Coagulation Performance of Durian Peel *(Durio Zibethinus Murr)* in the Removal of Pollutants in Chicken Slaughterhouse Wastewater

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Abstract *- Chicken slaughterhouse wastewater is increasing due to rapid poultry industry growth, causing serious environmental problems from high organic and suspended solid content. Conventional treatment methods commonly use chemical coagulants that are costly and may generate secondary pollution, creating the need for sustainable and low-cost alternatives. This study evaluated powdered durian peel (Durio zibethinus Murr) as a natural biocoagulant for treating slaughterhouse wastewater based on Biochemical Oxygen Demand (BOD_5) and Total Suspended Solids (TSS) removal efficiencies. Jar tests were conducted using dosages of 250–1500 mg/L with rapid mixing, slow mixing, and one-hour settling. Raw wastewater exceeded regulatory limits, with BOD_5 concentrations ranging from 380–860 mg/L and TSS from 232–280 mg/L. Durian peel powder achieved maximum BOD_5 removal efficiencies of 48.8% at 250 mg/L in Trial 1 and 31.5% at 500 mg/L in Trial 2. TSS removal was more effective, reaching 69.6% and 65.5% at 1500 mg/L, reducing some samples below the 100 mg/L regulatory limit. One-way ANOVA showed dosage significantly affected both parameters ($p < 0.05$). Findings indicate durian peel powder is effective mainly for suspended solids removal but insufficient alone for BOD_5 reduction. It is recommended that durian peel powder be used as a pre-treatment stage together with biological treatment, filtration, or other secondary processes to achieve DENR discharge standards and improve overall wastewater treatment efficiency.*

Keywords— *Durian peel powder; natural biocoagulant; chicken slaughterhouse wastewater; coagulation–flocculation; biochemical oxygen demand (BOD_5); total suspended solids (TSS); jar testing; wastewater treatment; removal efficiency; DENR Administrative Order No. 2016-08*

I. INTRODUCTION

The global demand for livestock products is driving higher meat production and, consequently, more wastewater from slaughterhouses. In many parts of Asia, poultry processing facilities are the primary sources of slaughterhouse effluents, with wastewater characteristics depending on operation scale, livestock type, and cleaning methods (Maroneze et al., 2014). The rapid growth of the meat industry has made slaughterhouse wastewater a major environmental concern, typically containing high levels of BOD, TSS, fats, oils, grease, and nutrients like nitrogen and phosphorus, which can deplete dissolved oxygen, trigger eutrophication, and disrupt aquatic ecosystems (Adeyemo et al., 2016).

Traditionally, physical and chemical treatments such as filtration, adsorption, precipitation, and coagulation have been used to treat slaughterhouse wastewater, with coagulation–flocculation being among the most common and cost-effective approaches. Conventional systems rely on chemical coagulants like aluminum sulfate (alum) or polyaluminum chloride (pac) to remove suspended and colloidal particles. However, synthetic coagulants present challenges for small-scale operations, generate non-biodegradable sludge, and may introduce health risks from residual metal ions, including neurological and allergic effects (Lacang et al., 2023).

Growing interest in sustainable wastewater management has turned attention to natural coagulants derived from agricultural and biological wastes, which are rich in polysaccharides, proteins, cellulose, and lignin to help neutralize particle charges and promote flocculation. Durian peel (*Durio zibethinus*), an abundant Southeast Asian fruit waste, exemplifies a promising source of such biocoagulants. With durian processing yielding substantial peel waste (about 70–85% of fruit weight) that is rich in cellulose, hemicellulose, and lignin, this biomass could be repurposed for water treatment.

Despite existing research on natural coagulants such as *Moringa oleifera*, banana peel, and cassava peel, limited studies have focused on the application of durian peel as a coagulant for high-strength industrial wastewaters such as chicken slaughterhouse effluent. Previous works have mostly evaluated its use in treating low- to medium-strength domestic or textile wastewaters, leaving a significant gap in assessing its performance in nutrient- and fat-rich effluents typical of poultry processing plants. Moreover, there is a lack of comparative analysis between durian peel powder and conventional chemical coagulants under optimized operational conditions.

This study therefore aims to fill this research gap by evaluating the efficiency of durian peel powder as a natural biocoagulant in treating chicken slaughterhouse wastewater and comparing its performance with aluminum sulfate in terms of BOD5 and TSS removal. The findings will contribute to the development of cost-effective and eco-friendly wastewater treatment alternatives suitable for small- to medium-scale slaughterhouse operations.

II. METHODOLOGY

A. Study Design and Sample Preparation

This experimental laboratory-based study evaluated durian peel powder as a natural biocoagulant for the treatment of chicken slaughterhouse wastewater. Fresh durian peels were collected from a fruit vendor near Golf Road, Zamboanga City. A total of 5 kg of peels without mold, rot, or visible damage was selected. The peels were cleaned, rinsed three times with distilled water, and manually scraped to remove the inner pulp. They were then drained for one hour, sun-dried for approximately 12 hours, and oven-dried at 100°C for one hour. After cooling, the dried peels were ground using a high-speed blender and passed through a 0.25-mm sieve to obtain a uniform powder. The prepared durian peel powder was stored in clean, airtight containers away from direct sunlight until use.

TABLE I. Materials, Tools, and Equipment Used in the Study

Material/Equipment	Quantity
Durian peel	5 kg
Transparent pitcher	6 pcs.
Funnel	6 pcs.
Auto-calibrated weighing scale	1 pc.
230 V, 60 Hz oven	1 pc.
Blender	1 pc.
Stirring rod	1 pc.
Airtight container	1 pc.
1-L water bottle	28 pcs.
Ice chest	1 pc.
Distilled water	10 L × 2
0.25-mm sieve	1 pc.
Tub	1 pc.

