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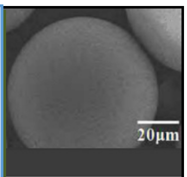

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Coagulation-Flocculation Process of Nutrient-Rich Suspended Solids from Aquaculture Effluent Using Bioflocculant

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ABSTRACT

Due to the growth and development of the aquaculture industry, appropriate wastewater treatment is needed to reduce uncontrolled pollution and environmental impacts. Therefore, this research uses green technology method, which is the coagulation-flocculation process to treat aquaculture wastewater. Natural flocculants have been the focus of research of many research due to the negative impact from using chemical flocculant. In this study, the potentiality of local plants of moringa leaves and seed (*Moringa oleifera*), banana pith (Musa), neem leave (*Azadirachta indica*) and Pandan leave (*Pandanus amaryllifolius*) as bioflocculant were studied. This study also focuses on nutrient recovery. The potential of sludge obtained through the coagulation-flocculation process as fertilizer was investigated in comparison with commercial fertilizer. Through this study, it is shown that *Moringa oleifera* seed recorded the highest rate of suspended solid removal from synthetic kaolin water at 36.7% and highest turbidity removal rate at 34.8%. Previous studies have shown that aquaculture sludge contains 1.27 % of nitrate, 0.32 % of phosphorus and 0.65 % of potassium. The characteristics of sludge produced through the process of coagulation-flocculation resembles organic fertilizer. This shows that treated aquaculture sludge has potential to be used as an organic fertilizer. With this, it can promote the use of sustainable green technology for effective aquaculture wastewater treatment.

INTRODUCTION

Aquaculture is a process of breeding freshwater, brackish, or saltwater fish species in a controlled environment [1]. Demand for the aquaculture industry is booming due to marine fisheries, whose production growth rate is shrinking due to limited marine fisheries stocks and catching over breeding capacity [2]. The high demand for seafood following the increase in human population has also triggered high demand in the aquaculture industry. Intensification of this aquaculture industry production will require more inputs [3] which will increase waste generation from aquaculture production systems. The small-scale Aquaculture industry in Malaysia started in 1930, now emerged as a lucrative commercially generating industry. There are several types of aquaculture industry in Malaysia, namely freshwater aquaculture, and saltwater aquaculture. Both types of aquacultures contribute to the national economy.

The aquaculture industry allegorizes a production company where there is input to produce the output of the product. Waste materials, such as unused inputs or by-products, will exist during product production. These wastes often have little or no economic value and are often harmful to the environment. The amount of waste generated from aquaculture production in Asian countries is very high, where 1 ton of fish generates an average of 0.8 kg of nitrogen (N) and 0.1 kg of phosphorus (P), equivalent to the waste produced daily by 73 people [4]. This emphasizes the need for sustainable and effective aquaculture effluent treatment methods to ensure the aquaculture industry's growth and development.

The aquaculture industry produces a lot of wastewater that contains suspended solids, phosphorus, and nitrogen. The nutrient components that exist in aquaculture wastewater attract researchers to export these nutrients into higher-value products. Therefore, effluents from the

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aquaculture industry will be analysed, and their content compared in terms of nitrogen, phosphorus, and suspended solids. Thus, the primary purpose of this experiment is to extract the nutrients from aquaculture effluent. Then, the nutrients are recycled to produce something useful, such as fertilizer. This study not only treats aquaculture wastewater but also emphasizes nutrient recovery.

Many aquaculture wastewater treatments have been highlighted, such as using membrane technology and phytoremediation. However, the difficulties and high operating costs make the method less implemented in the aquaculture industry. Thus, the effluent treatment process using coagulation-flocculation is selected due to the simple and low operation cost. The method of coagulation-flocculation is by using chemical or natural flocculant. The results of a survey of 20 water treatment plants showed that a coagulation-flocculation method is a renowned option in water engineering due to its simple operating parameters [5].

In the coagulation-flocculation process, the flocculants play an essential role in reducing water turbidity and the removal of other contaminants. Flocculants can be divided into artificial and natural flocculants. Natural flocculants include extracts of microorganisms, animals, or plants [6] Examples include nirmali (Strychnos potatorum) [7] *Moringa oleifera* seeds, chitosan, and cassava bark [8-9] Non-native clusters include aluminum sulphate (alum), aluminum chloride, sodium aluminate, ferric chloride and Polyaluminum chloride [10-11]. This study focuses on the treatment and acquisition of aquaculture wastewater nutrients using natural clumps. This can ensure the sustainability of the aquaculture industry and instil a 'waste to resource' mindset towards society. This method also provides returns in terms of nutrient acquisition, and the concept of zero emissions is also implemented.

