Progress in Engineering Application and Technology Vol. 4 No. 1 (2023) 74-83
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Potential of *Dendrocalamus Asper* (Betong Bamboo) Leaves as Natural Coagulant for Wastewater Treatment Agent

Muhammad Izzwan Syahmi Mohd Shamsuri[1], Nasrul Fikry Che Pa[1]*

[1]Department of Chemical Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, Malaysia

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2023.04.01.007
Received 15 January 2023; Accepted 12 February 2023; Available online 12 June 2023

Abstract: This study ventured to determine the effectiveness of bamboo leaves to become natural coagulant agent in wastewater treatment since the chemical coagulant produced adverse effect to the environment and human health. This study aims to produce bamboo powder coagulant from *Dendrocalamus asper* (Betong) type of bamboo via bamboo leaves grinding ball mill machine and to determine adsorbent properties of bamboo powder in jar test at different dosage and pH thus comparing it with commercial coagulant. Turbidity removal of wastewater is further analyzed using turbidity meter and pH meter and bamboo powder further characterize via Fourier Transform Infrared Spectroscopy. Result shows that 15 minutes of grinding with 600 rpm via grinding ball mill machine is sufficient to produce powdered form of bamboo leaves. The turbidity removal via jar test shows that the bamboo leaves powder coagulant were effective at the neutral pH range of 6.5 to 7.5 with the optimum dosage of 70 mg/L. Turbidity removal depicts the counterproductive for dosage below than 50 mg/L and environment that is too basic nor acidic. The bamboo leaves coagulant derived from *Dendrocalamus Asper* shows potential to compete with commercial coagulant such as Aluminum Sulphate even though the differences in term of turbidity removal percentage is 20 to 30%. FTIR results for functional groups confirmed the presence of protein which act as coagulant properties. Furthermore, the Langmuir adsorption isotherm fits more closely as compared to Freundlich which indicates the adsorption process is monolayer and favorable. Thus, as the adsorbent dosages increases, the bamboo leaves adsorption also increases. This means there will be significant increment in adsorption with further increase of adsorbents dosage. This finding can be set as benchmark of potential bamboo leaves as natural coagulant in treating wastewater treatment instead of using commercial coagulant that affected the environment and human life.

Keywords: *Dendrocalamus asper* , Bamboo Leaves Powder, Natural Coagulant, Optimum Dosage, Turbidity Removal, Langmuir Isotherm

**Corresponding author: nfikry@uthm.edu.my*

1. Introduction

Bamboo is a plentiful natural resource in Asia and South America, and its inherent properties such as low density, high tensile modulus, and low elongation at break [1]. Bamboo leaves possess a high concentration of active polysaccharides in addition to bioactive components such as flavonoids, glycosides, and polyphenols. Bamboo leaf extract (EBL) has been proven to be extremely safe and is commonly utilised as an antioxidant in food additives in China [2]. Coagulation has already been used since ancient years which eliminate colloidal pollutants as primary purpose thereby also eliminating turbidity from the water in wastewater treatment. Coagulation's major goal in wastewater treatment is to eliminate contaminants including cloudiness, thus it is common procedures for large-scale water purification. Numerous sectors make extensive usage aluminium and iron coagulants. Nevertheless, when these two components are employed as coagulants in wastewater treatment, they can have an adverse effects on human health, including intestinal discomfort, memory problems, energy loss, and developmental issues. This results in recent emerging researches on developing and utilizing natural coagulants in treating wastewater in recent years. Natural coagulants have recently being given a lot of attention in wastewater treatment. Natural coagulants are produced by animals, microbes, and plants [3]. These natural organic polymers are notable because, unlike synthetic organic polymers comprising acrylamide monomers, they pose no health risk to humans and are less expensive than regular chemicals [4].

Preliminary studies have shown that natural coagulants like *Dolichos lablab*, *Azadiracetum indica* and *Moringa Oleifera* are discovered to be high in proteins (27.745%) that are soluble in water as well as contain an overall positive charge while in solution [5]. These positively charged protein will attach to the negatively charged ions that generate turbidity in the fluid. Bamboo leaves had 12.92% protein on average, with comparatively high proportions of leucine and proline. Bamboo leaves also comprised relatively high concentrations of the macromineral elements potassium and calcium while relatively high concentrations of the micromineral elements manganese and iron [6]. This similarity of properties and characteristics between the natural coagulants and bamboo leaves has which make it a potential to become a natural coagulant for wastewater treatment.

