Utilization of Pectin Isolated from Orange Kisar (Citrus sp) peel as Phenol Adsorbent

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Abstract. Pectin isolated from orange kisar (Citrus sp) peel has been used as phenol adsorbent. The ability of the pectin as phenol adsorbent was examined at several contact times, pHs, and phenol concentrations. Determination of phenol adsorption was carried out by UV-Vis spectrophotometry method. The optimum conditions of phenol adsorption by the pectin were obtained at the contact time of 20 minutes, pH 3.0, and phenol concentration of 25 ppm. Phenol adsorption by the pectin follows the nonlinear model of the Freundlich adsorption isotherm with the correlation coefficient ($r^2$), Freundlich’s constant ($K_F$), and indicator of concentration dependence ($n$) were 99.51%, 0.6439 (mg/g) (L/mg)$^{1/n}$, and 1.620, respectively.

1. Introduction
Phenol is a colorless crystalline substance that has a distinctive odor with its chemical formula of C₆H₅OH (Fig. 1), toxic and corrosive to the skin (irritating) and its structure has a hydroxyl group (-OH) that binds to the phenyl ring. Phenol is contained in the waste produced by oil refining, steel, plastics, pharmaceuticals, fertilizers, paints, textiles, and formaldehyde industries [1–4]. In Indonesia, phenol is considered safe for the environment if the concentration ranges from 0.5–1.0 mg / L according to the Decree of the Minister of Environment Republic of Indonesia No. 51/MENLH/10/1995 and phenol limit in drinking water shall be 0.002 mg / L [5]. If these values are exceeded, side effects are likely to appear due to the presence of phenols for humans such as sour mouth, diarrhea, excretion of dark urine and impaired vision [4]. To reduce the presence of phenols in wastewater, electrochemical oxidation, solvent extraction [6], membrane separation [7], chemical coagulation [8], photocatalytic degradation [9] and bioremediation [10] methods can be used. From the available methods, adsorption method is the most widely used method to reduce phenolic compounds from wastewater [1,11] as there is plenty of presence of adsorbent in nature with a relatively low price. Some materials used as phenol adsorbent include activated carbon [12–14], peat, bentonite and fly ash [15], zeolites [16], silica gel and activated alumina [17], rice husk [18], rice straw [19], chitin [20,21] and chitosan [21–23].
Pectin (Fig. 2) or pectate compound is a complex polysaccharide found in middle lamella or intercellular space of higher plant tissue. Concentrated polysaccharide compounds and cellulose fibers bind together to form strong tissue that functions as an adhesive between cells, rich in galacturonic acid and has been reported as bioactive, biocompatible, and biodegradable [24]. Fruits and vegetables contain many of these compounds [25]. In orange fruit, the flesh is not the only thing that can be utilized, but also its peels can also be used to produce pectin. In previous studies, pectin has been used as a heavy metal adsorbent [26–29] and dyes [30–32].

This study is a follow up on a previous study [33] which has isolated and characterized pectin from the kisar orange peel (Citrus sp). The kisar oranges (Fig. 3) are endemic plants from Kisar Island (Southwest Maluku). This study aimed to determine the time, phenol concentration and optimum pH in the phenol adsorption process on isolated pectin and to determine the type of adsorption isotherm followed by phenol adsorption process on isolated pectin in a linear or nonlinear model.

2. Experimentals

2.1. Material
The materials used in this study were comprised of isolated pectin of kisar orange (Citrus sp) peels [33], phenol p.a (E. merck), Whatman 42 filter paper, potassium hydrogen phthalic (pa
Merck), HCl pa (E. Merck), KH$_2$PO$_4$ (pa Merck), K$_2$HPO$_4$ p.a (E. Merck); NaOH pa (E. merck), NaHCO$_3$ (Merck pa), aquades, KOH (p.amerck), H$_3$BO$_3$ p.a (E. merck) and 4-amino antipyrine (4-AAP) p.a (E. merck).

2.2. The effect of contact time
A 0.5 g (m) pectin was inserted into Erlenmeyer containing 25 mL (V) solution of 25 ppm ($c_0$) phenol standard. Then, the solution was shaken in the contact time variation of 20, 40, 60, 80, 100, and 120 minutes, respectively. After that, it was filtered through filter paper and its filtrate absorbance was measured with UV-Vis spectrophotometer in order to specify the remaining phenol or in a state of equilibrium ($c_e$) with 4-AAP method [34] as reported in our previous studies [14,23].

