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Optimization of the preparation of pectin from *Aloe* using a Box–Behnken design

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ABSTRACT

The extraction condition of pectin from *Aloe vera barbadensis* Mill was optimized by a Box–Behnken design. The effect of parameters of extraction water proportion (EWP), extraction pH (EpH), extraction temperature (ETe), extraction time (ETi), alcohol precipitation pH (APpH)and alcohol precipitation temperature (APTe) on the extraction yield of pectin was investigated by a software of Design Export 8.0.5b. The maximum extraction yield was obtained with the EWP of 20:1, EpH of 1.5, ETe of 90 °C, ETi of 120 min, APpH of 3.0 and APTe of 50 °C, which was consistent with the experimental value. We also found out that the pectin content decreased gradually during storage and sucrose concentration had a significant impact on the viscosity of pectin.

1. Introduction

Pectin is a polysaccharide widely used in food industries. It is used as thickening and gelling agents (May, 1990). Its medicinal uses are antidiarrhea, detoxification and blood glucose lowering (Voragen, Pilnik, Thibault, Axelos, & Renard, 1995). Classically, two main production steps of pectin include extraction from raw material with water and isolation of pectin from the extracted solution by precipitation with alcohol (May, 1990; Rolin, 1993; Voragen et al., 1995; Kalapathy & Proctor, 2001; Joye & Luzio, 2000). Commercial pectin is extracted at high temperature by hydrolyzing proto-pectin using acid (May, 1990; Minkov, Minchev, & Paev, 1996). In general, higher yield is obtained from high temperature and low pH extraction. Therefore, the suitable condition for each kind of raw material needs to be optimized. Our previous study showed that *Aloe vera barbadensis Miller* could be used as a source of high-methoxyl pectin. Their leaves are fairly large and considerable amount of the peel is biological waste. The aim of this study was to investigate the optimum condition for the extraction of high-methoxyl pectin from this waste.

An extraction process is the most important operation to obtain pectin from vegetal tissue. Pectin extraction is a multiple-stage physical–chemical process in which hydrolysis and extraction of pectin macromolecules from plant tissue and their dissolution take place under the influence of different factors, mainly temperature, pH and time (Kertesz, 1951). Pectin extraction has been studied by some authors. Virk & Sogi (2004) studied pectin extraction and characterization from apple peel waste and revealed that citric acid was more effective than hydrochloric acid. Rehmann et al. (2004) extracted pectin from mango peels with sulfuric acid, and the maximum yield was obtained at 80 °C and pH 2.5 with an extraction time of 120 min. Schemin et al. (2005) carried out a practical follow-up to pectin extraction from apple pomace and observed that the pectin yield was higher with 6.2 g per 100 mL of citric acid and a reaction time around 150 min. Faravash & Ashtiani (2007) determined the effects of extraction time and pH variation on the yield of pectin isolation from pomace peento peaches, and the maximum yield of pectin was obtained at initial pH 2.5, EV of 1.5 and acid washing time of 120 min. Chan and Choo (2013) found that the highest yield of pectin (7.62%) from cocoa husks was obtained using citric acid at pH 2.5 [1:25 (w/v)] at 95 °C for 3.0 h. Ma et al. (2013) demonstrated that the yield of pectin was directly correlated with the decrease of pH and reaction time, and the optimum yield of 17.2% was obtained at pH 1.5 and 2 h. Lv, Wang, Wang, Li, & Adhikari (2013) found that the optimal temperature, time and pH value of the extraction were 93.7 °C, 3 h, and 1.21, respectively. Santos, Espeleta, Branco, & de Assis (2013) found that the conditions that produced the highest yield (19.2%) were a temperature of 85 °C, extraction time of 60 min and a liquid/solid ratio of 2%.

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Moreover, the mainly extraction parameters, including extracting water proportion (EWP, v/w), extraction pH (EpH), extraction temperature (ETe), and alcohol precipitation pH (APpH), were optimized with a Box–Behnken design (BBD). The relationship between the extraction conditions and the extraction yield of pectin was studied by running an experimental design, constructing a mathematical model, and investigating the relationship by response surface methodology. The main objective of this paper was to develop a rapid and simple extraction method for the extraction of the four main pectin of *Aloe*. The impacts of parameters EpH, ETe and APpH on the extraction yield were investigated in detail. The results indicate that the extraction of pectin within a short time could obtain a considerable extraction yield.

