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Utilization of Durian Peel as Adsorbent in Tofu Industrial Wastewater Treatment

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Abstract. Tofu industry wastewater in Indonesia contains high concentrations of organic pollutants, especially chemical oxygen demand (COD), which often exceed regulatory discharge limits due to the lack of effective treatment systems in small-scale production units. This study was conducted to evaluate the performance of durian peel as a low-cost adsorbent for COD removal. The adsorbent was prepared through carbonization at 300°C for 1 hour and activated using 30% H_3PO_4 for 24 hours. Batch adsorption experiments were conducted by varying contact time (0–150 minutes) and adsorbent dosage (0.2–1.0 g) at constant shaking speed (150 rpm). The result showed that activated durian peel demonstrated potential as an adsorbent for tofu wastewater, though its iodine number fell below the SNI 06-3730-1995 standard. The optimum condition was achieved at 90 minutes and 0.6 g adsorbent, resulting in 85.75% COD removal. Adsorption equilibrium data were analysis using Langmuir and Freundlich isotherm models. The Freundlich model provided a better fit (R^2 = 0.7663), indicating multilayer adsorption on a heterogeneous surface. These findings confirm the potential of durian peel as an effective biosorbent for tofu wastewater treatment under optimal adsorption conditions.

Keywords: adsorption; durian peel; Freundlich isotherm; tofu liquid waste

1. Introduction

Due to its inexpensive price, savoury taste, and high nutritional value, tofu has become a popular local food in Indonesia. Tofu industry in Indonesia was primarily supported by small and medium-sized enterprises that lacked the necessary capital to handle the wastes that resulted from their operation processes (Elystia et al., 2023). Most tofu producers release their wastes into surface water without first treating it, which harms to environment. There are two various types of waste produced for every kilogramme of soybeans used to make tofu: liquid and solid waste (Farina Nury et al., 2023; Prawati et al., 2019). The amount of liquid waste from the tofu industry is 40-43 times greater than solid waste because almost all processes carried out use water, which requires 45 litres of water for the processing process, resulting in 43.5 litres of tofu wastewater (Adisasmito et al., 2018).

Liquid waste from tofu industrial processing is generated from the washing, boiling, pressing and cutting processes (Simaremare et al., 2022). The liquid waste from tofu industrial processing has a total a chemical oxygen demand (COD) of 5000–8000 mg/L and suspended solid (TSS) content of more than 1000 mg/L (Prawati et al., 2019). High COD levels in tofu industry wastewater is because the organic materials contained in the waste are generally very high in the form of 40% - 60% protein, 25% - 50% carbohydrates and fats (Adisasmito et al., 2018). Based on the Peraturan Menteri Lingkungan Hidup Republik Indonesia Nomor 5 Tahun 2014 Baku Mutu Air Limbah, the maximum level of COD in waste allowed for tofu industrial processing activities is 300 mg/L (Lestari & Nasra, 2022).

Several technologies are used to treat tofu wastewater such as by coagulation and flocculation process (Albi & Kartohardjono, 2020), conventional aerobic/anaerobic process (Adisasmito et al., 2018), membrane separation (Fathia & Kartohardjono, 2020) and adsorption process (Farina Nury et al., 2023). Although many treatment processes have been used for tofu wastewater treatment, adsorption is a more effective and economical process, and is suitable for application in water and wastewater treatment. In addition, the adsorption process requires an adsorbent as a sorbent. However, commercial adsorbents are very expensive, making them limited for large-scale applications. The use of low-cost and biomass-based adsorbents has become a concern for further study.

Agricultural waste that has the potential to be used as an adsorbent is durian peel (Durio

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zibethinus) because it is most commonly found in Bandar Lampung. Utilisation of durian peel waste as adsorbent can solve two problems at once: (i) reducing the volume of durian peel waste itself, and (ii) removing wastewater pollutants when used as an adsorbent (Farina Nury et al., 2023). In addition, durian peel contains cellulose (47.2%), hemicellulose (9.63%), lignin (9.89%), and ash (4.20%), so it is possible to be used as adsorbent raw material in biomass-based tofu wastewater treatment (Adunphatcharaphon et al., 2020).

This research focuses on the preparation of adsorbents from durian peel and determine the performance of adsorbents to reduce COD concentrations from tofu industrial wastewater using adsorption isotherm models using the Langmuir or Freundlich equations.

