peel, when the two components are added, in the form of PC1 and PC2, it means representing 100% of all data. The number of variables of the main components of one PC1 and two PC2 was higher than 70%. The main component plot results show a good two-dimensionally.

The Result of Partial Least Square (PLS)

The results of PLS from the three pectin sources (*kepok* banana peel, Surabaya *pedada* fruit and Pasuruan *pedada* fruit) are presented in Figure 3. PLS was used to build a model of the relationship between the data from the MAE extraction method and the methoxyl content produced by each sample. The PLS model was created using the results of the characteristic data of pectin as an estimator variable for the X matrix and the activity of methoxyl levels as the Y matrix.

The PLS is the orientation of a structural equation model used to test theories or develop theories (predictive purposes). The approach to estimating latent variables is considered a linear combination of indicators, thereby avoiding indeterminacy problems and providing a clear definition of the component of the score.

According to Wold, et al 2001, the PLS chemometric multivariate analysis obtained the R^2 value. R^2 value shows the relationship between the proximity of the actual value to the predicted value. The model shows a good result with a valid value if it has an R^2 value close to 1. If the R^2-value is closer to 1, the relationship formed from the classification model will be more correlated. Figure 3 also shows that the "Predicted vs Measured" values have an R^2 value of 0.78891. The results indicate that the pectin data set training model from each sample using the MAE method has a fairly good classification model with valid data.

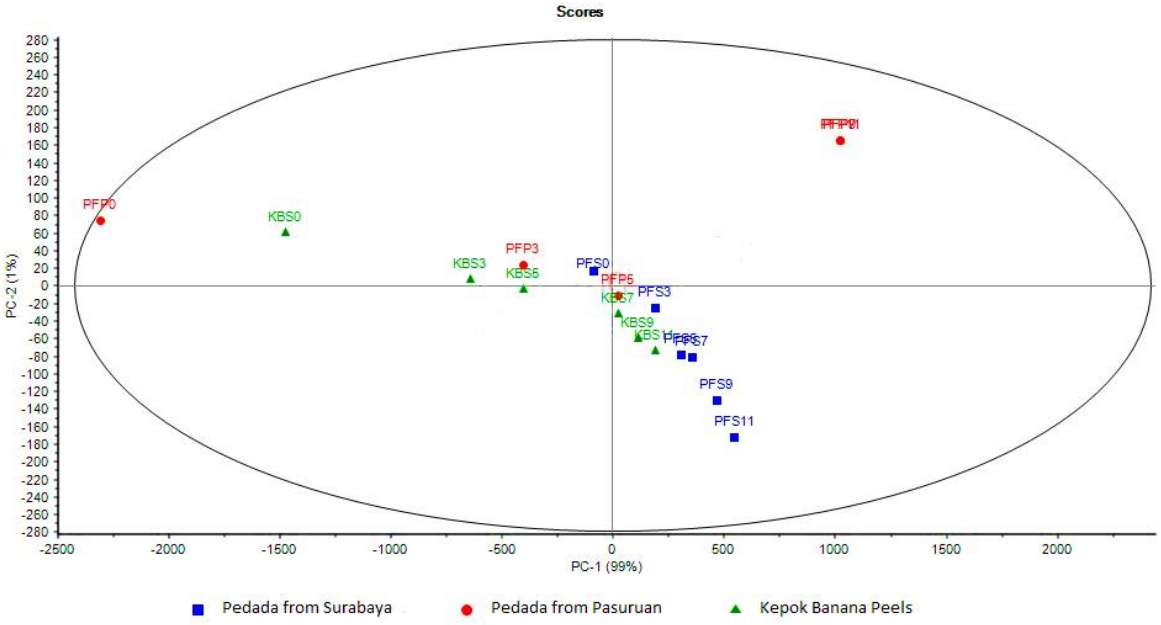

Figure 2. PCA Result from *Kepok* Banana Peels (KBS); *Pedada* from Surabaya (PFS) and *Pedada* from Pasuruan (PFP)

