Drying Kinetics and Optimisation of Pectin Extraction from Banana Peels via Response Surface Methodology

Chua Bee Lin[1,*], and Chong Yek Cze[1]

[1]School of Engineering, Taylor's University, 47500 Subang Jaya, Selangor, Malaysia

Abstract. Banana peels which are the waste in abundance, are used to extract valuable pectin. The gelling ability of the pectin has gained attention in food and pharmaceutical industries. This research aims to select the best drying kinetic model for banana peels and also optimize the pectin extraction process using Box-Behnken response surface design (BBD). Determination of pectin gelling mechanism using degree of esterification (DE) is also focused in this research. In this study, oven drying with temperature 50°C was chosen as the best drying temperature due to highest extraction yield. Furthermore, Page-Two-term model was selected as the best model to describe the drying kinetics of banana peels due to highest R^2 value (0.9991) and lowest RMSE value (0.001). The optimal extraction conditions given by BBD were 75°C extraction temperature, 23 min extraction time and 1:33.3 g/ml solid-liquid ratio. Likewise, the DE for both pectins extracted using unoptimised and optimised conditions were 71.92±1.38% and 76.1±2.07% respectively. Both of the pectins were classified as high-methoxyl pectins. The pectin with higher DE also indicated that the rate of gel formation is higher. The results showed that the pectin yield and gelling time has successfully improved after optimised the pectin extraction process.

1 Introduction

Banana (*Musa*) is one of the popular food crops that can found in the world market. Banana is generally processed into value-added product such as chips and jam. Because of the high demands of banana products, abundant of banana peels are produced every day and it has reported that about 39000 tons of banana peels are generated annually in U.S [1]. Hence, many scientists tend to find out the application of the banana peels to reduce the industrial waste and a valuable compound, pectin is found in the banana peels [2].

Pectin is a polysaccharide that consists of ∝-(1,4) galacturonic acid [1]. It is widely used as gelling agent for puree and jelly preparation [1]. Pectin is also proved to have wound healing and cholesterol-lowering effects [3]. Pectin is categorized based on the gelling mechanism using degree of esterification (DE) [2]. Pectin can be divided into low-methoxyl (LM) pectin (DE < 50%) and high-methoxyl (HM) pectin (DE > 50%). LM pectin forms

* Corresponding author: beelin.chua@taylors.edu.my

gels under divalent ions whereas HM pectin form gels under high sugar concentration solution [4]. Likewise, the gel formation rate of pectin can be determined by DE. Pectin is classified as slow gelling (DE 58-65%) or fast gelling (DE > 72%) [2]. It is important to analyze the esterification degree of pectin because it is used to determine the suitability of end products [2].

Drying is the primary process prior to pectin extraction process. It is normally performed using natural sunlight or artificial dryer such as oven [5]. Drying is used to preserve the quality and extend the shelf life of the foodstuffs by reducing the moisture content to desired level [6]. Sun drying is the conventional method to preserve foodstuffs as it is renewable and low in cost. Yet, large-scale production is not always preferred to use sun drying [7]. Hence, artificial dryer is the alternative to provide uniform and fast drying process. With regards to this, both methods were studied in this research.

Thin-layer drying kinetic models are the mathematical modelling that used to predict the drying behaviour and time of food products [6]. Many popular drying models such as Page, Logarithmic, Henderson and Pabis models have successfully described the drying kinetics of various plants [5], [8, 9]. Besides, some new models have developed to improve the accuracy [5], [10]. For instances, a new model which combined the Page and Two-term drying models has proved to give a promising results for cocoa beans [5]. These two models are chosen because both of them give favourable fitting in many applications according to past experience [5]. Yet, this new model, Page-two-term model has only been used in cocoa beans [5]. Regarding to this, this model was performed in this research to study the potential of this new model applies on banana peels and also compared with the Page and Two-term models.

Extraction of pectin can be achieved using acid, ultrasound-assisted (UAE) and microwave-assisted extraction (MAE) [11]. However, UAE which used the acoustic energy to break the cell wall, has gained a lot of attention these years [12]. This is because UAE reduces the extraction time and increases the extraction yield with lower energy consumption [12]. With this respect, UAE was selected to extract the pectin from banana peels in this research.

