A Preliminary Study on Dragon Fruit Foliage as Natural Coagulant for Water Treatment

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Abstract

In this study, the performance of using dragon fruit foliage as coagulant was investigated. Parameters affecting the coagulant performance such as drying temperature, pH, dosage, initial turbidity, and sedimentation time were studied using standard jar test method. From the study, the optimum drying temperature found for dragon fruit foliage was 50˚C, the optimum pH was 7 and the final pH was relatively unaffected by the coagulant added. The optimum dosage for 100 NTU, 200 NTU and 400 NTU found were 5 mg/L, 10 mg/L and 20 mg/L respectively. The sedimentation time found was very fast where 10 min was considered to be enough. The performance of dragon fruit foliage in turbidity removal was comparable to commercial alum and the optimum dosage for dragon fruit foliage was 1.5 times lower than alum. Combining dragon fruit foliage and alum showed better performance in turbidity removal. Hence, it can be concluded that dragon fruit foliage has a high potential as a natural coagulant for application in water treatment.

Keywords: coagulation, dragon fruit foliage, natural coagulants, turbidity removal, water treatment

1. Introduction

Coagulant plays a significant role in water treatment. Coagulant is used to remove the turbidity in raw water. There are many types of coagulants that can be used for water treatment. These coagulants can be classified into inorganic coagulant (aluminium sulfate, polyaluminium chloride and ferric chloride), synthetic organic polymer (polyacrylamide derivatives and polyethylene imine) and natural coagulant (Chitosan and plant extracts). Aluminum sulfate (alum) is the most commonly used for treating the raw water due to its effectiveness and has the lowest price as compared to other type of coagulants. However, the use of alum for water treatment has raised the concern towards the human's health. The usage of alum as coagulant produce high volume of sludge while the residue of alum content in treated water may induce Alzheimer disease [1]. The presence of residual monomer in the treated water resulting from the use of synthetic polymers as coagulant is not desirable because these monomers have strong carcinogenic and neurotoxicity properties [2].

Nowadays, there is a high demand to find an alternative coagulant which is preferably from natural, renewable sources and safe for human health. Several studies have been done on natural coagulants produced or extracted from plants, animals, or microorganisms [3]. *Moringa oleifera* is one of the effective coagulants and has been tested to be used as a primary coagulant in water and wastewater treatment. Others type of natural coagulant such as cactus plant has been discovered to have the potential as coagulant [4]. A preliminary study on cactus has been done and it has been found that the removal efficiency and COD were high when cactus has been used with alum simultaneously to treat sewage water, as compared to use cactus and alum solely [5].

In this study, dragon fruit which is a family of cactus is to be used as a natural coagulant. It is believed that this plant has a potential to act as coagulant based on previous works done on cactus. The species of dragon fruit used for this work was *Hylocereus polyrhizus* (red flesh). This plants are abundant in Malaysia since the fruits are edible and has a great source of nutrients such as betacyanins, carbohydrate, carotene, crude fiber, fat, flavonoid, glucose, iron, kobalamin, niacin, phenolic, phosphorus, polyphenol, protein, pyridoxine, thiamin, vitamin B1, vitamin B2, vitamin B3 and vitamin C [6]. The high content of phytoalbumins also provides the antioxidant properties to this fruit [7]. Consuming the dragon fruit regularly can helps the digestive system, prevent diabetes and colon cancer and can reduce high blood pressure and cholesterol levels [8]. Due to the commercial value of the fruit, only the foliage part of the plant will be used for this study. Currently, the publication regarding the dragon fruit foliage is very limited.

In this study, the main objective was to determine the optimum condition of the coagulation process using dragon fruit foliage. The parameters affecting the coagulant performance such as drying temperature, pH, dosage, initial turbidity, and sedimentation time were investigated.

2. Materials & methods

2.1. Preparation of dragon fruit foliage in powder form

The dragon fruit foliage was collected from the University Agriculture Park, Universiti Putra Malaysia, Serdang, Malaysia. The foliage was washed with tap water and subsequently cut into small pieces to facilitate drying. Then, it was dried in the oven at 50˚C (3 days) or 80˚C (1 day). The dried foliage was ground into a fine powder using domestic blender and subsequently sieved to sizes between 400 - 800 μm. The powder was stored in a tight container and kept in the refrigerator (4˚C) for further use.

