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Tempeh Industry Wastewater Treatment using Mix Natural Adsorbents (Zeolite, Bentonite, Water Hyacinth-Activated Carbon): Effect of Mass Ratio and Dosage of Mix Adsorbents on Turbidity and pH

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ABSTRACT

Adsorption is the agglomeration of dissolved substances in solution by the surface of an absorbent substance, making the material enter and collect in an absorbent substance. Natural adsorbents that treat tempeh wastewater are mixed adsorbents that consist of zeolite, bentonite, and activated carbon made from water hyacinth. This study aimed to determine the effect of the mass ratio and dose of mixed natural adsorbents on tempeh wastewater's turbidity and pH values and the isotherm that occurred. The mass ratio variation used was the ratio of each material in the form of zeolite: bentonite: activated carbon in the form of R1 (1:1:1), R2 (2:1:1), R3 (1:2:1) and R4 (1:1:2). The adsorbent dose carried out was 1.5 gr; 3 grams; and 4.5 gr per 100 ml volume of wastewater. The contact time between the adsorbent and the wastewater is every 15, 30, 60, 90, 120, 150 minutes. Tempeh wastewater was processed in laboratory-scale batches with 120 rpm stirring. The primary analysis carried out is turbidity and pH. The results showed that the adsorption reduced turbidity and increased the pH level by processing the mass ratio R2 (2:1:1) for 150 minutes with a dose of 4.5 grams. It was found that the turbidity decreased by 99.5% from 520.5 NTU to 2.47 NTU, and the pH level increased from 3.7 to 6.4 after processing for 150 minutes at a dose of 4.5 grams. The maximum adsorption capacity validation results were obtained based on the Langmuir analysis of 8.26-10.61 mg/g with a constant of 0.27-6.4. These results show that mixed natural adsorbent is effective and potentially develops on tempeh wastewater treatment.

1. INTRODUCTION

Tempeh is a food source of vegetable protein consumed by Indonesian people. According to the Badan Pusat Statistik, the average per capita consumption of tempeh per week in 2022 is 0.140 kg (Badan Pusat Statistik, 2022). This food is made from fermented soybeans using yeast. The relatively economical price is also a factor in tempeh being one of the mandatory consumptions for Indonesian people, thus causing the tempeh-making industry to spread in various regions of Indonesia.

The wastewater from tempeh processing contains impurities that pollute the environment. Based on research from Cundari et al. (2022), tempeh wastewater contains some pH, turbidities, Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD which is shown in Table 1. Based on The Minister of Environment and Forestry of The Republic of Indonesia Regulation No. 5 (2022), wastewater food processing should be at most the maximum standard. In addition, tempeh wastewater needs treatment for decreasing the pollution before being discharged into the environment.

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Trisnadewi et al. (2017) treated tempeh waste using natural zeolite. Treatment is carried out to decrease BOD and COD from tofu industrial wastewater. Before use, natural zeolite was activated using HCl 6 N and NH4NO3 N. The result was then calcined at 300°C. The results showed that the decrease in BOD has best decreased on 1.5 gr mass variation dosed, with an efficiency of 85.7%, while the decrease in COD was 35.7%. Natural zeolite has several weaknesses, including impurities such as Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, and Fe^{3+}, and its crystallinity could be better. The presence of these impurities will reduce the activity of natural zeolite (Setiawan et al., 2018). It is necessary to activate or modify the natural zeolite first to improve its character before using it as an adsorbent, catalyst, or application so that the activity increases (Darojah et al., 2018).

Maulani et al. (2021) treated tempeh waste using bentonite and PAC, resulting in a 53% TSS removal and a 95% reduction in TDS. In addition, the values of BOD and COD can decrease significantly, namely BOD of 87% and COD of 84%. The resulting bentonite had limited adsorption ability, which can be overcome through an activation process using acids, and is classified as a strong acid, causing a decrease in effectiveness, resulting in bentonite with a higher adsorption capacity (Kumar et al., 1995).

It is very possible to combine zeolite and bentonite for tempeh wastewater. Zeolite and bentonite can be easily found cheaply and are not harmful to the environment. In this research, water hyacinth-based activated carbon will be added. Using water hyacinth-based activated carbon can reduce water hyacinth, which is excessive and can pollute the environment. This research aims to get the turbidity and pH removal data on tempeh wastewater by using a mixed natural adsorbent and analyzing the isotherm that occurred.

2. METHODS

2.1. Preparation of Adsorbent as Raw Materials and Collection of Tempe Waste

The water hyacinth-based activated carbon was produced by pyrolysis at 600°C for 3 hours (Cundari et al.,2023). Zeolite and bentonite are technical-grade materials that were obtained from online stores. The materials were washed using clean water to remove the contaminants. The washed materials were dried. Tempe wastewater was obtained from one of the tempeh productions in a tempeh factory on Jl. Macan Lindungan Perumahan Kopti, Pabrik Tempe Kopti, Palembang, Indonesia.

2.2. Preparation and Activation of Zeolite

Zeolite was crushed into 100 mesh and then washed with distilled water before being dried in an oven at 110°C for 3 hours. Then, it will be activated with 0.4 M HCl laurate as an activator with magnetic stirring on a stirrer in a 250 ml Erlenmeyer covered with aluminum foil for 4 hours at a speed of 100 rpm (Lestari, 2018).