To the best of author's knowledge, no research has been conducted to study both drying kinetics and optimisation of pectin extraction from banana peels using RSM together [13, 14]. Hence, the present study is carried out with the objectives as follows:

1. To select the best drying models to describe the drying process of banana peels.
2. To optimise the pectin yield with different extraction parameters (extraction temperature, extraction time and solid-liquid ratio) using Box-Behnken response surface design (BBD).
3. To determine the gelling mechanism of pectin based on degree of esterification using titrimetric method of Food Chemical Codex 1981.

2 Methodology

This section discusses about the methods that carried out in this research in order to accomplish the objectives.

2.1 Pre-treatment of banana peels

Ripened banana peels were collected from a commercial fruit juice store in Taylor's University, Subang Jaya, Selangor, Malaysia. 100g of banana peels were washed with distilled water to remove dirt on the surface before cutting into slices.

2.2 Drying of banana peels

In this research, the oven drying was compared with the conventional method which is sun drying. The drying method that produced the highest pectin yield was selected for modelling. The initial moisture content of the samples was measured using moisture analyser (Model XM50, Precisa Gravimetrics AG, Switzerland) to estimate the bone-dry weight before drying. All the samples were spread evenly in single layer on an aluminium tray to avoid any overlapping.

For sun drying, the samples were dried under the sun from 9 a.m. to 5 p.m. and tempered from 5 p.m. to 9 a.m. until it reached constant weight [6]. Weighing balance (Model TX423L, Shimadzu, Japan) was used to measure the weight of the samples. The surrounding temperature (32°C), humidity (79.7%) and wind velocity (2.6 m/s) were measured using HVAC datalogger (Model DO2003, Delta OHM, Italy). For oven drying, The peels were dried in an oven (Model UN75, Memmert, Germany) with different temperature 40°C, 50°C, 60°C and 70°C until the weight of samples reached constant.

After drying, the dried banana peels were grinded into powder using a grinder (Model BL-1525 BG OEM, China). The powdered peels were kept in polyethylene bag at room temperature for further analysis.

2.3 Mathematical modeling and statistical analysis

The optimum drying method and temperature that produced the highest pectin yield was used to study the drying kinetic models. 100g of pre-treated banana peels were dried using the optimum drying method/temperature and the weight loss of the banana peels was measured every 5 minutes until constant weight was obtained. The moisture content (MC) and moisture ratio (MR) of banana peels were calculated using Eq. (1) and Eq. (2) [5], [15]

$$MC\ (\text{dry basis}) = \frac{w_i\text{-}w_{db}}{w_i} \tag{1}$$

where, w_i is the initial weight of the sample (g) and w_{db} is the bone-dry weight (g).

$$MR = \frac{M\text{-}M_e}{M_o\text{-}M_e} \tag{2}$$

where, M_o is the initial moisture content, M is the moisture content at time and M_ϵ is the moisture content at equilibrium.

The experimental data were fitted into the three drying kinetic models as shown in Table 1. Microsoft Excel SOLVER 2016 was used for non-linear regression analysis [5]. In non-linear regression analysis, statistical indicators, coefficient of determination (R^2) and root mean square error (RMSE) were used to determine the fitting goodness [5], [15]. The formula of R^2 and RMSE are as follow.

$$R^2 = 1\text{-}\frac{\sum_{i=1}^{N}(MR_{Exp.i}\text{-}MR_{Pred.i})^2}{\sum_{i=1}^{N}(MR_{Exp.i}\text{-}\overline{MR_{Pred.i}})^2} \tag{3}$$

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(MR_{Exp.i}\text{-}MR_{Pred.i})^2} \tag{4}$$

where, N is the data number has run, $MR_{exp,i}$ and $MR_{pred,i}$ are the experimental and predicted moisture ratio value respectively.

Table 1. Drying kinetic models

No.	Model	Equation	Ref.
1	Page	$MR = e^{-kt^n}$	[16]
2	Two-term	$MR = ae^{-kt} + ce^{-gt}$	[5]
3	Page-Two-term	$MR = ae^{-kt^n} + ce^{-gt^n}$	[5]