In this study, bamboo leaves are explored on its potential as a natural coagulant for wastewater treatment. Previous studies used other plant based coagulants such as algae, *Tamaris Indica* seeds and *Moringa Oleifera* seeds were among the most effective natural coagulants for water treatment. Benefits of these plant based over the conventional treatments are that it is natural and digestible. Thus, this study investigates the potential of powdered bamboo leaves as natural coagulant. Environmentally friendly coagulant usage in the coagulation – flocculation procedure might enhance effluent treatment. Natural coagulants have been shown to reduce turbidity in water towards acceptable levels in previous studies and can be single used or in combination with alum. Bamboo leaves would be an intriguing replacement to possibly dangerous chemical coagulants for reducing turbidity in water and making it more acceptable and secure for human consumption.

1.1 Objectives

The objectives of this study are:

i. To study the bamboo powder sample characteristic using Fourier Transform Infrared Spectroscopy (FTIR).
ii. To study the effectiveness of adsorbent derived from *Dendrocalamus asper* (Betong) leaves as a potential wastewater treatment agent.
iii. To compare the effectiveness of adsorbent derived *Dendrocalamus asper* with commercial coagulant such as aluminium sulphate.

1.2 Scope of study

This study is to observe the adsorbent derived *Dendrocalamus asper* that were made into a powder form by using planetary ball mill at the rate of 600 rpm for 15 minutes for each run. Then, the powder is being sieved by 75 µm siever. The samples are then turbidity tested with a turbidity meter to identify the most effective sample for municipal water treatment in term of turbidity removal percentage. As a result, the sample were evaluated employing FTIR. The jar test experiment will be carried out to investigate the coagulant ability of bamboo leaves under varying dosage 10mg/L, 30mg/L, 50mg/L, 70mg/L and 90mg/L with initial turbidity 120 NTU and pH 5.5, 6.5, 7.5, 8.5 and 9.5. The test water is kaolin wastewater. The turbidity removal result of sample will be compared with commercial coagulant aluminium sulphate in the jar test with same parameter. The level adsorption of *Dendrocalamus asper* will be determined by using Langmuir and Freundlich Isotherm model equation in Microsoft Excel.

2. Materials and Methods

2.1 Materials

The main material used are *Dendrocalamus asper* (Betong) leaves and kaolin clay powder. The bamboo leaves and kaolin clay powder were obtained via online platform retailer. Table 1 shows the apparatus used in the experiment.

Table 1: Apparatus used to conduct the overall experiment

Apparatus	Brand/Model	Remark
Ball mill grinder	Retsch PM 100	To grind the sample into small size
Flocculator test	Velp Scintifica JLT6	To run the jar test experiment
pH meter	Hanna Edge DO	To measure acidity or alkalinity in solution
Turbidity meter	Evtech Instrument	To measure nephelometric turbidity unit (NTU)
Fourier Transfrom Infrared Spectroscopy (FTIR)	Agilent Technologies CARY 630	To determine the existence of specific functional groups within sample

2.2 Preparation of Bamboo Leaves Powder

The bamboo leaves were washed with tap water and cleaned to remove dirt from the leaves and then sun dried for 5 days. Then, the bamboo leaves were removed from its stalk. The leaves were crushed into small pieces by using hand before entering the planetary ball mill. The ball mill was operated at 600 rpm for 15 minutes each run and sieved into size of 75 µm [7].

2.3 Preparation of Synthetic Wastewater

In 1 liter of distilled water, 20g of dried kaolin being distributed then mixed and stirred using magnetic stirrer for 1 hour. The prepared kaolin wastewater suspensions were left to sink for 24 hours to enable full hydration of the kaolin. For the testing, the kaolin suspension was employed as the stock solution for preparing water samples of initial turbidity of 120 NTU [8].

2.4 Jar Test Operation

6 beakers together with six spindle steel paddles added with 800mL of synthetic kaolin wastewater. The sample was homogeneously mixed prior being used in the flocculator test. The samples initial turbidity and pH should be recorded to indicate an initial concentration. In the beakers, different dosage of coagulants being introduced. The beakers were stirred at quick mixing 120 rpm for 3 minutes after required quantity of coagulants were introduced to the suspensions and gradual mixing 30 for 15 minutes. The suspensions then left to settle for 60 minutes after the agitation was ceased [9]. This jar

test operated for different coagulant dosage at 10mg/L, 30mg/L, 50mg/L, 70mg/L and 90mg/L and pH 5.5, 6.5, 7.5, 8.5 and 9.5.