Then, the zeolite will be calcined with a muffle furnace at 500°C for 5 hours (Lestari, 2018). The zeolite that has been calcined will be filtered and washed using distilled water so that the pH becomes neutral.

2.3. Preparation of Water Hyacinth-based Activated Carbon

The water hyacinth used in this study is part of the stems and leaves. Then, washing with water, distilled water, and soaking in a solution of 0.25 M Ethylene diamine tetra acetic acid at pH 10 for 24 hours to remove the metal ion content in the plants. The active carbon was washed three times using distilled water and dried in an oven at 110°C for 48 hours. The dried active carbon was then reduced in size to 100 mesh.

Active carbon biosorbent was impregnated in 1 M H_3PO_4 solution with a ratio of 3:1 for two days at room temperature, then dried in an oven at 110°C for 3 hours. Then, it is put into the muffle furnace, where a pyrolysis process occurs with little/no oxygen at 600°C for 3 hours (Cundari et al.,2023). The activated carbon that has been calcined will be rewashed using aquadest so the pH is neutral.

2.4. Preparation and Activation of Bentonite

Bentonite was crushed with a porcelain mortar and sieved with a size of 100 mesh. The resulting bentonite was weighed 50 g, soaked with 500 mL of 0.8 M H_2SO_4 in 1000 mL Erlenmeyer, covered with aluminum foil, and shaken at 9 rpm for 3 hours (Rizqullah, 2018). The immersion samples were washed with aquadest until SO_4^{2-} was no longer present. It can be known by the universal pH, which shows the pH according to aquadest. Samples were dried in an oven at 110°C for 2 hours, and then the bentonite solution was calcined for 5 hours at 500°C.

2.5. Experimental Procedure

The results were analyzed to validate the results obtained only on the best samples. The variations were analyzed starting from pH and turbidity to get the best data. The analysis was carried out up to two repetitions. After obtaining the initial waste sample analysis, then carry out the adsorption process using a mix of natural adsorbents (zeolite: bentonite: activated carbon) with variations R1 (1:1:1), R2 (2:1:1), R3 (1:2:1), R4 (1:1:2) with a dose of (1.5; 3.0; 4.5) gram/100 ml of tempeh wastewater.

The adsorption process was carried out using a stirrer with a speed of 120 rpm. Stirring time was 15, 30, 60, 90, 120, 150 minutes. The sample was then allowed to stand for 15 minutes so that the residual adsorbent could precipitate. Waste that has gone through filtration was analyzed for pH levels and turbidity values for two repetitions. Turbidity is a relative measure that determines water clarity. The more apparent the water, the lower the turbidity value. It is because light can penetrate to the bottom of the water. The power of hydrogen (pH) value is the degree of acidity of a solution. This value is the sum of the hydrogen ion concentrations in a solution. pH and Turbidity values are parameters that will be reviewed in this study.

The results of research on each variation were done. The stirred sample was then filtered using filter paper, and the remaining adsorbent that had been filtered was put into the oven heated to a temperature of 110°C for 2 hours. The turbidity data was used to calculate the isotherm that occurred as Langmuir of Freundlich isotherm.

2.6. Analysis Procedure

2.6.1. Turbidity, pH, TSS, COD, and BOD analysis

The analysis was conducted at the Palembang Health Laboratory Center (BBLK), which KAN certified. Turbidity analysis was carried out using the SNI 06-6989.25-2005 method. pH analysis was carried out using the SNI 6989.11.2019 method. Total Suspended Solid (TSS) analysis was performed using the Gravimetric method. Chemical Oxygen Demand (COD) analysis was carried out using the Spectrophotometric method. Biological Oxygen Demand (BOD) analysis was done using the Manometric method.

Table 1. Analysis of initial tempeh wastewater (Cundari et al., 2022)

Parameter	Units	Result of Analysis	Standard
pH	-	4,69	6 – 9
Turbidity	NTU	209	-
TSS	mg/L	0,3	200
COD	mg/L	431	300
BOD	mg/L	228	150

Table 2. Tempe Wastewater Water Analysis Results Before Processing

Parameter	Units	Analysis Result	Method	Environmental Quality Standards
pH	-	3.9	SNI 6989.11 : 2019	6 – 9
Turbidity	NTU	511.5	SNI 06-6989.25 - 2005	25
TSS	mg/L	1042	Gravimetric	200
COD	mg/L	791	Spectrophotometry	300
BOD	mg/L	97	Manometry	150

3. RESULT AND DISCUSSION

The sample of wastewater from the tempeh industry used in this study was from washing soybeans in tempeh production in Jl. Macan Lindungan Perumahan Kopti, Pabrik Tempe Kopti, Palembang, Indonesia. Before starting the waste treatment, samples were first analyzed for pH, turbidity, Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), and Biological Oxygen Demand (BOD), as seen in Table 2.

The waste generated from tempeh producers was analyzed first. It referred to the Regulation of the Minister of Environment of the Republic of Indonesia No. 5 of 2022 concerning Wastewater Quality Standards for Soybean Processing Businesses or Activities. The results of the analysis on wastewater did not meet quality standards where several parameters exceeded the maximum value, which is harmful to the environment. It resulted from an analysis of tempeh wastewater at The Health Laboratory Center (BBLK) Palembang.

3.1. Turbidity Removal

Turbidity can be caused by various factors, including organic and inorganic materials in the water, such as soybeans, which participate in the soaking process, and microbes. These pollutants can make natural waters more turbid and even form sediment. High turbidity strongly influences the concentration of dissolved oxygen present in the water. The effect of increasing turbidity is reducing the penetration of external light that enters the water. Turbidity can limit light in water due to the attractive force of attraction between molecules that occurs due to objects touching each other (Azhari, 2016).