2.4 Ultrasound-assisted extraction (UAE) of pectin

The UAE process was conducted based on publication with minor modification [11, 12]. Four gram of powdered banana peels was added into 0.1 M of citric acid with pH 1.5 and SLR 1:30 g/ml. The mixture was then placed in the ultrasonic water bath (Elmasonic P120H, Elma, Germany) with temperature 80˚C and sonicated for 60 min. The power and frequency of sonicator are set to 80 W and 37 kHz respectively. The mixture was left to cool down and then filtered out using a vacuum filtration. The filtrate was precipitated using 95% of ethanol with ethanol-to-filtrate ratio 2:1 v/v. The precipitate and filtrate were then separated using a centrifuge (Scanspeed 1236MG, LaboGene, Denmark) at 6000 RPM for about 30 min. The precipitated pectin was rinsed with 95% ethanol thrice to remove impurities and then dried in the oven with temperature 50 ˚C for 12 hours. The pectin yield based on the total peels used for extraction was calculated using Eq. (5).

$$\text{Pectin yield (\%)} = \frac{\text{weight of dried pectin (g)}}{\text{initial weight of dried banana peel powder (g)}} \times 100 \quad (5)$$

2.5 Experimental design using RSM

Box-Behnken Design (BBD) in Design Expert 7.0 Software was used to optimize the pectin extraction conditions from banana peels. Three independent variables (X_1: extraction temperature, X_2: extraction time and X_3: solid-liquid ratio) were employed as these factors were found to be important in affecting the pectin yield based on previous study from publication [17]. For each factor, the level of the factor was chosen by taking the reference from previous work [17]. The three variables with their corresponding coded and actual values is shown in Table 2. By inserting the parameters and levels into BBD, 17 sets of experiment with different extraction conditions were developed as shown in Table 6. The variables in different level combination arranged by the BBD were used for pectin extraction using UAE method as mentioned in Section 2.4.

Table 2. Extraction parameters and levels

Extraction Parameters	Code	Levels		
		-1	0	1
Extraction temperature (°C)	X_1	60	70	80
Extraction time (min)	X_2	20	40	60
Solid-liquid ratio (w/v)	X_3	1:20	1:30	1:40

2.6 Statistical analysis and validation of optimal conditions

Design Expert Statistical 7.0 Software was used to study the experimental data with regression analysis. F-test at P-value (0.05) was used to assess the significance of regression coefficients [7]. The regression model adequacy was evaluated by coefficient of determination, R^2 and adjusted R^2 [7]. Besides that, the significant independent variables in the model were assessed using ANOVA with confidence level 95%. Response surface graphs were then generated using the regression coefficients.

The optimum extraction conditions that obtained from BBD were carried out an experiment. Experimental and predicted values were compared to validate the model and error of less than 5% between both values indicates a good fit [15].

2.7 Determination of degree of esterification (DE)

The esterification degree (DE) of the sample was determined using titration method with a little modification from publication of [4]. 2 ml of ethanol was added to 0.2 g of dried pectin and the mixture was then dissolved in 20ml of distilled water. The mixture was stirred continuously until the pectin was completely dissolved. 3 drops of phenolphthalein were added to the mixture and 0.1M of $NaOH$ was used to titrate the mixture until it turned into pale pink. The titration volume (V_1) was recorded. Next, the mixture was added with 10ml of 0.1M $NaOH$ and stirred continuously for an hour. 10ml of 0.1M HCl was added and the mixture was shaken until the colour of pale pink disappeared. 3 drops of phenolphthalein were added and 0.1M $NaOH$ was used to titrate the mixture until it turned into pale pink. The titration volume (V_2) is recorded. The experiment was repeated for three times. The DE was calculated using Eq. (6).

$$\mathrm{DE}(\%) = \frac{V_1}{V_2+V_1} \times 100 \tag{6}$$

3 Results and discussion

3.1 Selection of drying process and drying temperature

Sun drying (conventional method) and oven drying were compared to select the suitable drying method for banana peels. The drying method was selected based on the highest pectin yield. Since the temperature in the oven can be adjusted, different temperature (40°C, 50°C, 60°C and 70°C) were also tested to select the optimum temperature based on the extraction yield. The pectin yield obtained from sun drying and oven drying was tabulated in the following Table 3. According to the results, oven drying with temperature of 50°C was selected as it gave a highest pectin yield.

