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Potency of Biocoagulant from Cationic Modified Starch of Balbis Banana Blossom Waste for Palm Oil Wastewater Treatment: Literature Study

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Abstract

Lampung is one of the provinces producing Indonesia's second-largest banana crop. Operational activities at the Palm Oil Mill produce a by-product of Palm Oil Mill Effluent (POME), which can potentially be the most enormous environmental pollution. Communities often use chemicals to treat liquid waste, which causes health problems, cannot be decomposed, and can damage the environment. Therefore, treating liquid waste using organic materials that are more environmentally friendly, safe for health and easily degraded is necessary. By modifying cationic starch, natural polymers found in banana blossom waste may be utilized for producing natural biocoagulant that are more effective. This paper aims to review the potential of cationic-modified balbis banana blossom waste starch as a natural biocoagulant for processing palm oil waste. Starch was first modified into cationic starch by etherification method with the help of HMMAHC cationic reagents. The mechanism of cationic starch as a biocoagulant is the exchange of starch cation ions and waste anions to form bridges between colloidal particles and then form flocs that can precipitate. The implementation technique of this idea is by collaborating with several parties to ensure the successful use of banana hump starch as a biocoagulant material, providing support and facilities for the industry and promoting the use of biocoagulant, conducting literature studies related to the use of banana hump starch as a natural biocoagulant, testing the effectiveness of biocoagulant, implemented in the palm oil processing industry.

Keywords: banana blossom; biocoagulant; cationic starch; POME.

INTRODUCTION

Indonesia is home to a predominant presence of banana plants, and one of its prominent regions for banana cultivation is the province of Lampung. Lampung is the second-largest banana-producing province in Indonesia, owing to its highly conducive geographical location, making it suitable for banana cultivation. According to data from the Central Agency on Statistics (2018), the Province of Lampung has yielded a total banana production of 1,438,559 thousand tons in 2018. Bananas are considered one of the tropical fruits that can be processed into food products or consumed fresh. Commonly utilized parts of the banana plant include the fruit pulp, the banana heart, and its leaves, while other parts, such as the blossom, often need to be addressed or treated as waste. Disposing this waste directly into the environment can lead to pollution, threatening the environmental balance (Hanifah et al., 2020). Hence, further processing is necessary to mitigate this pollution factor.

Palm Oil Mill operations produce primary products such as Palm Kernel Oil (PKO), Palm Kernel (PK), and Crude Palm Oil (CPO), as well as byproducts such as liquid waste, solid waste, and emissions released directly into the atmosphere (Ibe et al., 2014). According to Ibe et al. (2014), Palm Oil Mill Effluent (POME), a sort of liquid waste, is recognized as one of the primary waste streams from the palm oil processing sector with the most significant potential for adverse environmental effects. The potential of liquid waste pollution also arises from the sheer quantity of the generated waste, with the required water around 5-7.5 tons per ton of crude palm oil produced, and more than half of it ended up as POME. Bala et al. (2014) reported that POME consists of a viscous brownish liquid with a high-water content (95-96%), oil content (0.6-0.7%), and total solids content (4-5%), primarily derived from fruit debris, and exceptionally high Chemical Oxygen Demand (COD) (COD values frequently exceeding 80,000 mg/L) and Biochemical Oxygen Demand (BOD) values.

Communities commonly consider this, frequently using chemical substances to treat liquid waste, often requiring a conscious understanding of their potential side effects. For example, using aluminium sulfate in specific quantities and durations can lead to human health disturbances and environmental damage (Dwi & Gusmawarni, 2021). Therefore, there is a need to treat liquid waste using organic materials as coagulants to replace the role of chemical coagulants. This approach is safer for the environment, readily biodegradable naturally, and more cost-effective. Banana blossom are considered natural polymers with the potential for development in various industries due to their high starch content. Asni (2015) states that the starch content varies across different types of banana blossom. For instance, kepok banana *Musa acuminata* × *balbisiana*) blossom contain 64.20% starch, 'mas' banana (*Musa acuminata* Lady Finger) blossom contain 67.80% starch, and balbisana banana (*Musa balbisana*) blossom contain 69.13% starch. In order to improve the efficiency of coagulants, the modification of cationic starch modification is needed.

In this context, an alternative idea emerges regarding one of the preferred solutions, namely the use of synthetic natural coagulants, including the utilization of biocoagulant derived from natural materials such as banana blossom waste. This waste has often been considered an underutilized resource despite its potential for more cost-effective and environmentally friendly liquid waste treatment. The combination of these materials is intended to enhance the performance of the substances used and address the shortcomings of coagulants or flocculants derived from synthetic sources through an etherification process facilitated by cationic reagents.

This paper aims to review the potential of cationic-modified balbis banana blossom waste starch as a natural biocoagulant for processing palm oil waste.

METHODS

The method used is an effective literature review following the discussed topic. The method of discussion is based on the research results found by previous study, which are then integrated with other researchers to get solid results and conclusions.