2.3. The effect of pH
Three Erlenmeyers were filled with a solution containing pH variation of 3, 7 and 11 adjusted using a buffer solution. The buffer solution used for pH variation, respectively are: 0.1 M potassium hydrogen phthalate, 0.1 M HCl, and aquades; solution of 0.1 M KH$_2$PO$_4$, 0.1 M K$_2$HPO$_4$; and solution of 0.05 M NaHCO$_3$, 0.1 M NaOH, and aquades with differing ratio for each volume for each buffer solution. Maximum phenol concentration with pH of 3, 7, and 11 are mixed. Then, 25 mL of solution 25 ppm phenol was added with 0.5 g of pectin to each pH solution. Then the solution is stirred at 300 rpm for an optimum contact time. The pectin adsorbed solution was filtered with filter paper, and the filtrate absorbance was measured using UV-Vis spectrophotometer in a state of equilibrium phenol concentration using 4-AAP method.

2.4. The effect of initial phenol concentration
A total of 5 Erlenmeyers were added with 0.5 g pectin each, then each Erlenmeyer flask was added with 25 mL of 25 ppm, 30 ppm, 40 ppm, 50 ppm, and 60 ppm phenol, respectively. The five solutions were shaken and kept overnight so that it gets equilibrated, then each solution was filtered with Whatman filter paper and absorbances of its filtrate was measured with UV-Vis spectrophotometer in a state of equilibrium phenol concentration using 4-AAP method.

2.5. Determination of adsorption capacity and adsorptivity
The adsorption capacity of pectin adsorbents (x/m) and adsorptivity (Q) was calculated based on Equation 1 and Equation 2.

\[
\frac{x}{m} = \frac{(c_0 - c_e) x V}{m}
\]

\[
Q = \frac{c_0 - c_e}{c_0} \times 100\%
\]

3. Results and Discussion

3.1. Data on the measurement of absorbance after the adsorption process for various variations
Prior to the determination of phenol adsorbed by pectin isolated from kisar orange peel, absorbance measurement was performed on phenol standard solution. The measurement was
done using UV-VIS spectrophotometer at a wavelength of 650 nm. Based on this absorbance data, a phenol standard curve was created (Fig. 4). The linearity relation between absorbance and the concentration of standard phenol solution was used to calculate the final concentration at each stage by inputting the absorbance value of the sample on y function of the regression equation. The optimization stage included the variations in contact time, pH, and phenol concentration. From the data obtained can we would then determine the appropriate adsorption isotherms for this adsorption process.

![Figure 4. Standard phenol curve](image)

### 3.2. The effect of contact time

The effect of contact time on phenol adsorption, using 25 ppm phenol. The contact time variation of 20, 40, 60, 80, 100, and 120 minutes, stirred at a speed of 300 rpm with 0.5 g of adsorbent dosage. The results obtained is presented in Table 1.

| Contact time (min.) | Absorbance | $C_0$ (ppm) | $C_e$ (ppm) | Adsorbed concentration (ppm) | Capacity of adsorption (mg g$^{-1}$) | Q (%) |
|---------------------|------------|-------------|-------------|-----------------------------|-------------------------------------|------|
| 20                  | 0.023      | 25          | 3.4054      | 21.5946                     | 1.0793                              | 86.37|
| 40                  | 0.039      | 25          | 7.7297      | 17.2703                     | 0.8634                              | 69.08|
| 60                  | 0.042      | 25          | 8.5405      | 16.4595                     | 0.8228                              | 65.83|
| 80                  | 0.053      | 25          | 11.5135     | 13.4865                     | 0.6742                              | 53.94|
| 100                 | 0.087      | 25          | 20.7027     | 4.2973                      | 0.2148                              | 17.18|
| 120                 | 0.094      | 25          | 22.5945     | 2.4055                      | 0.1202                              | 9.62 |

Based in the data on Table 1, it can be seen that at 20 minutes of contact time, the concentration of adsorbed phenol was at its highest level and continued to the 40-120 minutes contact time, the concentration was shrinking. This result is due to the active site at adsorbent surface has been saturated by phenol. The gradually saturated adsorbents began to release the phenol and reverted to the solution, thus making the extension of time no longer increases the adsorption level. In other words, the process of phenol desorption by pectin adsorbents has occurred. In this study, at the contact time of 20 minutes, the optimum adsorption condition
was attained with an absorbed concentration of 21.5946 ppm and an adsorption capacity of 1.0793 mg g\(^{-1}\).