3.1.1. Turbidity in Adsorbent R1 Ratio (1:1:1)

Variations in the ratio of adsorbent mixture R1 were using a mass ratio of 1:1:1 from zeolite, bentonite, and active carbon. The results from the use of doses at various ratios of the R1 adsorbent mixture in reducing turbidity are shown in Figure 1.

Based on Figure 1, using this mix ratio, the decrease in turbidity has a very significant decrease, from 511,5 NTU to 29.3 NTU. The adsorption occurred fast in the first 15 minutes and reached equilibrium. The time and dosage used during the stirring process affect the reduction percentage. The longer the contact time and the greater the adsorbent dose, the greater the effectiveness of reducing turbidity.

The average percentage of turbidity reduction in this mixture is 88%. It was concluded that this mixture was less effective than other mixtures, with a more than 90% percentage, and needed to meet environmental quality standards.

3.1.2. Turbidity in Adsorbent R2 Ratio (2:1:1)

The use of variations in the ratio of adsorbent mixture R2 using a mass ratio of 2:1:1 from zeolite, bentonite, and active carbon effectively reduced the turbidity parameter, as shown in Figure 2.

Based on Figure 2, the adsorbent mixed ratio, where the adsorbent in zeolite, was used predominantly in this study with a dose variation of 2:1:1 for every 1.5, 3, and 4.5 grams. The decrease in turbidity that occurred experienced a very significant decrease. The decrease was more effective than the previous mixture ratio, where the turbidity value decreased by approximately 99.5% from the initial level (from 511.5 NTU to 2.475 NTU). The number of doses or the long contact time did not significantly affect the percentage of turbidity.

The optimum value was obtained at 15 minutes of stirring at a dose of 4.5 grams with a decrease of 511.5 NTU to 8.895 NTU with a reduction effectiveness of 98%. The maximum value obtained in this mixture was obtained at a dose of 4.5 grams with a stirring time of 150 minutes. It obtained a decrease from 520.5 NTU to 2.475 NTU with a reduction effectiveness of 99.5%. The average percentage of turbidity reduction is 97%. This mixture has the best percentage of the other mixed variations.

The research results of (Mulia et al., 2022) in reducing turbidity values used a mixture of rice husks, coconut shell charcoal, zeolite, and quartz sand. The results obtained for turbidity decreased from the value before filtration of 1153 NTU to 104 NTU (90.98%). The dosage variations of the adsorbent used were higher than in this research, but the results obtained were lower than in this research.

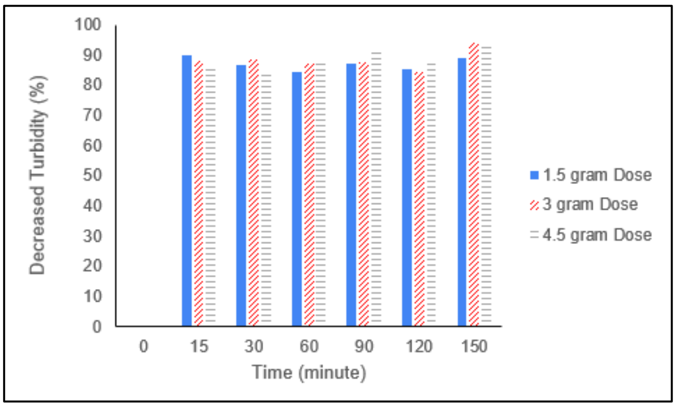


Figure 1. Turbidity reduction of tempeh wastewater at variations in the mass ratio R1

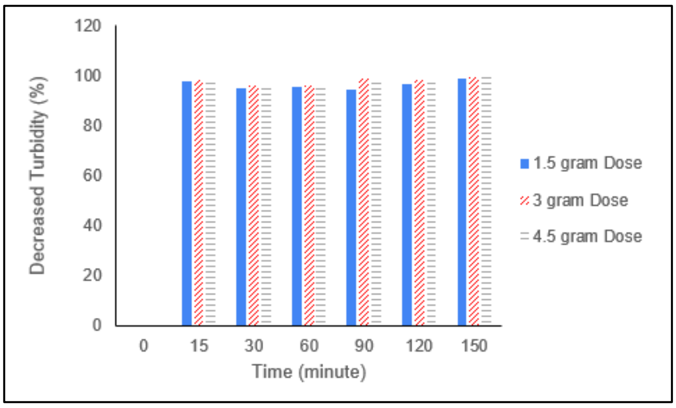


Figure 2. Turbidity reduction of tempeh wastewater at variations in the mass ratio R2

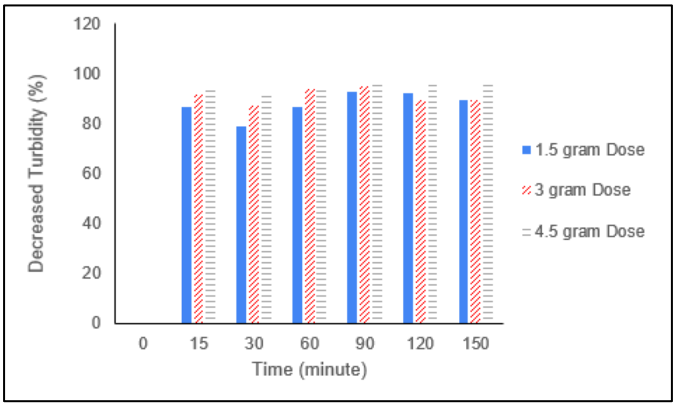


Figure 3. Turbidity reduction of tempeh wastewater at variations in the mass ratio R3