2. Materials and methods

2.1. Plant samples

Whole, freshly cut, *A. vera barbadensis Mill* leaves (100 kg) were harvested in September from farms in the Liaoning Medical University, Jinzhou of China. They were allowed to cool at 4 °C temperature and stored in dark until analysis. Leaves were analyzed at the day of processing (0) and after 10, 20, 30, 40, 50 and 60 days of storage at 4 °C.

2.2. Reagents

Analytical grade solvents, purchased from Hongda Co. (Jinzhou, China) were used throughout the study. Distilled and deionized water (ddH_2O) were prepared by Ultrapure™ water purification system (DAI Co., Ltd., Shenyang, China).

2.3. Pectin extraction

Pectin extraction from *Aloe* was carried out according to the method of Kratchanova, Pavlova, & Panchev (2004) and Kliemann et al. (2009) with some modifications. After smashed, the *Aloe* leaves were heated in boiling water bath for 5 min to inactivate the enzymes and then extracted by the distilled water according to the proportion of 5:1, 10:1, 15:1, 20:1, 25:1, 30:1 or 35:1 (Volume (ddH_2O): Weigh (*Aloe* leaves), v/w).

The sample solution was adjusted to EpH(1.0, 1.5 or 2.0) with 1 mol/L hydrochloric acid and was heated to ETe(80 °C, 90 °C or 100 °C) for a certain times(Eti = 60, 80, 100, 120, 140, 160 or 180 min). During the incubation, the mixtures were often stirred for promoting the proto-pectin hydrolysis, and then the mixtures were filtered. After cooling, the mixture was filtered. The filtrate was adjusted to APpH (3.0, 3.5 or 4.0) with aqueous ammonia (pH = 11.0) and then coagulated with an equal volume of 95% ethanol. After coagulation, the mixture was left at APTe (35 °C, 40 °C, 45 °C, 50 °C, 55 °C, 60 °C or 65 °C) for 12 h and then centrifuged at 3000 r/min for 10 min.The pectin was separated by filtration, washed 3 times with 95% ethanol. The resulting material was dried overnight at 45 °C in an air-forced oven. The pectin yield was calculated using Eq. (1):

$$y_{pec} = W - W_0 \quad (1)$$

where y_{pec} is the extracted pectin yield (g/20 g), W is the amount of extracted pectin in 20 g fresh *Aloe* leaves and weight paper in g, and W_0 is the amount of blank paper in g.

2.4. Experimental design

2.4.1. Single factor design for optimizing the extraction of pectin from Aloe

A single factor design was carried out with the aim to investigate the effects of the variables on the response y_{pec}: the variables investigated were extraction water proportion (EWP, v/w), extraction pH (EpH), extraction temperature (ETe), extraction time (ETi), alcohol precipitation pH (APpH) and alcohol precipitation temperature (APTe). Table 1 shows the levels of each factor used in the extraction experimental design. The experiments were performed in random order and in triplicate.

Table 1
The levels of each factor used in the extraction experimental design.

Level	Factors					
	EWP (v/w)	EpH	ETe (°C)	ETi (min)	APpH	APTe (°C)
1	5:1	0.5	50	60	2.0	35
2	10:1	1.0	60	80	2.5	40
3	15:1	1.5	70	100	3.0	45
4	20:1	2.0	80	120	3.5	50
5	25:1	2.5	90	140	4.0	55
6	30:1	3.0	100	160	4.5	60
7	35:1	3.5	110	180	5.0	65

2.4.2. Box–Behnkens design for optimizing the extraction of pectin from Aloe

Optimization of pectin extraction from *Aloe* has yet not been reported. Box–Behnken statistical screening design was used to optimize the compositional parameters. In this study, Box–Behnkens design was constructed to evaluate the effects of the following factors: EWP (*A*), EpH (*B*), ETe (*C*), and APpH (*D*). The factors selected are shown in Table 2. The levels of EWP (v/w) were used at 10:1, 15:1 and 20:1. The levels of EpH were used at pH = 1.0, pH = 1.5 and pH = 2.0. The levels of ETe were used at 80 °C, 90 °C and 100 °C. The levels of APpH were used at pH = 3.0, pH = 3.5 and pH = 4.0. A 4-factorial design used is suitable for exploring quadratic response surfaces and constructing second order polynomial models with Design Expert (Version 8.0.5b).