2.5 Turbidity Meter

A turbidity meter employs nephelometry (90º scattering) detection techniques. Every one of the samples were subjected to a turbidity test, which included taking NTU readings from kaolin wastewater first as initial turbidity. Next, NTU values of the solution were recorded after the jar test for the final turbidity reading [10].

2.6 Fourier Transform Infrared Spectroscopy (FTIR)

The Fourier Transform Infrared Spectrophotometer (FTIR) was being used to determine the existence of specific functional groups inside the sample. The particular set of absorption bands could also be used as a spectral fingerprints or identity or identify the presence of certain contaminants. The wavelength was set to 400 to 4000 cm^{-1} with the transmitter option was selected. The FTIR spectra graphs were then generated to identify every functional group which exhibited upon that surface of the samples [10].

2.7 Determination of adsorption level in *Dendrocalamus asper* by Langmuir Isotherm

Langmuir adsorption isotherm model assumed that the adsorption occurs with monolayer adsorption on specific homogenous surfaces containing finite number of adsorption. The Langmuir equation which been linearized is stated in Eq.1,

$$\frac{q_e}{C_e} = \frac{C_e}{q_m} + \frac{1}{K_L q_m}, Eq.1$$

The maximum adsorption rate of a monolayer state as q_m (mg/g). The Langmuir constant which states K_L (L/mg) as is proportional to the adsorption energy and the affinity of the binding sites. The Langmuir dimensionless constant separation factor R_L, which was used to determine either the adsorption was favourable or no equation through Eq. 2 as below,

$$R_L = \frac{1}{1 + K_L C_0}, Eq.2$$

If we obtain R_L less than 1, it shows that the adsorption is favourable, while if the R_L value is more than 1 it is not favourable. If we obtain 1, it is in linear and when then R_L is 0 it shows the adsorption is irreversible [11].

2.8 Determination of adsorption level in *Dendrocalamus asper* by Freundlich Isotherm

The multilayer adsorption of metal ions on heterogeneous surfaces is explained by the Freundlich isotherm equation. The Freundlich equation which been linearized is stated in Eq. 3 as below,

$$\log(qe) = \log kf + \frac{1}{n}\log(C_e), Eq.3$$

Where n shows the effectiveness of adsorbent and kf stands for the Freundlich constant, which describes the strength of the adsorptive bond [12].

3. Results and Discussion

3.1 Characterization of *Dendrocalamus asper* as natural coagulant using FTIR analysis

The functional group of *Dendrocalamus asper* leaves was presented in Figure 1 through Fourier Transform Infrared Spectroscopy (FTIR). The stretch at peak 3276.3 ± 0.1 cm^{-1} at first sight gives an impression of the presence amino acid group N-H which may indicates the secondary amine in the bamboo leaves. The O-H carboxylic acid group was observed at 2914.8 ± 0.1 cm^{-1} as well as the C≡C alkyne and C=C alkene groups found at 2109 ± 0.1 cm^{-1} and 1625 ± 0.1 cm^{-1} respectively [13]. The vibration around 1319.5 ± 0.1 cm^{-1} characterizes the O-H bond of phenol as well as medium band at 1155.5 ± 0.1 cm-1 confirm the presence of the C-N amine. The S=O of sulfoxide group was found at the strong peak 1032.5 ± 0.1 cm^{-1} [14]. The presence of amino acid group, carboxylic acid as well as unsaturated hydrocarbon in the chemical composition of bamboo leaves suggested that the relatively high presence of protein which act as the positively charged component to associates with and neutralises negative charges on the surface of the particles in the synthetic water [15].