2.2. Extraction method

1000 mg of dried powder was suspended in 100 mL distilled water. The suspension was stirred with a magnetic stirrer at room temperature (28˚C) for 60 mins. Then, it was filtered through the muslin cloth using a Buchner filter under the vacuum. The extract was collected before it can be used as coagulant.

2.3. Preparation of turbid water

Turbid water was prepared by adding 10 g of kaolin powder into 1 L of tap water. The suspension was stirred at 20 rpm for 60 mins using jar floc test unit to allow the uniform dispersion of the kaolin particle. The suspension was used as the stock solution to prepare the turbid water by diluting it with tap water to obtain the desired turbidity.

2.4. Coagulation tests

Coagulation tests were conducted using jar floc test unit (JLT 6 Velp Scientifica, Usmate, Italy). 500 mL of the turbid water was added into 6 beakers separately. Then, the coagulant was added into those beakers at different dosage. The speed and duration of the jar floc test used were based on the previous work done on *Moringa oleifera* where the steps involve rapid mixing at 100 rpm for 4 minutes and slow mixing at 40 rpm for 25 minutes before followed by sedimentation for 30 minutes [9]. After sedimentation, the residual turbidity of the clarified water collected from the middle of the beaker was measured using Hach Turbidimeter Model 2100 N. All experiments were conducted in duplicate.

2.5. The determination of optimum conditions for the coagulation process

2.5.1. Effect of drying temperature

To study the effect of drying temperature, dragon fruit foliage was dried in the oven at 50˚C or 80˚C. Then, the dried foliage in a powder form was extracted using distilled water. The initial turbidity of turbid water was set to be 400 NTU and the initial pH was 7.

2.5.2. Effect of pH

For this work, the pH was measured using Hanna Instruments pH meter (HI 8424). The pH of turbid water was adjusted from 2 to 12 using 1M NaOH and 1M HCl. The initial turbidity of turbid water used was 400 NTU while the dosage used were 0 mg/L (blank), 10 mg/L and 20 mg/L.

2.5.3. Effect of the coagulant dosage

To study the effect of the coagulant dosage, turbid water with the initial turbidity of 400 NTU was used. The pH of turbid water was adjusted to 7. In the first step, the dosage used were 5 mg/L, 10 mg/L, 30 mg/L, 50 mg/L, 70 mg/L, and 90 mg/L while for the second step, the dosage used were 2 mg/L, 5 mg/L, 10 mg/L, 20 mg/L, 30 mg/L, and 40 mg/L.

2.5.4. Influence of initial turbidity

Turbid water with the initial turbidity of 100 NTU, 200 NTU and 400 NTU were used. The pH of turbid water was adjusted to 7. The range of the coagulant dosage used was based on the result obtained from the previous section.

2.5.5. Effect of sedimentation time

The experiment was conducted with the initial turbidity of 400 NTU and initial pH of 7. The dosage used was 20 mg/L. The mixing speed and time was fixed while the sedimentation time was varied from 5 mins to 60 mins.

2.5.6. Comparison between dragon fruit foliage and alum

The experiment was conducted with the initial turbidity of 400 NTU and initial pH of 7. The sedimentation time used in the coagulation test was based on the result obtained from the previous section. The experiment was run using dragon fruit foliage as coagulant and was repeated using alum. Another experiment was run by using dragon fruit foliage as coagulant and alum as coagulant aid. The dosage ratio of dragon fruit foliage to alum used was 50:50.

3. Results & discussions

3.1. Effect of drying temperature

Figure 1(A) shows the turbidity removal using dragon fruit foliage at different drying temperature. From the graph, at the dosage of 10 mg/L the turbidity removal for 50˚C and 80˚C drying temperatures were 90.4% and 24.0%, respectively. The result from the current study demonstrates that 50˚C was the best temperature for drying the dragon fruit foliage since the turbidity removal was high as compared to 80˚C drying temperature. It is believed that some of the coagulant's active compound in dragon fruit foliage was losing its function at high drying temperature. From the observation, the coagulant solution extracted from the foliage dried at 50˚C was more viscous (mucilage) as compared to 80˚C drying temperature. Based on the other work done on cactus *Opuntia*, the high coagulation capability for this plant is most likely associated to the presence of mucilage and complex carbohydrate stored in inner and outer pads of cactus that has a large water retention capacity [10]. Another study has established that mucilage in cactus *Opuntia* contains carbohydrates such as l-arabinose, l-rhamnose, d-galactose, d-xylose, and galacturonic acid [11]. As for dragon fruit foliage, studies on active compounds have not been established yet. However, for this work, 50˚C has been chosen as the optimum temperature for drying the foliage since it gives the highest turbidity removal.