2. Methods

2.1. Preparation durian peel adsorbent

Durian peels were collected from fruit stalls in Way Halim, Bandar Lampung. Durian peels were cut into 2x2 cm size and dried in an oven for 5 h at 105°C to remove moisture content. Carbonisation of durian peels was carried out using a furnace to obtain adsorbents at a temperature of 300^{o}C for 1 h. Activation of the adsorbent was then carried out using H3PO4 activator at a concentration of 30% (v/v) with a soaking time of 24 h. Distilled water was used to wash the activated adsorbent until its pH was neutral. Prior to usage, the adsorbent was dried at 105°C until its weight kept constant.

2.2. Adsorption of tofu wastewater

Durian peel adsorbent was placed in erlenmeyer containing tofu industry wastewater to estimate the removal of chemical oxygen demand (COD), pH and colour. The experiment was conducted under batch condition using an orbital shaker at 150 rpm with variation of adsorbent mass (0.2; 0.4; 0.6; 0.8 and 1) g and contact time (30, 60, 90, 120, 150) minutes. The quality of the resulting adsorbent was evaluated based on moisture content, ash content, and iodine number. These parameters were determined using standard procedures as follows: moisture and ash contents were measured gravimetrically by drying and incinerating the sample in a muffle furnace, respectively, while the iodine number was determined using the iodometric titration method, referring to SNI 06-3730-1995.

The solution was filtered to separate the remaining solution and adsorbent. The remaining concentration of each solution was measured according to the parameters COD of tofu industry liquid waste was identified using the SNI-6989.2:2009 standard, the initial pH was found to be 9.5 and the color was seen physically. Adsorption and COD tests were performed in triplicate.

3. Result and Discussion

Physicochemical Analysis of Durian Peel-Based Adsorbent

The resulting durian peel adsorbent was uniformly sized 2 *x* 2 cm and black in colour. Activation of the adsorbent was carried out chemically using H_3PO_4 solution at a concentration of 30% (v/v) for 24 hours, this aims to expand the carbon surface. The quality of the resulting adsorbent was analysed as follows: moisture content, ash content, and iodine absorption. Table 1 presents the results of the physicochemical analysis of the durian peel adsorbent, including moisture content, ash content, and iodine number.

Table 1. Characteristics of Durian Peel Adsorbent

Parameters	Value	Standard SNI 06-3730-1995
Moisture content	10.89%	Maximum 15%
Ash content	6.75%	Maximum 10%
Iodine capacity	1239.34 mg/g	Maximum 750 mg/g

Table 1 shows that the durian peel-based adsorbent partially meets the quality specifications outlined in SNI 06-3730-1995. While certain parameters such as moisture content and ash content fall within acceptable ranges, other parameters may deviate from the standard values. This indicates that although durian peel waste demonstrates potential as a low-cost adsorbent, further treatment or modification may be necessary to fully comply with standard adsorbent specifications.

Effect of contact time on COD removal

Initial COD concentration Testing the optimum time of adsorption on tofu industry waste can be seen in Figure 1.

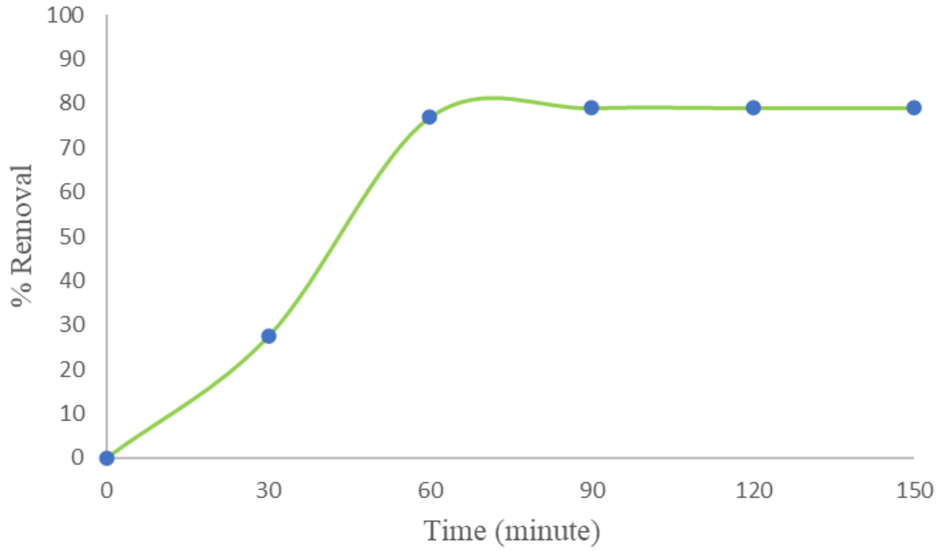

Figure 1. Optimum contact time

From Figure 1, it can be seen that the decrease in COD levels in tofu industry waste continues to increase from a contact time of 30 minutes to a contact time of 90 minutes with a percentage of absorption of 32.65%, 81.87%, and 85.75%. At a contact time of 30 minutes and 60 minutes, the adsorbent has not been able to absorb optimally the organic substances contained in the tofu industry waste because the interaction between the adsorbent and the adsorbate has not been maximised.