### 3.3. The effect of \(pH\) variations

At \(pH\) variation, 25 ppm phenol solution was used, the \(pH\) was conditioned by using buffer solutions respectively at \(pH\) 3, 7 and 11. Then, it was *shaken* with a speed of 300 rpm, with a contact time of 20 minutes, and an adsorbent weight of 0.5 g. The results are presented in Table 2.

#### Table 2. The measurement results of phenol absorbance in various \(pH\)s

| \(pH\) | Absorbance | \(C_0\) (ppm) | \(C_e\) (ppm) | Adsorbed concentration (ppm) | Capacity of Adsorption (mg g\(^{-1}\)) | \(Q\) (%) |
|-------|------------|---------------|---------------|-----------------------------|-------------------------------------|---------|
| 3     | 0.028      | 25            | 4.7567        | 20.2433                     | 1.0113                              | 80.97   |
| 7     | 0.033      | 25            | 6.1081        | 18.8919                     | 0.9440                              | 75.56   |
| 11    | 0.038      | 25            | 7.4594        | 17.5406                     | 0.8766                              | 70.16   |

The degree of acidity (\(pH\)) in a solution has an influence on the adsorption process. The adjustment of \(pH\) in a solution has an effect on the adsorbent surface load, the degree of ionization, stability, and color intensity of the compounds in the solution [35]. At \(pH\) variations, the acidic \(pH\) (\(pH\) 3), neutral \(pH\) (\(pH\) 7), and basic \(pH\) (\(pH\) 11) were used. In this study, the largest concentration of adsorbed phenol was at \(pH\) 3 with 20 minutes of adsorption time, with the adsorbed concentration of 20.2433 ppm, and shrunk at \(pH\) 7 and \(pH\) 11 at an adsorbed concentration of 18.8919 and 17.5406 ppm consecutively. Thus, it can be concluded that the less the \(pH\), the greater the concentration is absorbed. This result was also found in the phenol adsorption system by rice husk [18] which explains that at a high \(pH\), the phenolic ion fraction is higher than the phenol molecule because phenol is a weak acid (\(pK_a = 10\)), thus the process of phenol absorption at a high \(pH\) was reduced due to the repulsive force. Conversely, at a low \(pH\), the adsorbate surface would be surrounded by H\(^+\) ion which increased the interaction of phenolic compounds with the adsorbent bindings due to the increasing the attractive force. Thus, the optimum phenol absorption by pectin is at an acidic \(pH\).

#### 3.4. The effect of concentration variations

The effect of concentration on phenol adsorption using concentration variations of 25, 30, 40, 50, and 60 ppm which was conditioned at \(pH\) 3 using a buffer, with 0.5 g of adsorbent, shaken with a speed of 300 rpm, and contact time of 20 minutes. The results are then presented in Table 3.

Based on the data of phenol adsorption on the concentration variation presented in Table 3, the maximum concentration was adsorbed at a 25 ppm which has the highest \(Q\) value of 90.70%. The higher the initial concentration, the lower the \(Q\) value. This decrease in adsorption is due to desorption. Desorption is the process of releasing ions or molecules that are bound by an active group in the adsorbent. Thereby, the adsorption of phenol by isolated pectin from sweet orange peel would be better at a lower concentration.
3.5 The Determination of Adsorption Isotherms

The data of phenolic concentration variations help us determine the adsorption isotherms suitable for the adsorption systems of phenol by pectin isolated from sweet orange peels. The adsorption isotherms commonly used are Langmuir adsorption isotherms and Freundlich adsorption isotherms. Both of these isotherms can be written as a linear equation model or nonlinear equation model as presented in Table 4 and Table 5 [36–38].

