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Yellow Sweet Potato (*Ipomea batatas (L.) lam*) Residue as a Biocoagulant for Wet Market Wastewater Treatment

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***Abstract*—** *This study investigated the potential of Yellow Sweet Potato (Ipomea batatas (L.) Lam) Residue as an eco-friendly biocoagulant for treating high-strength wastewater from Magay Public Market in Zamboanga City. The study aimed to determine the optimum dosage of YSPR and evaluate its effectiveness in reducing turbidity, biochemical oxygen demand (BOD_5), and total suspended solids (TSS) compared with aluminum sulfate. YSPR was prepared by washing, drying, and grinding residues into fine powder and applied in jar tests at dosages of 50, 100, 150, 200, 250, 300 mg/L. Quadratic regression analysis modeled the relationship between dosage and turbidity reduction, producing the equation $y = 0.0153x^2 - 5.977x + 1106.85$. The model showed a U-shaped curve, indicating decreasing turbidity up to an optimum point before increasing due to overdosing. The vertex method identified an optimum dosage of approximately 195.3 mg/L, closely matching the experimental minimum near 200 mg/L.The raw wastewater recorded 1,076 NTU, 3,250 mg/L BOD_5, and 380 mg/L TSS. At optimum dosage, YSPR achieved removal efficiencies of 41.26% (turbidity), 30.15% (BOD_5), and 15.26% (TSS). One-way ANOVA confirmed a significant dosage effect on turbidity reduction ($F = 48.13$, $p < 0.05$). However, aluminum sulfate achieved over 94% turbidity removal, indicating higher efficiency. These findings show that YSPR has moderate but predictable coagulation performance with an optimal range of 195–200 mg/L. Further research is recommended to improve solubility, enhance active compounds, combine with other coagulants, optimize mixing and settling conditions, extend coagulation time, and conduct pilot-scale studies for real-world application.*

***Keywords*—** *Aluminum Sulfate; Biochemical Oxygen Demand (BOD_5); biocoagulant; coagulation; Ipomoea batatas (L.) Lam; natural coagulant; Total Suspended Solids (TSS); turbidity removal; wet market wastewater; yellow sweet potato residue.*

I. INTRODUCTION

1.1 Background of the Study

Water is the most essential resources for life. It sustains supports economic activities and is crucial to human health and development. The need for water in household and industrial activities is still increasing every year. Water management has become a major environmental challenge in the Philippines. The country's population grew from approximately 109 million in 2020 to nearly 113 million in 2024, with an average annual growth rate of around 0.8% (Philippine Statistics Authority, 2025). This growing pressure has led to serious pollution in rivers, lakes, and coastal areas putting both the environment and public health risk (Dela Rosa, 2024). The challenge of managing and treating wastewater has become increasingly urgent.

Wet markets play an important role in supplying fresh food to growing urban populations but they also produce large amounts of wastewater from activities such as slaughtering, fish cleaning, and washing meat and vegetables (FAO, 2020). This wastewater carries high levels of organic matter, fats, oils, detergents, and microbes that can pollute nearby waterways if not properly treated (WHO, 2021). Many facilities use chemical coagulants like alum and ferric chloride to remove these pollutants, but these chemicals can create sludge, leave residues, and are often too costly for markets with limited resources (Edokpayi et al., 2020).

Coagulation is the essential step in wastewater treatment that involves adding coagulants to disrupt and destabilize colloidal particles, encouraging them to clump together so they can be more easily separated and removed from water. This process plays a crucial role in reducing turbidity and removing contaminants from wastewater, thereby improving water quality (Bratby, 2016). Biocoagulants and bioflocculants offer a promising alternative to reduce environmental pollution and health hazards linked to chemical coagulants and flocculants. From natural sources, these substances are fully organic and biodegradable making them eco-friendly and safer for human health (Kurniawan et al., 2020).

One such promising material is yellow sweet potato residue, mainly peels which contains bioactive compounds such as starches, proteins, and polysaccharides capable of aiding in the coagulation process. Utilizing yellow sweet potato residues as a biocoagulant presents an environmentally friendly and cost-effective alternative to conventional chemical coagulant.

Sweet potato peel (SPP) has been studied as a natural coagulant for cleaning up dirty water. An existing study focused on the use of sweet potato peel (SPP) as a coagulant in different forms (single, dual, and composite) under varying pH conditions to treat sewage wastewater. SPP was used to look at how well it could reduce COD, TSS, and Ammoniacal Nitrogen to treat sewage water (Shaylinda et al., 2024).

In contrast, the present study focuses on the biocoagulant potential of yellow sweet potato residues (YSPR) for wet market wastewater (WMWW) treatment from activities such as fish cleaning, washing meat and vegetables. Dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L and 300 mg/L to assess its efficiency and will be tested to determine the best turbidity reduction performance. The study aims to evaluate how effectively YSPR can remove TSS, reduce BOD_5, and improve water clarity compared to conventional aluminum sulfate coagulant.

1.2 Statement of the Problem

Wet markets generate large volumes of wastewater that contain blood, oils and grease, food particles, soap residues, and various microorganisms. This type of wastewater can contribute to unpleasant odors, clogging issues, contamination of nearby environments, and potential public health concerns due to its high organic and microbial content. Although modern treatment technologies are available, they are often costly and difficult for local markets to operate and maintain. This situation creates a need for simple, low-cost, and environmentally friendly methods to improve the quality of wet market wastewater. However, studies evaluating natural coagulants for this specific type of wastewater remain limited.

This study aims to evaluate the effectiveness of yellow sweet potato residues from peeling left over in improving wet market wastewater quality and to determine whether they could serve as a practical, eco-*friendly alternative to chemical coagulants.*

1.3 Objectives of the Study

This study explores the use of YSPR as a biocoagulant. This study aims to present *a sustainable coagulant for treating WMWW. This study aims to:*

1. Determine the turbidity removal efficiency of YSPR biocoagulant at six dosages: 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L in treating WMWW.
2. Identify the optimal dosage of YSPR and Aluminum Sulfate based on the highest turbidity removal efficiency.
3. Determine the removal efficiency of TSS and BOD_5 of YSPR and aluminum sulfate at their respective optimal dosages in treating wet market wastewater.
4. Compare the effectiveness of YSPR biocoagulant and aluminum sulfate in the treatment of wet market wastewater based on their removal efficiencies for turbidity, TSS, and BOD_5.

1.4 Significance of the Study

The significance of this study lies in a new and natural way to help treat WMWW using something as simple as yellow sweet potato residues. The research looks at how the natural properties can help remove dirt and particles from used water instead of letting these residues go to waste. Wet market wastewater treatment is important especially in places where clean water is limited and expensive. If yellow sweet potato residues proves to be effective, it could offer a cheaper and more environmentally friendly treatment option compared to chemical treatments. This could make a big difference for communities that need affordable water solutions. This research helps reduce waste and supports the idea of reusing natural resources in smart and useful way and at the same time, contributes to the development of greener treatment for water while promoting more practical water treatment options.

1.5 Scope and Delimitation

This study investigates the effectiveness of yellow sweet potato residues as a biocoagulant for treating wet market wastewater which contains high levels of organic matter, suspended solids, and pollutants from activities such as stall washing, meat and fish cleaning, and produce preparation. The research focused on determining the optimum dosage of the biocoagulant using turbidity measurements. Jar test procedures were conducted at varying dosages and a turbidity meter was used to identify the dosage that produces the lowest turbidity value. This dosage were identified as the optimum.

Only the optimum dosage underwent further laboratory analysis for BOD_5 and TSS to confirm its overall treatment performance. Other dosage levels were subjected to these laboratory tests.

The study is limited to the use of yellow sweet potato peel residues as the sole biocoagulant material. The peels were thoroughly cleaned prior to processing to ensure consistency and to minimize interference from unwanted impurities. The research did not include comparisons with other sweet potato varieties and does not assess microbial contaminants or additional water quality parameters beyond turbidity, BOD_5, and TSS. Furthermore, the study utilized only one influent (raw wastewater) sample which may not fully represent variations in wastewater characteristics over time. In addition, only two trials were performed for each dosage level which may limit the statistical reliability of the results but is considered sufficient for preliminary evaluation.

For aluminum sulfate, only a single trial per dosage level was conducted since its coagulation efficiency and effective dosage range for approximately 50-*300 mg/L (Sharma, 2023).* This demonstrates consistent and well-documented performance under similar wastewater conditions. This approach was intended to serve as a comparative reference for the experimental biocoagulant rather than a full optimization analysis.

II. Review Of Related Literature

2.1 Wet Market Wastewater and its Characteristics

Wastewater from fresh produce, vegetable, and meat stalls usually contains high levels of nutrients and pollutants, including COD, BOD, and suspended solids. Because of this, releasing wet market wastewater directly into rivers or other natural water bodies can significantly increase pollution levels and harm the environment (Jais et al., 2016). Wet market wastewater has been identified as a serious risk to human health because it often contains harmful bacteria that can cause infections or trigger allergic reactions Lin (2021). This problem becomes more concerning in markets without proper wastewater treatment systems, where untreated wastewater is directly released into the surroundings. Studies show that wet market wastewater typically contains high levels of contaminants, including BOD, COD and nitrogen indicating strong organic pollution. Research also reports the presence of heavy metals, mainly because wet markets handle activities such as seafood cleaning, meat cutting, and poultry slaughtering, which release metal residues into the wastewater (Kassim et al., 2019). To prevent environmental pollution and protect public health these contaminants must be properly removed before the wastewater is discharged.