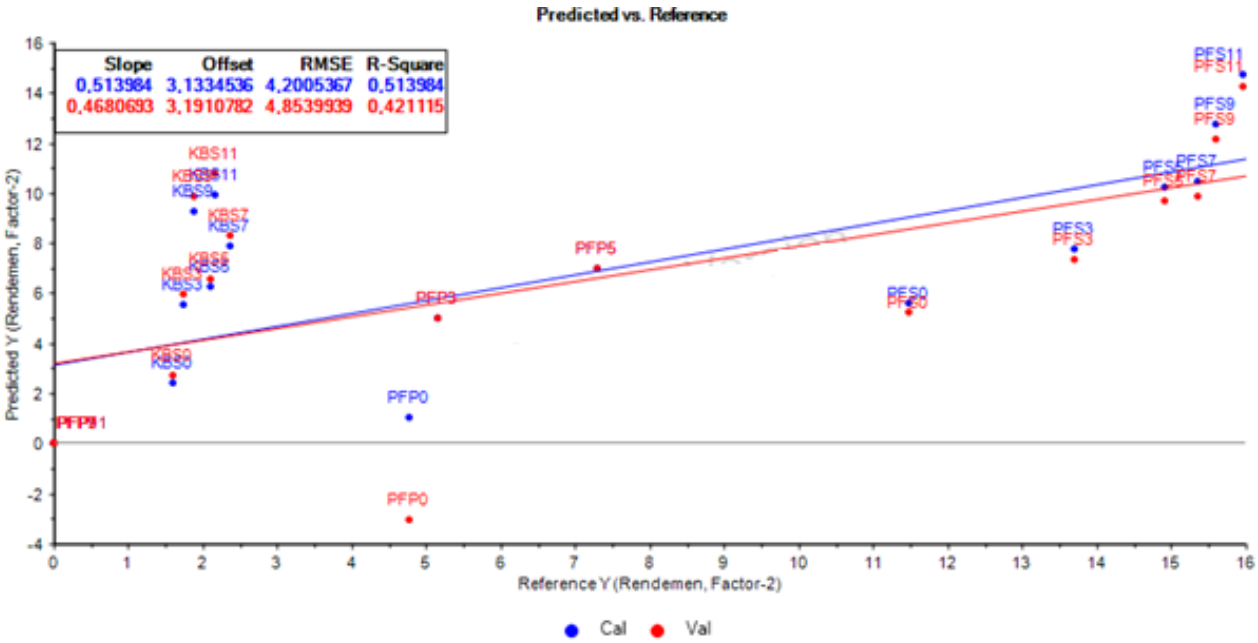

Figure 3. PLS Result from *Kepok* Banana Peels (KBS); *Pedada* from Surabaya (PFS) and *Pedada* from Pasuruan (PFP)