RESULTS AND DISCUSSION

Environmental Issue in Palm Oil Industry

Social issues commonly faced by palm oil companies involve the disposal of liquid and solid waste into rivers, which has garnered serious attention from the Indonesian public and government due to its highly detrimental impact on aquatic ecosystems. Liquid waste from the palm oil industry is a significant pollutant that can cause adverse environmental effects, particularly within water bodies (Chan et al., 2013). The liquid waste generated by the palm oil processing industry is known to be filled with highly concentrated pollutants, resulting in elevated pollution levels in the water, with the lowest recorded Total Suspended Solid (TSS) concentration being 5473 mg/L (Putra, 2014). The pollution of water bodies stems from the activities of large-scale palm oil plantations operating in the vicinity. Land clearing activities lead to the transport of suspended solids, a product of erosion during rainfall events. Increased turbidity occurs due to the suspended particles resulting from erosion, which obstructs the penetration of sunlight into the water and reduces the intensity of photosynthesis, consequently impeding phytoplankton growth.

Considering the high annual production, there is a significant likelihood that the generated waste is substantial, which can impact river water quality, making it cleaner. A coagulant is one of the supplementary substances that can be utilized in clean water treatment. Coagulant is a chemical compound added to water to precipitate colloidal particles that are difficult to remove. Using coagulants in the coagulation process aims to eliminate charges by compressing or eliminating the diffused layer, leaving only attractive forces among particles (Prihatinningtyas, 2013). Commonly used coagulants are synthetic, also known as chemical coagulants, such as alum and polyaluminium chloride (PAC). Some studies have also indicated that alum compounds can trigger Alzheimer's disease (Putra et al., 2019). Monomers present in some synthetic organic polymers, such as PAC and alum, are known to possess neurotoxic properties (Hendrawati et al., 2013).

There is increasing interest in developing natural materials as coagulants due to several advantages, including biodegradability, human safety, and cost-effectiveness. According to Prihatinningtyas (2013), natural coagulants are readily available as they can be extracted from natural occurring sources, such as plants and animals, including banana plants (*Musa acuminata*). The high banana production in Lampung Province generates waste in the form of banana peels, stems, leaves, and stalks. Therefore, using banana peel starch as a natural biocoagulant could be an alternative for environmentally friendly palm oil waste treatment.

Banana Blossom Starch Potency as Biocoagulant

Starch is a polysaccharide made up of amylose and amylopectin. Amylose is a glucose polymer with a linear structure joined by α-1,4 glycosidic linkages, whereas amylopectin has a branching structure with α-1,6 links (Niken & Adepristian, 2016). Balbis banana is a commodity that contains a significant amount of starch, especially in its unused blossom, with a starch content of 69.13% (Nofiandi et al., 2019).

Starch can be used to treat agro-industrial wastewater, especially palm oil mill effluent, as a coagulant.

However, before the application, starch needs to undergo physical or chemical modification because, if not modified, it will remain suspended in water, causing turbidity. Therefore, a starch modification process is required to enable its use as a natural coagulant. One of the modification methods that can be employed is the use of cationic starch. Positive ions have been introduced into cationic starch using functional groups such as amino, imine, ammonium, phosphonium, or sulfonium (Din et al., 2015). Consequently, quaternary ammonium groups are formed on the starch, making the modified starch capable of adsorbing anionic compounds. Researchers have widely employed this method to remove various ions and organic pollutants from wastewater (Simanaviciute et al., 2017). Furthermore, cationic starch synthesis is relatively cost-effective, exhibits effective coagulation properties, and is readily biodegradable (Oladoja, 2015).

Synthesis of Cationic Starch

Cationic starch synthesis is carried out through etherification with the assistance of a cationic reagent. One of the cationic reagents that can be used is hydroxymethyl dimethylamine hydrochloride (HMMAHC). The consideration for using HMMAHC is based on several advantages, including its cost-effectiveness, ease of preparation, and high electrophilic reactivity (Jiang et al., 2010).

The synthesis of cationic starch is performed using the dry mixing method developed by Jiang et al. (2010). The process begins with preparing HMMAHC, where a formaldehyde solution is introduced into a flask and stirred. Subsequently, dimethylamine is added slowly over 30 minutes. Dihydroxymethylation is achieved by gradually adding hydrochloric acid over 30 minutes until HMMAHC ($HO\text{-}CH_2\text{-}N(CH_3)_2\text{-}HCl$) is obtained. HMMAHC is then vigorously stirred to ensure a perfect reaction. The temperature is maintained at 5-10°C during the reaction process.

Next, the synthesis of cationic starch involves mixing banana blossom starch, HMMAHC, and water. The water removed by using a rotary vacuum evaporator (60°C) until achieved a constant weight. The mixture is then dried in an oven at high temperature until completely dry. After reaching room temperature, Soxhlet extraction with ethanol for 24 hours can be used to extract the product. The subsequent step involves separating chromatography to isolate cationic starch while removing unreacted HMMAHC and other by-products.

