# Extraction Optimization of Pectin from Unripe Banana (*Musa acuminata* × *balbisiana* var. Cardaba) Peel

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***Abstract*—Cardaba (Musa acuminata × balbisiana var. Cardaba) is one of the most important banana varieties in the Philippines. Unripe Cardaba banana peel is an underutilized waste from banana processing. This study aimed to extract and characterize pectin from unripe Cardaba banana peel. Following the Central Composite Design (CCD) with 15 treatments, three levels of extraction time (60, 90 & 120 min), temperature (80, 90 & 100) and peel:solvent ratio (1:10, 1:30 & 1:50) were used in the study. The optimum condition identified were 88 minutes, 95℃ and 1:28 peel:solvent ratio which would yield 13.25% pectin in dry basis, 13% moisture in dry basis, 8.25% ash, equivalent weight of 930, 7.5 % methoxyl content, 64% anhydrouronic acid and 66% degree of esterification. FTIR analysis shows similarities on the banana peel pectin with the pectin standard spectra confirming the isolation of pectin using the optimized extraction process. During the 3-week storage of the extracted pectin, an observable change is the rapid caking of pectin. However, it remained microbiologically safe after 3 weeks of storage.**

***Index Terms*—banana, Cardaba, optimization, CCD, pectin, FTIR**

## I. Introduction

Cardaba banana (*Musa acuminata* × *balbisiana* var. Cardaba) is a triploid hybrid (ABB) banana cultivar originating from the Philippines. This is the most popular variety for processing of banana chips in the domestic and export markets [1]. As pointed out by Dela Cruz et al. (2008) the edible portion of Cardaba banana is only 60%, thus the peel comprises a significant quantity of waste produced from banana processing. Many studies have been conducted in utilizing banana peels such as processing into bioethanol [2], citric acid [3] and burger patty [4]. However, most studies were using ripe banana peels. Because of its astringent mouthfeel and lower nutritional content, unripe banana peels are not considered in any food processing venture and end up as landfill wastes or as fertilizers.

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Pectin, a multifunctional constituent of cell wall is a high value functional food ingredient widely used as gelling agent and as stabilizer. Pectin concentration is highest at fruit unripe stages since during ripening, pectin is broken down by the enzymes pectinase and pectin esterase, resulting in the process where the fruit becomes softer [5]. The pectin extraction process should use a suitable method to obtain the maximum yield and quality of pectin. Pectin extracted from various materials can be different in molecular structure (i.e., molecular weight, degree of esterification and acetyl content) and therefore, possesses different functional properties [6].

The possibility of creating alternative processes, such as the production of a high value food ingredient, to give benefit to waste unripe peels must be considered. This study focused on determining the effects of various extraction conditions on pectin extraction from unripe Cardaba banana peel and to determine the optimum extraction condition that yields pectin with the highest yield and best physico-chemical characteristics.

## II. Materials and Methods

### A. Preparation of Cardaba Banana Peel

Banana peel were washed and sliced into small pieces using a stainless steel knife. It was soaked in water prior to drying. It was dried in a forced draft oven set at 55$^{o}$C for 24 hours.

### B. Extraction Process of Pectin from Banana Peels

Dried banana peel was added to 0.50 N citric acid, pH 2. Peel to solvent ratio was set at 1:10, 1:30 and 1:50. These was heated with continuous stirring at different extracting temperatures (80$^{o}$C, 90$^{o}$C & 100$^{o}$C) on a hot plate for 60, 90 and 120 minutes. The solution was cooled and filtered through an ordinary screen with 1-mm mesh size with two-layer cheesecloth. The filtrate was collected then added with 1:3 (v/v) of absolute ethanol then kept at room temperature overnight. The precipitate (ethanol-insoluble fraction) was filtered through Whatman filter paper No. 4. It was washed with 75% ethanol, and then


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with 80% ethanol to remove the soluble impurities. The residue was oven dried for 12 hours at 55 ℃ and weighed.

### C. Experimental Design for Optimization Experiment

The optimization experiment included three variables which gave significant effects on the pectin extraction based on a screening experiment. To further determine the optimum conditions and formulations of the product, a 3x3 fractional factorial experiment was used following the Central Composite Design (CCD) of Experiment with 15 treatments for experimental combinations.

