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TEMPERATURE AND pH OPTIMIZATION OF CHITIN FROM SHRIMP SKIN AS ADSORBENT FOR TEXTILE DYE WASTE

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ABSTRACT: Textile waste consists of insoluble solid particles, salts, dyes and heavy metals and is very difficult to degrade. Chitin derived from shrimp waste has the potential to overcome textile waste in chitin that causes environmental pollution through more economical absorption and easily available raw materials. Factors that improve adsorption performance include pH and temperature. This study was conducted to determine the effect of temperature, pH, and a combination of temperature and pH treatments on the ability of chitin to adsorb textile dye waste. The parameters observed were temperature, pH, combination of temperature and pH, functional groups (FTIR), chitin structure (SEM), and heavy metal test (AAS). Data analysis of statistical test results using two-way Analysis of Variance (ANOVA) followed by Duncan's further test. The ANOVA test results showed that the incubation treatment of temperature, pH, and a combination of different temperature and pH treatments resulted in ($p < 0.05$). This shows that incubation temperature and pH have an effect (significantly different) on the adsorption of chitin as an adsorbent on dyes. The results of Duncan's test showed that the best chitin adsorption was obtained in temperature incubation at 50°C (A3), incubation at pH 3 (B1), and the best combination adsorption at 50°C and pH 3 of 1,091±0.007a ppm.

Keywords: Temperatre, pH, Chitin, Remazol Brilliant Blue R Dye, Heavy Metals.

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INTRODUCTION

The textile industry is one of the industries that uses large amounts of water which causes the formation of liquid waste. For example, batik production produces turbid concentrate waste during the coloring stage (Baryatik, 2015). The textile industry grows annually by 0.85% and has an important role in Indonesia. One example is the textile industry in the first quarter of 2019 experienced an increase of 18,98 compared to 2018. The increase in 2018 only reached 8.73%. This shows that the textile industry in Indonesia is increasing in number (Ministry of Industry of the Republic of Indonesia, 2019). According to data published by the Indonesian Ministry of Environment and Forestry (KLHK), the total volume of textile waste generated in Indonesia in 2020 reached around 66.3 million per year. This textile waste must be managed so as not to cause environmental damage and disturb the lives of aquatic organisms.

Textile waste consists of insoluble solid particles, salts, dyes and heavy metals and is very difficult to degrade. Remazol Brilliant Blue R is one of the dyes classified as reactive dyes. The presence of the Remazol Brilliant Blue R chromophore group, resulting in this dye being able to provide bright colors in fabric fibers and not easily fade, so it is widely used in the textile industry (Hidayati et al., 2016). In addition to containing dyes, textile waste contains many heavy metals such as Lead (Pb), Chromium (Cr), Cadmium (Cd), Copper (Cu), and Mercury (Hg).

Waste treatment methods can be carried out by processing methods through 3 methods, namely biological, chemical, and physical. However, one of the most effective in textile waste treatment is physically through adsorption. This is because the adsorption method has low processing costs, is easy to do and is environmentally friendly (Wahyuni et al., 2021). Adsorption is an efficient technique that can remove odors and reduce the dye content of the solution without converting to more harmful compounds (Khateresan et al., 2018). Due to the availability of various types of adsorbents, the adsorption process is also relatively cheap and easy to perform (Sudibandriyo & Putri, 2020). The selection of the right type of adsorbent is a very important step in the success of the adsorption process. One type of adsorbent that can be used as adsorption is chitin. Chitin is the biopolymer with the largest abundance after cellulose (Rohmah et al., 2022). The use of chitin as an adsorbent is due to its abundance and availability in unlimited quantities (will not run out). Chitin can be found as a skeletal component of crustaceae (hard-shelled animals) such as shrimp, crabs, crabs, and squid (Sofika, 2017).

Chitin has properties associated with amino and hydroxyl groups that are bound, then chitin has high chemical reactivity and causes cation polyelectrolyte properties so that it can function as an adsorbent to compounds in wastewater. Therefore, chitin derived from shrimp waste has the potential to overcome various problems in environmental pollution through more economical absorption and easily available raw materials (Widodo, 2006). Research on the use of chitin as adsorption has been conducted by Ayu (2016), on the use of chitin as lead metal adsorption. This research shows the optimum contact time is 90 minutes with an effectiveness of 62.5 mg/g. Improving adsorption performance can be done by improving factors that affect adsorption performance.