Wet markets in Cagayan de Oro City are often surrounded by unclean conditions, mainly because wastewater is not properly handled. To understand the quality of wastewater in these markets, a study was conducted to analyze the physicochemical properties of wastewater collected from the Agora, Carmen, and Cogon Public Markets over a three-month period (January-March 2015). The results were compared with the standards set by the DENR through the DAO. The study found that temperature, pH, DO, and salinity of the wastewater were within acceptable limits. However, TDS conductivity, and turbidity were significantly high, indicating poor wastewater quality (Degracia et al., 2016). Because of this, the study recommends that public markets improve their waste management practices and treat wastewater before disposal to protect nearby water bodies.

Wet market wastewater is often released into the environment without any treatment, which can negatively affect both aquatic environments and human health. Studies show that wet market and other wastewaters commonly contain heavy metals such as lead (Pb), zinc (Zn), cadmium (Cd), mercury (Hg), and chromium (Cr). These metals are dangerous because they can easily dissolve in water and enter the aquatic food chain, where fish, seafood, and even vegetables can absorb them. Heavy metals also do not break down, meaning they can remain in the body for a long time once consumed. For example, too much zinc (Zn) can cause health problems like skin irritation, vomiting, and stomach pain (Gani et al., 2022).

A study examined nutrient pollution in wastewater coming from wet markets and found that this type of wastewater contains very high levels of nutrients, particularly nitrogen and phosphorus. These nutrients mainly come from activities such as washing meat, fish, and vegetables. Their study showed that when this untreated wastewater is released into the environment, it can contribute to water pollution and eutrophication, which reduces water quality and affects aquatic life. The findings highlight the need for proper wastewater treatment in wet markets to prevent environmental contamination (Phan et al., 2017). Another case study on the Muntinlupa Public Market reported that wastewater coming from the wet section of the market specifically the meat, fish, and poultry areas had an average BOD of about 600 mg/L before treatment. This value is much higher than typical domestic wastewater, showing that market wastewater is considered high-strength and requires proper treatment to reduce its pollution load (RTI, 2006).

Wet market wastewater is characterized by high organic pollutants (BOD/COD), suspended solids, fats and grease, nutrients (nitrogen and phosphorus), and pathogenic microorganisms. These pollutants originate from fish and meat washing, melting ice, stall cleaning, and vegetable handling. Studies consistently show that wet market effluents are among the strongest types of municipal wastewater (Nasrullah et al., 2016), often surpassing typical domestic wastewater loads (Amoah et al., 2019). The wastewater's composition makes it challenging to treat and necessitates effective primary treatment, grease removal, and biological processes for pollution reduction.

2.2 Coagulation

The coagulation and flocculation process is a common and reliable way to clean industrial wastewater. It's used to remove dyes, heavy metals, organic substances, and tiny particles that don't settle easily on their own (Badawi, 2023). People use this method because it's simple, cost-effective, and can be easily improved when needed. The process works by adding special substances called coagulants and flocculants. These can be chemicals or natural materials. Coagulants like aluminum sulfate, ferric chloride, or polyaluminum chloride help by neutralizing the electrical charges on the tiny particles, so they stop repelling each other (Morales, 2025). These compounds help neutralize the charges on suspended particles which causes them to stick together (Kumar et al., 2017). Then, flocculants such as polyacrylamide or chitosan help stick those neutralized particles together into bigger clumps (called flocs). This method helps turn hard-to-remove stuff in dirty water into larger pieces that can be easily taken out making the water cleaner and safer (Salama et al., 2023).

Coagulation is an essential part in treating wastewater for removing tiny particles and pollutants that are suspended in water (Ang et al., 2020). After the coagulation stage, sedimentation or filtration can remove these aggregated pollutants such as reducing turbidity, TSS, COD, and other contaminants (Babu et al., 2020). Researchers have focused extensively on optimizing the coagulation process by adjusting factors such as the type and amounts of coagulants used and settling time. These parameters influence how well the particles clump together and settle out.

Coagulation is a highly effective and practical method for treating various types of wastewaters. It helps remove tiny particles, harmful chemicals, and even color from water things that are often difficult to eliminate using other methods alone. Several scientific studies have shown that different coagulants work well for cleaning wastewater. For example, polyaluminum chloride (PAC) works better than alum and potash alum in removing dirt and chemicals from municipal wastewater, greatly reducing cloudiness and suspended particles (Dhanjal et al., 2018). Magnesium hydroxide is also effective, especially for wastewater that contains dyes. As the dose increases, it removes more cloudiness (Li et al., 2016). Ferric chloride is very good at removing color from palm oil mill wastewater, achieving up to 80% removal when the right dose and pH are used (Zahrim et al., 2017). Coagulants have been shown to perform very well under the right conditions. These substances not only improve water clarity but also make the entire treatment process faster and more efficient. Coagulation continues to be an essential step in modern water treatment system because of its affordability and works across many kinds of water (Mohamed et al., 2023).

2.3 Aluminum Sulfate

Alum is commonly used in both municipal and industrial wastewater treatment to help remove suspended solids, phosphorus, and other pollutants (Taki, 2023). Aluminium sulphate is the most commonly used aluminium-based coagulant in water treatment. It comes in different solid forms like blocks, granules, or powder and can also be used as a liquid solution. In many water treatment plants, aluminum sulfate is often called "alum,". When added to water, it reacts and forms aluminum hydroxide, a substance that clumps together tiny particles floating in the water. These clumps get heavy and sink to the bottom, making the water clearer. This process is really helpful in wastewater treatment plants where the water can be full of dirt, bacteria, or other harmful contaminants.

Alums are commonly used at the start of water treatment to help remove things like cloudiness (turbidity), color, organic matter, and microorganisms from raw water. Alums are quite effective at cleaning up the water by getting rid of particles and dirt. However, using alum can sometimes leave behind too much aluminum in the treated water. This usually happens if the dosing is not right and if the coagulant is not being used efficiently, or if something's off in the treatment process itself (Janvier, 2021). Some studies have raised concerns about traces of aluminum left in treated water suggesting a possible link to Alzheimer's disease (Díaz, 2024). Because of these potential risks, it's important to carefully control the amount of aluminum sulfate used and to monitor aluminum levels in treated water to ensure it stays safe for consumption (World Health Organization, 2011).

2.4 Biocoagulants

Biocoagulants are natural substances used to clean water by helping small dirt particles clump together so they can be removed more easily (Ahmed et al., 2025). Unlike many chemical coagulants, they are made from plants, animals, and other natural sources which means they are generally safer for people and the environment. They do not leave harmful residues in the water and reduce the risk of long-term damage to ecosystems because they are less toxic. Using biocoagulants is a more sustainable choice since they are often renewable and cause fewer side effects compared to synthetic chemicals (Balbinoti, 2023). This makes them a good alternative for communities that want cleaner water without harming nature.

Biocoagulants are now being studied as a safer option to replace chemical coagulants in treating water and wastewater (Kurniawan et al., 2021). They can help remove pollutants like turbidity, suspended solids, color, and organic matter. Among the different types, plant-based biocoagulants are considered the most promising because they are easy to find and give consistent results (Kumar et al., 2021). The active compounds in plants need to be properly extracted to make them effective. This process usually involves drying and grinding the raw materials, followed by extraction and purification. The steps of drying and grinding play an important role because they reduce moisture and improve the contact of the biocoagulant with water during treatment which increases its performance (Kurniawan et al., 2023).

Plant-based coagulants and flocculants are seen as a green technology for wastewater treatment and they are effective in taking out suspended solids from the water. These natural materials help small particles come together and settle which makes the water cleaner and safer to use (Alnawajha et al., 2022). Even though many studies have described the features of biocoagulants and bioflocculants, there are still research on the exact compounds that make coagulation and flocculation work and how these compounds affect the process (Owodunni et al., 2022).

2.5 Yellow Sweet Potato

Sweet potato, locally called "camote" and scientifically known as *Ipomoea batatas L.*, is often referred to in the Philippines as the poor man's crop. It is a highly nutritious food that people eat both as a staple and as a vegetable. For many years it was only seen as a small source of extra income for farmers, but today it has grown into an important livelihood crop. The demand for sweet potato continues to rise because it can be processed into many products such as flour, snacks, wine, and even animal feed. This growing market not only provides farmers with better income but also shows the versatility and value of sweet potato in food, agriculture, and wastewater treatment potential.

Ipomoea batatas, or sweet potato, had an annual production of about 9 million tons and covered a cultivated area of 110 million hectares according to Food and Agriculture Organization (FAO) in 2009. More than 95% of the world's sweet potato supply comes from developing countries where it ranks as the fifth most important food crop when measured by fresh weight. It is widely grown in rural areas because it can thrive even in poor soil and requires fewer inputs compared to other crops.

YSPRs are the main waste materials left after processing the tubers. These residues, mainly peels are actually rich in nutrients, bioactive compounds, and other valuable substances (Wang, 2024). YSPRs actually contain many useful compounds that make them promising for water treatment. What makes them special is their high starch and dietary fiber content. After starch extraction, the peel residue still contains about 61.6% starch made up of cellulose, pectin, hemicellulose, and lignin (Zhang et al., 2021). These natural fibers have strong water-holding and oil-holding capacities (up to 6.1 g water per gram and 2.5 g oil per gram), which means they can trap suspended particles found in wet market wastewater (Wang et al., 2010).