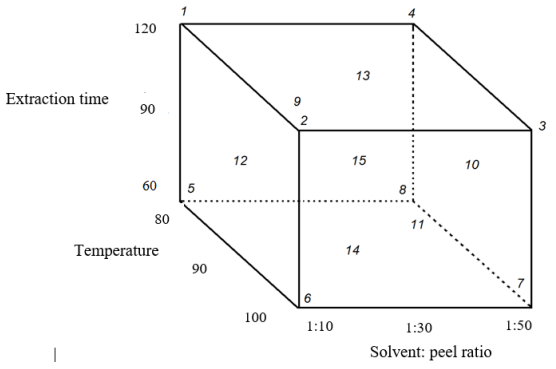


Figure 1. Central composite design experimental design for extraction optimization of pectin from unripe Cardaba banana peel

### D. Characterization of Pectin

#### 1) Pectin yield

Pectin yield was calculated as follows:

$$\text{Pectin } (\%) = \frac{\text{Weight (g) of pectin}}{\text{Weight (g) of peel taken for extraction}} \times 100 \quad (1)$$

#### 2) Moisture content determination

One gram of pectin sample was weighed, ground and placed in a metal dish or aluminum foil. The sample was dried in an oven for 5 hours at 100 ℃ cooled in a desiccator then weighed. One percent was added to the percent moisture observed to obtain agreement with the Fischer method [7]. The moisture content was determined using the equation:

$$\text{Moisture content } (\%) = \frac{\text{weight (g) of residue}}{\text{weight (g) of sample}} \times 100 \quad (2)$$

#### 3) Ash content determination

One to two (1-2) g of pectin was ground to pass an 80-mesh screen and placed into tared crucibles then was ignited in a furnace for 3-4 hours at 600 ℃.

The ash content was determined using the formula below:

$$\text{Ash Content } (\%) = \frac{\text{weight (g) of ash}}{\text{weight (g) of sample}} \times 100 \quad (3)$$

#### 4) Determination of equivalent weight

Equivalent weight was determined by Ranganna's method [9]. About 0.5 g sample was placed in a 250 mL conical flask and 5 ml ethanol was added. One g of NaCl and 100 ml of distilled water was added. About 6 drops of phenol red will be was added and the mixture was titrated against standardized 0.1 N NaOH.

The end point was indicated by a purple or faint pink color. This neutralized solution was stored for determination of methoxyl content. Equivalent weight was calculated by the formula:

$$\text{Equivalent weight} = \frac{\text{Weight of sample (g)} \times 1000}{\text{volume of alkali (mL)} \times \text{Normality of alkali}} \quad (4)$$

#### 5) Determination of methoxyl content (MeO)

Determination of MeO was done using the Ranganna's method [9]. The neutral solution was collected from determination of equivalent weight, and added with 25 mL of 0.25 N NaOH. The mixed solution was stirred thoroughly and kept at room temperature for 30 min. After 30 min, 25 mL of 0.25 N HCl was added and titrated against standardized 0.1 N NaOH. Methoxyl content was calculated by the following formula:

$$\text{Methoxyl content } (\%) = \frac{V \times N \times 3.1}{W} \quad (5)$$

where:
V- volume of alkali
N-Normality of alkali
W- weight of the sample

#### 1) Determination of Total Anhydrouronic Acid Content (AUA)

Total AUA of pectin was obtained by the following formula (Mohamed & Hasan, 1995).

$$\%\text{ of AUA} = \frac{176 \times 0.1z \times 100}{w \times 1000} + \frac{176 \times 0.1y \times 100}{w \times 1000} \quad (6)$$

when molecular unit of AUA (1 unit)=176 g
where:
z-mL (titre) of NaOH from Equivalent weight determination
y- mL (titre) of NaOH from methoxyl content determination
w- weight of sample

#### 2) Determination of Degree of Esterification (DE)

The DE of pectin was measured on the basis of methoxyl and AUA content (Owens et al., 1952) and calculated using this formula.

$$\%DE = \frac{176 \times \%MeO}{31 \times \%AUA} \times 100 \quad (7)$$

### E. Product Storage Stability Evaluation

After the determination of the optimum process for pectin extraction, Stability of Pectin was Determined by Storing it under Ambient0020temperature (28 -30 ℃).

#### 1) Physical evaluation

The extracted pectin from the optimized process condition was subjected to physical evaluation which includes appearance description, color change and water activity. This was done weekly for 3 consecutive weeks.