Hence, the main objective of this study is to determine the effectiveness of bioflocculants from local plants to form nutrient-rich suspended solids of aquaculture effluent and the second part of the study is to investigate the characteristic of sludge based on previous studies and compare them with commercial fertilizers in terms of nutrient content.

MATERIALS AND METHODS

Source and Characteristics of Aquaculture Effluent

Aquaculture wastewater is obtained from Aqasia Aquatic Enterprise with GPS coordinates of 2.766, 101.809. **Fig.** 1 displays a satellite map of the location of the fishing pond. The obtained aquaculture wastewater was placed in a 10 L solid bottle and stored in a cool room at 4°C. Laboratory tests (ex-situ) is conducted to determine some physicochemical parameters such as temperature, pH, conductivity, dissolved oxygen (DO), turbidity, colour of suspended solids (TSS), ammonia nitrogen (NO3 -N), phosphate (PO43-) chemical oxygen demand (COD) and biochemical oxygen demand (BOD).

In this study, banana tree stems (Musa), leaves and seeds (*Moringa oleifera*), neem leaves (*Azadirachta indica*), and pandan leaves (*Pandanus amaryllifolius*) are the sources of the bioflocculant. Specimens of these plants have been collected and cleaned in advance. The specimens are dried for a week. Then, the dried plants are grounded to a fine powder by using a grinder. Next, the powder was sieved into fine powder by using a 500 am sieve.

Fig. 1. Satellite map of the location of the aquaculture pond

Determination of The Effectiveness of Bioflocculant
The coagulation-flocculation process is conducted using a conventional jar test model (Model ZR4-6, Zhongrun Water, China). The concentrated stock solution (1 g / L) was prepared by weighing one gram (1 g) of *Moringa oleifera* leaves powder and transferred into a 1000 mL flask. Distilled water is added up to the mark. The flask is shaken vigorously for 15 minutes to produce a uniform solution. Doses of 0, 50, 100, 150 and 200 mg / L of the stock solution were measured and poured into the beakers, respectively. A similar method has been used to produce concentrated solutions labelled A to E for other thickening powders. Each beaker is added up to 1000 mL with water samples collected and placed under a stirrer. The mixer is turned on and the solutions are stirred for 1 minute at a speed of 120 rpm, followed by a slow mixing for 15 minutes at 30 rpm. Then, the mixer is turned off and the optimal dose and sample settling time are recorded. The coagulation-flocculation process takes place, and the flocks settle at the bottom leaving a transparent medium at the top due to the presence of water-soluble cationic coagulant protein.

Characterization of Sludge
The addition of bioflocculant to the beaker during the Jar Test will result in two different phases. The upper phase, also known as the supernatant, is in liquid form while the sludge will settle under the beaker. Characterization of sludge resulting from natural bioflocculant after optimization and commercial coagulation will be performed using Infrared Fourier Transform Spectroscopy (FTIR). This technique is used to identify organic and inorganic components in the sludge.

Nitrogen and Phosphorus Analysis
The amount of total nitrogen, NH_3^-N, is determined and recorded using the Nessler method and the HACH DR 2000 spectrophotometer. Ascorbic acid (reactive orthophosphate) method is applied to determine the total phosphate. The orthophosphate content will be determined through the formation of phosphomolybdate and subsequent reduction by using PhosVer® reagent (ascorbic acid). Next, the amount of phosphorus will be measured using the 2000 HACH DR spectrophotometer.

Quality Analysis of Aquaculture Effluent

Chemical and physical parameters, including pH, COD, colour, and turbidity, were measured to compare the efficiency of the bioflocculant in aquaculture wastewater treatment. The pH of the water sample is determined using the pH meter (Hanna Instruments Inc. USA). Meanwhile, the COD and colour of water samples were measured using the HACH DR2800 RFID-technology spectrophotometer (HACH, USA) with a standard program loaded on the machine. The turbidity in the aquaculture wastewater sample was measured using a direct reading spectrophotometer Hach DR / 2800 (HACH USA).

RESULTS AND DISCUSSION

This section discusses on the characterization of aquaculture wastewater, the selection of bioflocculants and the characterization of organic and chemical fertilizers. Characterization of wastewater from aquaculture industry and bioflocculant selection were compared to previous studies.