Sen et al. (2017) demonstrating synthesis of cationic starch using base catalyst. Cationic starch is produced by adding a positively charged group to the hydrogen atom of the starch hydroxyl group, using NaOH as a base catalyst. In a reaction flask, add 5 grams of corn starch, 2.5 grams of GTAC (glycidyl trimethyl ammonium chloride) as a cationization reagent, 1.5 mL of 1 mol/L NaOH solution, and 1.625 mL of distilled water. Then, all reactants in the flask are agitated for 5 hours in a water bath at 60°C. When the reaction is finished, 100 mL of ethanol is added to the flask, allowing the cationic starch to precipitate. To remove unreacted GTAC and NaOH, the cationic starch is vacuum-filtered and rinsed twice using ethanol. The final product is dried for 6 hours in an oven at 50°C. The resulting white cationic starch is subsequently ground into a fine powder.

Coagulation Mechanism

The structure of cationic starch can effectively function as a coagulant through charge neutralization and interparticle bridging. The mechanism of cationic starch absorption of anionic pollutants involves physical adsorption and ion exchange, and it possesses a high adsorption capacity, allowing anionic pollutants to be absorbed into the cationic sites on the surface. Long-chain polymers of polysaccharide molecules are adsorbed onto the surface of colloidal particles. The unadsorbed "tails" on these colloidal particles can adsorb other colloidal particles, thereby bridging between colloidal particles and forming flocs that can settle (Kristianto et al., 2020). Tran et al. (2022) reported regarding the application of cationic starch and polyaluminum chloride in wastewater flocculation processes, cationic starch successfully forms bridges to facilitate the aggregation and settling of colloidal particles. Additionally, cationic starch can treat a significant amount of nitrogenous and phosphorus compounds in wastewater. The mechanism illustrated in Figure 1.

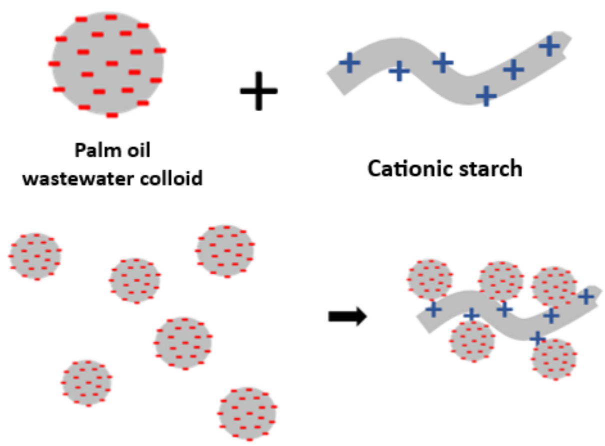

Figure 1. Illustration of interparticle bridging mechanism.

Further Implementation

Using starch as a biocoagulant material can be implemented by various stakeholders involved in waste management. To realize this concept, the involvement of the government, particularly the Ministry of Environment and Forestry, palm oil processing industries, waste management service providers, banana plantation owners, and banana farmers is essential. Industries can leverage this concept to enhance waste treatment efficiency and reduce its adverse environmental impact. The government can provide support and facilities to the industries and promote using starch-based biocoagulant as an environmentally friendly and sustainable waste treatment alternative. Banana farmers can also adopt this concept by utilizing banana blossom waste, often considered waste, to produce biocoagulant that can be sold to wastewater treatment companies or other industries.

CONCLUSIONS

One of the sources of water pollution is liquid waste from the palm oil industry. This waste is generated due to palm oil plantation activities carried out by several large-scale industries around these water bodies. Coagulants are chemical substances used in water to precipitate colloidal particles that are difficult to remove. Using coagulants in the coagulation process aims to destabilize charges by reducing or eliminating the diffused layer, leaving only attractive forces between particles (Prihatinningtyas, 2013). Using natural materials as coagulants is being increasingly explored due to several advantages, such as biodegradability, human safety, and improved economic aspects.

Banana plants, especially banana blossom, can be used as natural coagulants. The province of Lampung, which has a high banana production rate, generates waste in the form of banana blossom, stems, leaves, and peels. Therefore, using starch from banana blossom as a natural biocoagulant can be an environmentally friendly alternative in palm oil waste treatment.

This plan has a high likelihood of success in using banana blossom starch as a biocoagulant material. Lampung can serve as a pilot region for this concept's implementation, given that it is the second-largest banana producer in Indonesia. Parts of banana plants, like banana blossom, are often overlooked or considered waste. Advanced treatment is required to prevent environmental pollution resulting from this neglect. One solution is to use organic materials as coagulants in wastewater treatment, which can replace the role of chemical coagulants. This is expected to create a safer and environmentally friendly environment and facilitate natural degradation. Banana blossom are natural polymers with high starch content and can be developed for various industrial purposes. This concept is expected to address the pollution issues occurring in Indonesia and benefit all stakeholders.

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