Factors that improve adsorption performance include pH and temperature. Temperature affects the adsorption process because it can increase the rate of transfer of material to be adsorbed into the pore, but too high a temperature can cause desorption where desorption can occur at high temperatures (Zhou et al., 2022). Meanwhile, the pH condition of the solution can affect the adsorption capacity of the sensitized adsorbent due to changes in pH which can be caused by protonation or deprotonation of functional groups on the adsorbent. Therefore, this study was conducted with the aim of analyzing the temperature factor, pH factor and analyzing the combination of temperature and pH on the ability of chitin to adsorb textile dye waste.

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METHOD

As for the methodology in research consisting of time and place of research, research materials (tools and materials), research design, and work procedures in research.

Time and Place

This research was carried out from July to September 2023. The manufacture of chitin as an adsorbent, and characterizing textile waste through physical and chemical characteristics, namely pH and temperature, were carried out at the Chemical and Analytical Laboratory, Faculty of Fisheries and Marine Sciences, Airlangga University, Surabaya.

Research Materials

The tools used in this research were glassware, analytical balance, oven, thermometer, hotplate, Perkins-Elmer 1600 FTIR spectrophotometer, and 752W grating spectrophotometer (Shanghai Number 3 Analytical Instrument Factory), 210g analytical balance, erlenmeyer, oven, desiccator, porcelain cup, magnetic stirrer, 10 mL measuring pipette, bulb, blender, grinder, aluminum foil, plastic wrap, scissors, 500 mL measuring cup, UV-Vis spectrophotometry, cuvette, orbital shaker, 50 mL erlenmeyer, volume pipette (5, 10 and 25 mL), tissue, drop pipette, spray bottle, plastic measuring cup, tray, 100 mL volumetric flask. The materials needed in this study were H2SO4 96% CAS Number: 7664-93-9 Merck brand, Remazol Brilliant Blue R dye, shrimp skin, and water.

Research Design

This study used a Factorial Complete Randomized Design (CRD) with 2 factors and 3 repetitions. The first factor is adsorbent temperature and the second factor is adsorbent pH. The treatment in this study was incubation at different temperatures and pH with 16 treatments (3 repetitions) namely A1B1, A1B2, A1B3, A1B4, A2B1, A2B2, A2B3, A2B4, A3B1, A3B2, A3B3, A3B4, A4B1, A4B2, A4B3, A4B4. using an initial concentration of 100 ppm with a duration of 2 hours. From this study can determine the best incubation temperature and pH treatment (optimum) on chitin as a textile dye waste adsorbent.

Work Procedure

Active Compound Analysis

The working principle of FTIR spectroscopy is by firing infrared rays towards a sample whose originally constant molecules undergo vibrational energy changes and rotational energy changes. Vibrations that occur in the bonds formed find infrared wavelengths that are absorbed by the sample. The waves that have been absorbed are forwarded to the interferogram and then converted into an IR spectrum which shows the transmittance value and wave number (Prachayawakorn & Pomdage, 2014).

This FTIR test is used to analyze the functional groups contained in the sample. The sample is mounted (in solid form or pelleted) on a slab and a magnet is placed on it. The sample in solid form (powder) is homogenized together with KBr in a ratio of about 1:200 (sample:KBr). It is then put in a pellet press and pressed with a pressure of about 5 tons. After that, the sample can be moved to the sample container and placed on a device that has infrared rays. The test results are

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obtained in the fractogram which shows the relationship between the wave and the intensity of the test results (Prachayawarakorn & Pomdage, 2014).

Preparation of Treatment

Adsorption of dyes using chitin obtained from *Litopaneus vannamei* shrimp shell waste. Textile industry waste was made using Remazol Briliant Blue R dye. Adsorption experiments can be carried out by filling the beaker in each treatment as much as 100 ml of the prepared Remazol Briliant Blue R dye sample. Chitin was weighed as much as 4 g and put into the beaker, and the parent solution of textile dye was poured as much as 70 mL which already contained chitin, then hotplate for 2 hours (Ngatijo et al., 2021). Each temperature and pH treatment, then checked the pH of the chitin that has been plate by using pH indicator strips and temperature using a thermometer according to the research treatment.