#### 2) Microbial analyses

The determination of total plate, yeast and mold count of the pectin using the optimum process was analyzed at the Microbiology Laboratory of the Department of Food Science and Technology. Instead of the conventional

petri dish agar plate, rapid selective enzyme-based 3M petrifilms was used. This was consistently done for 3 weeks. Analysis for the presence of yeast and molds was performed using 3M Petrifilm plates for yeast and molds. Total plate count was performed using 3M Petrifilm Aerobic Count plates. With the pipette perpendicular to the inoculation surface, 1 mL of sample suspension at $10^{-1}$, $10^{-2}$ and $10^{-3}$ dilutions was dispensed onto the bottom of the film. Once the top film was dropped, the inoculum was spread over the entire petrifilm using the 3M Petrifilm spreader. The spreader was removed and the films were incubated. YM petrifilms were incubated for 5 days at 20-25℃ while AC petrifilms were incubated for 48 hours at 35oC. Evaluation of the sample was done weekly for 3 consecutive weeks of storage.

$$\text{CFU/ml} = \frac{\text{no. of colony} \times \text{dilution factor}}{\text{volume plated}} \quad (8)$$

where the dilution factor is the reciprocal of the dilution.

### F. Fourier Transform Infrared (FTIR) Analysis

The determination of the spectra for confirmatory test for pectin was conducted in the Department of Pure and Applied Chemistry (DOPAC). The optimized sample was analyzed using Fourier transform-infrared (FT-IR) spectrophotometry (Perkin Elmer RX1 FT-IR). The spectra were recorded in the absorbance range from 4000 to 650 cm-1 (mid-infrared region).

### G. Statistical Analysis and Modelling

Results in the analysis was subjected to Response Surface Regression (RSREG) analysis using Statistical Analytical Software version 9 (SAS, 2008). The Statistica 8.0 software was used for the graphical presentation of the response surface plots.

## III. Results and Discussion

Pectin was produced using 15 treatments for experimental combinations. All other variables was set constant and were subjected to different physico-chemical analysis for optimization.

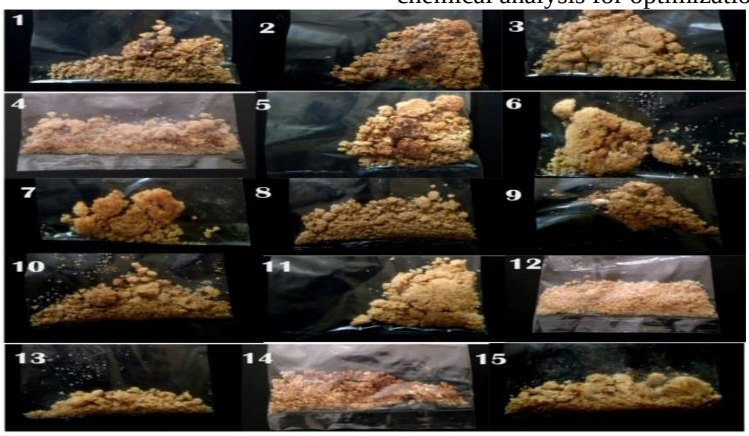


Figure 2. Appearance of banana peel pectin extracted from each treatments of the optimization experiment

TABLE I. Analysis of Variance (ANOVA) for the Different Physico-Chemical Tests for Pectin

| | F-Ratios | | | | | | |
|---|---|---|---|---|---|---|---|
| Regression | Yield (%) | Moisture (%) | Ash (%) | Equivalent Wt. | MEO (%) | AUA (%) | DE (%) |
| Linear | 7.49** | 3.72* | $2.81^{ns}$ | 46.08** | $1.21^{ns}$ | $2.41^{ns}$ | 14.26** |
| Quadratic | 5.86** | $0.85^{ns}$ | $0.18^{ns}$ | 19.68** | $0.73^{ns}$ | $0.33^{ns}$ | 5.83** |
| Cross Product | 3.02* | $0.27^{ns}$ | $1.24^{ns}$ | $2.78^{ns}$ | $0.11^{ns}$ | $0.71^{ns}$ | $1.55^{ns}$ |
| Total Regression | 5.46** | $1.41^{ns}$ | $1.45^{ns}$ | 22.85** | $0.68^{ns}$ | $0.99^{ns}$ | 7.21** |

Legend: $^{ns}$ not significant (p>0.05); *significant (p≤ 0.05); **significant (p≤ 0.01)