2.5. Pectin characterization

2.5.1. Determination of the pH

2% pectin solutions were prepared by distilled water, and their pH were measured at 25 °C.

2.5.2. Degree of methoxylation (DM)

The DM of pectin samples were determined by the potentiometric titration method of Bochek, Zabivalova, & Petropavlovskii (2001).

2.6. Pectin viscosity measurement

Pectin viscosity was detected according to Kurita, Fujiwara, Yamazaki. (2008) by a sine-wave viscometer (SV-10, A&D, Tokyo, Japan) with a water-jacket assembly (AX-SV-37, A&D). The vibration frequency was a constant 30 Hz with negligible degradation of *Aloe* pectin structure. Pectin was dissolved in distilled water at room temperature at the concentrations of 1.0% (w/v). The viscosities of pectin were measured at 25 °C.

The viscosity of 80 mL *Aloe* pectin was measured at different concentrations of pectin or after they had been mixed with 20 mL different concentration of sucrose, citric acid and NaCl, or at different temperatures. Measure the pectin viscosity at the five different pectin concentrations of 0.2%, 0.6%, 1.0%, 1.4% and 1.8%, at the five different final sucrose concentrations of 5%, 15%, 25%, 35% and 45%, at the five different final citric acid concentrations of 2%, 4%, 6%, 8% and 10%, at the five different final NaCl concentrations of 2%, 4%, 6%, 8% and 10%, and at the five

Table 2
Observed responses in Box–Behnken design for 29 analytical trials.

Run	Independent variables				Dependent variables
	EWP (v/w) *A*	EpH *B*	ETe (°C) *C*	APpH *D*	Retardation factor (y_{pec})
1	15:1	1.0	90	5.0.	1.1393
2	10:1	1.5	90	3.0	1.0646
3	15:1	2.0	100	4.0	1.1140
4	15:1	1.5	90	4.0	1.2066
5	15:1	1.5	100	5.0	0.9980
6	15:1	1.5	80	3.0	1.0603
7	15:1	1.5	80	5.0	1.0571
8	20:1	1.5	90	5.0	1.2651
9	10:1	2.0	90	4.0	1.0031
10	20:1	1.5	80	4.0	1.2537
11	10:1	1.0	90	4.0	1.2200
12	15:1	1.0	80	4.0	1.1443
13	15:1	2.0	80	4.0	0.9980
14	10:1	1.5	100	4.0	1.0745
15	15:1	1.5	90	4.0	1.2714
16	15:1	1.5	90	4.0	1.2725
17	15:1	2.0	90	3.0	1.2405
18	20:1	1.0	90	4.0	1.2927
19	10:1	1.5	80	4.0	0.9437
20	15:1	2.0	90	5.0	1.2220
21	15:1	1.0	90	3.0	1.2956
22	15:1	1.5	90	4.0	1.2758
23	15:1	1.0	100	4.0	1.1964
24	15:1	1.5	100	3.0	1.2373
25	15:1	1.5	90	4.0	1.2836
26	20:1	1.5	100	4.0	1.1964
27	10:1	1.5	90	5.0	1.0624
28	20:1	2.0	90	4.0	1.3440
29	20:1	1.5	90	3.0	1.3802

different temperatures at 60 °C, 70 °C, 80 °C, 90 °C and 100 °C, respectively.

3. Results and discussion

3.1. Effect of EWP, EpH, ETe, ETi, APpH and APTe on the pectin extraction

In order to obtain the main compositional parameters of the Pectin extraction, several parameters were investigated. According to the analytical results in Fig. 1, the effects of EWP, EpH, ETe, and APpH on the Pectin yield were more obviously than other factors. And the data show that the maximum yield for EWP was its level 5, that for EpH was its level 3, that for ETe was its level 5, that for ETi was its level 4, that for APpH was its level 3, and that for APTe was its level 4. In other words, the optimum conditions were listed as follows: extraction water proportion (EWP, v/w): 1:20, extraction pH (EpH): 1.5, extraction temperature (ETe): 90 °C, extraction time (ETi): 120 min, alcohol precipitation pH (APpH): 3.0 and alcohol precipitation temperature (APTe): 50 °C.