Heavy Metal Analysis

Heavy metal analysis through water sampling using the grab sample method. Water samples were preserved by adding concentrated NHO3 to pH 2 and then analyzed for Lead (Pb), Chromium (Cr) metal levels, using the Atomic Absorption Spectrometry (AAS) method with reference to SNI No. 06-6596-2001 on the treatment of water samples for metal analysis (measurement of total metal content) can be measured by Atomic Absorption Spectrophotometer (SSA) (Ayu, 2016).

Chitin Structure Analysis

The morphological structure of chitin as adsorbent was analyzed using SEM (Scanning Electron Microscopy) with 1000 times magnification. Morphological analysis with SEM photos was carried out to show the surface of the chitin biosorbent in binding the dye. Samples were tested using SEM by preparing the tested specimens, then sanding part of the surface of the specimen to be tested until the fibers are visible, then cutting the specimen according to the size of the SEM testing machine. after that coating the surface of the specimen to be tested with gold (platinum), then placing the specimen that is ready to be tested into the SEM testing machine, and finally testing is carried out (Najakh, 2017). Based on the results of SEM analysis, it can be seen that the morphological structure of chitin has a pore structure that can bind dyes. The smaller pore structure of chitin will be more effectively used as an adsorbent (Ahmed et al., 2020).

Adsorbent Analysis

The concentration of dye adsorbed by chitin during the adsorption process was measured by testing the chitin filtrate using UV-Vis spectrophotometry. Testing using UV-Vis spectophotometry was carried out at a wavelength of 625 nm. Measurement results in the form of dye concentration. The measurement of the adsorbed dye per g sample can be calculated by the adsorbing capacity equation formula:

$$Wads = \frac{(C1 - C2)}{1000} xVx\frac{1}{B}$$

Description:

Wads = Weight of adsorbed dye (mg/g);
B = Weight of the sample used (g);
C1 = The initial concentration of dye solution (ppm);
C2 = The final concentration of dye solution (ppm); and
V = The volume of solution used (ml).

Then, the absorbance value produced by the chitin filtrate at the specified wavelength was recorded. Furthermore, the absorbance data obtained was analyzed, by comparing the control solution or by analyzing changes in absorbance before and after adsorption (Cañas et al., 2014).

Data Analysis

Quantitative data were analyzed using the R square value on the calibration curve to obtain the % removal value and this analysis was carried out with SPSS 25 software using 2-factor ANOVA analysis. The research design can be used to determine the effect of the main parameters on the adsorption rate on textile waste chitin in influencing the research results.

RESULTS AND DISCUSSIONS

Function Group Analysis

Fourier Transform Infrared Spectroscopy (FT-IR) is one of the instruments that apply spectroscopic principles. Spectroscopy is infrared equipped with a fourier transform to be able to detect and analyze the results of the spectrum. Infrared spectroscopy is useful as an identification of organic compounds because of its very complex spectrum consisting of peaks. Chemical bonding in chitin based in its wave number are shown in Table 1.

Table 1. Chemical Bonding in Chitin is Based on its Wave Number.

Prediction of Functional Groups	Wave Number (cm^{-1})		Wave Number Range (cm^{-1})
	Chitin (Standard)	Chitin (Spectrum)	
OH	3461.32	3459.39	3000-3750
CH ($-CH_2^-$)	2921.24	2921.24	2900-3300
C=O ($-NHCOCH_3^-$)	1641.45	1637.59	1605-1740
C-O (-C-O-C-)	1152.49	1153.45	1000-1300

The FTIR spectrum of standard chitin contained four peaks in the range of 3461.32; 2921.24; 1641.45; 1152.49 $cm-^{1}$. While the FTIR spectrum of the results of this study has the same number of peaks between 3459.39; 2921.24; 1637.59; 1053.45 $cm-^{1}$ are revealed in Picture 1.