3.2. Effect of pH

Figure 1(B) shows the effect of pH on turbidity removal using dragon fruit foliage. The averages of turbidity removal by dragon fruit foliage were 95.4% and 96.4% for 10 mg/L and 20 mg/L, respectively. It was found that turbidity removal of dragon fruit foliage was high and independent of the pH value. For the blank sample of turbid water, it was found that turbidity removal was low at pH 5 to 10. At other range of pH, the turbidity removal observed was high (> 75%) although there was no coagulant added. For example, at pH 3 the turbidity removal of a blank sample was achieved up to 89.4%. This is because, at acidic condition the concentration of hydrogen ions was high where it can neutralize the negative charge of the kaolin particle and allows the particle to attach and form a floc. Based on the observation, by adding only acid during the pH adjustment of turbid water to pH 4 and less, small flocs were formed and it could be seen immediately. At pH 5 to 10, pH has only little effect on coagulant performance and the real performance of coagulant on turbidity removal can be seen. Earlier work done on *Moringa oleifera* was found that it was not easy to confirm the optimum pH [12]. However, in this study, operating variables such as pH need to be fixed for every experiment. Therefore, the optimum pH needs to be selected and pH 7 (neutral pH) was selected as the optimum pH because it is closed to pH of river water and suitable for drinking purpose.

Figure 1(C) shows the final pH of turbid water treated with 20 mg/L dosage of dragon fruit foliage. The results show that the final pH of treated water differs only slightly from its initial pH. This result is found to be similar to the cactus where the final pH of treated water was relatively unaffected as compared to chemical-based coagulants [13]. Another work done on *Jatropha curcas* also reported that the usage of this natural coagulant will not alter the pH of treated water [14]. The usage of commercial coagulant such as alum can alter the pH of treated water and causes the pH to decrease rapidly to around 4.2 [15]. This means that by using alum as coagulant, the pH adjustment will be needed after the coagulation process to restore the pH to a normal pH of water. However, by using natural coagulation such as dragon fruit there is no pH adjustment of water needed since the usage of this coagulant will not alter the pH of treated water.

3.3. Effect of the coagulant dosage

Figure 1(D) and Figure 1(E) show the optimization dragon fruit foliage dosage in turbidity removal. In the first step, a larger range of coagulant dosage was used. The results show that the optimum dosage was between 10 mg/L to 30 mg/L. For this reason, in the second step of dosage optimization, a smaller range of coagulant dosage was used. It was found that the optimum dosage of dragon fruit foliage for 400 NTU was 20 mg/L where the turbidity removal was 95.3 %. It can be observed that turbidity removal was decreased when the coagulant dosage is increased above the optimal dosage (20 mg/L). Overdosing can cause the saturation of the polymer bridge sites and can lead to the restabilization of destabilization particles because the numbers of particles are insufficient to create more bridges among them [16]. Earlier work done on *Moringa oleifera* in treating turbid water with the initial turbidity of 390 NTU showed that the turbidity removal was 94.0% at the dosage of 400 mg/L [3]. It shows that the turbidity removal of dragon fruit foliage with the same range of initial turbidity was similar with *Moringa oleifera* but with the optimum dosage of dragon fruit foliage was 20 times lower.

3.4. Influence of initial turbidity

To study the influence of initial turbidity in coagulation, the initial turbidity of 100 NTU, 200 NTU and 400 NTU were used. Based on Figure 1(F), the optimum dosage for the initial turbidity of 100 NTU, 200 NTU and 400 NTU were 5 mg/L, 10 mg/L and 20 mg/L respectively. By comparison, the optimum dosage of dragon fruit foliage increased by the increment of initial turbidity. The optimum dosage was found to be directly proportional to the initial turbidity where 400 NTU has 2 times the higher dosage than 200 NTU and 4 times the higher dosage than 100 NTU. The turbidity removal for 100 NTU, 200 NTU and 400 NTU at optimum dosage were 85.5%, 89.6% and 95.3%, respectively. Based on the result, the turbidity removal was found to be increased by the increasing of the initial turbidity. This is because higher turbidity has more suspended particles where the frequency of effective collision will also increase. This will help the flocs to agglomerate faster and larger flocs can be formed easily and settles faster. Previous study done on *Moringa oleifera* has also found that the optimum dosage and turbidity removal were increased as the initial turbidity increased [3].