YSPR are rich in bioactive compounds such as phenolic acids, carotenoids, and anthocyanins. For example, purple sweet potato peels can contain up to 229 mg of anthocyanins per 100 g, while white varieties are rich in phenolic acids like caffeic and cinnamic acid (over 400 mg per 100 g) (López et al., 2025). These compounds are not only strong antioxidants but also show antimicrobial activity, which could help reduce bad odors and microbial growth in wastewater. The combination of starch, pectin, cellulose, and natural antioxidants makes sweet potato peels (SPPs) effective natural coagulants.

YSPPs which are residues of sweet potato are best for water treatment because they contain high levels of starch and pectin, have strong water- and oil-holding capacity which is ideal for WMWW with oils and soaps, and are safe, cheap, and sustainable (Kwok et al., 2010). These residues are rich in starch, which can make up more than 60% of the dry weight of peel residues. The starch and fibers help clump together suspended solids and oils, while the phenolics and anthocyanins add extra antimicrobial and antioxidant effects (Zhang et al., 2021).

2.6 DENR Administrative Order No. 2016-08

DAO 2016-08 sets the Water Quality Guidelines and General Effluent Standards of 2016 in the Philippines. It establishes the allowable limits for pollutants in water bodies and wastewater discharges to protect public health and maintain environmental quality.

In this study, the water quality will be assessed based on the beneficial use classification set by the Department of Environment and Natural Resources (DENR) Administrative Order No. 2016-08.

The study will ensure that the performance of yellow sweet potato residues (YSPRs) as a biocoagulant is measured against nationally recognized water quality standards by aligning the evaluation with this classification.

TABLE 2.1. *Effluents Standards Guideline for Primary Parameters*

Parameter	Unit	Water Body Classifications				
		AA	A	B	C	D
BOD	mg/L	NDA	20	30	50	120
Total Suspended Solid	mg/L	NDA	70	85	100	150

Source Table 9. DAO 2016-08. Effluent Standards Guideline for Primary Parameters

TABLE 2.2. *Applicable Industry Category and Parameters based on DAO 2016-08*

Industry Category	Significant Parameters
Wet markets, public markets, stalls selling meat, fish, poultry, and vegetables	pH, BOD, COD, TSS, Oil and Grease, Ammonia (as NH_3-N), Nitrate (as NO_3-N), Phosphate (as PO_4-P), Sulfide, Detergents (MBAS), Temperature, Color, Total Coliform, Fecal Coliform / *E. coli*

Source Table 8. DAO 2016-08. Significant Effluent Quality Parameters

2.7 Biocoagulants Related Studies

Determining the optimal dosage of natural coagulants is essential to maximize pollutant removal while avoiding overdosing effects such as particle restabilization or increased residual turbidity (De Andrade et al., 2022). A study evaluated sweet potato peel (SPP) as a coagulant in single, dual, and composite forms for sewage treatment. A stock solution by dissolving 3 g of SPP powder in 100 mL of distilled water then followed by gelatinization, and applied at an operational dosage of 100 mg/L during jar tests. At this dosage and an optimal pH of 9 achieved moderate removals of COD (25%), suspended solids (16%), and ammoniacal nitrogen (12%), indicating that this concentration provided sufficient starch-based polymeric chains for charge neutralization and inter-particle bridging mechanisms. Higher dosages were required for combined systems, such as 300 mg/L PAC + 200 mg/L SPP for the dual coagulant and 4000 mg/L for the composite PAC–SPP formulation, reflecting the increased coagulant mass needed to enhance multi-component flocculation efficiency. However, excessive dosages resulted in overdosing, where surplus organic polymers led to particle restabilization and poorer settling performance, consistent with previous findings (Lee et al., 2020). Studies explored starch-based coagulants similarly highlights that optimal dosages often fall within 100-150 mg/L for plant-derived coagulants, with lower doses insufficient for floc formation and higher doses leading to destabilization of flocs. A study examined the tapioca starch and cassava peel coagulants have reported optimum doses near within 100-150 mg/L range, reinforcing that around 100 mg/L is a practical and effective dosage for starch-rich biocoagulants, including SPP (Hidayat et al., 2022). These findings position 100 mg/L as the optimal working dosage for SPP alone, aligning with broader trends in natural polymer coagulant performance alternative to chemical coagulants.

In one study, sweet potato (Ipomoea batatas L.) leaf extract was tested and found to be very effective, removing over 90% of suspended particles from synthetic wastewater when the right dosage and mixing conditions were applied. The effectiveness was attributed to the natural compounds in the leaves that help bind impurities together. To support the findings, the researchers used predictive models and found that the Artificial Neural Network (ANN) was more accurate than the Response Surface Methodology (RSM) (Kusuma et al., 2021). This showed that sweet potato leaves have strong potential as a safe and eco-friendly coagulant that could be scaled up for industrial wastewater treatment.

A study focused on Hagonoy (Chromolaena odorata) was investigated for its ability to remove turbidity, total dissolved solids (TDS), and improve dissolved oxygen (DO) in wastewater. Laboratory experiments using both synthetic sewage (COPAS) and actual wastewater showed optimal coagulation at 50 mg/L, achieving 69.3% turbidity reduction in COPAS and 82.8% in real wastewater, with minimal impact on DO. FTIR analysis identified hydroxyl, carboxyl, amide, and carbonyl groups responsible for coagulation (Cruz et al., 2025). Treated sludge analysis indicated lignocellulose content and adsorption of heavy metals such as arsenic, copper, and lead, demonstrating dual pollutant removal.

Another study explored Talisay leaves (*Terminalia catappa*) have been investigated as a potential natural coagulant. The active coagulating agents were extracted using 1.0 M NaCl solution and applied to Cagayan River water with an initial turbidity of 200 NTU. Using doses of 2–5 ml/L, the 5 ml/L treatment achieved the highest turbidity removal of 88%, while pH remained stable between 7.27 and 7.46. Total coliform counts exceeded 6500 cfu/ml, indicating no antibacterial effect (Nozaleda, 2019). These results demonstrate that Terminalia catappa leaf extract effectively reduces turbidity without altering water pH, highlighting its potential as a natural coagulant for surface water treatment.

Natural coagulants are gaining attention for sustainable wastewater treatment. Corchorus olitorius L. has been studied the University of Science and Technology of Southern

Philippines for its ability to remove turbidity, total suspended solids (TSS), and biochemical oxygen demand (BOD) from domestic wastewater. Optimization using the jar test showed effective coagulation at a low dose of 50 mg/L with a settling time of 90 minutes. FTIR analysis indicated functional groups that enhance coagulation. At pH 7, removal efficiencies were highest with BOD at 89.78% (A75C25), 85.98% (A25C75), and 88.76% (A50C50); TSS at 88.50%, 85.56%, and 87.16%; and turbidity at 83.47%, 80.27%, and 80.27%, respectively (Lacang et al., 2023). Results varied significantly across treatment designs. Future studies should explore different pH levels, settling times, stirring speeds, and other operational factors to optimize performance.

A study investigated the use of banana peel waste as a biodegradable coagulant, Results showed that the removal efficiency improved when the pH was between 6 and 8. It achieved 86% removal of zinc, 96% removal of copper, and 97% removal of turbidity, while hydroxyapatite achieved 68% removal of zinc, 99% removal of copper, and 97% removal of turbidity (Benbiyi et al., 2024). The study concluded that banana peel powder is a cost-effective and eco-friendly alternative for wastewater treatment and can also promote better use of agricultural waste.

Another Chitosan-based film enhanced with moringa seed powder and bentonite have been studied for water treatment applications. Moringa seed powder reduced tensile strength, while bentonite improved it at concentrations below 15 wt%. Chitosan with 15 wt% moringa seed powder achieved 73% removal in 3 hours, while adding 10 wt% bentonite further increased removal to 83% in 3 hours and 96% in 12 hours. The films were reusable, maintaining 85% turbidity removal after five cycles without breakage, demonstrating both efficiency and durability for water clarification. (Soma et al., 2025). Chitosan, a non-toxic biopolyaminosaccharide derived from deacetylated chitin in Perna viridis shells, has been explored as an eco-friendly coagulant. Its efficacy in treating swine biogas digester effluent was evaluated under varying dosages (8 and 10 g/L) and agitation speeds (30 and 50 rpm). The extracted chitosan had a deacetylation degree of 74.65%. Optimal treatment at 8 g/L and 30 rpm significantly improved effluent quality, reducing phosphate and nitrate levels and partially lowering BOD, while pH and TSS showed no significant change (Conception et al., 2025). These results demonstrate chitosan's potential for enhancing effluent quality in compliance with water quality standards.

Another study has examined natural coagulants as alternatives for natural rubber processing. Natural rubber coagulated with 8% (w/v) citric acid showed the lowest ash and nitrogen content compared to 10% and 12% concentrations and was comparable to the standard 2% (v/v) formic acid coagulant. Plasticity retention index, dirt content, and volatile matter did not differ significantly across all coagulants, indicating similar performance (Paragas et al., 2024). These results suggest that 8% citric acid from Citrus aurantiifolia is an effective and comparable alternative to conventional coagulants for natural rubber.