TABLE II. Parameter Estimate of Physico-Chemical Tests for Pectin

| Parameter | ATTRIBUTES | | | | | | |
|---|---|---|---|---|---|---|---|
| | Yield (%) | Moisture (%) | Ash (%) | Equivalent Wt. | MEO (%) | AUA(%) | DE (%) |
| Mean | 12.02 | 12.41 | 8.06 | 899.55 | 7.47 | 65.02 | 65.31 |
| Intercept | $15.82^{ns}$ | $-5.534^{ns}$ | $-0.897^{ns}$ | 4588.37** | $11.50^{ns}$ | $9.11^{ns}$ | 157.94** |
| Ratio | $0.210^{ns}$ | $0.175^{ns}$ | $-0.147^{ns}$ | 17.985** | $0.042^{ns}$ | $-0.023^{ns}$ | $0.386^{ns}$ |
| Ratio*Ratio | -0.005** | $-0.001^{ns}$ | $0.000^{ns}$ | -0.194** | $0.000^{ns}$ | $0.001^{ns}$ | -0.0050* |
| Temp | $-0.403^{ns}$ | $0.208^{ns}$ | $0.107^{ns}$ | -99.376** | $-0.129^{ns}$ | $1.193^{ns}$ | -2.3759* |
| Temp*Temp | $0.004^{ns}$ | $-0.001^{ns}$ | $0.000^{ns}$ | 0.591** | $0.001^{ns}$ | $-0.006^{ns}$ | $0.013^{ns}$ |
| Time | $0.158^{ns}$ | $0.070^{ns}$ | $0.076^{ns}$ | 8.679* | $0.017^{ns}$ | $0.017^{ns}$ | $0.146^{ns}$ |
| Time*Time | $0.000^{ns}$ | $0.000^{ns}$ | $0.000^{ns}$ | -0.038* | $0.000^{ns}$ | $0.001^{ns}$ | $-0.001^{ns}$ |
| Ratio*Temp | $-0.001^{ns}$ | $-0.001^{ns}$ | $0.001^{ns}$ | -0.104 | $0.000^{ns}$ | $0.001^{ns}$ | $-0.003^{ns}$ |
| Ratio*Time | 0.001* | $0.000^{ns}$ | $0.000^{ns}$ | $0.002^{ns}$ | $0.000^{ns}$ | $-0.001^{ns}$ | $0.001^{ns}$ |
| Temp*Time | $-0.001^{ns}$ | $0.000^{ns}$ | $-0.001^{ns}$ | $-0.008^{ns}$ | $0.000^{ns}$ | $-0.002^{ns}$ | $0.001^{ns}$ |

Legend: $^{ns}$ not significant (p>0.05); *significant (p≤ 0.05); **significant (p≤ 0.01)

### A. Pectin Characterization

#### 1) Pectin yield

The average yield was found to be 12.02% dry basis. The response surface regression analysis shown in Table I and II indicate a significant linear, quadratic and cross product effect on yield which implies that an interaction between the three variables significantly influences the extraction yield. The regression model for yield is predicted the equation below:

$$\text{Yield}=1.0795+0.1521X_1+0.05045X_2+0.2342X_3+0.00035X_1^2+0.0007X_2^2-0.0045X_3^2-0.0015X_1X_2+0.0012X_1X_3-0.0006X_2X_3 \quad (9)$$

Equation (9) shows that there is a positive linear effect for yield as extraction time ($X_1$), temperature($X_2$) and peel: solvent ratio ($X_3$) are increased. Low yield at lower temperature could be caused by the inefficient diffusion of the solvent into the peels. Increasing the extraction temperature and at sufficient time would increase the solubility of the extracted pectin, giving a higher rate of extraction.

#### 2) Moisture content

The overall response mean for moisture is 12.41% dry basis. Low moisture content is necessary for pectin for safe storage as well as to inhibit the growth of microorganisms that can affect the quality due to the production of pectinase enzymes [10].

$$\text{Moisture}=-6.7613+0.10525X_1+0.43155X_2+0.13085X_3-0.00055X_1^2-0.0021X_2^2-0.00125X_3^2+0.0005X_1X_2-7.2902E\text{-}5X_1X_3-0.0012X_2X_3 \quad (10)$$

Equation (10) shows that increasing the individual variables $X_1$ (time), $X_2$ (temperature) and $X_3$ (peel solvent ratio) caused the moisture content to increase. However, quadratic interactions of the variables caused a negative effect on the moisture content.