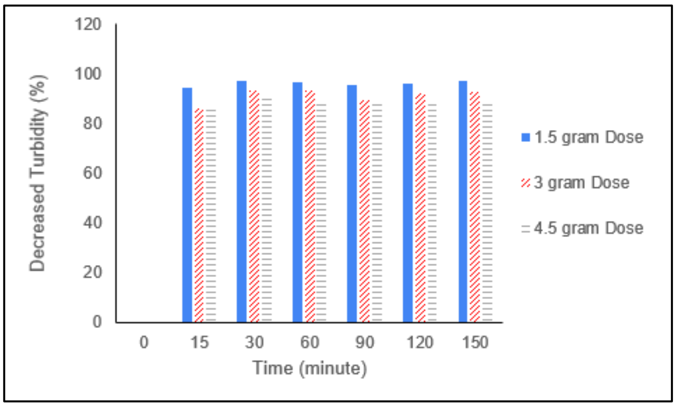


Figure 4. Turbidity reduction of tempeh wastewater at variations in the mass ratio R4

3.1.3. Turbidity in Adsorbent R3 Ratio (1:2:1)

This method used variations in the ratio of the adsorbent mixture R3 using variations in mass ratio of 1:2:1 from zeolite, bentonite, and activated carbon. The following results from using doses at various ratios of the adsorbent mixture R3 in reducing the turbidity parameter are shown in Figure 3.

Based on Figure 3, variations in the ratio of the adsorbent mixture R3 where the adsorbent in bentonite was used predominantly in this study with a dose variation of 1:2:1 for every 1.5; 3; 4.5 grams. Based on Figure 3, the contact time during the mixing process did not significantly reduce turbidity. However, the number of doses does have a significant effect during the process. The more doses used, the better the effectiveness of reducing turbidity.

The optimum value was obtained at 15 minutes of stirring at a dose of 4.5 grams with a decrease of 511.5 NTU to 30.85 NTU with a reduction effectiveness of 93%. The maximum value obtained in this mixture was obtained at a dose of 4.5 grams with a stirring time of 90 minutes. An impairment loss of 488.5 NTU was obtained to 14.73 NTU with a reduction effectiveness of 97%. The average percentage of turbidity reduction is 91%. This mixture has a better percentage than the R1 but is less effective than the R2 mixture.

3.1.4. Turbidity in Adsorbent R4 Ratio (1:1:2)

This method used variations in the ratio of the adsorbent mixture R4 using variations in the mass ratio of 1:1:2 from zeolite, bentonite, and active carbon. The following results from the use of doses at varying ratios of the R4 adsorbent mixture in reducing turbidity levels are shown in Figure 4.

Based on Figure 4., variations in the R4 mixture ratio where the adsorbent in the form of active carbon activated carbon was used dominantly in this study with a dose variation of 1:1:2 for every 1.5; 3; 4.5 grams. In using this mixed variation, the decrease in turbidity experienced a very significant decrease. Based on Figure 4, the contact time during the process did not significantly affect the decrease in turbidity. Judging from the addition of adsorbent doses, the effectiveness of reducing turbidity has a better value at a dose of 1.5 grams of adsorbent compared to other doses.

The optimum value was obtained at 15 minutes of stirring at a dose of 1.5 grams with a decrease of 511.5 NTU to 30.5 NTU with a reduction effectiveness of 94%. The maximum value was obtained at a dose of 1.5 grams with a stirring time of 30 minutes, obtaining a decrease from 506.5 NTU to 14.87 NTU with a reduction effectiveness of 97%. The average percentage of turbidity reduction was 91%. This mixture has the same percentage as the R3 mixture, better than R1, but less effective than the R2 mixture.

Research conducted by Cundari et al. (2022) used the active carbon adsorbent of water hyacinth as much as the adsorbent in tempeh wastewater. The results showed that turbidity decreased to 81% from the initial level. Compared to the research conducted, the effectiveness is much better because of the effect of the addition of a mixture of zeolite and bentonite in reducing turbidity in waste. The results showed that the adsorption process with variations in the ratio of the R4 adsorbent mixture reduced turbidity according to environmental quality levels.

3.2. The Effect of the Adsorption Process on the PH Value of Wastewater

Industrial waste from tempeh is usually acidic, and volatile substances are easily released in this acidic state. These substances can cause an unpleasant odor from the tempeh industrial wastewater. pH has a significant impact on water treatment processes. The quality standard of the pH is 6-9. The effect that occurs when the pH is too low is reduced dissolved oxygen. Suparno et al. (2020) state that the long immersion treatment factor significantly affects pH. The longer the contact time in waste treatment, the better the pH level will be.

3.2.1. pH in Adsorbent R1 Ratio (1:1:1)

The following results from varying doses of the R1 adsorbent mixture ratio in stabilizing pH levels are shown in Figure 5.

Based on Figure 5, the effectiveness of adsorption in raising the pH increases every minute during the stirring process. At each dose, stirring at 15 minutes had not reached the pH standard according to quality standards. The new pH level exceeded the quality standard when the stirring time was 30 minutes for each dose of adsorbent mass except for the 1.5-gram dose, which has yet to reach the standard for tempeh wastewater.