Characterization of Aquaculture Wastewater
The amount of wastewater generated from the aquaculture industry creates concern on a global level. This is because aquaculture wastewater contains high amounts of organic matter, nutrients, and living organisms, such as algae and plankton [12-13]. BOD concentration, COD, and high nutrients are critical issues in terms of water pollution if effluent is released into the environment [14]. There are several factors that influence the characteristics of aquaculture wastewater. Among these factors are livestock reared, dietary diet and so on [4, 15]. The characteristics of aquaculture industry wastewater are shown in **Table 1**.

Table 1 shows that aquaculture wastewater contains high concentrations of COD. High content of organic matter in aquaculture wastewater is due to excretion, faeces of fish and uneaten fish pellets. High concentrations of organic matter in aquaculture effluent can cause water pollution, especially the eutrophic phenomenon if organic materials are released directly to the body of water. Different livestock species and aquaculture systems produce different characteristics of wastewater. In addition to the high concentration of COD, wastewater also contains a large amount of nutrients (nitrogen and phosphorus). High nutrients in wastewater can also cause pollution when released directly to the body of water. High concentrations of nutrients are the main cause of eutrophication in aquatic environments [16].

When compared to the characteristics of aquaculture effluents that are standardised under the Environmental Quality Act 1974 (Ministry of Natural Resources and Environment 2009), it is found that most of the aquaculture effluents stated in **Table 1** are within a safe range. However, the study conducted by [17] on aquaculture wastewater shows that the effluent is within toxic range. This is because the amount of chloride and COD readings of aquaculture wastewater produced has exceeded the specified range. This indicates that each aquaculture wastewater has different characterization according to the type of livestock and the aquaculture system implemented.

Screening and Selection of Bioflocullants
The screening and selection of bioflocculant has been carried out using synthetic kaolin wastewater. The comparison between bioflocculants was studied using synthetic kaolin wastewater whereby the initial turbidity was maintained in the range of 755 NTU-765 NTU. Low mixing speed (50 rpm), medium mixing speed (160 rpm) and indentation time (20 minutes) were maintained throughout the experiment. The main considerations for the most effective comparison of bioflocculants are the percentage of turbidity removal and percentage of suspended solid removal from the synthetic kaolin wastewater. One of the most important parameters for determining the efficiency of bioflocculant is the dosage of the bioflocculant. This is because an overdose or under-dose is able to affect the performance and the efficiency of bioflocculant [17]. In this study, the effects of bioflocculant doses ranging from 0 mg//L to 50 mg/L on suspended solids and the turbidity of synthetic kaolin wastewater were studied. Generally, a high dose of

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flocculant will increase the percent of turbidity and solid removal achieved. This is because it will encourage the interaction between the bioflocculants molecules and in turn lead to the separation of suspended solid particles and contaminants from the water. However, according to [20] the theory does not always reflect the relationship between welders and the percentage of turbidity removal and suspended solids. [21] further explained that insufficient doses may result in inefficient neutralization of charges against negative charges on kaolin particles. On the other hand, excessive dosages can cause saturated polymer bridge sites. This will result in the stabilization of unstable particles due to insufficient number of suspended particles to form more bridges between particles [22].

Table 1. Characterization of aquaculture wastewater.

Parameter	Units	This study (2021)	[17]	[18]	[19]	Environmental Protection Agency 1974
Country		Malaysia	Nigeria	Canada	China	-
Fish species		Prawns	-	Eels	Prawns	-
Aquaculture system		-	-	Recycling system	Recycling system	-
pH		6.4	7.9	6.3	7.78	5.5-9.0
Temperature	°C	27.7	30.4	-	-	40
Colour		Tanned green	Yellowish green	-	-	-
BOD	mg/L	84	317	-	-	50
COD	mg/L	178	758	-	8.5	250
DO	mg/L	-	9.6	-	-	-
Turbidity	NTU	-	404	-	-	-
Suspended solid	mg/L	34	45	0.41	-	100
Chloride	mg/L	-	2.44	-	-	2.0
Calcium	mg/L	-	5.45	-	-	-
NH_4^+N	mg/L	-	-	1.6	4.24	20
NO_3^-N	mg/L	-	0.83	0.05	2	-
PO_4	mg/L	-	0.91	3.6	0.42	-

Fig. 2 shows the chart of suspended solid and percentage of suspended solid removal for each type of bioflocculants which are Moringa leaves, moringa seeds, neem leaves, and banana tree trunks. It is noticeable that the percentage of suspended solid removal increases progressively when the bioflocculants dose is increased. Based on **Fig. 2**, moringa seeds recorded the highest percentage of suspended solid removal at 37% at a dose of 50 mg/L. At doses of 0 mg/L up to 40 mg/L, Moringa leaves and Moringa seeds showed an equivalent percentage of suspended solid removal. Nevertheless, there was a significant difference when the concentration of flocculant dose at 50 mg/L. Percentage of suspended solid removal by Moringa seeds was greater than that of other bioflocculants. This is because at a dose of 50 mg/L, the efficiency of Moringa seeds as bioflocculant is optimum.