#### 3) Ash content

The overall response mean for ash is 8.06%. Low ash content (below 10%) and maximum limit of ash content at 10% are one of the good criteria for gel formation [11]. Therefore, the ash content found in this experiment indicates the purity of the pectin. Lower ash content is also one of the two criteria governing its purity, DE being the other [12]. Based on the analysis of variance, the response for ash content is not affected by any regression of the different independent variables in the extraction process. The model built for the ash content is the equation below.

$$\text{Ash}=6.17903333+0.02315X_1+0.0021X_2-0.08505X_3+0.00015X_1^2+0.0004X_2^2+0.0005X_3^2-0.0011X_1X_2+6.4833E\text{-}5X_1X_3+0.0014X_2X_3 \quad (11)$$

#### 4) Equivalent weight

The overall response mean for equivalent weight is 899.550735. Equivalent weight of pectins is another indicator of its jelly-forming ability, with high molecular weight pectins having better ability [13]. The mean equivalent weight is comparable with that of pectin extracted in table banana with value of 925.01 [14].

$$\text{EQ WT.}= 2607.68417+3100.086X_1-72.6172X_2+12.8326X_3-0.0405X_1^2+0.43165X_2^2-0.1852X_3^2-0.0076X_1X_2+0.0018X_1X_3-0.1042X_2X_3 \quad (12)$$

Equation (12) depicts a linear positive response of the equivalent weight on increased values of time ($X_1$) and peel: solvent ratio ($X_3$) and a negative effect on increased temperature. However, quadratic effects of $X_1$ and $X_3$ showed decreased equivalent weight and $X_2$ gave a positive effect. Cross-product interactions between time and peel: solvent ratio ($X_1X_3$) gave a positive effect while other interactions are negative.

The changes in equivalent weight caused by extraction time, temperature and solvent is due to the depolymerization of pectin. Pectin which consists mostly of D galacturonic acid (GalA) units is joined in chains by means of α-(1-4) glycosidic linkage (Srivastava and Malviya, 2011). Pectin depolymerization during heating involves acid-catalyzed hydrolytic splitting of glycosidic bonds (T≥ 60℃; pH < 3). The rate of acid hydrolysis increases with increasing temperature [15].

#### 5) Methoxyl Content (MeO)

Methoxyl content is an important factor in controlling the setting time of pectins and the ability of the pectin to form gels [16].The overall response mean for methoxyl content is 7.472113%. This result is approximately similar to those as found for peel of mango (7.33%), banana (7.03%) [17]. Methoxyl content of pectin extracted from different sources was found to vary from 0.2-12% depending on the source and mode of extraction [18].

Methoxyl content of commercial pectins generally varies from 8-11% and can form high sugar gels (>65% sugar). On the other hand, low methoxyl pectins (less than 7.0%) can form gels with lower concentrations of sugars. Methoxyl content also influence the dispersability of pectin in water, higher methoxyl content being more readily dispersible in water than that with less than 7.0% methoxyl content [19]. Therefore, based on the methoxyl value of the pectin extracted in this study can categorized as high methoxyl pectin.

Equation (12) shows the influence of variables on the methoxyl content of pectin:

$$\text{MeO}=8.8349+.01635X_1-0.08105X_2+0.03195X_3-5.9E\text{-}05X_1^2+0.0005X_2^2-0.0004\text{-}5E\text{-}05X_1X_2-3.6478E\text{-}05X_1X_3-0.0002X_2X_3 \quad (13)$$

#### 6) Anhydrouronic acid (AUA)

The anhydrouronic Acid (AUA) indicates the purity of the extracted pectin and its value should not be less than < 65% [20]. The overall response mean for AUA is 65.018311%. This value resembles and lie between the AUA content found in apple pomace pectin, commercial

apple pectin and dragon fruit pectin which was 59.52 to 70.50% [2]. AUA content of less than 65% may indicate impurities due to the presence of proteins, starch and sugars in the precipitated pectin [11].

Based on DE, pectin can be classified as low methoxyl pectin with ≤ 50% DE and high methoxyl pectin with > 50% DE [6]. Thus, the pectin extracted from banana peel is high-methoxyl pectin which is in agreement with the result in methoxyl content determination. The pectin extracted from banana peel can also be considered as slow set pectin. Pectins could be classified as rapid-set (DE >72%) and slow-set (DE 58-65%), which describes the rate of gel formation [2].