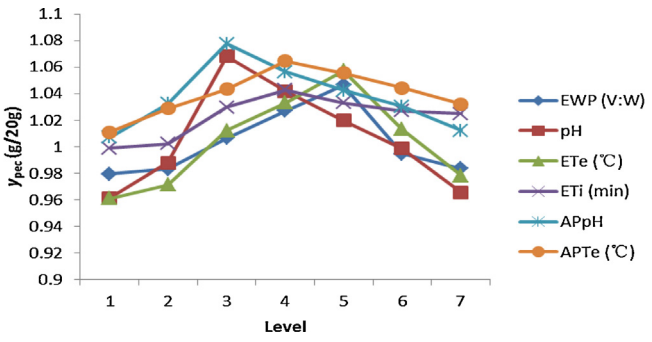

Fig. 1. Effect of EWP, EpH, ETe, ETi, APpH and APTe on the pectin extraction.

3.2. Model fitting

To obtain a more realistic model, it was necessary to investigate the extraction variables. Preliminary trials enabled a range of EWP (10:1–20:1), EpH (1.0–2.0), ETe (80–100 °C), and APpH (3.0–4.0) to be tested. So the main factors of EWP (*A*), EpH (*B*), ETe (*C*), and APpH (*D*) were selected to optimize. In this study, utilized Box–Behnkens design was applied to arrange and optimize experiment conditions. The entire design consisted of 29 experimental points as listed in Table 2 at the center of the design were used to estimate a pure error sum of squares. The experiments were performed in triplicate at all design points in a random order.

Table 3 shows the results of the analysis of variance (ANOVA) for the significance of the main factors. The pectin extraction yield was affected most significantly by EWP (*A*) and APpH (*D*) ($p < 0.01$), followed by EpH (*B*) and ETe (*C*) ($p < 0.05$). It was evident that one quadratic parameter (C^2) and two interaction parameters (*AB*, *CD*) were significant at the level of $p < 0.01$.

As Tables 3 and 4 show, an analysis of variance (ANOVA) of extraction yield of pectin indicated that the experimental data had a determination coefficient (R^2) of 0.9495 with the calculated model and no significant lack of fit at $p > 0.05$. This finding means that the calculated model was able to explain 94.95% of the results. The results indicated that the model used to fit response variables was significant ($p < 0.01$) and adequate to represent the relationship between the response and the independent variables. An *F*-test suggested that the model had a very high model *F*-value ($F = 18.80$), indicating that this model was highly significant. The R^2_{adj} (adjusted determination coefficient), which is the correlation measure for testing the goodness-of-fit of the regression equation, was 0.900. The predicted response *Y* for pectin yield could

Table 3
Summary of ANOVA for formulation variables from Box–Behnken design.

Source[a]	SUM[b]	Df[c]	MS[d]	*F*-value	*P*-value	Significant
Model	0.362772	14	0.025912	18.79866	<0.0001	**
A-A	0.154996	1	0.154996	112.4452	<0.0001	**
B-B	0.011206	1	0.011206	8.129453	0.0128	*
C-C	0.010770	1	0.010770	7.813350	0.0143	*
D-D	0.023816	1	0.023816	17.27816	0.0010	**
AB	0.017983	1	0.017983	13.04603	0.0028	**
AC	0.008845	1	0.008845	6.417093	0.0239	*
AD	0.003187	1	0.003187	2.311791	0.1507	
BC	0.001021	1	0.001021	0.740564	0.4040	
BD	0.004747	1	0.004747	3.443969	0.0847	
CD	0.013936	1	0.013936	10.11004	0.0067	**
A^2	0.004696	1	0.004696	3.406827	0.0862	
B^2	0.001133	1	0.001133	0.822315	0.3798	
C^2	0.110034	1	0.110034	79.82645	<0.0001	**
D^2	0.008716	1	0.008716	6.323190	0.0248	*
Residual	0.019298	14	0.001378			
Lack of fit	0.015373	10	0.001537	1.566769	0.3529	
Pure Error	0.003925	4	0.000981			
Cor Total	0.382070	28				