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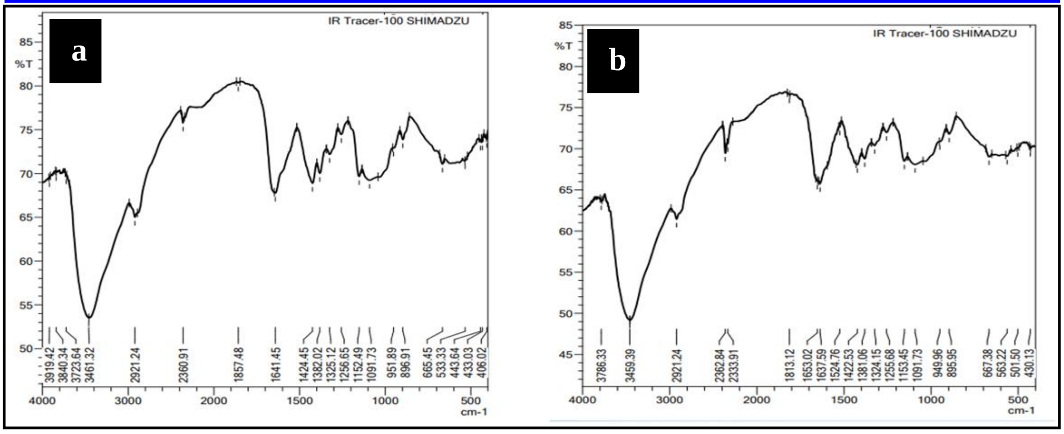

Picture 1. Specktrum of Chitin Using FTIR. a) Standard Chitin (Before Temperature and pH Incubation Treatment); and b) Chitin After Incubation at 50°C pH 3.

The groups in α-chitin are hydroxyl groups, C-O groups, and aliphatic CH groups. The FTIR test results from the study, the resulting wave numbers show the chemical bonds in chitin. The bands around 1653.02cm-^{1} and 1641.45 cm-^{1} indicate amide groups. In addition, the absorption peaks at 3461.32 cm-^{1} and 3459.39 cm-^{1} indicate O-H (hydroxyl group). The spectrum of standard chitin shows the symmetry stretching vibration of aliphatic C-H bond of β-glycosidic bond. Another characteristic marker is the presence of C=O bonds in the extracted chitin (treatment at 50°C and pH 3), which can be indicated by the presence of stretching vibrations at wave number 1153.45 cm-^{1}, the spectrum of standard chitin also shows the same absorption pattern at wave number 1152.49 cm-^{1}. The results of FTIR spectroscopy testing showed that the chitin used had an α-chitin crystal structure. Table 1 shows that the functional groups contained in the dye adsorption chitin are a combination of functional groups from chitin.

The presence of C-O-C bonds in the spectrum of extracted chitin is expressed by stretching vibrations at wave number 1153.45 cm-^{1}. The same pattern occurs in the spectrum of standard chitin, the presence of stretching vibrations in the wave number 1152.49 cm-^{1}. Another characteristic marker is the presence of OH bonds in the extracted chitin (treated at 50°C and pH 3, which can be shown at wave number 3459.39 cm-^{1}, while the spectrum of standard chitin shows a wave number of 3461.32 cm-^{1}.

Similar results have been reported by Zakaria et al. (2012) which explained that the spectrum of the hydroxyl group band was 3438 cm-1, the amide band was between 1639 and 1561 cm-^{1}. The wave number of -CH2- in the research results was obtained at 2921.24 cm-^{1}. This shows that in the study (Mohan et al., 2021), the stretching absorption of the -CH3 and -CH2- groups. The FTIR band of chitin present in this study is similar to the FTIR band of *α*-chitin extracted from different shrimp shells in a previous study (Dompeipen et al., 2016). One of the signs that chitin compounds are β-glycosidic bonds.

The spectrum of standard chitin also shows the same pattern. With the absorption of the main spectrum in certain wave number regions that indicate the presence of certain functional groups that indicate that the extracted compound is chitin shows the same pattern. With the absorption of the main spectrum in certain

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wave number regions that indicate the presence of certain functional groups that indicate that the extracted compound is chitin. This makes the acetamide structure resemble acetic acid, but the hydroxyl group (-OH) in acetic acid is replaced with an amine group (-NH2) in acetamide. This is because, the glucose that makes up chitin is also called N-acetylglucosamine (N -Acetylglucosamine , GlcNAc).