3.5. Effect of sedimentation time

In the previous work, the method of coagulation test was based on the previous work done on *Moringa oleifera* [9]. The original method used for sedimentation time was 30 mins. However, for this study the effect of sedimentation time on turbidity removal was investigated. Based on Figure 1(G), sedimentation time for dragon fruit foliage was very fast and 10 min was considered to be enough. Increasing the sedimentation time will not significantly affect the final result of turbidity removal. It can be seen in Figure 2 that the flocs of dragon fruit foliage were formed immediately during rapid mixing and it became larger in size during slow mixing. Hence, during sedimentation the bigger flocs of dragon fruit foliage can settle easily in a short time. This is an advantage in the real water treatment plant where by reducing the sedimentation time, the operation time can be reduced while the production rate can be increased.

3.6. Comparison between dragon fruit foliage and alum

Figure 1(H) shows the comparison between dragon fruit foliage and alum on turbidity removal. By comparing both coagulants, the optimum dosage of dragon fruit foliage was 20 mg/L where turbidity removal was 95.3% while for alum the optimum dosage was 30 mg/L and the turbidity removal was 97.9%. The optimum dosage for dragon fruit foliage was 1.5 times lower than alum. The performance of alum in turbidity removal was slightly better than dragon fruit foliage where the difference in turbidity removal was only 2.6%. Another study was done by combining both coagulants where dragon fruit foliage was added as coagulant and alum was added as coagulant aid. At the dosage of 30 mg/L (15 mg/L dragon fruit foliage and 15 mg/L alum), the turbidity removal was achieved up to 99.3% where the residual turbidity was 2.8 NTU. This result shows that by combining both coagulants, the performance in turbidity removal was improved than using dragon fruit foliage and alum alone. Besides, by combining both coagulants, 50% dosage of alum can be reduced. This is good because by reducing the dosage of alum, the cost also can be reduced. The residual turbidity was also found to be less than 5 NTU where it complies with the regulation of water treatment.