[a] Source A: extraction water proportion (EWP,W:V); Source B: extraction pH (EpH); Source C: extraction temperature (ETe, °C); and Source D: alcohol precipitation pH (APpH).
[b] Sum of square.
[c] Degree of freedom.
[d] Mean of square.
* Significant at $P \leq 0.05$
** Significant at $P \leq 0.01$, respectively.

be expressed by the following second-order polynomial equation in terms of coded values:

$$y_{pec} = -12.86124 + 0.12201 \times A - 0.86794 \times B + 0.27036 \times C + 0.76125 \times D + 0.026820 \times AB - 5.90250E-003 \times CD - 1.07627E-003 \times A^2 - 0.052877 \times B^2 - 1.30244E-003 \times C^2 - 0.036657 \times D^2$$

where y_{pec} is the yield of the pectin (g/20 g), and *A*, *B*, *C* and *D* are the coded variables for EWP, EpH, ETe and APpH, respectively.

3.3. Analysis of response surface

The regression equation was graphically represented by three-dimensional response surface and two-dimensional contour plots. To visualize three-dimensional response surfaces, the response model was obtained against two experimental factors, whereas the third was held constant at its optimum value (Li et al., 2012). From the three-dimensional response surface curves and contour plots shown in Fig. 2, the effects of the independent variables and their mutual interaction on the yield of pectin in *Aloe* can be seen.

Fig. 2 (A) shows the interaction between extraction water proportion (EWP, Factor *A*) and extraction pH (EpH, Factor *B*) with a fixed extraction temperature (ETe, Factor *C*) of 90 °C and alcohol precipitation pH (APpH, Factor *D*) of 4.0 on the yield of pectin in AYB. Fig. 2 (B) shows the interaction between EWP (*A*) and ETe (*C*) with a fixed EpH (*B*) of 1.5 and APpH (*D*) of 4.0 on the yield of pectin in AYC. Fig. 2 (C) shows the interaction between EWP (*A*) and APpH (*D*) with a fixed EpH (*B*) of 1.5 and ETe (*C*) of 90 °C on the yield of pectin in AYD. Fig. 2 (D) shows the interaction between EpH (*B*) and ETe (*C*) with a fixed EWP (*A*) of 15:1 and APpH (*D*) of 4.0 on the yield of pectin in BYC. Fig. 2 (E) shows the interaction between EpH (*B*) and APpH (*D*) with a fixed EWP (*A*) of 15:1 and ETe (*C*) of 90 °C on the yield of pectin in BYD. Fig. 2 (F) shows the interaction between ETe (*C*) and APpH (*D*) with a fixed EWP (Factor A) of 15:1 and EpH (Factor B) of 1.5 on the yield of pectin in CYD. An increase in EWP from 10:1 to 20:1 could result the obvious increase of pectin yield. An increase in EpH from 1.0 to 2.0 and APpH from 3.0 to 5.0 could result the obvious decline of pectin yield in the response. With the increase of ETe from 80 to 100 °C, there was a maximum pectin yield. These findings could be explained by the fact that increasing EWP and decreasing EpH and APpH may result in a higher pectin extraction yield.

Table 4
Summary of results of regression analysis for models and response (Y) Regression equations for the finally suggested quadratic model.

Models	R^2	Adjusted R^2	Predicted R^2	SD
Linear	0.525527	0.446448	0.30905	0.08691
2FI	0.655656	0.464354	0.095776	0.085493
Quadratic	0.949492	0.898983	0.75219	0.037127
Cubic	0.984992	0.929963	0.302038	0.030914

Regression equations of the fitted quadratic model: $y_{pec} = -12.86124 + 0.12201 \times A - 0.86794 \times B + 0.27036 \times C + 0.76125 \times D + 0.026820 \times AB - 9.40500E-004 \times AC - 5.64500E-003 \times AD + 3.19500E-003 \times BC + 0.068900 \times BD - 5.90250E-003 \times CD - 1.07627E-003 \times A^2 - 0.052877 \times B^2 - 1.30244E-003 \times C^2 - 0.036657 \times D^2$.