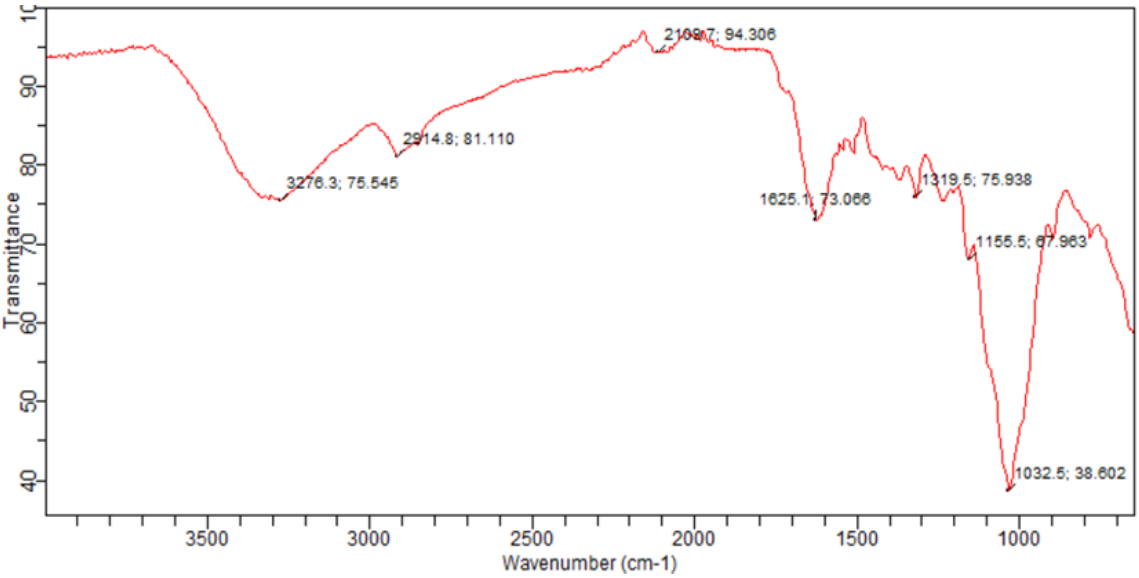

Figure 1: FTIR spectra of *Dendrocalamus asper* leaves

3.2 Comparison of Bamboo Leaves Coagulant with Aluminium Sulphate Coagulant

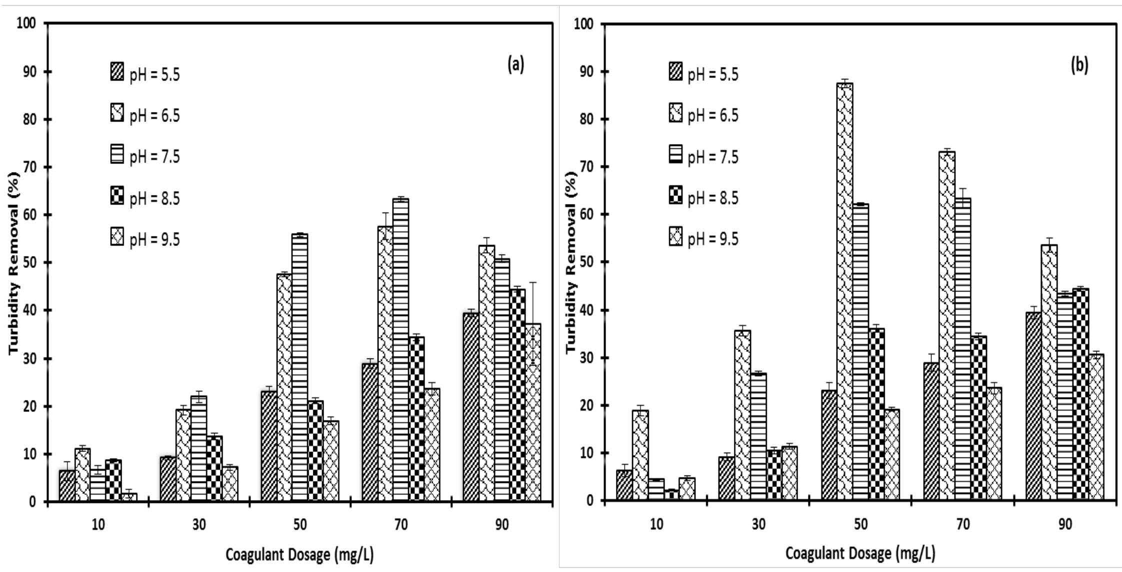

Figure 2: Coagulation activity of (a) bamboo leaves (b) aluminium sulphate

Figure 2 depicts the results of comparative coagulation tests between the bamboo leaves coagulant and inorganic coagulants of aluminium sulphate. The coagulant dosages of bamboo leaves gives lower turbidity removal percentage than aluminium sulphate. The best performance of turbidity removal for bamboo leaves was at a dosage of 70mg/L in pH of 7.5 (61.67%) whereas (87.50%) at a dosage of 50mg/L in pH of 6.5 for aluminium sulphate. Among the dosage of bamboo leaves coagulant, 70mg/L gave the highest yield which is 61.67%, followed by 50mg/L and 90mg/L, at 55.83% and 52.78% respectively within pH of 7.5. However, aluminium sulphate gives better results than bamboo leaves due to flocs having a higher settling velocity. According Mesdaghinia et al. [16] have stated that aluminium sulphate shows better performance in coagulation due to the hydrolysis process which forms precipitates instantaneously. This has been attributed to the fact that aluminium sulphate is effective over a base range of pH values starting from 6.5 above and also to the difference in specific area where it offers a larger surface area for adsorption purposes.