Table 3. Pectin yield at different drying process

Method	Temperature (°C)	Pectin Yield (%)
Sun drying	32	1.38±0.07
Oven drying	40	2.84±0.12
	50	2.88±0.07

	60	1.92±0.09
	70	1.78±0.08

Sun drying gave the lowest pectin yield (1.38±0.07%) due to rainy season on September 2017. The drying process became less effective as the average daytime temperature was only about 32°C with low wind velocity of 2.6 m/s and high humidity of 79.7%. These conditions increased the enzymatic degradation since the moisture in the peels could not be removed as soon as possible and this activated the microbiological activity, leading to spoilage of the peels [18]. Thus, the cell structure had destroyed by microbiological activity and this resulted in low pectin yield. The limitation of sun drying is the samples could only dry at day time with sunlight whereas oven drying does not have this limitation. Hence, the samples were able to dehydrate faster than sun drying to prevent microbiological spoilage to produce higher pectin.

For oven drying, results showed that the pectin yield increased from 40°C to 50°C and started to decrease after 50°C. Temperature of 50°C gave the highest pectin yield (2.88±0.07%) while 70°C gave the lowest pectin yield (1.78±0.08%). This could be explained as at low temperature, the heat energy was not strong enough to eliminate the moisture as soon as possible and this led to samples spoilage due to microbiological activity [18]. Yet, high temperature dried and harden the peels surface, blocking the moisture to escape [19]. This is also called as "case hardening" [19]. In other words, high temperature dried the food outside but inside still remained moist. This caused the moisture inside the peels could not be evaporated and the trapped moisture caused bacteria growth and spoilage, resulting in low pectin yield [19].

3.2 Drying kinetics and modeling

The initial moisture content of the banana peels before drying was measured as 92.15%. It is normal to have high initial moisture content because most of the fruits contain more than 90% of water [20]. It is important to measure the initial moisture content because it is used to estimate the bone-dry weight of the sample. The collected moisture content data was converted to moisture ratio and then plotted in graph as shown in Figure 1. Referring to Figure 1, moisture ratio decreased continuously with time and remained constant after 1400 min. The exponential decreasing curve also shows that internal mass transfer had governed by diffusion [15]. The constant zero moisture ratio at the later phase of the process indicated that the moisture of the samples were fully removed. The moisture ratio data was then fitted to the drying models and the following table 4 shows the goodness of fit of each drying model.

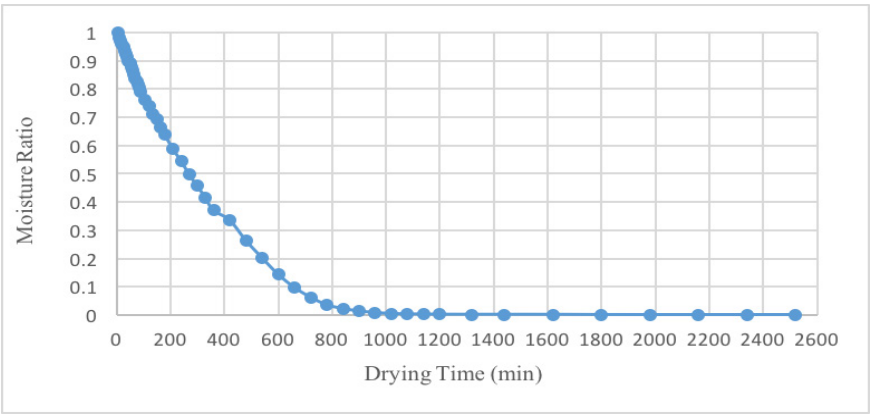


Fig. 1. Graph of moisture ratio against drying time

Table 4. The fitness of different models at 50°C drying temperature

No.	Model name	Coefficients and Constants	R^2	RMSE
1	Page	n = 1.164, k = 0.001098	0.9975	0.0026
2	Two-term	a = 0.0181, k = 1.4819, c = 1.0359, g = 0.00297	0.9947	0.0056
3	Page-Two-term	a = 0.09, k = 0.00405, c = 0.9012, g =0.000207, n = 1.4221	0.9991	0.001

According to Table 4, the fitting goodness of the models according to the statistical indicators (R^2 and RMSE) were in the order of: Page-Two-term > Page > Two-term. Page-two-term was selected as the best-fitted drying model to describe the drying process of banana peels as it gave the highest R^2 value (0.9991) and lowest RMSE value (0.001). Similar result has been obtained in cocoa beans plant in previous study [5]. Since Page-Two-term model is the new model that specially developed to describe the drying kinetics of cocoa beans, it can be concluded that this new model is also applicable in banana peels according to the satisfactory results.