A study explored the use of tamarind seed shell waste as a natural coagulant. Researchers tested different combinations of tamarind seed shell and sweet orange peel biocoagulants at varying ratios (Ratnawati et al., 2024). They found that using 1.5 grams of tamarind seed shell gave the best results, removing 51% of turbidity, 80% of BOD, and 77% of COD. This shows that tamarind seed shell can work well as a low-cost option for improving water quality.

A study tested the use of pineapple peel waste as a natural coagulant and found it effective in reducing water turbidity. The highest turbidity removal recorded was 7%, lowering the level from 40 to 11.6 NTU. Even without drying the peels or allowing a settling period, the treatment still removed about 61.69% of turbidity, which shows it can be both practical and time saving (Samah et al., 2025). The statistical results confirmed that the model used was reliable, with strong accuracy in explaining turbidity reduction. These findings suggest that pineapple peel waste can serve as a promising and eco-friendly material for producing natural coagulants.

Natural coagulants have been studied for dye wastewater treatment to reduce chemical usage and improve sustainability. Rambutan seeds (Nephelium lappaceum L.) were evaluated for their ability to lower Chemical Oxygen Demand (COD) using coagulation, with characterization by FTIR and SEM-EDX. COD removal was influenced by pH, coagulant dosage, and coagulation time. Optimal conditions occurred at acidic pH, 35 minutes coagulation, 15 minutes flocculation, and 1g coagulant, achieving up to 75.64% COD reduction (Riyanto et aal., 2024). These results indicate that rambutan seeds are an effective natural coagulant for treating dye-contaminated wastewater.

Recent research has explored rambutan (Nephelium lappaceum) seed powder as a biocoagulant compared with aluminum sulfate for greywater treatment. Using jar tests with dosages of 50-150 mg/L, the study found that rambutan seed was able to reduce pH, BOD_5, and TSS at varying degrees, with its best performance generally occurring at higher dosages (Anas et al., 2022). While alum showed slightly higher removal efficiencies overall, statistical results indicated no significant difference between alum and rambutan seed for BOD_5 and TSS, suggesting that rambutan can function as a viable natural coagulant.

2.8 Portable Turbidity Meter Apparatus

The use of turbidity meters is a common practice in water and wastewater treatment studies to assess water clarity and the concentration of suspended particles (Matos, 2024). Turbidity which is expressed in Nephelometric Turbidity Units (NTU) is an important indicator of treatment efficiency, as it reflects the amount of particulate matter present in a water sample (APHA, 2017). Portable turbidity meters provide rapid and accurate measurements across a wide range of water clarity, making them suitable for both highly turbid and relatively clear samples. Their reliability and small margin of error allow researchers to obtain values that closely represent the actual conditions of the water, facilitating consistent monitoring before and after treatment (Parsons et al., 2017). In coagulation and flocculation studies, turbidity readings are widely employed to determine the optimum coagulant dosage with the sample achieving the lowest turbidity considered to have the highest treatment efficiency (Mahmudabadi et al., 2018).

2.9 Jar Tester Apparatus

Laboratory-scale coagulation and flocculation experiments commonly utilize jar tester apparatus to evaluate the performance of coagulants in water and wastewater treatment (Sánchez et al., 2012). This equipment is specifically designed for laboratory-scale coagulation and flocculation tests, allowing multiple samples to be mixed simultaneously under controlled conditions. Each jar will contain a measured volume of wastewater and a specific dosage of coagulant. The device operates with adjustable stirring speeds to simulate the rapid mixing and slow mixing stages of the coagulation process. Rapid mixing helps disperse the coagulant evenly throughout the sample, while slow mixing promotes particle collisions and floc formation (Lacang et al., 2023). The jar tester provides consistent and repeatable conditions, making it ideal for determining the optimum dosage and treatment efficiency of the coagulant (Ligaray et al., 2023).

III. METHODOLOGY

3.1 Data Gathering

The relevant information and data for this study were gathered by thoroughly searching through books, research articles, official documents, and government guidelines available in various libraries, offices, and online resources. The DENR Administrative Order No. 2016-08 was used as reference which provides important regulations related to the topic.

In addition, other relevant materials such as scientific studies, reports, and policy documents were reviewed to deepen the understanding and support the findings of the study. This careful gathering of secondary data ensured that the study is well-informed and based on credible sources.

3.2 Location of the Experimental Study

The researcher conducted the experiment at the Zamboanga City Water District (ZCWD) laboratory located in Pasonanca, Zamboanga City. This location was selected because the jar tester required for the study was borrowed from ZCWD and the experiment was performed using their laboratory facilities. Conducting the experiment in this controlled laboratory setting allows the researcher to closely monitor and manage every stage of the experimental process to ensure accuracy and proper execution of procedures. The wastewater to be treated was collected accordingly to maintain consistency and reliability of the data used in the study.

3.3 Preparation of Coagulants

YSPR were thoroughly washed and oven-dried to remove excess moisture and impurities. The dried material was then grounded using a mechanical grinder to obtain a uniform consistency. The ground YSPR were passed through a 0.25 mm mesh sieve to produce a fine and homogeneous biocoagulant powder, ensuring consistent particle size and improved dispersion during the coagulation process.

An alum solution was prepared (see Figure 3.1) and used as the chemical control for comparison. Both the YSPR biocoagulant and alum were weighed accurately using an analytical balance to obtain the required dosages for the jar test experiments.

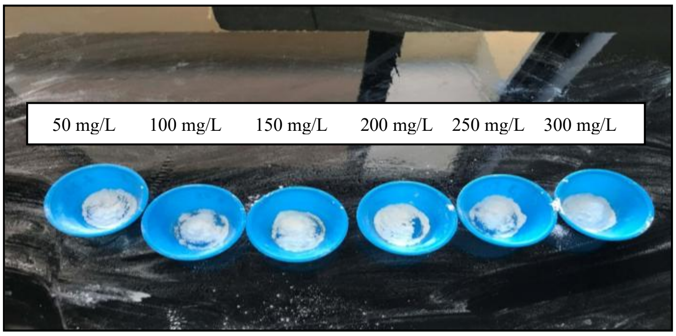

Figure 3.1 Aluminum Sulfate Coagulant at Different Dosages

3.4 Preparation of Material

The materials, tools, and equipment needed for this study were bought from different stores in Zamboanga City and online shops. The full list is shown in Table 3.1.

TABLE 3.1 *Materials, Tools and Equipment*

Quantity	Product
6 pcs.	Transparent Pitcher
6 pcs.	Beaker (100ml, 250ml)
1 pc.	Airtight container
1 pc.	Weighing scale auto calibrated pocket scale
1 pc.	Grinder
1 pc.	Oven
1 pc.	Funnel (2 cm spout)
10 L	Distilled Water
1 pc.	Fine Sieve (0.5-1.0 mm, 0.15-0.35 mm)
1 pc.	Dalkem Aluminum Sulfate (250g)
6 pcs.	PET bottles (1L)

3.5 Collecting Wet Market Wastewater Samples

Wet market wastewater was collected from a common outfall, with a total volume of 35 liters obtained. The collected wastewater was mixed thoroughly to ensure a uniform and representative batch for testing. From the total volume, 4.5 liters were set aside as baseline samples for initial characterization of the wastewater before treatment. The remaining 30.5 liters were allocated for the coagulation experiment. All samples were transferred into clean and properly labeled PET bottles to prevent contamination and to ensure easy identification and traceability throughout the analysis.

3.6 Yellow Sweet Potato Residue (YSPR) Powder Preparation

A total of two (2) kilograms of fresh sweet potato residues was transported from a family farm of the researcher in Tungawan, Zamboanga Sibugay. The residues were washed thoroughly with clean water to remove any soill particles or other unwanted residues that could affect the quality of the final product. After cleaning, YSPRs were weight to record their initial mass before drying. The drying process starts with sun exposure for 2 days, about 3-4 hrs each day to reduce the bulk moisture naturally. This step helped lower the water

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content while mainol]taining the structure of the peels. To complete the drying, the residues were placed in an oven at 130 °C for half an hour to ensure that any remaining moisture will be removed.

After drying, the residues were weighed again to determine the moisture content using the standard formula:

$$W_c\,(\%) = \frac{W1 - W2}{W1}\,(100) \qquad \text{Equation 3.1}$$

Where W_1 is the weight before drying, W_2 is the weight after drying, and W_c is the moisture content.

Figure 3.2 Sun-drying of YSPR

Figure 3.3 Oven-drying of YSPR at 130°C

Figure 3.4 Weighing YSPR after Sun and Oven Drying

Figure 3.5 Grinding/Powdering of YSPR

The dried residues were grounded into a fine powder using a grinder and subsequently passed through a 0.25 mm sieve to obtain a uniform particle size. This ensures material consistency and facilitates easier handling and effective dispersion during the coagulation experiments. The resulting powder was carefully transferred into airtight jars to protect it from contamination.

Figure 3.6 The Sieved YSPR using 0.25-mm Mesh

3.7 Collection of Raw Wet Market Wastewater Samples

Wet market wastewater was collected from Magay-Zamboanga City Public Market in Zamboanga City as shown in Figure 3.7. A total of 35 liters of wastewater was obtained from a common outfall from multiple stalls. This collected wastewater was mixed thoroughly to form a single, uniform batch for testing. Before dividing the wastewater into samples, the entire 35-liter batch underwent coarse screening to remove solid contaminants commonly found in wet markets. A fifty (50) mm strainer was used to eliminate materials such as food scraps, fish scales, vegetable pieces, packaging debris, and other large particles. Screening ensures that the wastewater sample used in experiments is consistent and prevents interference during coagulation testing.