Based on **Fig. 2**, the letter "a" represents a significant difference in TSS concentration (NTU) between each bioflocculants dosage and type of bioflocculant. The letter "b" represents a significant difference in percentage removal of TSS (%) for each bioflocculant dosage and each type of bioflocculant. ($p < 0.05$). The TSS removal was significantly higher at $p < 0.05$, for treatments with *Moringa oleifera* seed than for treatments with other types of bioflocculant (represented by the letter "b" in **Fig. 2**). Based on the statistical analysis, it is shown the result between *Moringa oleifera* leaves and seed was insignificant at dosage of 20 mg/L. This proves that the effectiveness of the *Moringa oleifera* leaves and seed were similar. However, as dosage increased, it was proven, that *Moringa oleifera* is the best, as the result was significant in comparison with *Moringa oleifera* leaves.

Fig. 3 displays chart on turbidity and percentage of the turbidity removal for each type of bioflocculant. At doses of 0 mg/L up to 30 mg/L, Moringa leaves recorded the highest percentage of turbidity removal. However, there was a significant difference in the doses of 40 mg/L and 50 mg/L, when the percentage of turbidity removal by Moringa seeds increased dramatically. This suggests that the dose of moringa seeds may have reached the optimum dose of bioflocculants.]. The significance of type of bioflocculant and dosage of bioflocculant was analyzed using this software.

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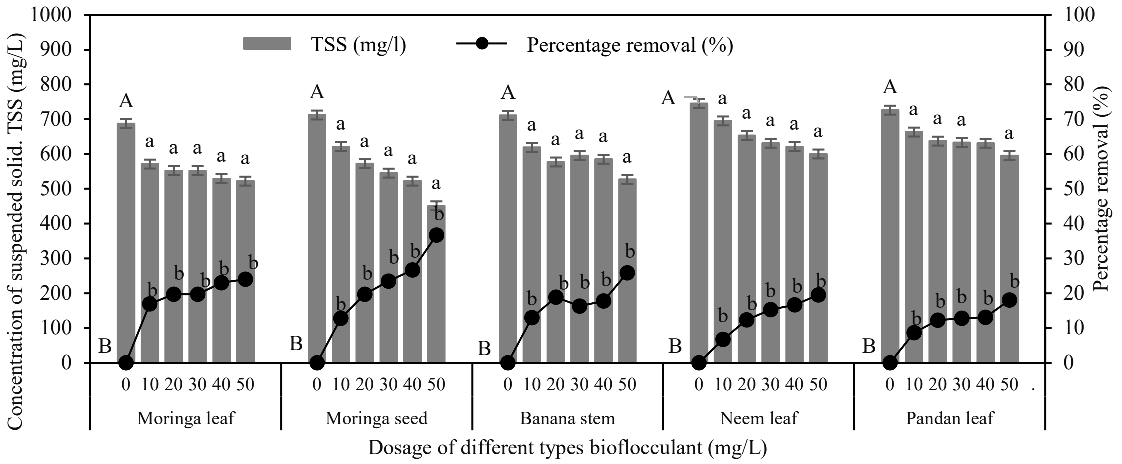

Fig. 2. Concentration of suspended solid and percentage of suspended solid removal (%) for different types of Bioflocculant