3.4. Optimization of extraction parameters and validation of the model

In this study, the aim of the optimization was to find conditions that gave the maximum extraction yield of the four main pectin of *Aloe*. Software (Design Expert 8.0.5b) predicted the optimum extraction water proportion (EWP, v/w), extraction pH (EpH), extraction temperature (ETe), and alcohol precipitation pH (APpH) as 20:1, 1.59, 91.7 °C and 3.0, respectively. The software also predicted the extraction yield of total pectin as 1.38864 g/20 g. As shown in Table 5, three parallel experiments were carried out under the optimal conditions of EWP of 20:1, EpH of 1.5, ETe of 90 °C, and APpH of 3.0, and the average extraction yield of pectin was 1.382 g/20 g. Compared with the value predicted by Design Expert 8.0.5b, the results showed that the predicted value was very close to the actual results, indicating that the optimization was reliable in the present study.

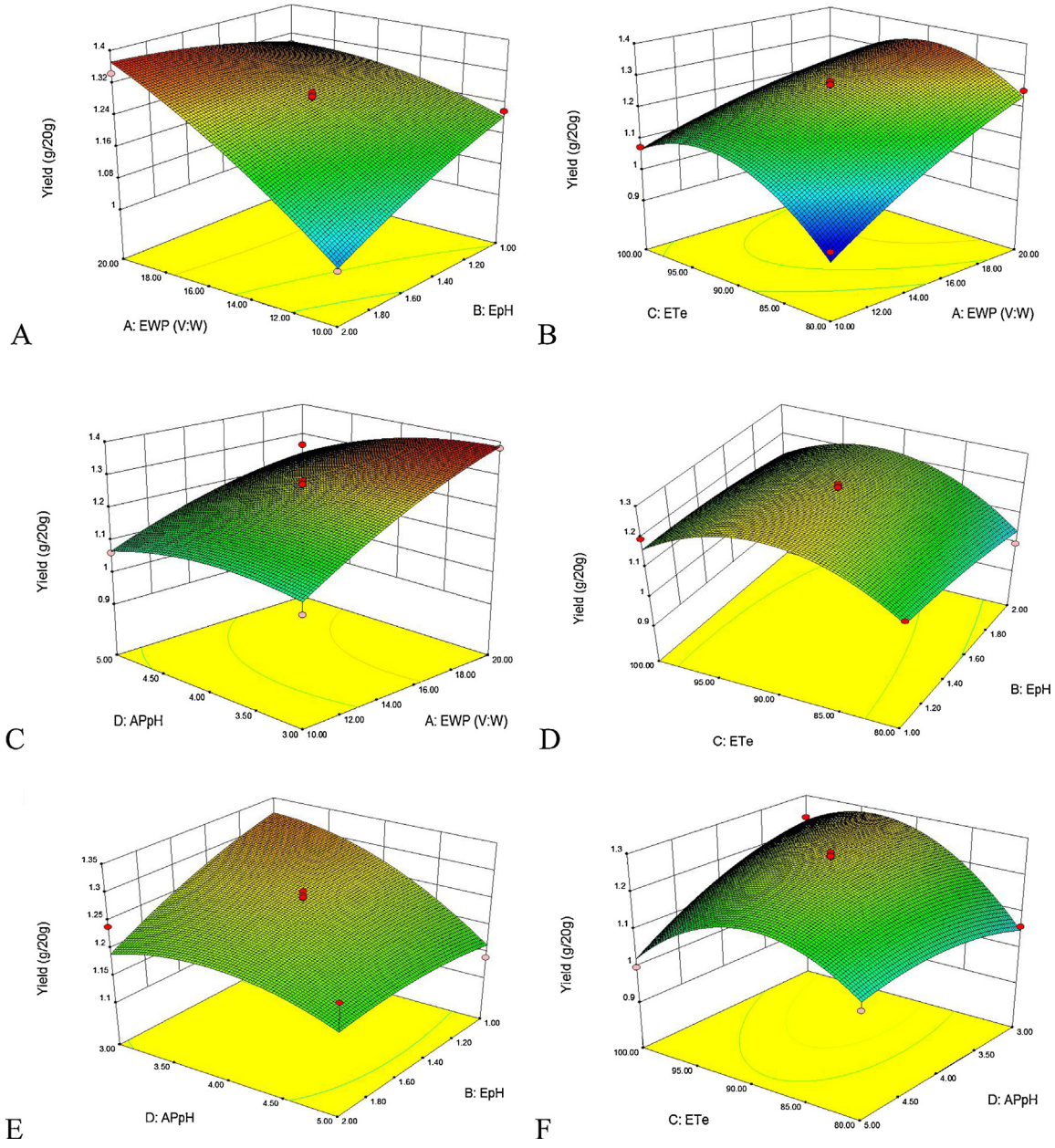

Fig. 2. Response surface of any two extraction factors. *Note*: (A) Response surface of extraction water proportion (EWP, Factor *A*) and extraction pH (EpH, Factor *B*). (B) Response surface of EWP(*A*) and extraction temperature(ETe, Factor *C*). (C) Response surface of EWP(A) and alcohol precipitation pH (APpH, Factor *D*). (D) Response surface of EpH (*B*) and ETe (*C*). (E) Response surface of EpH (*B*) and APpH (*D*). (F) Response surface of ETe (*C*) and APpH (*D*).

3.5. Alterations of pectin content relative to freshly Aloe storage

The level of pectin decreases gradually during storage, losing about 46.8% from the value recorded one day after processing at the end of 60 days of storage (Fig. 3). Prolonged storage may affect hydrolysis of compounds and lead to gradual reduction in pectin content, as observed in our study. The pectinase content may be increase in *Aloe*, which may break down the pectin during storage, decreasing the pectin yield. Therefore, the *Aloe* pectin extraction processing should be suggested during 0–20 d after picking.