The optimum value for this mixture was obtained at a stirring time of 60 minutes, one of which was at a dose of 4.5 grams, with an increase in value reaching 6.4 with an increase in effectiveness of 62%. The maximum value obtained for this mixture was obtained at a dose of 4.5 grams with a time stirring of 150 minutes. The increase in pH occurred at the initial level value of 3.82 to 6.6 with an effective increase of 72%, which is almost close to the neutral pH.

The average increase that occurred in the mixed variation R1 was 62%. The results showed that the adsorption process with a mixture ratio of R1 had the best effectiveness of the four variations of other natural adsorbent mixtures and had achieved standardization of environmental quality standards.

3.2.2. pH in Adsorbent R2 Ratio (2:1:1)

The following results from varying doses of the R2 adsorbent mixture ratio in stabilizing pH levels are shown in Figure 6.

Based on Figure 6, the pH value at each stirring time increased gradually. Of the three doses, only the two doses experienced an increase in pH according to the pH standardization target at a stirring time of 120 minutes. The 3-gram dose reached the standardization line at a stirring time of 60 minutes, while the 4.5-gram dose had only reached the target at 120 minutes. The 1.5-gram dose experienced a less effective increase because it had yet to reach the pH standardization target according to the maximum stirring time.

The optimum value for this mixture was obtained at a stirring time of 90 minutes, one of which was at a dose of 3 grams with an increase in value reaching 6.4 with an increase in effectiveness of 67%. The maximum value obtained for this mixture was obtained at a dose of 3 grams with a stirring time of 150 minutes. The increase in pH occurred at the initial level value of 3.82 to 6.6 with an effective increase of 72%, which is almost close to the neutral pH.

The average increase in the mixed variation of R2 was 53%. The results showed that the process with a variation of the adsorbent mixture R2 could stabilize the pH according to environmental quality levels. However, it was not very effective compared to the variation of the R1 mixture.

3.2.3. pH in Adsorbent R3 Ratio (1:2:1)

The following results from varying doses of the R3 adsorbent mixture ratio in stabilizing the pH are shown in Figure 7.

Based on Figure 7, the increase in pH had a less significant increase each time of stirring. The three total doses had yet to reach the pH standardization target according to environmental quality standards. The 3-gram dose has the most stable increase compared to the other three doses and almost melts the pH standardization target according to quality standards.

The optimum value for this mixture was obtained at a stirring time of 60 minutes, one of which was at a dose of 3 grams with an increase in value reaching 5.5 from the initial concentration with an increased effectiveness of 43%. The maximum value obtained for this mixture was obtained at a dose of 3 grams with a stirring time of 150 minutes. The increase in pH occurred at the initial level value of 3.82 to 5.8 with an increased effectiveness of 49%, which is still below the pH target.

The average increase in the mixed variation of R3 was 44%. The results showed that the adsorption process with the ratio of the adsorbent mixture R3 was not able to increase the pH according to the environmental quality levels and was a less effective mixture variation compared to the other three mixtures.

3.2.4. pH in Adsorbent R4 Ratio (1:1:2)

The following results from varying doses of the R4 adsorbent mixture ratio in stabilizing the pH are shown in Figure 8.

Based on Figure 8, the increase in pH did not experience a significant increase compared to the R1 and R2 mixture variations but was better than the R3 variation. Based on all the doses tested, only the 4.5-gram dose reached the pH standardization target according to environmental quality standards with a stirring time of 150 minutes. The 1.5-gram and 4.5-gram doses experienced an ineffective increase each time the stirring was carried out and had yet to reach the pH standardization target.

The optimum value for this mixture was obtained at a stirring time of 90 minutes, one of which was at a dose of 4.5 grams, with an increase in value reaching 5.7 from the initial concentration with an increased effectiveness of 49%. The maximum value obtained for this mixture was obtained at a dose of 4.5 grams with a stirring time of 150 minutes. The increase in pH occurred at the initial level value of 3.82 to 6.1 with an effective increase of 59%, which has reached the standardization target but is still far from being neutral (7).

The average increase in the mixed variation of R4 was 43%. The results showed that the adsorption process with a variation of the R4 mixture stabilized the pH according to environmental quality levels with only a dose of 4.5 grams at 150 minutes of stirring. This mixture is less effective than the R1 and R2 mixture variations. However, it is better than the R3 mixture.