Nevertheless, the addition of *Dendrocalamus asper* leaves powder to the sample resulted in the formation of flocs visible to the naked eye after approximately 10 min of slow mixing. The bamboo leaves forming the flocs via bridging effects compared to aluminium sulphate. These linkages is resistant even though at high shear stress level. Therefore, the natural coagulant produces a better flocs as stated by Karoliny et al. [17]. The flocs formed were fine in nature and increased in number with increase in dosage. As a result the settling rate was seen to be much faster due to the formation of denser flocs. Therefore, in this study can be conclude that the bamboo leaves powder can compete with commercial coagulant as coagulant even though the gap in the percentage of turbidity removal.

3.3 Effect of Coagulant Dosage on pH

An important role is played by pH value in the coagulation of both organic and inorganic molecules. Figure 3 below show the after effect of dosage on pH for bamboo leaves powder and aluminium sulphate at different pH. As depicted in Figure 3, the differential pH after the coagulation process for bamboo leaves does not change significantly. This result implied that even though the dosages of bamboo leaves powder were substantially increased, the final pH values of the water sample were relatively unaffected as compared to the usage of chemical coagulants of aluminium sulphate. The use of the bamboo leaves powder as a natural coagulant has no significant variation on pH and alkalinity of treated water [18].

On the other hand, when the dosages of alum increase from 50mg/L to 90 mg/L, the final pH value of the water is noticeably decreased for every pH towards acidic. This is due to the fact that alum has the capability to react with the alkali present in the water sample. This reduces the pH value of the neutral water sample. This is also attributed to the fact that aluminium sulphate in the water treatment process produced sulphuric acid which lowered the pH levels. The other reason in increment of acidity nature of the treated water sample by alum could be due to the trivalent cation of aluminum which serves as Lewis acid [19]. Moreover, aluminum act as Lewis acids in solution and can consume the alkalinity of water and may demand the addition of an alkalizing agent to maintain the hydrolysis reactions [20].

The relationship between the optimum dosage, pH and turbidity reduction value shows that the optimum dosage of bamboo leaves with respect to reduction in turbidity is smaller in acidic solutions. This phenomenon can be attributed to the increase in number of protonated amine groups on bamboo leaves at lower pH. Similar results were obtained when chitosan is used as a coagulant by Jill et al [21], in their experiments where they stated that the destabilization of particles was enhanced by the increase in charged groups followed by charge neutralization, resulting in a decrease in optimum dosage. Turbidity removal is observed at lower pH, the resulting floc diameter is smaller, accompanied by a slower settling velocity. This may be explained by the variation in the configuration of bamboo leaves. In neutral solutions, because of the more coiled structure, the bamboo leaves able to produce larger and denser flocs. In acidic solutions, it becomes a more extended chain (more charged), and, therefore, produces smaller and looser flocs.