3.6. Pectin characterization

2% pectin solutions were dissolved in distilled water, and their pH were measured to be 2.79 ± 0.21 at 25 °C. The Degree of methoxylation of pectin samples were 8.518%, which were determined by the potentiometric titration method of Bochek et al.

Table 5
Optimum conditions and the predicted and experimental values of response under optimum conditions.

	EWP (W:V) *A*	EpH *B*	ETe (°C) *C*	APpH *D*	Yield of pectin (g/20 g) *R*
Optimum conditions	20.00	1.59	91.70	3.00	1.38864
Modified conditions	20.00	1.60	90.00	3.00	1.38472 (predicted) 1.382 ± 0.021 (experiments)

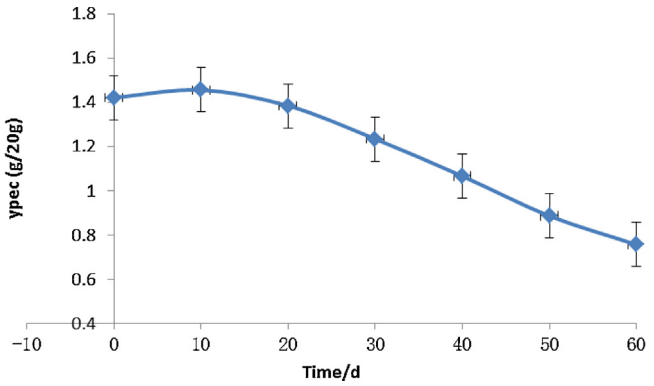

Fig. 3. Alterations of total pectin content in *Aloe* as effect of storage time.

(2001). Typically more than 7% methoxy content of pectin is the high-methoxyl pectin, so the extraction pectin of *Aloe* is the high-methoxy pectin.

As the temperature increases, a β-elimination starts which results in chain cleavage of pectin (Van Buren, 1979). Just as expected, the treatment at the high temperature showed the lowest viscosity. As the temperature increases, the thermal motion strengthened to increase repulsion between molecules, ionizing reduced, resulting in reduced viscosity.

As the pectin content increases, the pectin of high level treatment showed the lowest viscosity. The increasing of pectin solution concentration led to increase in the number of pectin molecules. The molecules combined and greatly increased degree of entanglement, the viscosity of the solution increases dramatically.