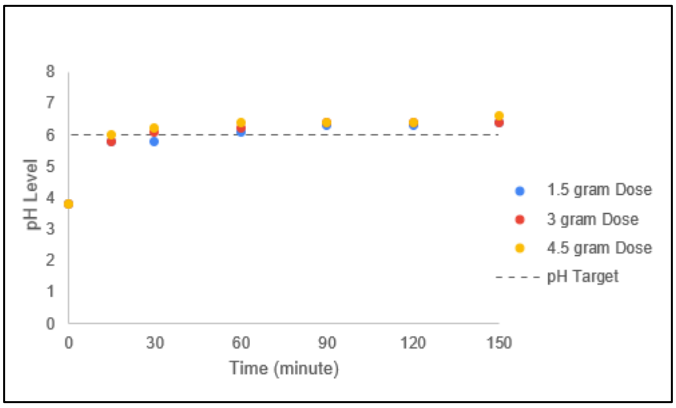


Figure 5. The pH value of tempe wastewater on variations in the mass ratio of R1

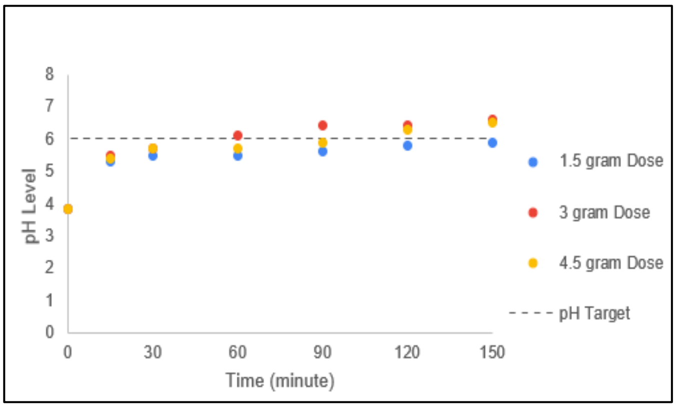


Figure 6. The pH value of tempe wastewater on variations in the mass ratio of R2

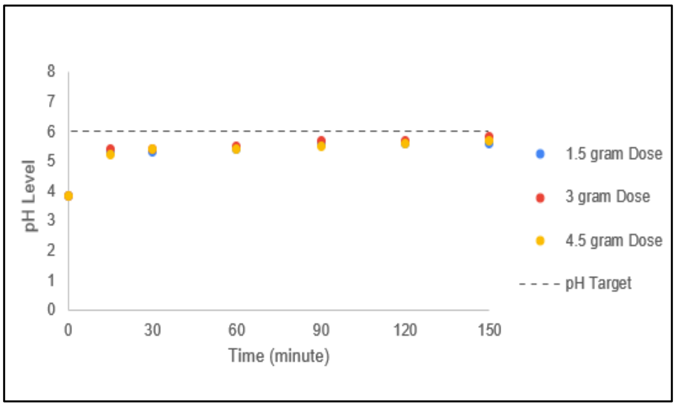


Figure 7. The pH value of tempe wastewater on variations in the mass ratio of R3

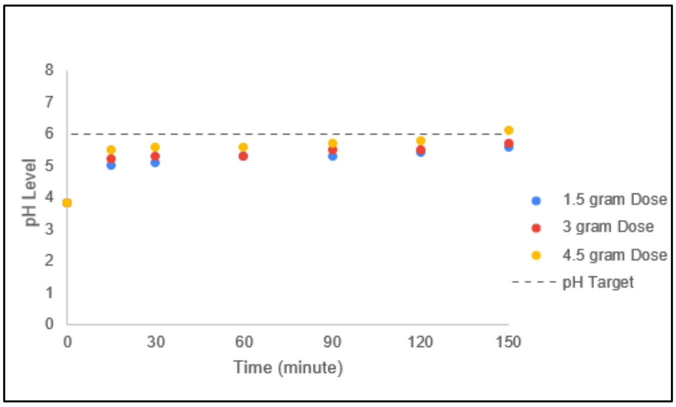


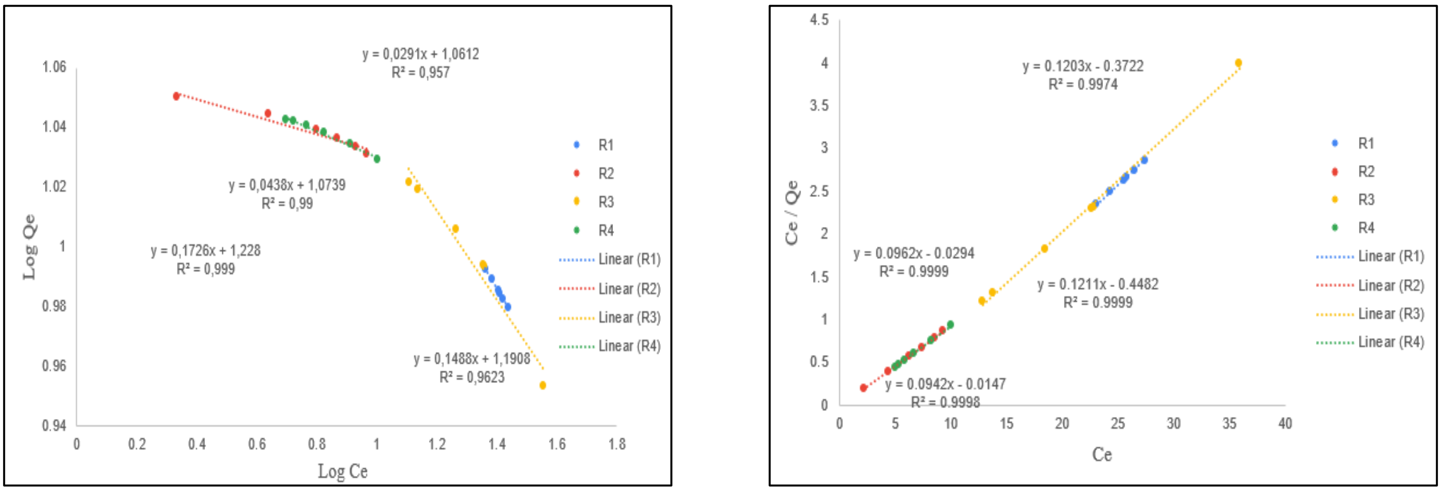
Figure 8. The pH value of tempeh wastewater on variations in the mass ratio of R4

3.3. Adsorption Capacity of Natural Adsorbents

Determination of the adsorption capacity value aims to determine the ability of the adsorbent to bind components in managing tempeh wastewater. These can be seen in Figures 9, 10, and 11 below the Langmuir and Freundlich isotherm graph.