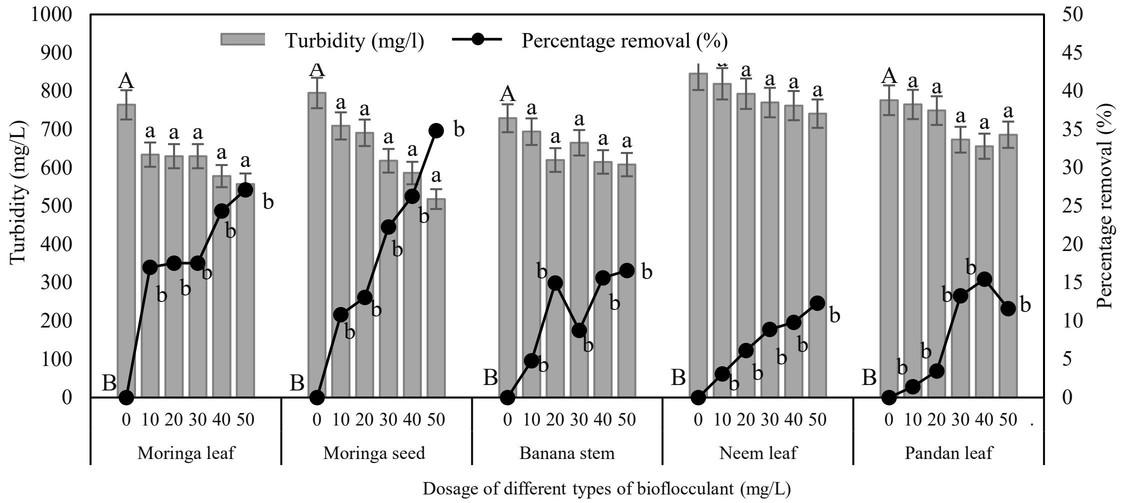

Fig. 3. Removal percentage of turbidity(%) based on different types of bioflocculant.

Based on **Fig. 3**, the letter “a” represents a significant difference in turbidity concentration (mg/L) between each bioflocculants dosage and type of bioflocculant. The letter “b” represents a significant difference in percentage removal of turbidity (%) for each bioflocculant dosage and each type of bioflocculant. (p <0.05). The turbidity removal was significantly higher at $p< 0.05$, for treatments with *Moringa oleifera* seed than for treatments with other types of bioflocculant (represented by the letter "b" in Fig. 3). The statistical analysis also proves at dosage 10 mg/L, the turbidity removal of *Moringa oleifera* seed and *Moringa oleifera* leaves was insignificant. However, as the dosage increased, the *Moringa oleifera* seed performed better as the result was significant.

Based on **Fig. 2** and **Fig. 3**, it is inferred that moringa seeds are the most effective bioflocculants as Moringa seeds recorded the highest percentage of solid removal and the highest percentage of turbidity removal compared to other bioflocculants. This is because Moringa seeds contain water-soluble dimer cationic proteins. Therefore, Moringa seeds have the potential to be effective bioflocculant. Moringa seed powder receives hydro xylene group due to the reaction of proteins in Moringa as natural polyelectrolyte [25, 26].

There are scientific studies suggest that Moringa seeds can act as an effective natural bioflocculant as they contain low molecular weight of water-soluble proteins. Protein will be charged positively when dissolved in water.

Protein will act as a positively charged synthetic substance and can be applied as a synthetic polymer flocculant. Thus, Moringa can be classified as a natural bioflocculant. This is because the bioflocculant is derived from plant and without any synthetic processes. The mechanism that is most likely to occur in the coagulation-flocculation process is the trapping and neutralization of the bonding charge between unstable particles. When processed Moringa seed powder is added to the synthetic wastewater of kaolin, proteins in Moringa seeds will bind negatively charged particles, such as clay, bacteria, dust, etc. Therefore, the particles are collected and form a larger lump. The lump settles at the bottom and becomes a sediment. This will facilitate the separation of water and contaminants [25].

The result of the removal of turbidity in synthetic water by the seeds and leaves of *Moringa oleifera* shows a strong correlation between protein content and the efficiency of removal. This suggests that the protein in *Moringa oleifera* has the potential to be used as an effective natural bioflocculant. In addition, the results of this study showed that *Moringa oleifera* seeds have a high advantage as bioflocculant compared to *Moringa oleifera* leaves due to the higher percentage of removal by *Moringa oleifera* seeds compared to *Moringa oleifera* leaves.

Comparison of Bio-Flocculant Efficiency

The negative impact due to the use of chemical flocculants has driven researchers' interest in natural bioflocculant to be utilized in wastewater treatment [27, 28]. Nowadays, there are various efforts to produce natural bioflocculant from native plants. Mostly, natural bioflocculant is used in the treatment of wastewater in the form of powders or stock solutions. However, this study is more focused on bioflocculants that are derived from natural plants. **Table 2** shows a comparison of the efficiency of native bioflocculants.

Meanwhile**, Fig. 4** shows the percentage of turbidity removal from wastewater for each type of natural bioflocculant. Margaritarea discoidea, Jatropha curcas seeds and Maerua decumbent and Moringa seeds recorded the highest percentage of turbidity removal. The use of natural bioflocculant in wastewater treatment is an environmentally friendly approach. Through the usage of bioflocculant derived from natural plants, medical issues associated with aluminium-based chemicals (such as Parkinson's disease, Alzheimer's disease, and other neurological infections) can be avoided. Sludge obtained from this treatment can be implemented for other useful purposes. This is because sludge is safe and does not pollute the environment [27]. Thus, the sludge is suitable to be used as fertilizer for the improvement of nutrient content in the soil [29].