The sucrose treatment led to increased viscosity of pectin. Sucrose is including polyhydroxyl group. The hydroxyl groups are acceptors of water molecules to form hydrogen bonding. Pectin molecules as well as sucrose contain both these functional groups so it is highly possible they attract each other as pectin produces a negative charge on the molecule. As the bound amounts of sucrose to pectin increase, the viscosity correspondingly increases.

As the concentrations of citric acid increased, acidity enhanced. It suppressed the ionization of pectin and pectin intermolecular force is weakened. Another, the citric acid treatment led to decrease the pH of pectin solution. All affected the viscosity of pectin correspondingly decreases.

As the concentrations of sodium chloride increased, the viscosity of pectin decreased. With the increase of ionic concentration of NaCl, pectin ionization decreases and viscosity decreases.

Thus, we have examined whether concentration of pectin, sucrose, citric acid, NaCl or temperature was bound to the extracted pectin with its treatment. Interestingly, significant correlation between the viscosity of the pectin and the bound amounts of citric acid, NaCl or temperature was observed (Fig. 4). As the bound amounts of citric acid, NaCl or temperature to pectin increase, the viscosity correspondingly increases. Sucrose concentration affected the viscosity more obviously than other conditions.

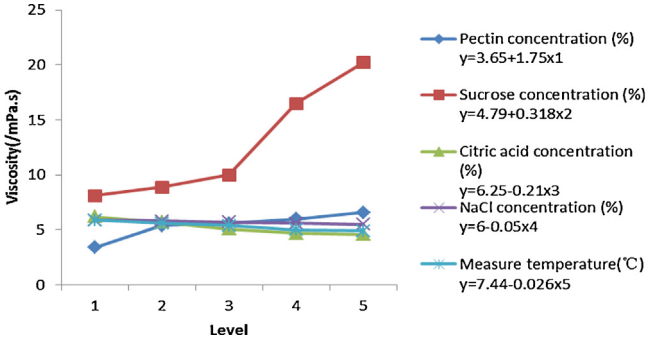

Fig. 4. Alterations of the viscosity properties of pectin in different conditions. Measure the pectin viscosity at five different pectin concentrations of 0.2%, 0.6%, 1.0%, 1.4% and 1.8%, at five different final sucrose concentrations of 5%, 15%, 25%, 35% and 45%, at five different final citric acid concentrations of 2%, 4%, 6%, 8% and 10%, at five different final NaCl concentrations of 2%, 4%, 6%, 8% and 10%, and at five different temperature at 60 °C, 70 °C, 80 °C, 90 °C and 100 °C, respectively. Results showed that the linear relationships of the pectin concentrations, the sucrose concentrations, the citric acid concentrations, the NaCl concentrations, and the measurement temperature with the pectin viscosity were $y = 3.65 + 1.75x_1$ (y was pectin viscosity, x_1 was pectin concentration, R^2(Coefficient of determination) = 0.839), $y = 4.79 + 0.318x_2$ (x_2 was sucrose concentration, $R^2 = 0.8904$), $y = 6.25–0.21x_3$ (x_3 was citric acid concentration, $R^2 = 0.9525$), $y = 6–0.05x_4$ (x_4 was citric acid concentration, $R^2 = 1$), $y = 7.44–0.026x_5$ (x_5 was measurement temperature, $R^2 = 0.9769$), respectively.

4. Conclusions

An adequate quadratic polynomial model for predicting pectin yield from *Aloe* was determined according to an optimized design. ANOVA analysis indicated that four parameters – extraction water proportion (EWP, *v/w*), extraction pH (EpH), extraction temperature (ETe) and alcohol precipitation pH (APpH) – significantly influenced extraction efficiency. The optimal condition derived using a BBD was determined to be EWP of 20:1, EpH of 1.5, ETe of 90 °C, and APpH of 3.0. And the other conditions were extraction time (ETi) of 120 min and alcohol precipitation temperature (APTe): 50 °C. Under optimal conditions, the experimental value was consistent with the predicted value by ANOVA. Compared with the conventional extraction method, the optimized extraction method provided higher extraction efficiency in a shorter time with low solvent consumption. And the *Aloe* pectin extraction processing should be suggested during 0–20 d after picking. Sucrose concentration affected the viscosity more obviously.

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