The response surface regression analysis shown in Table I and Table II shows that response for methoxyl content is not affected by any regression of the different independent variables in the extraction process, this implies that methoxyl content is not influenced by the different independent variables. Equation (13) shows the influence of variables on the methoxyl content of pectin:

$$AUA=42.6682667-0.0818\ X_1+0.79185\ X_2-0.0249X_3+0.00085\ X_1^2+0.00385\ X_2^2+0.0014\ X_3^2-0.0018\ X_1X_2-0.0012\ X_1X_3+0.0012\ X_2X_3 \quad (14)$$

*7) Degreee of Esterification (DE)*

The response surface regression analysis shown in Table I indicate a linear and quadratic effect on yield which implies that an interaction between the three variables significantly influences the extraction yield. Equation (15) shows the influence of variables on the DE of pectin:

$$DE=100.7761+0.23215\ X_1-1.55045\ X_2+0.3035\ X_3-0.0014X_1^2+0.00875X_2^2-0.0049\ X_3^2+0.0012\ X_1X_2+0.0008\ X_1X_3-0.0025\ X_2X_3 \quad (15)$$

Increased values of time ($X_1$) and peel: solvent ratio ($X_3$) increases the DE while a decrease in DE is predicted in increased temperature ($X_2$) (15). Quadratic effects of $X_1$ and $X_3$ showed decreased DE. Cross-product interaction between time and peel: solvent ratio ($X_1X_3$) is predicted to increase DE.

The decrease in pectin yield by the increase in extraction period may be due to the thermal degradation of the extracted pectin. The degradation is mainly caused by the depolymerization mechanism of galacturonan chain of pectin, which is known as beta-elimination [21]. Thus, only a small amount of pectin can be recovered by precipitation with alcohol.

*B. Optimized Region of the Experiment*

Superimposing the contour plots in the results of the evaluation of physico-chemical characteristics of unripe banana peel pectin with time (90 minutes), temperature (90°C) and peel-solvent ration (1:30) being held constant, the location of the optimum region for the extraction process was established. The contour plots were obtained by using the mean values of the different tests carried on. This would provide an idea on the values of extraction time, temperature and peel:solvent ratio that can produce a high quality pectin. The shaded region presented in Fig. 3a, Fig. 3b and Fig. 3c indicates the value(s) corresponding the optimum condition for the extraction process. Any point of combination within the shaded region represents the optimized combinations.

TABLE III. OPTIMIZED RANGES FOR THE RELEVANT VARIABLES

| Variable | Optimized Range |
|---|---|
| Extraction Temperature (℃) | 93-96 |
| Extraction time (℃) | 85.5-89 |
| Peel-solvent ratio | 1:27-1:28.5 |

Middle point of each optimum range was selected and used in the production of pectin from banana peel. The values used for extraction temperature, extraction time and peel-solvent ratio were 95 ℃, 88 minutes and 1:28, respectively. This optimum process combination was found to be within the treatments used during the optimization process.

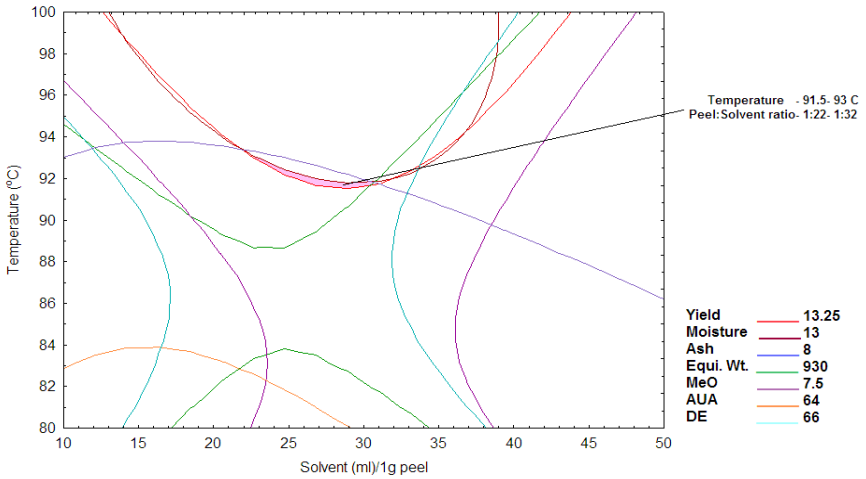


Figure 3a. Optimum region at constant time (min) obtained by superimposing physico-chemical tests indicated (right).