Natural bioflocculant is also cost effective. According to [30], the use of natural bioflocculant is not only environmentally friendly but also requires a lower cost compared to chemical flocculants [30]. Natural bioflocculants are privately sourced and exist in large quantities. In addition, the natural bioflocculant will produce less sludge and decompose easily. Unlike chemical flocculants, natural bioflocculants require a larger scale and require more complex preparation and storage methods [31].

However, there are some drawbacks to the selection of natural bioflocculants from plants. The first is the optimal pH range. The main drawback of using natural bioflocculants is the failure an effective bioflocculant in a large pH range. Most natural bioflocculants are only effective in certain pH ranges. For instance, *Moringa oleifera* is widely used in the treatment of dairy wastewater. However, studies conducted by [27] show that the efficiency of *Moringa oleifera* seeds is best in the pH range of 5-8.

Most natural bioflocculants have a wide range of applications and are not just limited to wastewater treatment processes. For example, *Moringa oleifera* is also used to treat various types of diseases such as asthma, syphilis and so on. [32]. In addition, the okra also has various other functions besides being used as bioflocculant. For example, okra is eaten as vegetables in Southeast Asia and West Africa [33]. In addition, *Moringa oleifera*, mushrooms, peanuts, orange, and jackfruit are sources of food. The production of bioflocculants from these plants will increase competition for food supply. This will only contribute to the global food shortage issue.

Furthermore, not all the natural bioflocculants discussed in **Table 2** are accessible throughout the year and this raises concerns about the possibility of meeting large-scale demand for bioflocculants for commercial applications. In addition, the cost of natural bioflocculants is likely to be higher than commercial flocculants. This is because the distribution of plants is not uniform. This would create some difficulties in obtaining non-local Malaysian plants such as Margaritarea discoidea and Maerua decumbent as resources for bioflocculant manufacturing. Thus, a potential solution to this is using local plants as a bioflocculant source This is because local plants thrive in the climate and weather in Malaysia. This will guarantee ongoing resources for the natural lipoedema sizing [27]. Natural bioflocculant contains natural tissue and can rot over time. This reposition will affect the productivity and efficiency of bioflocculants in the process of wastewater treatment. Therefore, studies on potential disasters are needed to identify issues or problems that can occur because of using natural bioflocculant [27].

Sludge from wastewater treatment in the agriculture sector, such as aquaculture, palm oil industry, sago production, and coffee making, usually consists of high organic and nutrient content. The content of organic matter in sludge can be further modified and used as a soil conditioner, while existing nutrients will act as fertilizers.

The use of contaminants will not only reduce the potential harm to the environment but can also benefit the agricultural sector [50]. **Table 3** shows the various types of chemical and organic fertilizers. Chemical fertilizers such as N, P and K played an important role in improving the yield and quality of plants during the early seventies. But in recent years the use of chemical fertilizers is often unbalanced. The chemical fertilizers described in **Table 3** resulted in several problems such as loss of fertility, soil health and various nutrient deficiencies and loss of microbially activity etc., which ultimately resulted in reduced productivity and crop quality [53].

Table 2. Comparision on Efficiency of each type of bioflocculant.

Types of Bioflocculant	Type of wastewater	Optimum parameters			Percentage of removal (%)				Reference
		pH	Dosage (mg/L)	Turbidity	TSS (mg/L)	Cod (%)	Colour (%)	Suspended solid (SS) (%)	
Sago starch	Sewage water	4	7000	-	-	13.1	-	27.9	[34]
Peanut seeds	POME		5000	94.6	-	77	-	-	[35]
Rice starch	Synthetic wastewater	4	120	50	-	-	-	-	[36]
Banana starch	River water	4	100000	98.5	-	-	-	96.0	[37]
Potato starch	Textile wastewater	3	2%(w/v)	87.0	-	-	-	-	[38]
Moringa oleifera seeds	River water	6.5	50	98.80	50	24.76	-	-	[39]
Moringa oleifera seeds	Textile wastewater	6.2	100	98.6	-	33.7	-	-	[25]
Moringa oleifera	Coffee wastewater	5-7	2000-3000	-	54	-	-	-	[40]
Moringa oleifera	Surface water	7.5	50	84	-	-	-	-	[41]
Roselle Seeds	Synthetic wastewater	4	40	93	-	-	-	-	[42])
Roselle Seeds	Industrial wastewater	10	60	87	-	-	-	-	[42]
Tannin Acacia mearnsii	Coloured residual water	3.4	40	-	-	-	86	-	[43]
Orange seed skin	Dairy wastewater	7.5	200	97	-	-	-	-	[44]
Jackfruit seeds	Water puree	-	60	43	-	-	-	-	[45]
Osimum Basilicum	Textile wastewater	7.7	1.6	-	-	61.6	68.5	-	[46]
Margarita discoidea	Synthetic wastewater	-	10	98	-	-	-	-	[47]
Jatropha curcas seeds	Synthetic wastewater	3	120	99	-	-	-	-	[46]
Decumbent	Residual water paint industry	5-7	8000	99.2	-	78.6	-	-	[37]
Abelmoschus esculentus (Okra)	Textile wastewater	6.0	160	97.61	-	68.11	97.30	-	[29]
Abelmoschus esculentus (Okra)	Synthetic wastewater	6.8	75	92	-	-	-	-	[13]
Chitosan of Mushroom	POME	11	20	99	-	-	-	-	[48])
Sesamum indicum seeds	Aquaculture wastewater	2-4	500	82	-	-	-	-	[17]