Meanwhile, at a contact time of 90 minutes, the adsorbent absorption reached its optimum time. This can also be seen in the contact time at 120 minutes and 150 minutes, where the decrease in COD levels did not change from the 90 minutes contact time. This is because the adsorbent has experienced saturation where the surface is covered by absorbed organic substances, so that the adsorbent is no longer able to absorb organic substances in the tofu industry waste (Farina Nury et al., 2023; Nabilla & Rusmini, 2019).

Table 2. Influence mass of durian peel adsorbent to removal COD concentration

Adsorbents (g)	**Final removal COD (mg/l)**	**% Removal COD (%)**
0.2	824.11	32.88 %
0.4	421.05	66.44 %
0.6	336.84	73.15 %
0.8	336.84	73.15 %
1	336.84	73.15 %

From Table 2, it can be seen that the percentage of removal COD also increases when the mass of adsorbent used is increased. In the range of adsorbent mass addition of 0.2 to 0.6 g, the decrease in COD levels in tofu industry waste increased for each sample concentration variation. This is also supported by research conducted by Ria Komala et al. on the addition of adsorbent masses of 1, 2 and 3 g resulted in a percentage decrease in COD levels of 20.58%, 26.94%, and 46% (Komala et al., 2021).

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Isotherm Adsorption

After 90 minutes of optimal contact time, the adsorption process yielded a pH of 8. The most important managing parameter in the adsorption process is the pH of the aqueous solution. This pH value affects the surface charge of the adsorbent, the degree of ionisation of the adsorbate during the adsorption process (Ali et al., 2020; Dehmani et al., 2022). Acidic organic compounds are more easily adsorbed at lower pH, and basic organic compounds are more easily adsorbed at higher pH (Sriwuryandari et al., 2019). The data from the adsorption isotherm calculations are presented in Figure 2 and Figure 3.