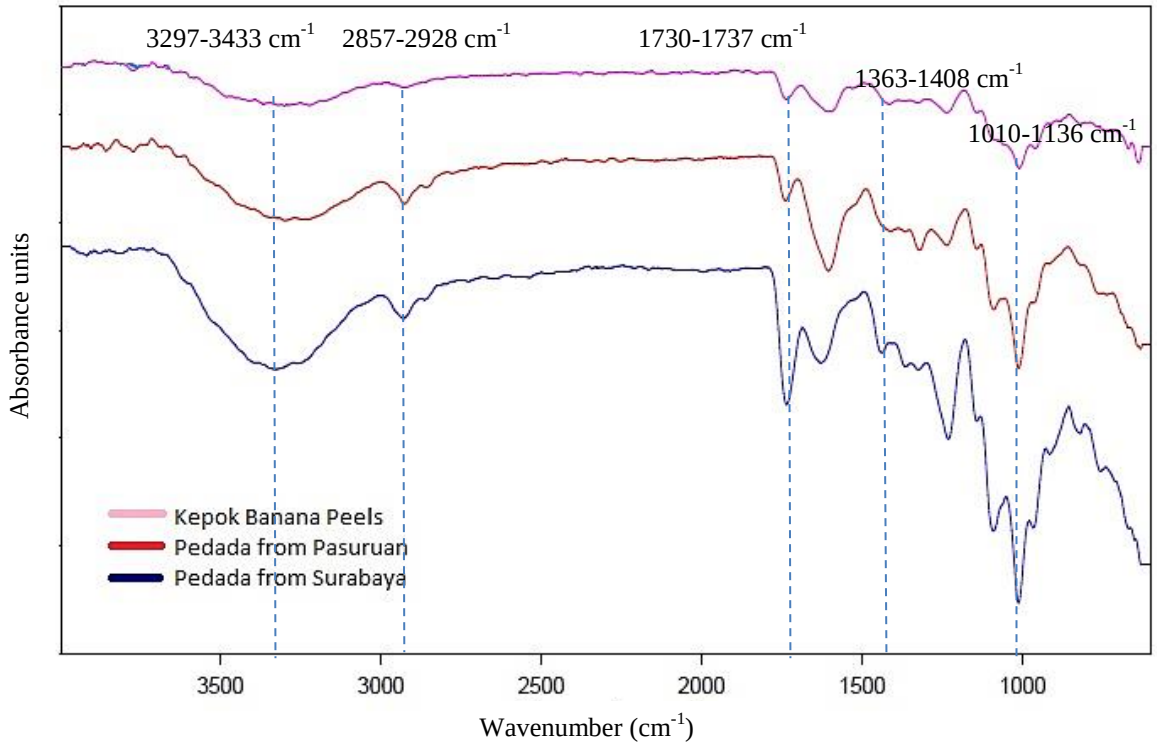

Figure 4. FTIR Result from *Kepok* Banana Peels (KBS) (purple); *Pedada* from Surabaya (PFS) (blue) and *Pedada* from Pasuruan (PFP) (red)

Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

The FTIR analysis was taken from the highest methoxyl content of each pectin source, from flour of *kepok* banana peels, Surabaya *pedada* fruit, and Pasuruan *pedada* fruit. The result is presented in Figure 4. The presence of an O-H hydroxyl group is shown in wave number 3433 cm^{-1} for *pedada* fruit from Pasuruan, 3321 cm^{-1} for *pedada* fruit from Surabaya and 3297 cm^{-1} for *kepok* banana peels.

The presence of aliphatic C-H groups is shown in the wave number 2928 cm^{-1} for *pedada* fruit from Pasuruan, 2863 cm^{-1} for *pedada* fruit from Surabaya, and 2857 cm^{-1} for *kepok* banana peels. In addition, the typical pectin is also shown in the wave number of 1730 cm^{-1} for *pedada* fruit from Pasuruan, 1734 cm^{-1} for *pedada* fruit from Surabaya, and 1737 cm^{-1} for *kepok* banana peels, indicating the presence of carbonyl group C = O. The presence of CH_3 methyl groups is shown in the wave number 1408 cm^{-1} for *pedada* fruit from Pasuruan, 1363 cm^{-1} for *pedada* fruit from Surabaya, and 1364 cm^{-1} for *kepok* banana peels. The presence of C-O groups in alcohol, ether, ester, and carboxylic acid are shown in wave numbers 1136 cm^{-1} for *pedada* fruit from Pasuruan, 1089 cm^{-1} for *pedada* fruit from Surabaya, and 1010 cm^{-1} for *kepok* banana peels. The FTIR spectrumdemonstrated that all tested samples have similar functional groups, where each absorption in a certain wavelength area of the pectin structure. This is characterized by the presence of an OH vibration, a - CH_3 bond on the methoxyl branch ($COOCH_3$), the C-H bond, a carbonyl group (-C = O), and an ether group (-O).

Conclusion

In conclusion, the MAE extraction method could be optimized by the addition of HCl at different concentrations. An increase in HCl concentration was parallel to an increase in the yields, methoxyl content, galacturonic acid content, and molecular weight. The findings also confirmed that the pectin yields from *pedada* fruit varied from that of *kepok* banana peels. The locations of *pedada* fruit affect the characteristics and yield of pectin. The results of the PLS pectin extraction of *pedada* fruit from Surabaya and Pasuruan and *kepok* bananas peels have R^2 value of 1, indicating the pectin data model of each sample using the MAE method has a very good classification.

Declarations

Conflict of interests The authors declare no competing interests.

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