Figure 3.7 Collection of Wastewater Samples in Magay Zamboanga City Public Market Common Outfall

3.7.1 Setting Aside Baseline Samples

From the screened 35 liters, three (3) containers with 1.5 liters each were set aside for analysis of BOD_5, TSS, and turbidity.

3.7.2 Preparation of Experimental Samples

The remaining 30.5 liters of screened wastewater were used for the coagulation experiments. This volume was portioned depending on the number of coagulant dosages or repetitions required for testing. Any excess wastewater was served as a buffer for repeated or additional trials to ensure accuracy and reliability.

3.7.3 Storage and Labeling

After screening and division, all wastewater samples were transferred into clean and sanitized PET bottles to maintain sample integrity. Each PET bottle was securely capped to avoid contamination, properly labeled with: sample type, volume, date and time of collection, source location.

3.8 Experimental Procedure

Coagulation test was conducted using six clean 1-liter pitchers. Six pitchers were prepared for sweet potato residue (YSPR) powder as the biocoagulant. Each pitcher was filled with 1 liter of wet market wastewater. Dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L and 300 mg/L were tested for YSPR biocoagulant. The two sets were tested separately to maintain accuracy and consistency. A precision digital balance was used to measure the required dosages accurately.

A jar tester apparatus was used to mix the samples and was calibrated before use to ensure proper operation. Each jar contained a measured volume of wet market wastewater and a specific dosage of coagulant. The paddles of the jar tester were facilitated a uniform mixing across all samples. Before every test, the jars and paddles were rinsed thoroughly with distilled water to prevent cross-contamination between samples. Mixing was conducted at 100 rpm for 2 minutes to simulate rapid mixing, followed by 30 rpm for 15 minutes to promote floc formation. After mixing, the samples were left undisturbed for 30 mins to allow the flocs to settle.

Figure 3.8 Filling the 1-liter Beaker of Raw Wastewater Sample for Jar Testing

The turbidity of each treated sample was measured by the researcher using a turbidity meter to determine the clarity of the water and identify the optimum coagulant dosage. The dosage that produces the lowest turbidity value, indicating the highest removal efficiency were considered the most effective. This optimum dosage was then used for further laboratory analysis to evaluate additional water quality parameters such as BOD_5 and TSS. Figure 3.11 shows the YSPR illustration at 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L and 300 mg/L dosages in a jar tester apparatus. Tables 3.8–3.17 illustrate the actual laboratory experimentation conducted during the treatment process.

Figure 3.9 Weighing of Aluminum Sulfate Coagulant

Figure 3.10 Weighing of 250 mg YSPR Biocoagulant

Figure 3.11 Jar Test Running at 100 rpm for Rapid Mixing

Figure 3.12 Jar Test Running at 30 rpm for Slow Mixing

Figure 3.13 Jar Testing Setup – Trial 1 for 30 rpm Slow Mixing

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Figure 3.14 Jar Testing Setup – Trial 2 for 30 rpm Slow Mixing

Figure 3.15 Turbidity Analysis for Treated Samples

Figure 3.16 YSPR Treatment Turbidity Result (Optimal Dosage) – Trial 1

Figure 3.17 YSPR Treatment Turbidity Result (Optimal Dosage) – Trial 2

3.9 Preparing Samples for Laboratory Analysis

Six (6) liters of wet market wastewater treated with the optimum YSPR dosage were collected as shown in Figure 3.18, along with a sample treated with Alum for comparison. The raw wastewater and the treated water corresponding to the optimum dosage were transferred into clean, 1.5 liters labeled PET bottles, stored in an ice box, and transported to the laboratory within 2-6 hours for further analysis of BOD_5 and TSS.

Figure 3.18 Samples for CHEMPRO Laboratory Analysis

3.10 Laboratory Analysis of Wastewater with Optimum Biocoagulant Dosage

The laboratory analysis focused on the wastewater sample corresponding to the identified optimum coagulant dosage which was determined from six different concentrations: 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L and 300 mg/L. These dosages were first tested during jar test experiments to determine which concentration produces the lowest turbidity indicating the highest treatment efficiency. The corresponding sample undergoes laboratory analysis to measure BOD_5 and TSS once the optimum dosage is identified.

A total of 6 liters of treated wet market using the identified optimum dosage of the biocoagulant was prepared for laboratory analysis. For comparison, an additional sample treated with alum under the same dosage and conditions was analyzed. All treated samples were transferred into clean and properly labeled PET bottles and stored in an ice box (see Figure 3.19) before being transported to the laboratory within 2-5 hours. In the laboratory, both the biocoagulant and alum-treated samples were analyzed for BOD_5 and TSS to evaluate and compare their treatment performance and effectiveness in improving wetmarket wastewater quality.

Figure 3.19 Wastewater Sample Stored in an iced box Packed with Ice

3.11 Data Analysis and Interpretation

The findings from the raw wastewater, the control sample treated with aluminum sulfate, and the treated sample using Yellow Sweet Potato Residue (YSPR) biocoagulant served as the primary basis for data analysis and interpretation. The results were presented through tables and graphs to clearly illustrate the effectiveness of aluminum sulfate and YSPR in removing pollutants such as total suspended solids (TSS), turbidity, and biochemical oxygen demand (BOD_5).

A descriptive statistical analysis was conducted to summarize the gathered data, including the computation of mean values, standard deviations, and removal efficiencies for each parameter. This analysis provided an overview of the treatment performance, trends, and variations observed among the different coagulant dosages.

To determine whether the differences in turbidity removal among the tested dosages of YSPR and aluminum sulfate were statistically significant, a one-way Analysis of Variance (ANOVA) was applied. The analysis was performed at a 95% confidence level with a significance level (α) of 0.05. Prior to conducting ANOVA, the assumptions of normality and homogeneity of variances were verified. The Shapiro–Wilk Test was used to confirm that the data were normally distributed, while Levene's Test was applied to verify the equality of variances across treatment groups. A p-value less than 0.05 indicated a statistically significant difference among the tested dosages. By combining descriptive statistics with inferential statistical analysis, the study comprehensively evaluated the treatment efficiency of both aluminum sulfate and YSPR biocoagulant and identified their optimal dosages for maximum turbidity removal efficiency.

IV. RESULTS AND DISCUSSION

4.1 Raw Wastewater Characteristics

The 35-L raw wastewater used in this study was collected from Magay Public Market in Zamboanga City. It came from a mixture of wet market sources, including fish, meat, and vegetable washing areas. The wastewater had a strong, foul odor, a clear sign of decomposing organic matter. It appeared dark gray to brown and was highly turbid, containing noticeable suspended solids such as fish gills and other organic debris.

TABLE 4.1 *Result of Raw Wastewater Analysis*

Parameters	Test Method	Result
BOD_5	5-day BOD Test/ SMEWW 5210B	3,250 mg/L
TSS	Gravimetric, Dried at 103-105°C / SMEWW 2540D	280 mg/L
Turbidity	Portable Turbidity Meter	1,076 NTU

Note. SMEWW - Standard Method for the Examination of Water and Wastewater

The raw wastewater collected from the wet market exhibited a very high BOD_5 concentration of 3,250 mg/, indicating an extremely strong organic pollution load. This value is significantly higher than the typical BOD_5 concentrations reported for ordinary domestic wastewater and even exceeds many values commonly observed in wet market wastewater studies. The elevated BOD_5 level can be attributed to the decomposition of organic materials such as fish residues, meat scraps, blood, vegetable wastes, and suspended solids present in the collected wastewater (Deng et al., 2022). Wastewater originating from meat, fish, and vegetable washing activities contains high concentrations of biodegradable organic matter, fats, oils, grease, nitrogen, phosphorus, and suspended solids, which contribute to elevated BOD_5 levels (Abdulla et al., 2023).

4.2 Jar Testing

Jar testing was performed by adding varying dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L of aluminum sulfate (alum) and yellow sweet potato residue (YSPR) biocoagulant to determine the most effective dosage. Each sample underwent rapid mixing at 100 rpm for 2 minutes to evenly disperse the coagulant and initiate particle destabilization. This was followed by slow mixing at 30 rpm for 15 minutes to promote the aggregation of particles and formation of flocs. After mixing, the samples were allowed to stand undisturbed for 30 minutes to enable the flocs to settle before turbidity measurement was conducted.

The formation of flocs varied depending on the dosage applied. Lower dosages produced smaller and less stable flocs due to incomplete destabilization of suspended particles. As the dosage increased, larger and more compact flocs were observed, resulting in clearer supernatant after settling particularly at the optimum concentration range. However, further increase in dosage led to weaker floc structure, likely due to overdosing and particle restabilization. These results emphasize the importance of selecting the appropriate coagulant dosage and maintaining proper mixing conditions to achieve effective coagulation and sedimentation.

4.2.1 Yellow Sweet Potato Residue (YSPR) Coagulation Observation

The coagulation performance of the yellow sweet potato residue (YSPR) biocoagulant was evaluated at dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L under the specified mixing conditions. At lower dosages (50-150 mg/L), limited improvement in water clarity was observed, and visible flocs were not distinctly formed. In addition, it was noted that the YSPR powder did not completely dissolve in the water during rapid mixing, resulting in the presence of fine suspended particles. This incomplete dissolution may have affected the interaction between the active components of the biocoagulant and the suspended solids in the sample.