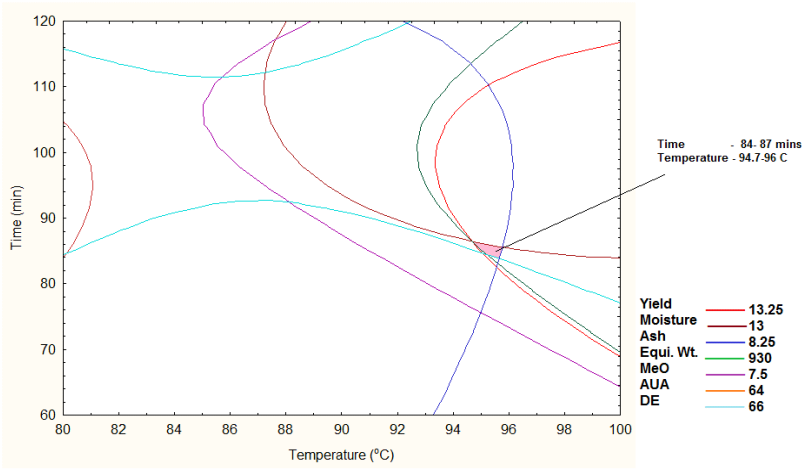


Figure 3b. Optimum region at constant peel-solvent ratio obtained by superimposing physico-chemical tests indicated (right).

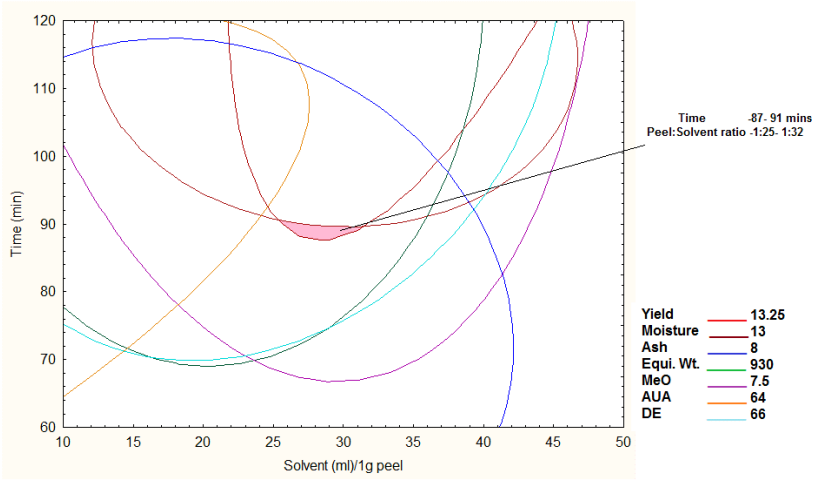


Figure 3c. Optimum region at constant temperature (oC) obtained by superimposing physico-chemical tests indicated (right).

### *C. Product Storage Stability Evaluation*

After 3 weeks of storing the pectin under ambient temperature (28 -30℃), physical and microbial evaluations were conducted.

During the 3-week storage of the pectin, the observable change in appearance was caking which could be due to moisture contact from outside environment even if sealed in a 0.003 mm thick polyethylene zip-lock. Results show that only a slight change on water activity (0.686 to 0.724) was detected. Water is recognized as being very important, if not critical, to the stability of most products. Caking of powdered products happens at $A_w$ between 0.3 to 0.5 and rapidly increases beyond this $A_w$ level. Knowledge on the water activity of powders as a function of moisture content and temperature is essential during processing, handling, packaging and storage to prevent the deleterious phenomenon of caking, clumping, collapse and stickiness. Caking is water activity, time, and temperature dependent and is related to the collapse phenomena of the powder under gravitational force [22].

Results of the microbial test, revealed zero to a few growth of bacterial and yeast and mold colonies. The highest yeast and mold counts, having 40 Estimated Standard Plate Count (ESPC) were found at 3 weeks of storage.

Bacterial count remains the same having 10 to 100 ESPC during the third week of storage period. Mold and yeast counts increased slightly which could indicate the growth of molds during storage. In general, bacteria require higher Aw and moisture compared to yeast and molds. With a moisture content of 12.51% dry basis and Aw of 0.686-0.724 of the extracted pectin, it is possible that molds could proliferate during storage.