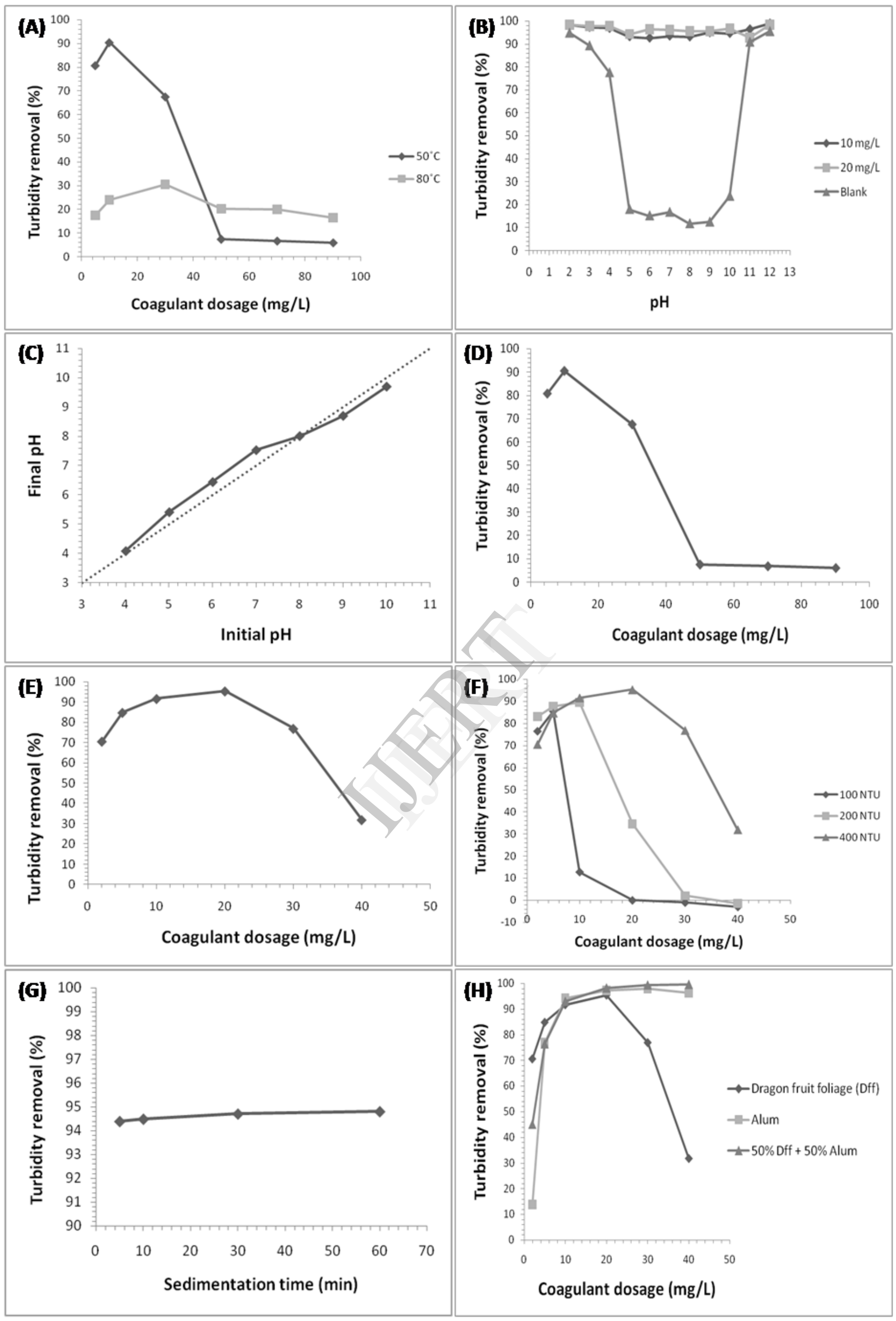

Figure 1. (A) Turbidity removal at different drying temperature; (B) Turbidity removal at different pH; (C) Final pH of treated water; (D) Step 1 of dosage optimization; (E) Step 2 of dosage optimization; (F) Turbidity removal at different initial turbidity; (G) Turbidity removal at different sedimentation time; (H) Comparison of turbidity removal between dragon fruit foliage and alum.

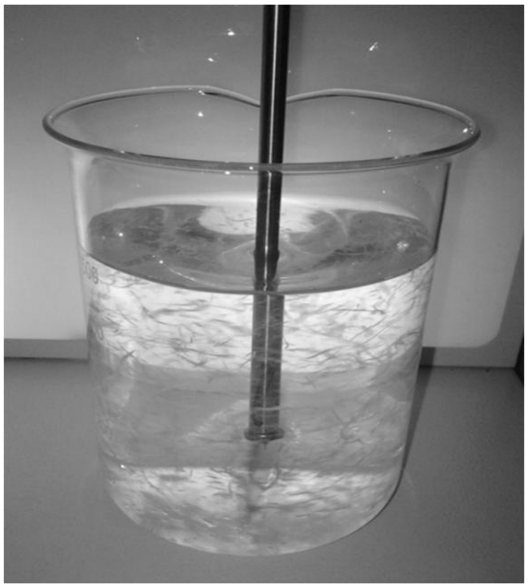

Figure 2. Bigger flocs were formed by using dragon fruit foliage as coagulant

4. Conclusion

From this study, it can be concluded that dragon fruit foliage has a high potential to be used as a coagulant in water treatment. The optimum drying temperature for dragon fruit foliage found was 50˚C, the optimum pH found was 7 and the final pH was relatively unaffected by the coagulant added. The optimum dosage for 100 NTU, 200 NTU and 400 NTU were 5 mg/L, 10 mg/L and 20 mg/L, respectively. The sedimentation time was very fast where 10 min was considered to be enough. By comparing both coagulants, the performance of dragon fruit foliage in turbidity removal was comparable to commercial alum and the optimum dosage for dragon fruit foliage was 1.5 times lower than alum. Combining dragon fruit foliage and alum showed better performance in turbidity removal. Dragon fruit foliage has a bright future in large scale application in water treatment. However, further analysis is needed to improve the performance in coagulation. Besides, the mechanism and characterization of dragon fruit foliage also needs to be identified.

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6. References

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