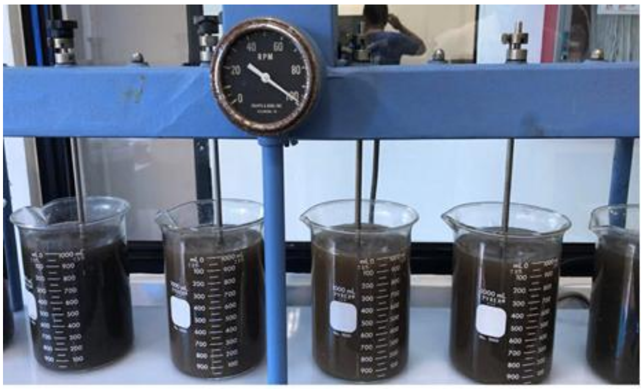

Figure 4.1 YSPR Treatment at 100 rpm for Rapid Mixing

The optimum dosage was identified as 200 mg/L, where the greatest reduction in turbidity was achieved despite the absence of clearly visible flocs. The improvement in clarity suggests that particle destabilization and aggregation occurred at a microscopic level, even though large, compact flocs were not observed. At higher dosages (250-300 mg/L), no significant additional improvement was noted which may be attributed to overdosing and the excess presence of undissolved YSPR particles in the water.

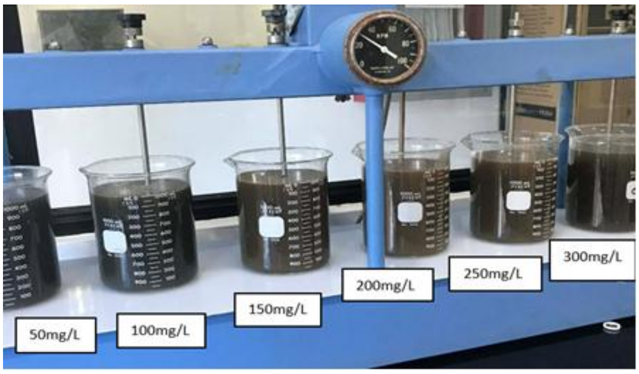

Figure 4.2 YSPR Treatment at 30 rpm for Slow Mixing

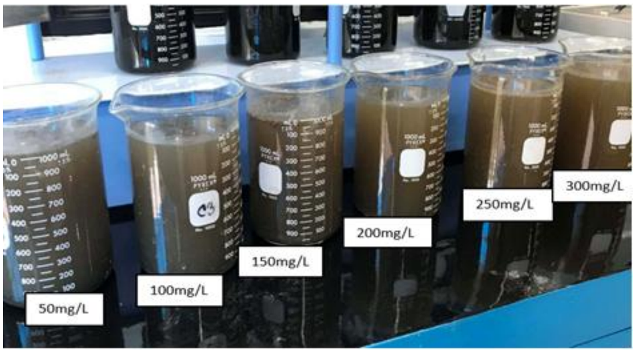

Figure 4.3 YSPR Treatment Settling for Thirty (30) Minutes

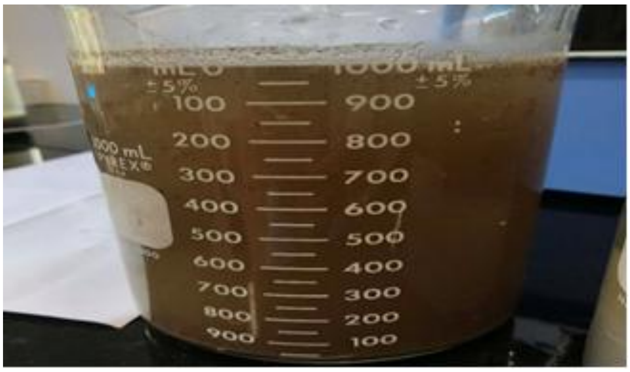

Figure 4.4 Traces of Undissolved YSPR Biocoagulant

4.2.2 Aluminum Sulfate Coagulation Observation

The coagulation performance of aluminum sulfate (alum) was evaluated at dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L under the established mixing conditions. At 50 mg/L, only small and loosely formed flocs were observed, and the supernatant remained slightly turbid, indicating insufficient destabilization of suspended particles. As the dosage increased to 100 mg/L, more distinct and compact flocs formed during the slow mixing phase, and improved settling was observed after sedimentation.

The optimum dosage was determined to be 100 mg/L using turbidity meter, where the largest and most stable flocs were formed, resulting in the clearest supernatant among all tested concentrations. At dosages higher than 100 mg/L (150-300 mg/L), no significant improvement in turbidity reduction was observed. In some cases, excessive dosage led to smaller or less stable flocs which attributed to charge reversal or restabilization of particles (Lapointe et al., 2020). These findings indicate that 100 mg/L is the most effective aluminum sulfate dosage for achieving efficient coagulation and sedimentation under the given experimental conditions.

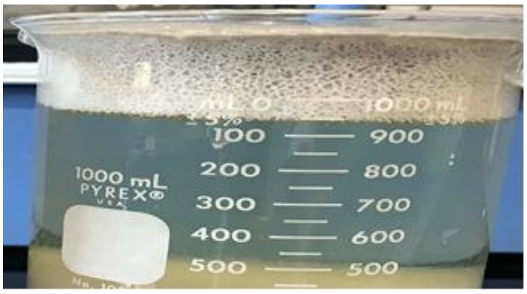

Figure 4.5 Formation of Visible Alum Floc after Flocculation

4.3 Determination of YSPR Optimal Coagulant Dosage Using Turbidity Removal

The turbidity of the treated wastewater samples using YSPR biocoagulant was measured to determine the most effective coagulant dosage. Different dosages of coagulant (50, 100, 150, 200, 250, and 300 mg/L) were tested with two trials for each dosage level. The results showed that turbidity decreased as the dosage increased from 50 mg/L to 200 mg/L. However, the turbidity values began to increase again beyond 200 mg/L. The mean turbidity values obtained are summarized in Table 4.2.

TABLE 4.2 *Turbidity Values at Different Coagulant Dosages*

Dosage (mg/L)	Trial 1 (NTU)	Trial 2 (NTU)	Mean (NTU)
50	869	823	846
100	735	729	732
150	677	650	663.5
200	635	629	632
250	690	684	687
300	790	775	782.5

Among the tested dosages, 200 mg/L produced the lowest average turbidity value of 632 NTU, indicating the highest turbidity removal efficiency for YSPR biocoagulant. Lower dosages such as 50 mg/L and 100 mg/L resulted in higher turbidity values suggesting insufficient coagulation activity. This may be attributed to the inadequate amount of coagulant available to neutralize the negative charges of suspended and colloidal particles present in the wastewater. When the coagulant dosage is too low, particle destabilization is incomplete resulting in weak floc formation and reduced turbidity removal efficiency (Alazaiza et al., 2022).

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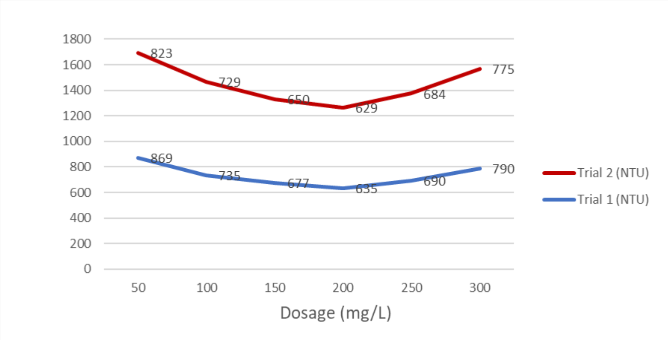

Figure 4.6 YSPR Turbidity Removal

As the dosage increased, turbidity removal improved until it approached the optimal range near 200 mg/L. The quadratic regression analysis produced the equation $y = 0.0153x^2 - 5.977x + 1106.85$ (As shown in Table 4.3), which describes the relationship between YSPR dosage and turbidity. The positive coefficient of the squared term ($a = 0.0153$) indicates that the curve opens upward, forming a U-shaped pattern. This behavior is typical of coagulation processes where turbidity initially decreases as dosage increases, reaches a minimum point (optimal dosage), and then increases again due to overdosing effects.

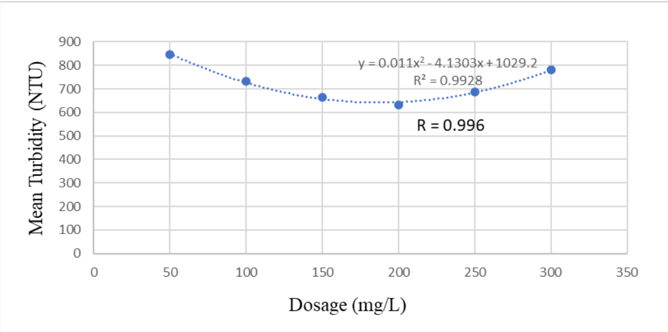

Figure 4.7 Optimal Dosage Result

The computed vertex of the quadratic model gives the optimal dosage using $x = -b / 2a$, resulting in an estimated optimum of approximately 195.3 mg/L. At this point, the turbidity is minimized, indicating the most effective particle destabilization and aggregation of suspended solids. This confirms that YSPR performs most efficiently within this dosage range.