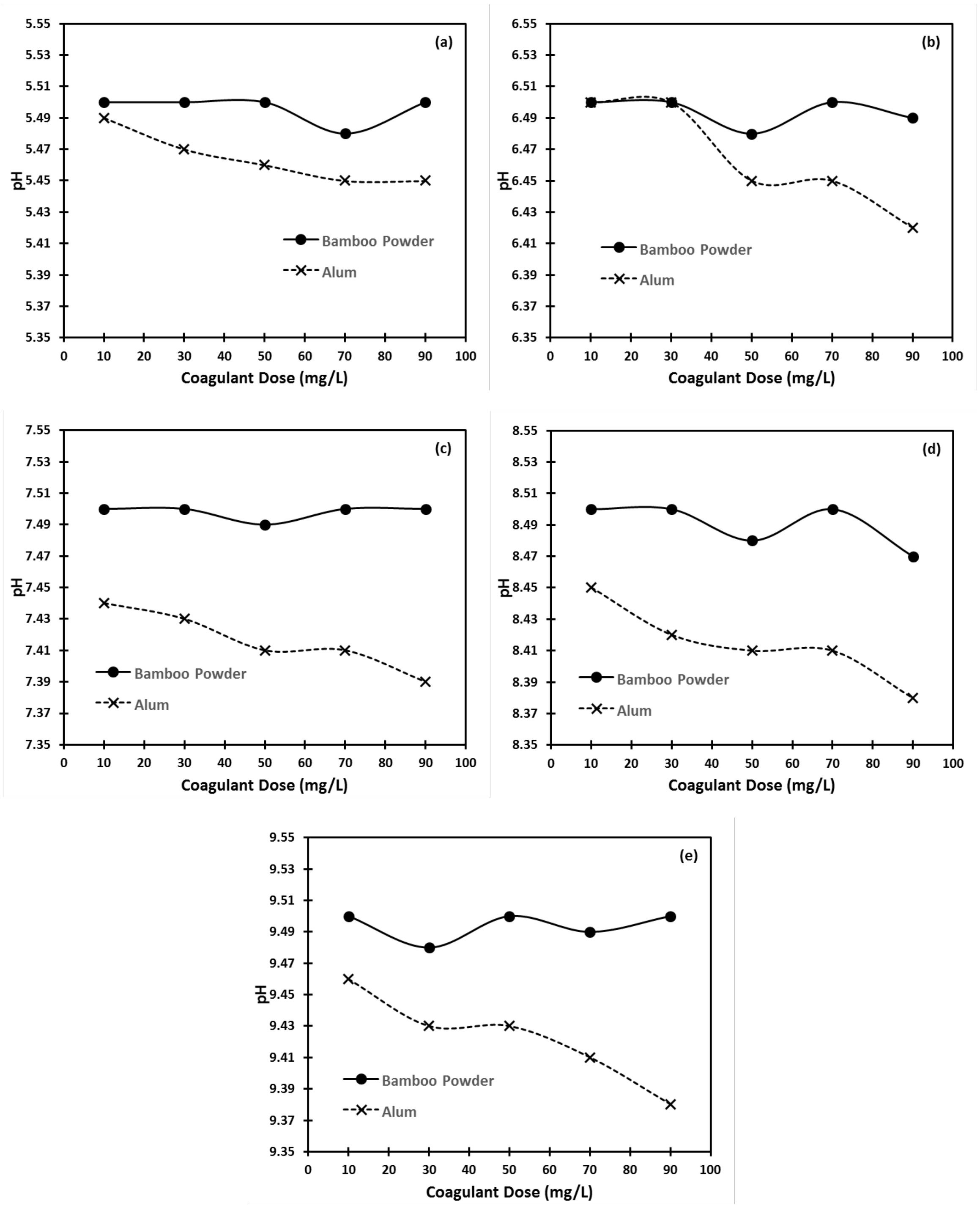

Figure 3: Effect of coagulant dose on pH for bamboo leaves and aluminium sulphate at pH of (a) 5.5 (b) 6.5 (c) 7.5 (d) 8.5 (e) 9.5

3.4 Adsorption Isotherm of Langmuir and Freundlich Model

To study the adsorption process, the experimental data was fitted into Langmuir and Freundlich isotherms. The adsorption process greatly depends on the R_L value. The R_L value in the result was found to be 0.352, which confirmed that the adsorption process is progressive and favorable. From the Langmuir isotherm graph, slope and intercept values were obtained, which verified the adsorption process may be favorable or unfavorable, reversible or irreversible, as shown in Table 2. The graph was plotted between Ce/qe and Ce, as shown in Figure 4(a). The results indicated that the maximum adsorption capacity was found to 79.3651 mg/g, coefficient correlation factor (R^2) value was (0.99919) achieved, while Langmuir constant value was (K_L = 0.0519) found, respectively.

Table 2: Adsorption isotherm models for *Dendrocalamus asper* leaves coagulant

Isotherm Model	R^2	Kf	1/n	K_L	qm (mg.g)	R_L
Langmuir Isotherm	0.9919	-	-	0.0519	79.3651	0.2784
Freundlich Isotherm	0.9548	5.7306	0.6238	-	-	-