### *D. Fourier Transform Infrared (FTIR) Analysis*

In order to confirm the identity of the banana peel pectin, the optimized sample was analyzed using Fourier transform-infrared (FT-IR) spectrophotometry (Perkin Elmer RX1 FT-IR). The spectra were recorded in the absorbance range from 4000 to 650cm-1 (mid-infrared region).

Shown in Fig. 4, similarities were found between the FTIR spectra of banana peel pectin and commercial pectin. FTIR spectra of extracted and standard pectin samples have characteristic peaks at 3259.77, 2935.44, 1718.04 and 1009.48cm− 1 corresponding, respectively, to –OH, –CH, CO of ester and acid, and –COC–

stretching of the galactouronic acid, the backbone of pectin.

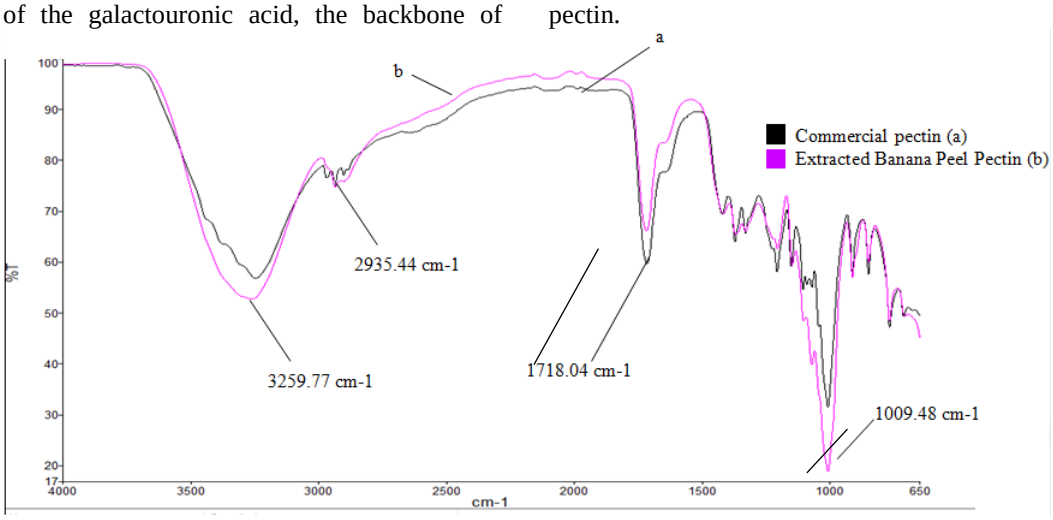


Figure 4. FTIR results for extracted banana peel pectin versus standard commercial pectin at 4000 to 650 cm-1 absorbance.

It was found that banana peel pectin spectra exhibited similarities in its absorption pattern to that of commercial pectin standards. FTIR spectrum in the wavelength range of 950 and 1200 cm-1 are considered as the 'finger print' region for carbohydrates as it allows the identification of major chemical groups in polysaccharides [22]. Similarities of the banana peel pectin with the pectin standard spectra in the "fingerprint" region suggest that the isolated substance is effectively pectin.

## IV. Conclusion

Extraction process for banana (*Musa acuminata* × *balbisiana* var. Cardaba) peel pectin was optimized. The optimum condition identified for extraction time, extraction temperature and peel: solvent ratio were 88 minutes, 95 ℃, and 1:28, respectively. This would yield 13.25% pectin in dry basis, 13% moisture in dry basis, 8.25% ash, equivalent weight of 930, 7.5 % methoxyl content, 64% anhydrouronic acid and 66% degree of esterification. FTIR spectra of different pectin samples have characteristic peaks at 3260.0, 2936.0, 1718.0 and 1072.1cm−1 corresponding, respectively, to –OH, –CH, C O of ester and acid, and –COC– stretching of the galactouronic acid, the backbone of pectin. Result of the FTIR analysis shows similarities on the banana peel pectin with the pectin standard spectra confirming the isolation of pectin using the optimized extraction process. During the 3-week storage of the extracted pectin, an observable change is the rapid caking of pectin was noted. However, it remained microbiologically safe after 3 weeks of storage.

The potential of extracting pectin from unripe Cardaba banana peel is demonstrated in this study. This would create new opportunities to local processors, especially banana chips processors, and provide additional income by utilizing not only the banana pulp but also its peel.

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