Structurally, chitin molecules are similar to cellulose molecules, but the C (2) atom in the cellulose unit binds to hydroxyl, while in chitin it binds to acetamide (Casadidio et al., 2019). Acidic changes in hydroxyl groups found in the research results, can undergo changes in acidic conditions, this can affect the hydrophilic (hydrophobic molecular) properties. The (C-O) group can undergo hydrolysis in acidic environmental conditions in the presence of enzymes, and the amide group can undergo dehydration resulting in changes in bonds (amide form) which are influenced by environmental factors (temperature and pH). Aliphatic CH groups can undergo oxidation (reduction) due to environmental factors such as the formation of ketone groups (carboxylic acids).

Combination of Temperature and pH on Chitin Absorbance in Textile Dyes

The temperature and pH of chitin incubation affect the amount of textile dye that is fibers in 16 treatments including; A1B1, A1B2, A1B3, A1B4, A2B1, A2B2, A2B3, A1B1, A1B2, A1B3, A1B4, A2B1, A2B2, A2B3, A2B4, A3B1, A3B2, A3B3, A3B4, A4B1, A4B2, A4B3, A4B3, A4B4. The results of the study can be seen in Table 2.

Table 2. Final Concentration of Dye After Incubation at a Specific Temperature and pH for 2 Hours (ppm).

Suhu	**pH**			
	B1	**B2**	**B3**	**B4**
A1	22.72±1.039^{f}	19.75±0.901^{fg}	91.89±3.51^{ab}	86±8.10^{bc}
A2	25.25±0.850^{ef}	31.35±0.680^{e}	82.05±3.90^{c}	94.72±7.0^{a}
A3	12.75±0.585^{h}	30.09±0.472^{e}	93.3±4.03^{ab}	93.75±7.27^{a}
A4	14.52±0.458^{h}	23.15±0.472^{f}	86.62±1.20^{bc}	59.35±4.71^{d}

Description:
A1: 30°C temperature treatment; A2: 40°C temperature treatment; A3: 50°C temperature treatment; A4: 60°C temperature treatment; B1: pH 3 treatment; B2: pH 5 treatment; B3: Treatment 7; and B4: Treatment 9.

The results of the ANOVA test showed that the combination of different pH and incubation temperature had an effect and significantly different from the final concentration of Remazol Brilliant Blue R dye ($p<0.05$). Duncan's test results showed that the lowest final dye concentration was obtained by incubation at 50°C and pH 3 (A3B1) at 12.75 ± 0.585 ppm which was not significantly different from 60°C and pH 3 (A4B1) with a value of 14.52 ± 0.458 ppm. The highest final dye concentration results were obtained by incubation at 40°C and pH 9 (A2B4) with a value of 94.72 ± 7.0a ppm which was not significantly different from 50°C pH 9 (A3B4) at 93.75 ± 7.27a ppm.

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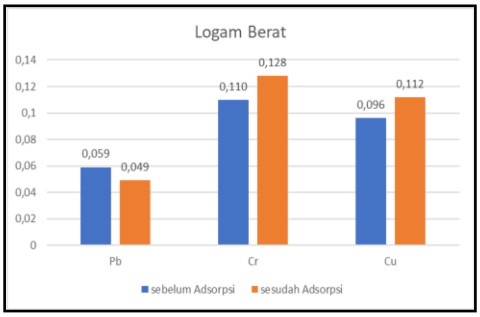
Table 3. Absorbency of Chitin to Dye at Different Incubation Temperature and pH (mg/g Chitin).