Table 3. The measurement results of phenol absorbance in various concentrations

| C₀ (ppm) | Absorbance | Cₑ (ppm) | Adsorbed concentration (ppm) | Q (%) |
|----------|------------|----------|-----------------------------|-------|
| 25       | 0.019      | 2.3243   | 22.6757                     | 90.70 |
| 30       | 0.023      | 3.4054   | 26.5946                     | 88.64 |
| 40       | 0.029      | 5.0270   | 34.9730                     | 87.43 |
| 50       | 0.037      | 7.1891   | 42.8109                     | 85.62 |
| 60       | 0.044      | 9.0810   | 50.9190                     | 84.86 |

Table 4. Linear equation model of Langmuir adsorption isotherm and Freundlich adsorption isotherm

| Type       | Forms of linear method equation                                      | Plot                  | No. Equation | Parameters                                                                 |
|------------|-----------------------------------------------------------------------|-----------------------|--------------|---------------------------------------------------------------------------|
| Langmuir   | Cₑ/(x/m) = 1/(x/m)max + 1/(x/m)max                                   | cₑ/(x/m) vs cₑ       | 3            | (x/m)max = 1/M; K_L = M/C                                                  |
| Linear-1   |                                                                 |                       |              |                                                                           |
| Langmuir   | 1/(x/m) = (1/(x/m)max + 1/(x/m)max)/(1/cₑ)                           | 1/(x/m) vs 1/cₑ      | 4            | (x/m)max = 1/C; K_L = C/M                                                  |
| Linear-2   |                                                                 |                       |              |                                                                           |
| Langmuir   | 1/cₑ = (K_L/(x/m)max)(1/(x/m)) – K_L                                 | 1/cₑ vs 1/(x/m)      | 5            | (x/m)max = - M/C; K_L = - C                                                |
| Linear-3   |                                                                 |                       |              |                                                                           |
| Langmuir   | (x/m)/cₑ = (K_L/(x/m)max)(1/(x/m)) – K_L                              | (x/m)/cₑ vs (x/m)    | 6            | (x/m)max = - C/M; K_L = - M                                                |
| Linear-4   |                                                                 |                       |              |                                                                           |
| Freundlich | ln(x/m) = ln K_F + ln cₑ/n                                             | ln (x/m) vs ln cₑ    | 7            | K_F = exp(C); n = 1/M                                                      |
Table 5. Nonlinear equation model of Langmuir adsorption isotherm and Freundlich adsorption isotherm

| Type            | Forms of nonlinear method equation | Plot          | No. Equation | Persamaan Nonliner | Parameters                                |
|-----------------|------------------------------------|---------------|--------------|--------------------|-------------------------------------------|
| Langmuir Nonlinear | \( \frac{x}{m} = \frac{x}{m_{\text{max}}} \frac{K_Lc_e}{1 + K_Lc_e} \) | (x/m) vs c_e | 8            | \( y = \frac{A}{1 + Bx} \) | \( (x/m)_{\text{max}} = \frac{A}{B} \); \( K_L = B \) |
| Freundlich Nonlinear | \( \frac{x}{m} = K_F c_e^{1/n} \) | (x/m) vs c_e | 9            | \( y = A x^B \) | \( K_F = A \); \( n = 1/B \) |

The calculation results of the phenol adsorption system by pectin isolated from orange peels as Langmuir adsorption isotherms and Freundlich adsorption isotherms are presented in Fig. 5 to Fig. 9 for a linear equation model and Fig. 10 for nonlinear equation model, while the adsorption parameters are presented in Table 6.

**Linear equation:**
\[
y = 1.711 + 0.2170x \\
r^2 = 95.59\%
\]

**Adsorption parameters:**
\( (x/m)_{\text{max}} = 4.6083 \text{ mg/g} \)  
\( K_L = 0.1270 \text{ L/mg} \)

**Figure 5.** Linear equation model of Langmuir type-1 adsorption isotherm (Langmuir linear-1) and its parameters
Linear equation:
\[ y = 0.2542 + 1.533x \]
\[ r^2 = 97.33\% \]

Adsorption parameters:
\[ (x/m)_{\text{max}} = 3.9339 \text{ mg/g} \]
\[ K_L = 0.1658 \text{ L/mg} \]

Figure 6. Linear equation model of Langmuir type-2 adsorption isotherm (Langmuir linear-2) and its parameters

Linear equation:
\[ y = -0.1552 + 0.6349x \]
\[ r^2 = 97.33\% \]

Adsorption parameters:
\[ (x/m)_{\text{max}} = 4.0908 \text{ mg/g} \]
\[ K_L = 0.1552 \text{ L/mg} \]

Figure 7. Linear equation model of Langmuir type-3 adsorption isotherm (Langmuir linear-3) and its parameters
Linear equation:
\[ y = 0.5991 - 0.1341x \]
\[ r^2 = 87.04\% \]