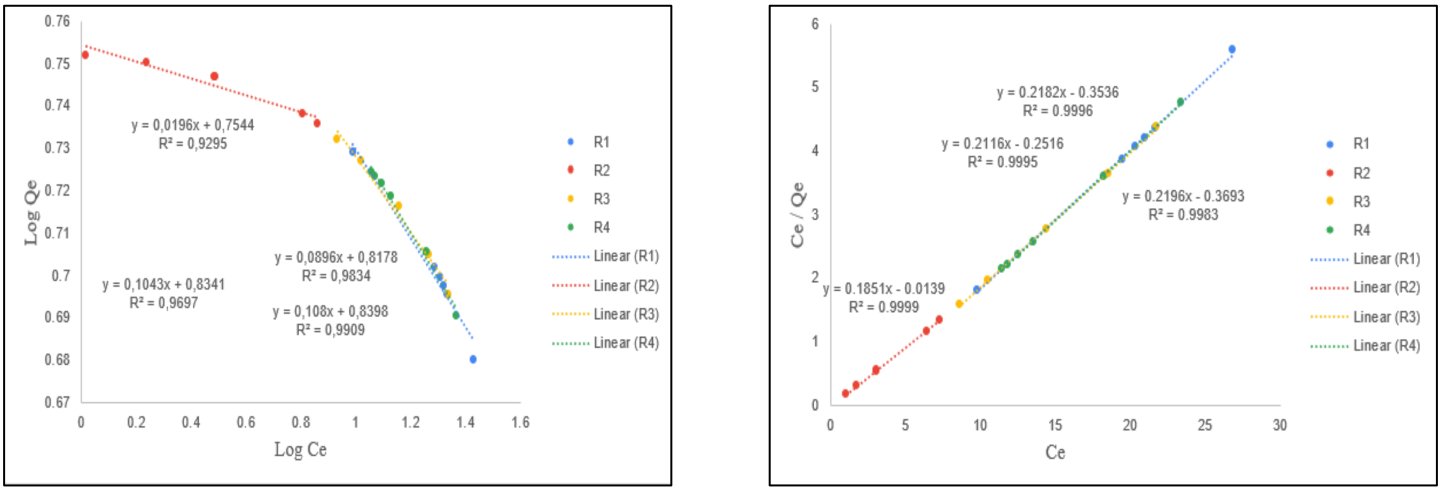
Based on the analysis using the Freundlich and Langmuir adsorption model, the regression results for each mixture variation are almost close to 1 so that it can be used to analyze the adsorption process because the square of the regression is close to 1 (Wijayanti et al., 2018). Analysis of the Freundlich isotherm results on tempeh waste with a dose of 1.5 grams had a maximum capacity of 3.43-22.83 mg/g with a Freundlich constant of 1.06-1.22 l/mg. A dose of 3 grams has a maximum capacity of 9.26-51.02 mg/g with a Freundlich constant of 0.75-0.83 l/mg. A dose of 4.5 grams has a maximum capacity of 7.07-49.75 mg/g with a Freundlich constant of 0.67-0.70 l/mg.

Analysis of the Langmuir isotherm results in tempeh waste with a dose of 1.5 grams with a maximum capacity of 8.26-10.61 mg/g and a Langmuir constant of 0.27 - 6.40 l/mg. A dose of 3 grams has a maximum capacity of 4.55-5.40 mg/g with a Langmuir constant of 0.59 – 13.31 l/mg. A dose of 4.5 grams has a maximum capacity of 2.90-3.57 mg/g with a Langmuir constant of 0.38 – 10.89 l/mg. It can be concluded that the maximum adsorption capacity based on Langmuir analysis is 8.26-10.61 mg/g with a Langmuir constant of 0.27-6.40 l/mg, which was obtained at a dose of 1.5 grams.



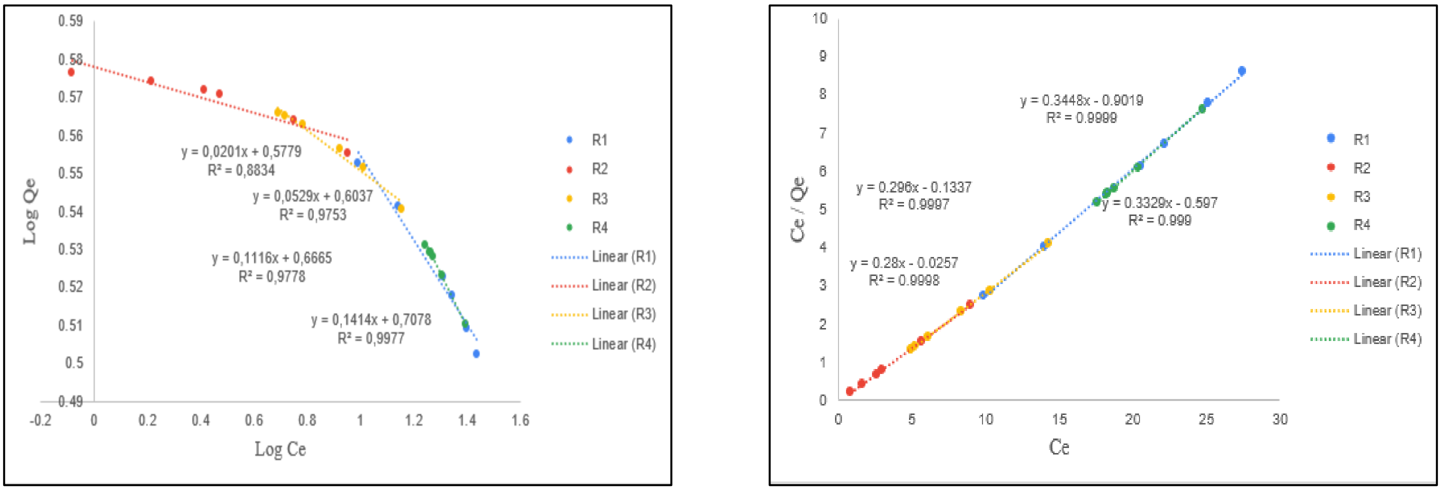
(a) (b)