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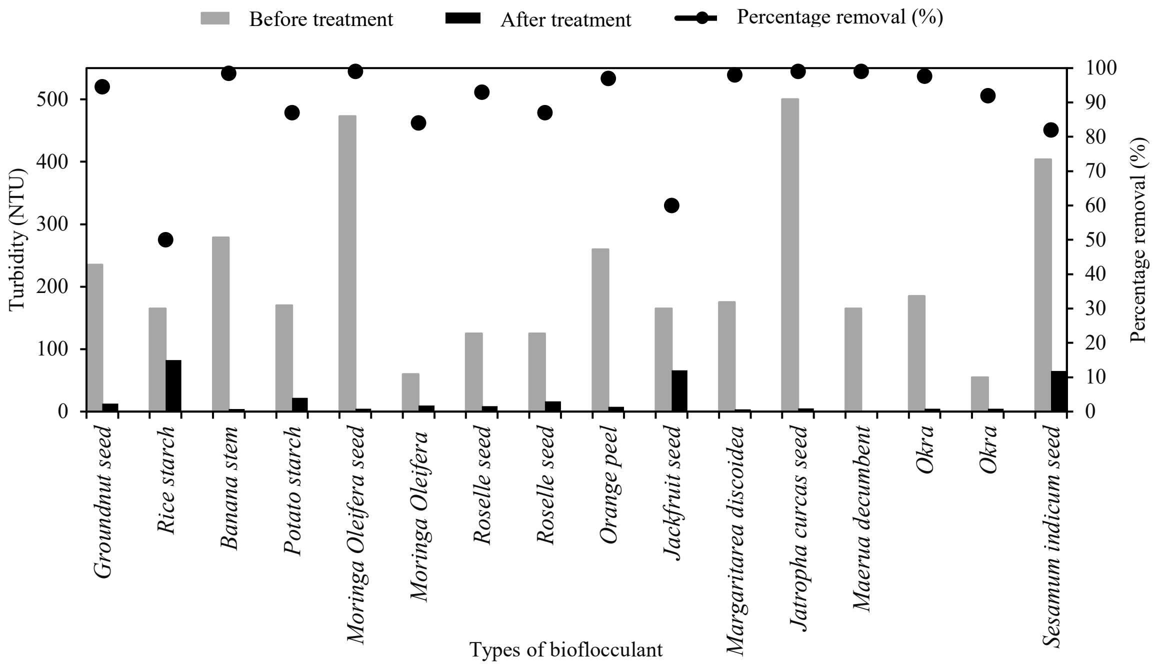

Fig. 4. Turbidity removal for each type of natural bioflocculant.

Long-term use of chemical fertilizers will be expected to lower the soil pH, promote the proliferation of certain microbes, and activate heavy metal ions in the soil and will further degrade the physiochemical properties of plants [54]. However, the long-term use of organic fertilizers can reduce some of these negative effects. The use of organic fertilizer is encouraged in the farming industry. This is because organic fertilizer is easily decomposed and environmentally friendly. In addition, organic fertilizers can also be made from various sources. Most sources of organic fertilizer are chicken faeces, cow faeces and aquaculture sludge. Indirectly, waste value will increase using organic fertilizer, this also forms an environmentally friendly cycle. There are several advantages of organic fertilizers that it increases soil fertility: increasing organic matter in the soil that improves soil structure, creates more air space and water retention in the soil and increases soil nitrogen content, the availability of enhanced nutrients in soil, releases nutrients at a slower and more consistent rate, improves nutrient mobilization and protects the soil against rain and wind erosion. Organic fertilizers also increase soil biological activity.