Adsorption parameters
\( (x/m)_{\text{max}} = 4.4676 \text{ mg/g} \)
\( K_L = 0.1341 \text{ L/mg} \)

**Figure 8.** Linear equation model of Langmuir type-4 adsorption isotherm (Langmuir linear-4) and its parameters

Linear equation
\[ y = -0.4119 + 0.6005x \]
\[ r^2 = 99.30\% \]

Adsorption parameters
\( K_F = 0.6624 \text{ (mg/g) (L/mg)}^{(1/n)} \)
\[ n = 1.6653 \]

**Figure 9.** Linear equation model of Freundlich adsorption isotherm and its parameters
Nonlinear Equation of Langmuir:
\[ y = \frac{0.5650x}{1 + 0.1177x} \]
\[ r^2 = 98.38\% \]
\[ (x/m)_{\text{max}} = 4.8003 \text{ mg/g} \]
\[ K_L = 0.1177 \text{ L/mg} \]

Nonlinear Equation of Freundlich:
\[ y = (0.6439)x^{0.6172} \]
\[ r^2 = 99.51\% \]
\[ K_F = 0.6439 \text{ mg/g} \]
\[ n = 1.620 \]

Figure 10. Nonlinear equation model of Langmuir adsorption isotherm (Langmuir Nonlinear …..), Freundlich adsorption isotherm (Freundlich Nonlinear ----) and parameters of adsorption

According to Atkins (1998) [39], the Langmuir model is based on the assumption that the isotherm is applicable for one-layer adsorption and all sites are equivalent as well as the surface is uniform. At an adsorbent surface, there are certain active sites which are proportional to the adsorbent surface area, thus if the active site on the adsorbent cell surface wall has been saturated, the concentration addition can no longer increase the adsorbent adsorptivity. Each active site of adsorbent can only adsorb one adsorbent molecule which then forms monolayer adsorption. The Freundlich adsorbent isotherm is assumed to have a heterogeneous surface and each molecule has different adsorption potentials, with a number of active adsorption centers [39].

Table 6. The adsorption parameters of Langmuir adsorption isotherm and Freundlich adsorption isotherm

| Type          | Equation Model | \( r^2 \) | Parameters                                      |
|---------------|----------------|-----------|-------------------------------------------------|
| Langmuir Linear-1 | \( y = 1.711 + 0.2170x \) | 95.59%    | \( (x/m)_{\text{max}} = 4.6083 \text{ mg/g} \)  |
|               |                |           | \( K_L = 0.1270 \text{ L/mg} \)                  |
| Langmuir Linear-2 | \( y = 0.2542 + 1.533x \) | 97.33%    | \( (x/m)_{\text{max}} = 3.9339 \text{ mg/g} \)  |
|               |                |           | \( K_L = 0.1658 \text{ L/mg} \)                  |
| Langmuir Linear-3 | \( y = -0.1552 + 0.6349x \) | 97.33%    | \( (x/m)_{\text{max}} = 4.0908 \text{ mg/g} \)  |
|               |                |           | \( K_L = 0.1552 \text{ L/mg} \)                  |
| Langmuir Linear-4 | \( y = 0.5991 - 0.1341x \) | 87.04%    | \( (x/m)_{\text{max}} = 4.4676 \text{ mg/g} \)  |
|               |                |           | \( K_L = 0.1341 \text{ L/mg} \)                  |
| Freundlich Linear | \( y = -0.4119 + 0.6005x \) | 99.30%    | \( K_F = 0.6624 \text{ (mg/g)(L/mg)}^{(1/n)} \) |
|               |                |           | \( n = 1.6653 \)                                 |
| Langmuir Nonlinear | \( y = \frac{0.5650x}{1 + 0.1177x} \) | 98.38%    | \( (x/m)_{\text{max}} = 4.8003 \text{ mg/g} \)  |
|               |                |           | \( K_L = 0.1177 \text{ L/mg} \)                  |
| Freundlich Nonlinear | \( y = (0.6439)x^{0.6172} \) | 99.51%    | \( K_F = 0.6439 \text{ (mg/g)(L/mg)}^{(1/n)} \) |
|               |                |           | \( n = 1.620 \)                                 |
Based on Table 6, it can be concluded that the phenolic adsorption by pectin isolated from kisar orange peels better fits the nonlinear adsorption model of Freundlich isotherms with the coefficient of determination ($r^2$) close to 1 which is 0.9951. Thus, it means that the adsorption occurred at the heterogeneous layer [40]. Based on nonlinear graph of Freundlich isotherm (Fig. 10), the value of $K_F$ and $n$ can be calculated using nonlinear Freundlich isotherms equation which resulted in the $K_F$ value of 0.6439 mg g$^{-1}$ and $n$ value of 1.620. The $K_F$ value showed that the greater $K_F$ value capacity of an adsorbent adsorptivity, the bigger the capacity of the adsorbent to adsorb the adsorbent [40]. The $K_F$ value obtained in this study is quite significant. This means that the capacity of pectin from sweet orange peel in adsorbing phenol is relatively good. A value of $1/n$ indicates the concentration dependence associated with adsorption. If the value is $1/n < 1$, the adsorption process is beneficial making the adsorption capacity increases and new adsorption sites occur. Conversely, if $1/n > 1$, the adsorption bond is weakened and unfavorable adsorption occurs making the adsorption capacity decreases [41]. Thus, the phenol adsorption process by pectin isolated from orange peel is categorized as a favorable adsorption process.