Figure 9. Isotherms at a Dose of 1.5-gram (a) Langmuir Isotherm, and (b) Freundlich Isotherm



(a) (b)

Figure 10. Isotherms at a Dose of 3-gram (a) Langmuir Isotherm, and (b) Freundlich Isotherm



(a) (b)

Figure 11. Isotherms at a Dose of 4.5-gram (a) Langmuir Isotherm, and (b) Freundlich Isotherm

Table 3. Comparison of Analysis Results of Tempe Waste Samples Before and After the Adsorption Process

Parameters	Before Adsorption	After Adsorption (optimum condition, 15 minutes adsorption)			
	First Sample	R1	R2	R3	R4
pH[1]	3.9	5.4	5.8	6.0	5.7
pH[2]	3.8 – 3.9	5.8 – 6.6	5.3 – 6.5	5.3 – 5.7	5 – 6.1
Turbidity[1] (NTU)	511.5	33.400	23.200	24.100	–
Turbidity[2] (NTU)	488.5 - 521	82.35 – 29.3	27.85 – 2.47	68.55 –11.35	74.2 – 9.44
TSS[1] (mg/L)	1042	794	723	702	–
COD[1] (mg/L)	791	437	369	191	–
BOD[1] (mg/L)	97	80	69	58	–

(*1 Analysis Result at BBLK, *2 Analysis Result at Separation and Purification Laboratory)

3.4. Comparison of Optimum Results after Adsorption

Based on the research, the waste treatment results were carried out using various natural adsorbents, where the pH, turbidity, TSS, COD, and BOD values were tested at the Palembang Health Laboratory Center. There were several tests on a small laboratory scale in the form of pH and Turbidity, which were tested at the Separation and Purification Laboratory of Universitas Sriwijaya. The results of the analysis are presented in Table 3. The samples that were analyzed after adsorption was the optimum sample that occurred at 15 minutes of operation.

Based on Table 3. tempeh wastewater treatment was more effective at every variation of adsorbent ratio. R2 dose at 15 minutes of stirring time reduced turbidity to 95.3% from 557.91 NTU to 24.100 NTU. However, these results were not significantly different from the R2 dose, with a yield of 23.200 NTU with a reduction percentage of 95.46%. R3 had an effective concentration level increase at the pH value compared to other dose variations, where the percentage increase is 53.84% from 3.9 to 6.0. The TSS value can be reduced by up to 33.26% from 1042 mg/L to 702 mg/L. This value still needs to be able to pass the waste disposal quality standard value. The high and low TSS and turbidity values are not always linear. The particles that cause water turbidity can consist of particles with different properties and weights, so they are not included in the comparable TSS residual weight (Fatimah, A. 2014). The COD value can be reduced to 75.85% from 791 mg/L to 191 mg/L at R3. The BOD value can be reduced to 40.20% from 97 mg/L to 58 mg/L. The sample with variation R4 was not analyzed because the turbidity and pH data showed less removal than the others.

The results obtained from the analysis of the two different places have several differences that are not significant. The difference is from the research results that have been done before and are being done now. Table 3 shows that the adsorption process in these studies reduced turbidity, TSS, COD, and BOD up to 95%, 33%, 76%, and 40%, respectively. Research conducted by (Novita et al., 2019) reduced turbidity by 85.03% and BOD by 77.91% in processing tempeh wastewater using active carbon.

Research conducted by (Lia Cundari et al., 2022) resulted in the highest percentage of TSS reduction, namely 73% in the processing of tempeh wastewater using active carbon. The highest percentage of COD reduction, 89.3%, was obtained in a study by Widianti et al. (2022) in processing Tempe wastewater using natural zeolite. The comparison of research results can be seen in Table 4.

4. CONCLUSION

Adsorption using a mixture of natural adsorbents can reduce turbidity in tempeh wastewater and increase the pH. The best percentage was the removal of 99% turbidity and a pH level of 6.5 at the mass ratio R2 with 150 minutes of stirring at a dose of 4.5 grams. Adsorption using a variety of natural adsorbents can stabilize some of the impurities under standard parameters of environmental quality standards. Adsorption of Tempeh waste with a mixture of zeolite, bentonite, and active carbon adsorbents follows the Langmuir isotherm. The maximum adsorption capacity was

8.26-10.61 mg/g with a Langmuir constant of 0.27-6.40 l/mg.

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