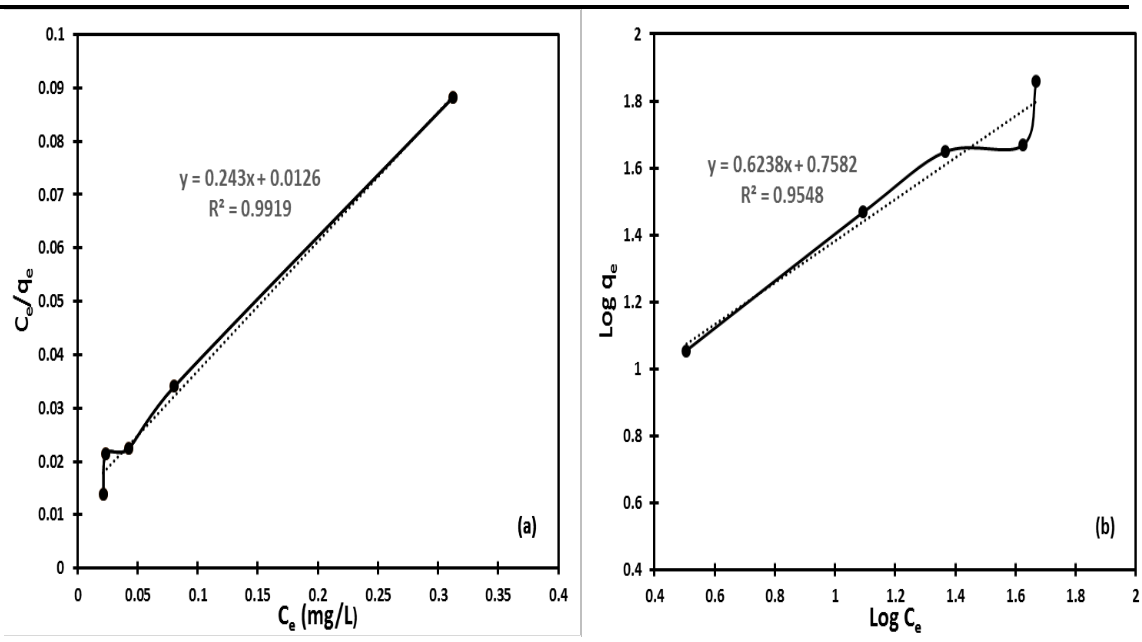

Figure 4: Plots of (a) Langmuir adsorption isotherms and (b) Freundlich adsorption isotherms

The Freundlich adsorption isotherm gives information about whether the adsorption process is heterogeneous or not. The slope and intercept values are achieved with the Freundlich adsorption isotherm graph, as presented in Figure 4(b). In the Freundlich isotherm, 1/n value achieved 0.6238, which indicates that the adsorption process is applies over the whole range of concentrations. The current result indicates that the R^2 values for Langmuir and Freundlich adsorption isotherm were found to be (0.996) and (0.9548), respectively, which means Langmuir adsorption isotherm fits more closely as compared to Freundlich. Likewise, the R_L value was found to be 0.2784, which indicates the adsorption process is monolayer and favorable.

4. Conclusion

Therefore, this study concluded that the presence of amino acid group, carboxylic acid as well as unsaturated hydrocarbon in the chemical composition of bamboo leaves characterized by FTIR suggested that the relatively high presence of protein which act as the positively charged component for coagulation to associates with and neutralizes negative charges on the surface of the particles in the synthetic water. Moreover, the *Dendrocalamus asper* leaves powder as a natural coagulant was effectively utilized to remove the turbidity of sample water at the neutral pH range of 6.5 to 7.5 with optimum dosage of 70mg/L. It shows that the *Dendrocalamus asper* leaves has a potential as wastewater treatment agent. Besides that, the differential pH after the coagulation process for *Dendrocalamus asper* leaves does not change significantly. This result implied that even though the dosages of *Dendrocalamus asper* powder were substantially increased, the final pH values of the water sample were relatively unaffected as compared to the usage of chemical coagulants of aluminium sulphate. The use of the bamboo leaves powder as a natural coagulant has no significant variation on pH and alkalinity of treated water. Langmuir adsorption isotherm fits more closely than Freundlich isotherm for *Dendrocalamus asper* which indicates the adsorption process is monolayer and favorable as the adsorbent dosages increases, the bamboo leaves adsorption also increases. Thus, this shows that the bamboo leaves powder can compete with commercial coagulant such as aluminium sulphate.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Fei, P., Xiong, H., Cai, J., Liu, C., Zia-Ud-Din, & Yu, Y. (2016). Enhanced the weatherability of bamboo fiber-based outdoor building decoration materials by rutile nano-TiO2. Construction and Building Materials, 114, 307–316. https://doi.org/10.1016/J.CONBUILDMAT.2016.03.166

[2] Lu, B., Wu, X., Shi, J., Dong, Y., & Zhang, Y. (2006). Toxicology and safety of antioxidant of bamboo leaves. Part 2: Developmental toxicity tests in rats with antioxidant of bamboo leaves. Food Chemistry Toxicology, 44(10), 1739–1743.

[3] Asrafuzzaman, M., Fakhruddin, A. N., & Hossain, M. A. (2011). Reduction of turbidity of water using locally available natural coagulants. ISRN Microbiology, 2011, 1–6. https://doi.org/10.5402/2011/632189

[4] Makki, M. M. (2017). Assessment Of Turbidity Removal Efficiency Of Pea Pod Extract For Surface Water Treatment. 4(5).