Beyond the optimal point, the model shows a rise in turbidity values, which suggests the occurrence of overdosing. Excess coagulant likely leads to charge reversal or restabilization of colloidal particles, preventing effective floc formation. This explains why higher dosages result in reduced treatment efficiency despite increased coagulant input.

The regression results strongly validate the experimental observations, where the lowest turbidity was recorded near 200 mg/L. The close agreement between the calculated optimum (195.3 mg/L) and the experimental optimum supports the reliability of the quadratic model in predicting coagulation performance with a regression coefficient of $R = 0.996$. This confirms that YSPR is most effective as a biocoagulant within the range of approximately 195–200 mg/L, beyond which efficiency declines due to overdosing effects.

The computed optimum dosage was determined to be approximately 195.3 mg/L, indicating that maximum treatment efficiency occurs slightly below 200 mg/L. At this concentration, sufficient active compounds from the YSPR were available to destabilize suspended particles and enhance floc formation, resulting in improved sedimentation and turbidity reduction. Plant-based coagulants are most effective at their optimal dosage due to the presence of natural polymers that promote particle aggregation through adsorption and bridging mechanisms (Mohammed Jagaba et al., 2020).

At this optimum dosage, YSPR achieved a turbidity removal efficiency of 41.26%, along with 30.15% reduction in BOD_5 and 15.26% reduction in TSS, indicating moderate treatment performance. These results suggest that while YSPR is capable of improving wastewater quality, its efficiency remains limited.

However, turbidity levels increased again when the dosage was further raised to 250 mg/L and 300 mg/L. This can be attributed to the overdosing effect of the biocoagulant. Excessive coagulant concentration may lead to the restabilization of previously destabilized particles or disruption of floc structure, producing smaller and weaker flocs that remain suspended in the treated water (Ismail et al., 2021).

The increase in turbidity at higher dosages may also be associated with the incomplete dissolution of the YSPR biocoagulant in the wastewater. Plant-based coagulants often contain insoluble organic components such as cellulose fibers and starch residues that may not fully dissolve during mixing. These undissolved particles can remain in suspension and contribute to higher turbidity readings (Alazaiza et al., 2022).

Overall, the results indicate that the optimal dosage of YSPR is approximately 195.3 mg/L, where sufficient active compounds are present to effectively destabilize suspended particles and promote floc formation without causing overdosing effects or introducing excess suspended matter into the treated water.

The required assumptions of normality and homogeneity of variance were first verified before performing the one-way ANOVA to ensure the validity and reliability of the statistical analysis. To assess the normality of the data, the Shapiro-Wilk Test Calculator was used. The results showed that the data were normally distributed with $W(12) = 0.94$ and a p-value of 0.540. Furthermore, the homogeneity of variance was evaluated using the Levene's Test Calculator, which indicated that the variances across all dosage groups were similar, with $F = 0.033$ and a p-value of 0.8586, confirming that the group variances could be considered equal. Since all assumptions required for one-way ANOVA were satisfied, the data were subsequently subjected to ANOVA for statistical analysis.

Table 4.3 shows the summary of one-way ANOVA for turbidity values at different coagulant dosages. The table indicates that the sum of squares between groups (SS = 63,726.67) is much larger than the sum of squares within groups (SS = 1,589), suggesting that the differences between the dosages contribute more to the overall variability than the differences within each dosage group. The mean squares (MS) were 12,745.33 for between groups and 264.83 for within groups, leading to a calculated F-value of 48.13. This F-value is substantially higher than the critical F-value (F_{crit} = 4.387), and the associated p-value ($p = 9.19 \times 10^{-5}$) is much less than 0.05, indicating that the differences in mean turbidity among the dosages are statistically significant. In other words, the coagulant dosage has a significant effect on turbidity removal, confirming that 195.3 mg/L is the optimal dosage for achieving the lowest turbidity.

TABLE 4.3 *Summary of ANOVA Results for Turbidity Values at Different Dosages*

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	63726.67	5	12745.33	48.12587	9.19E-05	4.387374
Within Groups	1589	6	264.8333			
Total	65315.67	11				

4.4 Determination of Alum Coagulant Optimal Dosage Using Turbidity Removal

The optimal dosage of alum was determined by evaluating the turbidity of treated wastewater at different coagulant concentrations. Alum is a commonly used and well-established coagulant in wastewater treatment due to its ability to destabilize suspended particles and promote floc formation (Tsoutsa et al., 2024). Because the effectiveness of alum in coagulation processes has been widely documented in previous studies, the experiment was conducted using a single trial to determine the most effective dosage under the given conditions. Table 4.5 presents the turbidity values obtained for the different alum dosages tested, namely 50, 100, 150, 200, 250, and 300 mg/L.

TABLE 4.4 *Turbidity of Treated Wastewater at Different Alum Dosages*

Alum Dosage (mg/L)	Turbidity (NTU)
50	21.1
100	13.6
150	27.7
200	38.9
250	50.0
300	53.0

As shown in Table 4.4, turbidity initially decreased as the alum dosage increased from 50 mg/L to 100 mg/L. At a dosage of 50 mg/L, the turbidity of the treated wastewater was measured at 21.1 NTU, indicating that the amount of coagulant added was not sufficient to achieve maximum particle destabilization and removal. When the dosage was increased to 100 mg/L, the turbidity decreased to 13.6 NTU, which represents the lowest turbidity value among all the tested concentrations.

This result indicates that the coagulation process was most effective at 100 mg/L, as the alum was able to neutralize the charges of suspended particles and promote the formation of larger flocs that settled more efficiently during the treatment process. However, when the alum dosage was further increased beyond 100 mg/L, the turbidity values increased. At 150 mg/L, the turbidity rose to 27.7 NTU and continued to increase to 38.9 NTU, 50.0 NTU, and 53.0 NTU at dosages of 200 mg/L, 250 mg/L, and 300 mg/L, respectively. This trend suggests the occurrence of coagulant overdosing. Excessive addition of alum can cause charge reversal or the restabilization of particles which disrupts previously formed flocs and results in higher turbidity levels in the treated water (Aguilar, 2022).

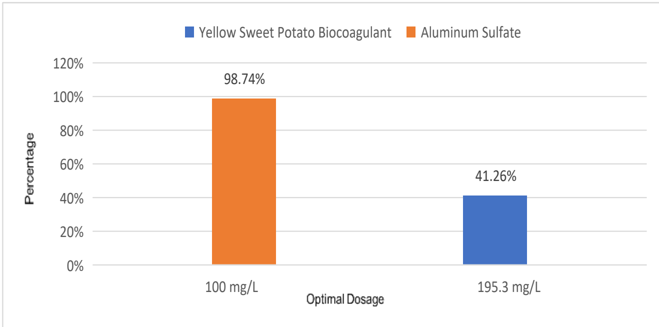

Figure 4.8 Alum Turbidity Removal

Based on these findings, 100 mg/L was identified as the optimal alum dosage for turbidity removal in the treated wastewater. The coagulation process achieved the lowest turbidity value among the tested dosages at this concentration indicating the highest treatment efficiency under the experimental conditions.

4.5 Turbidity Laboratory Result and Removal Efficiency

Table 4.5 shows the laboratory results of turbidity for both aluminum sulfate and yellow sweet potato coagulant. The raw wastewater had an initial turbidity of 1,076 NTU. After coagulation using aluminum sulfate, the turbidity was reduced to 13.6 NTU at a dosage of 100 mg/L. For yellow sweet potato, the turbidity was reduced to 632 NTU at an optimal dosage of 195.3 mg/L.

TABLE 4.5 *Result of Turbidity Analysis*

Coagulant	Test Method	Raw Water	Optimal Dosage	Final Turbidity	Removal Efficiency (%)
Aluminum sulfate (Control)	SMEWW 5210 B	1,076 NTU	100 mg/L	13.6 NTU	98.74
Yello Sweet Potato Treatment)			195.3 mg/L	632 NTU	41. 26

Note. SMEWW – Standard Method for the Examination of Water and Wastewater

Figure 4.9 also shows the turbidity removal efficiency of the two coagulants. The graph indicates that aluminum sulfate achieved a higher removal efficiency of 98.74%, while yellow sweet potato only reached 41.26%. This demonstrates that aluminum sulfate is very effective in reducing turbidity, whereas yellow sweet potato shows a moderate reduction.

Based on the results, the optimum dosage for aluminum sulfate is 100 mg/L, where maximum turbidity removal (98.74%) is observed. For yellow sweet potato, although there is a significant reduction in turbidity, the removal efficiency (41,26%) is lower, indicating that the natural coagulant has limited effectiveness under the conditions tested. The results suggest that while natural coagulants like yellow sweet potato may offer environmentally friendly alternatives, further optimization is required to achieve performance comparable to conventional coagulants like aluminum sulfate.

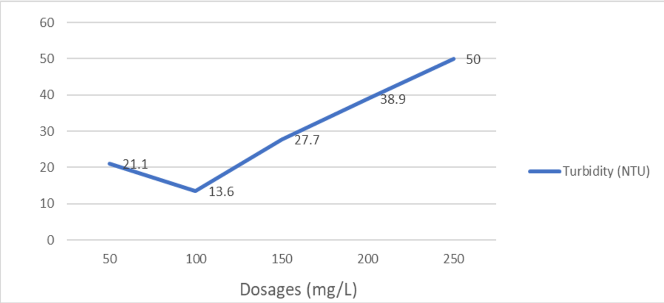

Figure 4.9 Turbidity Reduction Efficiency

Based on the results, the optimum dosage for aluminum sulfate is 100 mg/L, where maximum turbidity removal (98.74%) is observed. Aluminum sulfate is widely used as a chemical coagulant because it effectively destabilizes suspended particles through charge neutralization and rapid floc formation allowing particles to settle quickly. Alum produces stronger and denser flocs compared with natural coagulants, resulting in higher turbidity removal efficiency (Sharma, 2023).