Suhu	pH			
	B1	**B2**	**B3**	**B4**
A1	0.966±0.012[c]	1.003±0.011[bc]	0.101±0.043[gh]	0.169±0.100[fg]
A2	0.934±0.010[cd]	0.858±0.008[d]	0.224±0.049[f]	0.066±0.087[h]
A3	1.091±0.007[a]	0.874±0.006[d]	0.084±0.050[gh]	0.078±0.090[h]
A4	1.069±0.0056[ab]	0.961±0.0.0056[c]	0.167±0.015[fg]	0.508±0.058[e]

The results of the ANOVA test showed that the combination of pH and incubation temperature treatment had an effect (significantly different) on the absorbency of chitin to Remazol Brillian Blue R dye with a value of (Sig,) ($p < 0.05$). The results of Duncan's test showed that the lowest chitin absorption was obtained at 40°C pH 9 (A2B4) of 0.066 ± 0.087h ppm which was not significantly different from the temperature of 50°C pH 9 (A3B4) with a value of 0.078 ± 0.090h ppm. The highest chitin absorption results were obtained at 50°C pH 3 (A3B1) of 1.091 ± 0.007a ppm.

Dwijayanti et al. (2020), said that at low pH conditions the adsorption is small, because the presence of H+ from the solution will prevent the interaction of the dye with the active groups on the adsorbent surface. The achievement of the optimum pH at pH 3 can be interpreted that in acidic conditions, chitin is able to coagulate organic matter well. pH above 6 decreases adsorption, because at that pH too many OH- ions cause interactions between OH- ions and dyes that repel so that the absorption capacity is further reduced. At alkaline pH or pH above 6, the number of protons is relatively small and causes the opportunity for dye binding to be greater, so that dye ions can form hydroxide deposits and can reduce the dyes absorbed. Adsorption of dyes at temperature and pH produces more influential absorption power produced at a temperature of 50°C and pH 3. This is because, the more adsorbent on the dye absorbs more will produce the best adsorbent. Picture 2 below illustrates the color absorption combination of heavy metal.



Picture 2. Color Absorption Combination Results Heavy Metal Test.

This metal analysis was carried out based on the best results of chitin absorption of dyes, namely the metal Pb. The analysis showed that Pb metal decreased by 17%, before chitin adsorption resulted in 0.059 ppm, and after adsorption the optimal treatment of 50°C and pH 3 resulted in 0.049 ppm. Cr metal produced before adsorption of 0.110 ppm and after adsorption of 0.128 ppm and increased by 16%. Cu metal increased by 17%, before adsorption of 0.096

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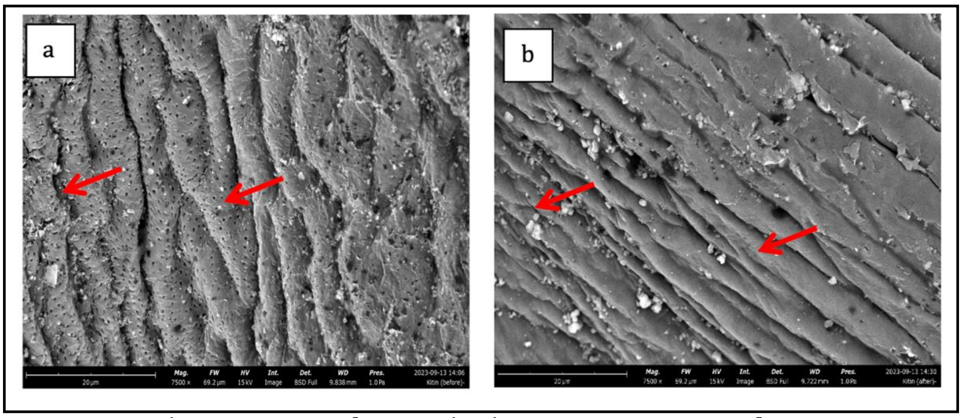
ppm and after adsorption of 0.112 ppm. The results of heavy metal data can be seen in Picture 2.

The results of the study after comparison showed that the ability of chitin to adsorb heavy metals Pb was more optimal than heavy metals Cu and Cr. This can be seen from the graph that heavy metals decreased by 17%, compared to Cr and Cu levels which increased by 16% and 17%. The effectiveness of lead adsorption increased with increasing contact time. The optimum contact time of adsorption obtained at 60 minutes, the longer the contact time (0-90 minutes) of the solution to be absorbed with the adsorbent.