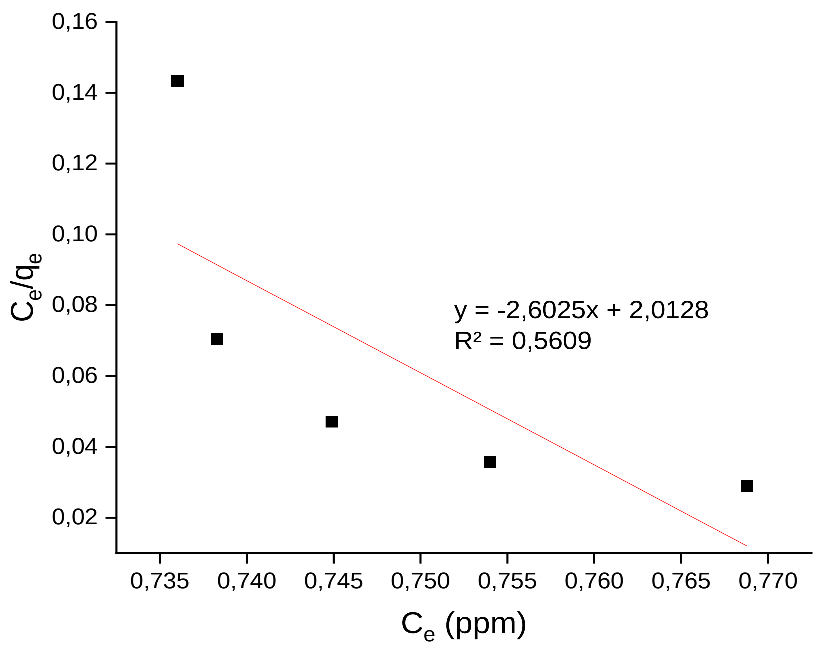

Figure 2. Langmuir isotherm

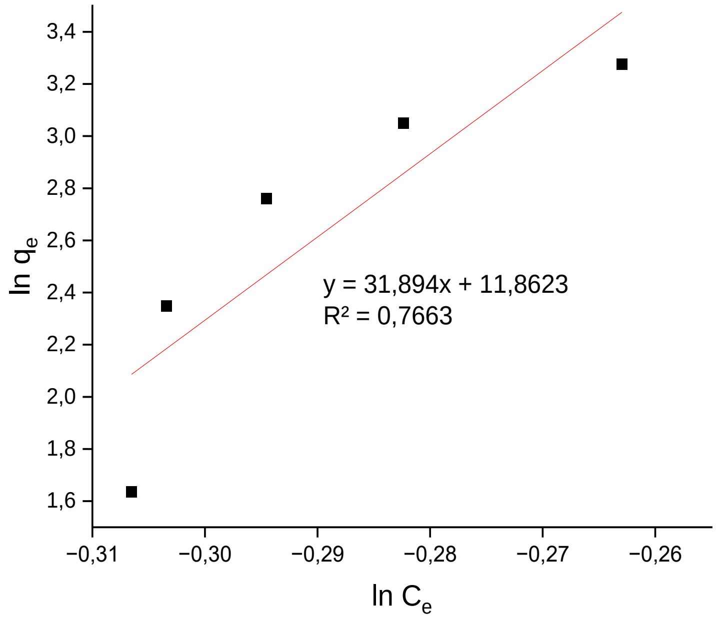

Figure 3. Freundlich isotherm

Figure 2 is a Langmuir isothermal graph which is a plotting between C_e/q_e and C_e. From the data, the equation is obtained in the form of a linear equation y = -2.6025x + 2.0128 with a value of R^2 = 0.5609. The linear equation is used to solve the Langmuir equation by determining the slope and intercept of the curve. The Langmuir equation is shown in Equation 1.

$$\frac{C_e}{q_e} = \frac{1}{q_{max}.b} + \frac{C_e}{q_{max}} \quad (1)$$

Where:

q_e = Amount of adsorbate adsorbed per g of adsorbent at equilibrium (mol/g)

C_e = Equilibrium concentration of adsorbate after adsorption (mol/L)

q_{max} = maximum amount of adsorbate per g of adsorbent

b = adsorption constant.

The relationship curve of ln Ce and ln qe for Freundlich isotherm is shown in Figure 3. On the Freundlich isotherm curve which is the result of plotting between ln qe and ln Ce, an equation

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in the form of a linear equation y = 31.894x + 11.862 with a value of R^2 = 0.7663. The Freundlich equation curve plots the relationship between ln qe and ln Ce and then a linear regression of the curve is determined to obtain a linear equation and the value of the correlation coefficient (R^2). The linear equation is used to solve the Freundlich equation by determining the slope and intercept of the curve, written in Equation 2.

$$ln\ q_e = \frac{1}{n} lnC_e + \ln K \qquad (2)$$

Where:

K = Freundlich isotherm constant (mol/g)

n = Intensity of adsorption

C_e = Equilibrium concentration of adsorbate after adsorption process (mol/L)

q_e = Amount of adsorbate adsorbed per g of adsorbent at equilibrium (mol/g)

The values of K and n serve as indicators of the approximate adsorption capacity.

Based on the data displayed in Figures 2 and 3, it can be seen that the highest correlation coefficient (R^2) value is found in the Freundlich isotherm, this indicates that the adsorption of tofu liquid waste on COD parameters using adsorbents from durian peel fitted to Freundlich isotherm approach. The values obtained in Figures 2 and 3 are summarised in Table 3.

Table 3. Isothermal adsorption of durian peel adsorbents

Isothermal Langmuir			**Isothermal Freundlich**		
b (L/mg)	**q_{max} (mg/g)**	**R^2**	**1/n**	**K (mg/g)**	**R^2**
-0.773	0.496	0.560	31.894	141775.5	0.766

By using the Freundlich isothermal equation on the adsorption concentration of tofu liquid waste, the capacity or ability of durian peel as adsorbent can be calculated. Based on the calculation data presented in Table 3, the K value of 141775.5 mg/g and 1/n of 31.894 were obtained which shows the concentration dependence indicator of the amount of energy associated with the adsorption process.

Based on the above data, it can be indicated that the adsorbent treatment gives a very large 1/n value. This is expected, because the surface of the adsorbent is small and selective so that in a mixture of substances, there are some components that are absorbed by certain solid

4. Conclusions

Durian peel activated with H_3PO_4 shows potential as an adsorbent for tofu liquid waste treatment. Although it meets some of the quality parameters specified in SNI 06-3730-1995, the iodine number does not fully meet the standard. The optimum COD reduction was achieved at 90 minutes with 0.6 g adsorbent, following the Freundlich isotherm model ($R^2 = 0.7663$).

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