4.6 BOD_5 Laboratory Result and Removal Efficiency

Table 4.6 shows the laboratory results of BOD_5 concentration for both aluminum sulfate and yellow sweet potato coagulant. The raw wastewater had a BOD_5 value of 3,250 mg/L, indicating a high level of organic pollution. After coagulation using aluminum sulfate (control) at an optimal dosage of 100 mg/L, the BOD_5 was reduced to 40 mg/L, showing a very high removal efficiency. For yellow sweet potato, the BOD_5 was reduced to 2,270 mg/L at a dosage of 195.3 mg/L, resulting in a moderate removal efficiency.

TABLE 4.6 *Result of BOD_5 Analysis*

Coagulant	Test Method	Raw Water	Optimal Dosage	Final BOD_5	Removal Efficiency (%)
Aluminum sulfate (Control)	SMEWW 5210 B	3,250 mg/L	100 mg/L	40 mg/L	98.77
Yello Sweet Potato (Treatment)			195.3 mg/L	2,270 mg/L	30.15

Note. SMEWW – Standard Method for the Examination of Water and Wastewater

Figure 4.10 shows the BOD_5 removal efficiency of the two coagulants. The graph illustrates that aluminum sulfate achieved a removal efficiency of 98.77%, which is significantly higher than yellow sweet potato at 30.15%. This indicates that aluminum sulfate is highly effective in reducing organic matter from wastewater, whereas yellow sweet potato shows only moderate effectiveness.

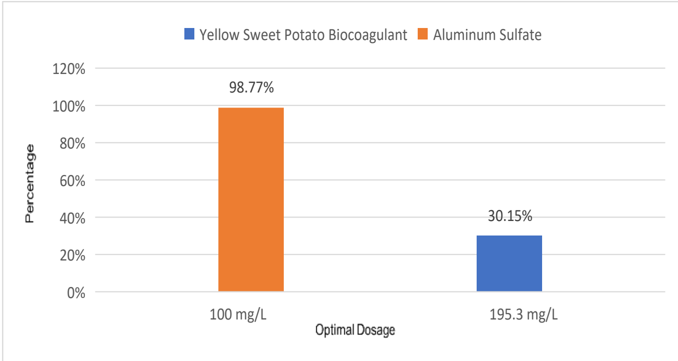

Figure 4.10 BOD_5 Reduction Efficiency

Based on the results, the optimum dosage for Aluminum sulfate was 100 mg/L, determined from the highest turbidity removal and corresponding maximum BOD_5 reduction (98.74%). In contrast, the lower removal efficiency observed with yellow sweet potato (BOD_5 removal = 41.26%) may be due to incomplete coagulation, which can occur when the water contains a very high organic load, such as the wet market wastewater tested (BOD = 3,250 mg/L). According to Lwasa et al. (2024), natural coagulants tend to be less effective at destabilizing and aggregating large quantities of organic pollutants compared with conventional chemical coagulants, especially under conditions of high organic load, because the weaker bio-polymers require more active sites and stronger interactions to form stable flocs. Additionally, naturally occurring soluble sugars, proteins, and other biodegradable compounds in the sweet potato biocoagulant may persist in the treated water, contributing to residual BOD (Verma, 2022).

4.7 TSS Laboratory Result and Removal Efficiency

Table 4.7 shows the laboratory results of Total Suspended Solids (TSS) for both aluminum sulfate and yellow sweet potato coagulant. The raw wastewater had a TSS value of 380 mg/L, indicating a high concentration of suspended solids. After coagulation using aluminum sulfate (control) at an optimal dosage of 100 mg/L, the TSS was reduced to 20 mg/L, showing a very high removal efficiency. For yellow sweet potato, the TSS was reduced to 322 mg/L at a dosage of 195.3 mg/L, demonstrating a moderate removal efficiency.

TABLE 4.7 *Result of TSS Analysis*

Coagulant	Test Method	Raw Water	Optimal Dosage	Final TSS	Removal Efficiency (%)
Aluminum sulfate (Control)	SMEWW 5210 B	380 mg/L	100 mg/L	20 mg/L	94.74
Yello Sweet Potato (Treatment)			195.3 mg/L	322 mg/L	15.26

Note. SMEWW – Standard Method for the Examination of Water and Wastewater

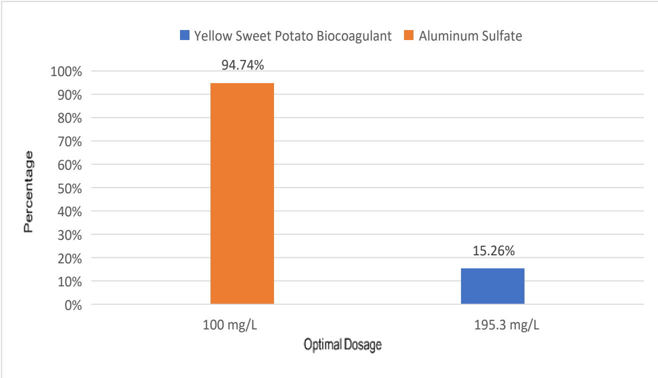

Figure 4.11 TSS Reduction Efficiency

Figure 4.11 shows the TSS removal efficiency of the two coagulants. The graph indicates that aluminum sulfate achieved a removal efficiency of 94.74%, while yellow sweet potato achieved only 15.26%. This clearly demonstrates that aluminum sulfate is highly effective in removing suspended solids from wastewater, whereas yellow sweet potato shows limited effectiveness under the tested conditions.

The raw wastewater had a high concentration of suspended solids with 380 mg/L. Coagulation with aluminum sulfate at 100 mg/L reduced TSS to 20 mg/L (94.74% removal), while yellow sweet potato at 195.3 mg/L reduced TSS to 322 mg/L (15.26% removal). The lower efficiency of the yellow sweet potato coagulant is likely due to its composition, as soluble sugars, proteins, and low starch/polysaccharide content may be insufficient to form strong flocs in wastewater with high suspended solids (Gupta et al., 2023). Residual organic compounds in yellow sweet potato may also contribute slightly to TSS since it measures the solids still floating or suspended, these leftover organic compounds contribute to the TSS because they fail to settle during sedimentation (Kumar et al., 2021).

V. CONCLUSION AND RECOMMENDATION

This study investigated the effectiveness of Yellow Sweet Potato Residue (YSPR) as a natural biocoagulant for treating wet market wastewater (WMWW) and compared its performance with the conventional chemical coagulant aluminum sulfate (alum). The conclusions and recommendations based on the study objectives are as follows:

5.1 Conclusions

1. The turbidity removal efficiency of Yellow Sweet Potato Residue (YSPR) biocoagulant varied across the six tested dosages of 50 mg/L, 100 mg/L, 150 mg/L, 200 mg/L, 250 mg/L, and 300 mg/L in treating wet market wastewater. The results showed that turbidity removal efficiency increased as the dosage increased up to a certain point. However, excessive dosage resulted in reduced efficiency due to particle restabilization and the presence of excess undissolved residue in the treated water.
2. The optimal dosage of YSPR biocoagulant was determined at 195.3 mg/L, which achieved the highest turbidity removal efficiency of 41.26%. In comparison, the optimal dosage of aluminum sulfate was identified at 100 mg/L, achieving a significantly higher turbidity removal efficiency of 98.74%, indicating better coagulation performance than YSPR.
3. At their respective optimal dosages, YSPR biocoagulant exhibited moderate removal efficiencies of 30.15% for BOD_5 and 15.26% for TSS. On the other hand, aluminum sulfate demonstrated substantially higher treatment performance with removal efficiencies of 98.77% for BOD_5 and 94.74% for TSS in treating wet market wastewater.
4. Based on the removal efficiencies for turbidity, TSS, and BOD_5, aluminum sulfate was found to be more effective than YSPR biocoagulant in the treatment of wet market wastewater. Although YSPR showed potential as a biodegradable and sustainable alternative coagulant, its treatment efficiency remained limited under high organic load conditions. The findings suggest that further optimization of YSPR, such as improved extraction methods, pretreatment processes, or combination with other coagulants, may enhance its coagulation performance and applicability in wastewater treatment.

5.2 Recommendations

1. Further research should focus on enhancing the performance of Yellow Sweet Potato Residue (YSPR) by improving its solubility, extracting higher concentrations of active compounds, combining it with other natural or chemical coagulants, and applying wastewater dilution to reduce high organic and suspended solids loads.
2. Additional experimental trials are recommended to further assess the efficiency, consistency, and reliability of YSPR under varying conditions.
3. Process adjustments such as optimizing mixing intensity, extending settling time, and incorporating pre-treatment steps such as filtration or dilution can improve floc formation and overall treatment efficiency of YSPR.
4. Extending the coagulation–flocculation time is recommended to allow sufficient dissolution of solids and better interaction between particles, thereby enhancing treatment performance.
5. Pilot-scale testing is recommended to evaluate the practical feasibility and scalability of using YSPR, either alone or in combination with conventional chemical coagulants, in treating wet market wastewater under real operating conditions.