The faster the chitin absorbs the metal solution. This happens because of the stirring that makes the particles in the solution intersect with chitin particles. This has been done by Venugopal (2018), on the Effect of pH and Contact Time on Pb (II) Adsorption Using Phosphorylated Chitin Adsorbent from Snail Shell Waste *(Achatina fulica)*, in his research obtained contact time at 60 minutes.The higher the absorption of Pb metal, the more Pb metal is adsorbed by chitin. This is due to the increase in initial concentration, the residual concentration also increases so that the concentration of lead adsorbed by chitin is higher.

The increase in Pb heavy metal absorption in the results of the study related to changes in functional groups, thus causing the pores in chitin to close after the factor of incubation at 50°C and pH 3 which absorbs the dye. Acidic conditions (pH 3-6) functional groups on chitin will be protonated (at pH 3 will be fully protonated which makes the polymerchain, this make chitin able to dissolve in organic acid compounds.

Chitin in dyes is able to bind to various metal ions due to the presence of hydroxyl groups (Indah & Safnowandi, 2020; Samoila et al., 2019). Chitin has high stability and has pyranose rings connected through β-glycosidic bonds that allow the formation of a straight chain structure close together with strong inter-chain hydrogen bonds (Xi, 2016). The acetamide group on N-acetylglucosamine plays an important role in the stability of hydrogen bonds in chitin.



Picture 3. SEM Characterization at Temperature and pH.

Description:

Figure chitin SEM test; (a) Results before incubation temperature and pH treatment (b) Results after incubation at 50°C pH 3: Red arrows (a) indicate the condition of the chitin surface (pores) open a lot and the absence of white powder (b) the condition of the chitin surface (pores) closed and smooth, and the presence of dye in the form of white powder attached to the surface.

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The results of condition a chitin SEM test on the surface of the pores before temperature and pH treatment show that there are many pores and open and not much white powder attached to the surface. The results of condition B on the surface of the pores after treatment at 50°C pH 3, show that the condition of chitin shows the presence of dyes in the form of white powder attached to the surface, and closed pores so that the surface looks smooth (flat). It can be seen that chitin works in a dye that is carried out in the incubation treatment at 50°C and pH 3.

The results of imaging using electron microscopy (SEM) at 7500x magnification show that the surface morphology of standard chitin (before incubation treatment and temperature) that on the surface of chitin, the dye is not visible and there are still many impurities covering the surface. the best temperature treatment of 50°C and pH 3, the impurities will be degraded and the surface on the chitin will be clean and flat.

The dye attached to the chitin surface resembles white powder on the chitin surface. After going through the incubation stage of the best temperature treatment of 50°C and pH 3, the impurities will be degraded and the surface on the chitin will be clean and flat. The dye attached to the chitin surface resembles white powder on the chitin surface. This is similar to the research of Mohan et al. (2021), which states that the small pores present in each type of chitin function to absorb textile dyes and can indicate that the surface is more suitable for absorbing metal ions.

CONCLUSION

Based on the results of research conducted on temperature and pH optimization of chitin from shrimp skin as an adsorbent on textile dye waste, it can be concluded that the ANOVA test results show that the temperature incubation treatment produces ($p < 0.05$). This shows that temperature incubation has an effect (significantly different) on the adsorption of chitin as an adsorbent on dyes. The results of Duncan's test showed that the best chitin adsorption was obtained at 50°C (A3). The ANOVA test results showed that the pH incubation treatment resulted in ($p < 0.05$). This shows that pH incubation has an effect (significantly different) on the adsorption of chitin as an adsorbent on dyes. The results of the Duncan test showed that the lowest (best) chitin adsorption was obtained at pH 3 (B1). The ANOVA test results on the incubation of temperature and pH treatment resulted ($p < 0.05$). This shows that the combination of incubation of different temperature and pH treatments has an effect (significantly different) on the adsorption of chitin as an adsorbent on dyes. The results of Duncan's test showed that the best absorption of the combination of temperature and pH treatment was obtained at a temperature of 50 ° C and pH 3 (A3B1) of 1,091 ± 0.007a ppm.

RECOMMENDATIONS

Further optimization research is needed on other parameters such as contact time, adsorbent-waste ratio, and certain types of dyes to get the most efficient and economical conditions get the most efficient and economical conditions. Also, other immobilization techniques need to be carried out using other blending materials as a comparison to determine the effectiveness of the adsorbent. as a comparison to determine the effectiveness of the adsorbent.

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