3.3 Experimental design and regression analysis

17 experiments were conducted according to the conditions arranged by BBD as shown in Table 5. The experimental results showed the pectin yield ranging from 2.75% to 6.03%. Experiment 17 (X_1= 70°C, X_2 = 20 min and X_3 = 1:20) gave the maximum pectin yield (6.03%±0.11%) whereas experiment 1 (X_1= 60°C, X_2 = 40 min and X_3 = 1:20) gave the minimum pectin yield with only 2.75%±0.13%. The influence of extraction parameters on pectin yield was discussed in details in Section 3.4.

Table 5. Box-Behnken design with experimental and predicted pectin yield

Std	Run	Temp, X_1 (°C)	Time, X_2 (min)	SLR, X_3 (g/ml)	Pectin Yield, Y (%)	
					Experimental	Predicted
5	1	60	40	1:20	2.75±0.13	2.725

1	2	60	20	1:30	4.50±0.15	4.278
8	3	80	40	1:40	4.50±0.10	4.525
16	4	70	40	1:30	6.00±0.14	5.540
12	5	70	60	1:40	3.75±0.18	3.503
14	6	70	40	1:30	5.20±0.09	5.540
11	7	70	20	1:40	5.75±0.28	5.804
3	8	60	60	1:30	3.50±0.13	3.578
17	9	70	40	1:30	5.50±0.08	5.540
6	10	80	40	1:20	4.85±0.13	4.682
7	11	60	40	1:40	3.00±0.10	3.167
4	12	80	60	1:30	5.00±0.22	5.221
10	13	70	60	1:20	5.00±0.15	4.946
13	14	70	40	1:30	5.60±0.13	5.540
9	15	70	20	1:20	3.83±0.15	4.076
15	16	70	40	1:30	5.40±0.17	5.540
2	17	80	20	1:30	6.03±0.11	5.951

In addition, Table 6 below shows the regression analysis based on the experimental results. ANOVA was used to study the model adequacy and the significant of corresponding variables. Based on rule of thumb, high F-value and p-value lower than 0.05 indicate the model and variable are significant. Referring to the results, quadratic model fitted adequately to the experimental results due to large F-value (19.45) and small p-value (0.004). Likewise, R^2 and adjusted R^2 are used to check for the model adequacy and suitability. The experimental and predicted values showed a good correlation due to high value of R^2 (0.9616) and adjusted R^2 (0.9121) [1]. Besides, adequate precision measures the error related to the predicted response and the desirable value is above 4 [1]. The results showed that the model's adequate precision value was 13.839 which denoted that the model can be used inside the operation region [1].

Likewise, the significant of the corresponding variables on pectin yield (Y) can also be determined by F-value and p-value in Table 6 as shown as below. The higher the F-value and the smaller the p-value, the more significant the variable is. Linear term of extraction temperature (X_1) had the largest effect because of highest F-value and smallest p-value, followed by the quadratic term of extraction temperature ($X_1{}^2$) and SLR ($X_3{}^2$) and the interaction term of X_2X_3 whilst extraction time (X_2) showed the least significant influence

on the pectin yield. However, the results revealed that linear term of SLR (X_3), quadratic effect of extraction time ($X_2{}^2$) and interaction effect of X_1X_2 and X_2X_3 did not have significant effects due to p-values more than 0.05. The following Eq. (7) is the polynomial equation that formulated by the surface model to describe the relationship between the extraction parameters and pectin yield.

$$Y\,(\%) = -55.405 + 1.24237X_1 + 0.10112X_2 + 0.85263X_3 - 0.0000375X_1X_2 - 0.0015X_1X_3 - 0.0039625X_2X_3 - 0.00795X_1^2 + 0.00003125X_2^2 - 0.0097X_3^2 \quad (7)$$

Referring to Eq. (7), the coefficient with higher value indicates it has higher impact on the response. Linear variables (X_1, X_2 and X_3) and quadratic variable ($X_2{}^2$) had positive effect on the pectin yield due to positive coefficients in the equation. Positive coefficient indicated the variable was directly proportional to the response value. Oppositely, negative coefficients of interactions (X_1X_2, X_1X_3 and X_2X_3) and quadratic variables ($X_1{}^2$ and $X_3{}^2$) indicated negative effect on the pectin yield. Negative coefficient showed a curvilinear relationship between the variable and response [21]. Curvilinear relationship means the response increases with the variables (negative coefficient) only up to certain point and starts to decrease after that.