Similar results were also obtained at phenol adsorption on rice-husk [18] and rice straw [19] which were $1/n < 1$ while at phenol adsorption on chitosan [23], activated carbon from rice husk [14], peat and bentonite [15] which obtained the value of $1/n > 1$. Conversely, in some phenol adsorption systems by other adsorbents generated Langmuir adsorption isotherms, such as fly ash [15] and activated carbon [13,18]. The findings summary of phenol adsorption systems by several adsorbents is presented in Table 7.

| Adsorbent                | Isotherm and Parameters                      | References |
|--------------------------|----------------------------------------------|------------|
| Chitosan isolation from shrimp | Freundlich ($K_F = 0.479; n = 0.214$)        | [23]       |
| Activated carbon from rice husk | Freundlich ($K_F = 0.057; n = 0.2586$)       | [14]       |
| Peat                     | Freundlich ($K_F = 4.6 \times 10^{-4}; n = 0.529$) | [15]       |
| Bentonite                | Freundlich ($K_F = 5.1 \times 10^{-1}; n = 0.251$) | [15]       |
| Fly ash                  | Langmuir ($((x/m)_{\text{max}} = 22 \text{ mg/g}; K_L = 0.211 \text{ mg/L}$) | [15]       |
| Rice husk                | Freundlich ($K_F = 33.58; n = 1.855$)        | [18]       |
| Activated carbon         | Langmuir ($((x/m)_{\text{max}} = 11.23 \text{ mg/g}; K_L = 44.5 \text{ mg/L}$) | [18]       |
| Rice straw               | Freundlich ($K_F = 4.540; n = 3.610$)        | [19]       |
| Activated carbon         | Langmuir ($((x/m)_{\text{max}} = 49.72 \text{ mg/g}; K_L = 0.1099 \text{ mg/L}$) | [13]       |
| Pectin isolation from kisar orange peel | Freundlich ($K_F = 0.6439; n = 1.620$)       | This study |

Nonlinear adsorption isotherms model is better than the linear models found in the adsorption systems of safranin dyes on rice husk [38], phenol on soil [37] and nitrate ion on OS-nZVI [36]. The most significant disadvantage of the linear model is the distribution of non-constant errors. If the nonlinear isotherm is converted into a linear form, the structure and distribution of errors changes and this may affect the variation of errors and normality
assumptions from the least standard squares. In addition, isotherm parameters for nonlinear models can be directly obtained without prior conversion as compared to linear models [36]. The same finding was also obtained for nonlinear model of tartrazine adsorption kinetics on chitosan [42].

4. Conclusion
Based on the findings of our study, the following conclusions can be drawn:
1. Pectin from sweet orange peels can adsorb phenol at an optimum contact time of 20 minutes, pH solution is in acidic condition (pH 3), as well as an optimum concentration at 25 ppm.
2. Phenol adsorption by pectin isolated from sweet orange peels is consistent with nonlinear isotherm Freundlich with correlation coefficient \( r^2 \) of 99.51\%, \( K_F \) of 0.6439 (mg/g) \((L/mg)^{(1/n)}\) and \( n \) value of 1.620, which indicated that the process of adsorption is favorable.

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