Characterization of Chemical and Organic Fertilizer

There have been several research studies on the reuse of aquaculture sludge [51] Studies conducted by [53] show that sludge from marine aquaculture (bioflocculant solids) can provide the essential nutrients needed for *Roemerianus juncus.* Similarly, studies reported by [52] showed that sludge from marine aquaponic systems is suitable for use as fertilizer. **Table 4** shows the sludge characterization of aquaculture sludge.

Table 4 shows that aquaculture wastewater contains high concentrations of COD. High organic materials in aquaculture wastewater come from fish faeces, dead organism corpses, and uneaten fish pellets [49]. High concentrations of organic matter in sludge can cause water pollution, especially the eutrophication phenomenon if organic matter is released directly to the body of water. Aquaculture sludge also contains a large amount of high nutrients (nitrogen and phosphorus). Sludge can cause pollution when released directly to the body of water. However, if the concept of acquiring organic or nutrients is pre-applied, sludge resulting from aquaculture wastewater treatment has the potential to be used as fertilizer.

The use of bioflocculant will result in highly biodegradable contaminants. The current trend also shows the potential for use of sludge produced from aquaculture wastewater treatment as soil/fertilizer conditioner. Organic fertilizers increase root growth due to improved soil structures, promote soil aggregates, increase cation exchange capacity. Organic fertilizer acts as a buffer agent against fluctuation of pH of soil [60]. Through comparison of the sludge characterization in **Table 3** with the fertilizer content in **Table 4**, indicates that aquaculture sludge has approximately the same characteristics to organic fertilizers. This leads to the potential for usage of aquaculture sludge as an organic fertilizer. The nutrient content and value of fertilizers depend on fish feed sources, aquaculture effluent collection and storage methods, and aquaculture systems [61].

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Table 3. Types of chemical fertilizers and organic fertilizers.

Steel Type	Name	Nitrates (%)	Phosphorus (%)	Potassium (%)	Reference
Chemical	Ammonium Nitrate	34	-	-	US EPA (2000)
	Ammonium Sulphate	21	-	-	
	Urea	46	-	-	
	Potassium nit	13	-	45	
	Potassium sulphate	-	-	50	
	Potassium chloride	-	-	60	
Organic	Vermicompost	1.99	3.02	1.26	[10]
	Mushroom compost	1.65	2.27	1.81	
	Steel compost faeces chicken	1.71	2.03	2.81	
	Compost remaining fish	11.4	3.07	3.75	[59])
	Aquaculture sludge	1.27	0.32	0.65	[58]

Table 4. Characterization of aquaculture sludge

Parameter	Units	[55]	[56]	[57]	[58]
pH	-	6.65	6.50	7.9	-
Ammonia (NH_3-N)	(mg/L)	10.70	-	181	-
Nitrite (NO_2 −-N)	(mg/L)	0.27	5	0.10	-
Nitrates (NO_3 −-N)	(mg/L)	0.7	-	-	-
Total solids (TS)	%	-	5	-	-
Total suspended solids (TSS)	(mg/L)	-	57450	8700	3066.67
COD	(mg/L)	-	17480	6000	64197.53
Number of Ammonia Nitrogen (NH_3-N^{-1})	(mg/L)	-	110	705	0.44
Number of phosphorus	(mg/L)	-	-	135	0.44

According to a study conducted by [61], aquaculture effluent is suitable to be used as compost steel. This is because the earthworms used during the vermicompost process can have the potential to decompose various types of organic materials that exist in aquaculture waste. This will provide stability to decomposed organic matter of aquaculture sludge. [61].

CONCLUSIONS

There are many local Malaysian plants that could potentially be used as bioflocculant. The effectiveness of bioflocculant from *Moringa oleifera* seeds and leaves, Neem leaves, banana stem and pandan leaves were studied. The results showed that *Moringa oleifera* seeds recorded the highest percentage of turbidity removal at 34.84% and the percentage of suspended solid removal at 37 % higher compared to another bioflocculant. Previous studies have characterized sludge derived from aquaculture wastewater in terms of the content of nitrate, phosphorus, and potassium. The sludge contained nitrate at 1.27 %, phosphorus at 0.32 % and potassium at 0.65 %. Sediments produced through aquaculture effluent treatment has high nutrient content and has the potential to be used as fertilizer in line with the concept of nutrient acquisition. Through the concept of nutrient acquisition, fertilizers produced from aquaculture wastewater deposits can compete with commercial fertilizers. Further research should be carried out to study the suitability of sediment produced as organic fertilizer.

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