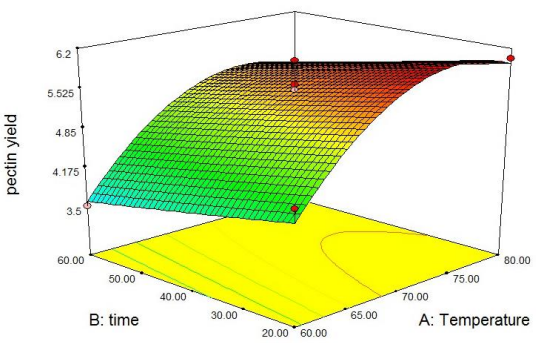
Table 6. Variance analysis for quadratic model of response surface

Source	DF	Sum of Square	Mean Square	F-value	p-value
Model	9	16.18	1.80	19.45	0.0004
X_1	1	5.49	5.49	59.47	0.0001
X_2	1	1.02	1.02	11.07	0.0126
X_3	1	0.041	0.041	0.44	0.5285
X_1X_2	1	2.25×10^{-4}	2.25×10^{-4}	2.435×10^{-3}	0.9620
X_1X_3	1	0.090	0.090	0.97	0.3565
X_2X_3	1	2.51	2.51	27.19	0.0012
$X_1{}^2$	1	2.66	2.66	28.80	0.0010
$X_2{}^2$	1	6.579×10^{-4}	6.579×10^{-4}	7.12110^{-3}	0.9351
$X_3{}^2$	1	3.96	3.96	42.88	0.0003
Residual	7	0.65	0.092		
Lack of Fit	3	0.29	0.098	1.12	0.4412
Pure Error	4	0.35	0.088		
Cor Total	16	16.82			

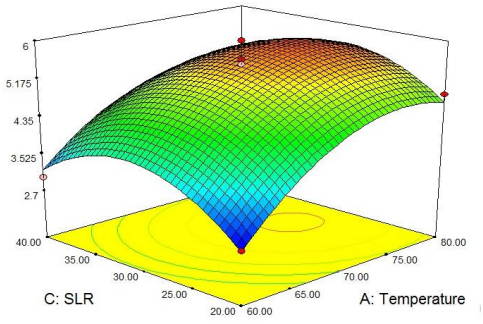
Std. Dev.	0.30				
Mean	4.72				
R^2	0.9616				
Adj-R^2	0.9121				
Adeq Precision	13.839				

3.4 Effect of extraction parameters

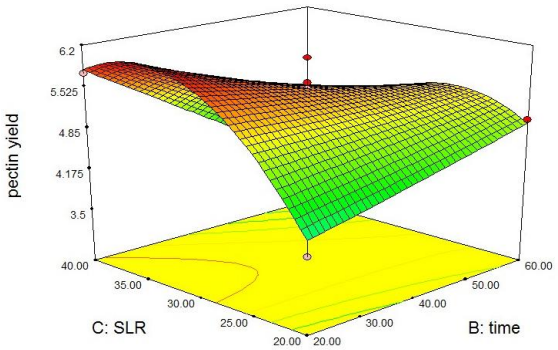
The relationship between the extraction variable was studied with the help of three-dimensional (3-D) response surface graphs in Figure 2 and the influence of extraction variables on response was discussed in Section 3.4.1 to 3.4.3.



(a)



(b)



(c)

Fig. 2. Influence of extraction variables on pectin yield. (a) Time vs temperature at 1:30 g/m SLR. (b) SLR vs temperature at 40 minutes. (c) SLR vs time at 70°C temperature.

3.4.1 Effect of extraction temperature on pectin yield

Fig. 2 shows that pectin yield increased significantly with temperature. The pectin yield decreased slowly after reaching the temperature of 76°C. Similar results has been obtained from previous study of [14]. Increasing temperature disrupt the hydrogen bonds and ester linkages, enhancing the solvent penetration to cause higher extraction yield [12]. However, further increasing the temperature decreases the viscosity and surface tension of the extraction solvent [14]. This reduces the cavitation effects and mass transfer intensity, leading to low pectin yield [14]. Moreover, previous study has also reported that high temperature caused thermal degradation of pectin and this resulted in low pectin yield [22].