[5] Cissouma, A. I., Tounkara, F., Nikoo, M., Yang, N., & Xu, X. (2013). Physico chemical properties and antioxidant activity of Roselle seed extracts. Advance Journal of Food Science and Technology, 5(11), 1483–1489. https://doi.org/10.19026/ajfst.5.3371

[6] Ming Li Wang, M. Li Wang, Brian Irish, B. Irish, Brandon D. Tonnis, B. D. Tonnis, David Pinnow, D. Pinnow, Mike W. Hotchkiss, M. W. Hotchkiss, & Melanie L. Harrison, M. L. Harrison. (2017). Exploring Bamboo Leaf Nutrient Value in the USNPGS Germplasm Collection. Austin Food Science, 2, 1030.

[7] Abidin, Z. Z., Mohd Shamsudin, N. S., Madehi, N., & Sobri, S. (2014). Optimisation of a method to extract the active coagulant agent from Jatropha curcas seeds for use in turbidity removal. Industrial Crops and Products, 41(1), 319–323. https://doi.org/10.1016/J.INDCROP.2012.05.003

[8] Fathinatul, N., Binti Saharudin, A., & Nithyanandam, R. (2014.). Wastewater Treatment by using Natural Coagulant.

[9] Asrafuzzaman, M., Fakhruddin, A. N., & Hossain, M. A. (2011). Reduction of turbidity of water using locally available natural coagulants. ISRN Microbiology, 2011, 1–6. https://doi.org/10.5402/2011/632189

[10] Hariz Amran, A., Syamimi Zaidi, N., Muda, K., & Wai Loan, L. (2018). Effectiveness of Natural Coagulant in Coagulation Process: A Review. International Journal of Engineering & Technology, 7(3), 34–37. www.sciencepubco.com/index.php/IJET

[11] Wang, J., & Guo, X. (2020). Adsorption isotherm models: Classification, physical meaning, application and solving method. Chemosphere, 258, 127279. https://doi.org/10.1016/j.chemosphere.2020.127279

[12] Ali, A., Saeed, K., & Mabood, F. (2016). Removal of chromium (VI) from aqueous medium using chemically modified banana peels as efficient low-cost adsorbent. Alexandria Engineering Journal, 55(3), 2933–2942. https://doi.org/10.1016/j.aej.2016.05.011

[13] Benalia, A., Derbal, K., Panico, A., & Pirozzi, F. (2018). Use of acorn leaves as a natural coagulant in a drinking water treatment plant. Water (Switzerland), 11(1), 1–12. https://doi.org/10.3390/w11010057

[14] Selvamony Jenitha, J. J. (2014). Phytochemical and FT-IR Spectral Analysis of Certain Bamboo Species of South India. Journal of Biodiversity, Bioprospecting and Development, 01(01), 1–9. https://doi.org/10.4172/2376-0214.1000103

[15] Ahmaruzzaman, M., & Gupta, V. K. (2011). Rice husk and its ash as low-cost adsorbents in water and wastewater treatment. Industrial and Engineering Chemistry Research, 50(24), 13589–13613. https://doi.org/10.1021/ie201477c

[16] Mesdaghinia, A., Rafiee, M. T., Vaezi, F., and Mahvi, A. H. (2005) Evaluation Of Ferric Chloride And Alum Efficiencies In Enhanced Coagulation For Toc Removal And Related Residual Metal. Iranian Journal of Environmental Health, Science and Engineering (ISSN: p-ISSN: 1735-1979) Vol 2 Num 3

[17] Karoliny, T.; Souza, F.; Almeida, C.A. (2018). Textile Science and Clothing Technology book series (TSCT) Detox Fashion.

[18] Besha, A. A. (2007). Institute for Water Education. Current, May.

[19] Debora Peruço Theodoro, J., Felipe Lenz, G., Fiori Zara, R., & Bergamasco, R. (2013). Coagulants and Natural Polymers: Perspectives for the Treatment of Water. 2(3), 55–62. www.seipub.org/papt

[20] U. Hashim and M. Wesam Al-Mufti, "Plant seeds-potential alternative as natural coagulant to treat water for turbidity,"Journal of Applied Sciences Research, vol. 9, pp. 1067–1073, 2013.

[21] Jill RP, Chihpin H, Shuchuan C, Ying-Chien C (1999) Evaluation of a modified chitosan biopolymer for coagulation of colloidal particles. Coll Surf Physicochem Eng Asp 147(3):359–364