3.4.2 Effect of solid to liquid ratio (SLR) on pectin yield

Pectin yield was found to increase with SLR until approximately 1:30 g/ml and further increase the solvent volume results in low extraction yield even though SLR was not the significant influence factor according to ANOVA. Similar trend has been found in previous work of [14]. Other than that, 1:30 g/ml of SLR has also been found to produce maximum pectin yield in previous research of [17]. This can be explained as increasing the volume of extraction solvent enhanced the driving force for mass transfer during extraction, leading to higher pectin released into the surrounding solvent [23]. Yet, excess amount of solvent decreased the pectin yield because the solvent was saturated with the solute and this reduced the penetration and mass transfer rate of the pectin into the extraction solvent [24].

3.4.3 Effect of extraction time on pectin yield

Based on the ANOVA results in Table 7 and Fig. 2c, the extraction time and SLR had significant relationship. At low SLR, the pectin yield increased with extraction time whilst the pectin yield decreased with time at high SLR. This can be explained as at low SLR, the driving force is low due to less amount of extraction solvent hence, more reaction time is required for the mass transfer of pectin to the solution [23]. Nonetheless, the pectin yield decreased with longer sonication time at high SLR because the structure of pectin side chain was destructed and decomposed after prolonged exposure of excessive ultrasound waves [22]. Other than that, as mentioned in Section 3.4.2, high SLR saturated the extraction solvent and this reduced the mass transfer between the pectin and the solvent. Therefore, longer extraction time at high SLR resulted in low extraction yield.

3.5 Determination and validation of optimal extraction conditions

The optimum extraction conditions (extraction temperature, extraction time and SLR) generated by the Design Expert 7.0 Software were 74.34°C, 22.73 min and 1:33.3 g/ml respectively with the predicted pectin yield of 6.19%. By considering the operability and limitation of apparatus in real process, the optimal extraction temperature and extraction time were round off to 75°C and 23 min respectively. The suitability of optimized conditions was validated experimentally. The experimental pectin yield obtained was 6.08%$\pm$0.2% while the error percentage based on the predicted value was only 1.78 %. The small deviation between the experimental and predicted value might due to the decimal place of the extraction conditions value was round off for operability. Using the

unoptimised conditions, only 5% of pectin yield was obtained but the yield had successfully improved by 21.66% after optimisation.

3.6 Esterification degree of pectin before and after optimisation

The degree of esterification (DE) of the pectin before and after optimisation were compared to determine the gelling mechanism. The DE of the pectin before and optimisation were found as 71.92%±1.38% and 76.1%±2.07% respectively. Both of the DE values were acceptable because the tissue pectin is usually in the range of 60 to 90% [2]. However, the DE of pectin after optimisation was slightly higher than the pectin before optimisation because of lower temperature was used in optimised conditions. Previous research has reported that DE values reduced with higher temperature because the methly esterified carboxyl groups that presented in the pectin chains could be destroyed at high temperature [25].

Since both DE values were above 50%, the pectins were classified as high methoxyl (HM) pectins which can form gel with high sugar concentration. In food industry, HM pectin is suitable to process into high sugar jam and canned food [26]. Besides, the pectins were also classified as fast gelling pectins as the DE values were more than 71% [27]. Since the setting rate increased with DE values, the optimized pectin could form gels faster than the pectin before optimisation due to higher DE value [28]. Based on the results, it can be concluded that, the type of gel formation remained unchanged after optimisation yet the gelling speed had improved.

4 Conclusion

In this study, oven drying with 50°C was suggested as the optimum drying temperature for banana peels because it provided the highest pectin yield. Among three drying models (Page, Two-term and Page-Two-term), Page-Two-term Model was selected as the most suitable model to describe the drying kinetic of banana peels with 0.9991 R^2 value and 0.001 RMSE. Three extraction conditions of pectin extraction from banana peels were optimized using Box-Behnken Design and the optimal conditions were 75°C of extraction temperature, 23 min of extraction time and 1:33.3 g/ml of SLR. Using the optimal conditions, the experimental pectin yield was found as 6.08±0.2% which was not much different with the predicted yield of 6.19%. After optimised the extraction process, the isolated pectin was still remained as high-methoxyl pectin (DE>50%) yet the extraction yield and gelling time had successfully improved.

The authors would like to acknowledge Taylor's University Lakeside for providing financial support under TRGS/MFS/1/2016/SOE/004.

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