B. Collection and Treatment of Wastewater Samples

Untreated chicken slaughterhouse wastewater was collected from the poultry slaughterhouse processing line between 7:00 and 8:00 a.m. A total of 40 L of wastewater was allocated for the experiment. A 2-L portion was immediately placed in an ice-cooled container and transported to the CHEMPRO laboratory for initial analysis of five-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS).

Coagulation experiments were conducted using a jar tester. Six 1,500-mL wastewater samples were treated with durian peel powder at dosages of 250, 500, 750, 1,000, 1,250, and 1,500 mg/L, with each dosage tested in triplicate. Rapid mixing was performed at 100 rpm for 2 minutes, followed by slow mixing at 30 rpm for 10 minutes. The samples were subsequently allowed to settle for one hour. The treated water was carefully decanted and stored in clean 1-L bottles in a cooler prior to laboratory analysis.

C. Laboratory Analysis and Statistical Treatment

Raw and treated wastewater samples were analyzed for BOD_5 and TSS. The laboratory results were used to determine the pollutant removal efficiency of each durian peel powder dosage. The treatment results were compared with the applicable effluent standards under DENR Administrative Order No. 2016-08 and DAO 2021-19 Class C.

The results were presented using tables and graphs to evaluate treatment trends and effectiveness. Analysis of Variance (ANOVA) was employed to determine whether significant differences existed among the different durian peel powder dosages in terms of pollutant removal efficiency and to identify the most effective treatment dosage.

III. RESULTS AND DISCUSSION

3.1 Raw Wastewater Characteristics

The raw wastewater used in this study was collected from a chicken slaughterhouse located in Zambowood, Zamboanga City. Slaughterhouse wastewater is typically characterized by high concentrations of organic matter and suspended solids due to the presence of blood, fats, feathers, and undigested feed materials generated during poultry processing activities.

During the sampling period, two wastewater samples were collected on February 10, 2026 at 7:30 AM and February 23, 2026 at 9:30 AM to determine the baseline characteristics of the untreated effluent. The first sample was collected at 7:30 AM on February 10, 2026, coinciding with the peak of slaughterhouse operations, during which production was at its highest intensity. The high volume of poultry being processed at this time resulted in a significant discharge of blood and other organic byproducts into the wastewater stream, which accounts for the distinctly red coloration as shown in Figure 3.1. The second sample was collected at 9:30 AM on February 23, 2026, as the facility's operations on that date began slightly later than usual, commencing at approximately 9:00 AM with a moderate level of production activity. Despite the later start and comparatively reduced operational intensity, the wastewater collected during the second trial similarly exhibited a red coloration, as shown in Figure 3.2, attributed to the continued presence of blood-laden effluent generated during the slaughtering process. The collected wastewater from both sampling dates appeared darkish red in color and highly turbid. Unlike typical expectations for slaughterhouse wastewater, the odor was not strong and did not produce an offensive smell, indicating that the level of odor-causing compounds may have been relatively low at the time of collection.

Figure 3.1. Trial 1 Slaughterhouse Raw Wastewater Collected Last February 10, 2026

The strength and properties of wastewater generated from chicken slaughterhouses result from various influencing factors. These include the facility's production volume, the

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type and weight of the chickens processed, transportation methods, how animals are received and kept before processing, the technologies and techniques used during operations, the quantity of carcasses handled, the temperature of water used for washing, the cleaning and sanitization practices followed, and the work habits and behaviors of the employees (Sengupta et al., 2015).

Figure 3.2. Trial 2 Slaughterhouse Raw Wastewater Collected Last February 23, 2026

Laboratory analysis revealed that the raw wastewater had significantly high levels of Biochemical Oxygen Demand BOD5 and Total Suspended Solids (TSS).

TABLE 3.1. Raw Chicken Slaughterhouse Wastewater Results for Trials 1 and 2

Parameter	Trial 1	Trial 2
BOD5 (mg/L)	860	380
TSS (mg/L)	280	232

Table 3.1 presents the laboratory analysis results of the raw chicken slaughterhouse wastewater for trials 1 and 2. These parameters are commonly used indicators of organic pollution and particulate matter in wastewater. Siwiec et al. (2018).

The BOD_5 concentration recorded in Trial 1 was 860 mg/L, while Trial 2 obtained a lower value of 380 mg/L. Despite the variation between trials, both values exceeded the allowable limit of 50 mg/L under DAO 2016-08 class C effluent standards, indicating a high level of biodegradable organic matter in the wastewater. The elevated BOD5 concentrations may be attributed to the presence of blood, proteins, fats, and other organic residues generated during slaughtering and cleaning operations. According to Yordanov (2010), slaughterhouse wastewater commonly exhibits 930 to 2,477 mg/L due to its significant organic load, while Yaakob et al. (2018), similarly emphasized the strong organic characteristic of poultry slaughterhouse effluent. Although the value obtained lower than 930 to 2,477 mg/L as reported by Yaakob et al., 2018, it still reflects considerable organic contamination that requires treatment prior to disposal.

For TSS, Trial 1 recorded 280 mg/L, whereas Trial 2 showed 232 mg/L. Both values also exceeded the regulatory limit of 100 mg/L under DAO 2016-08, indicating the substantial pretense of suspended materials in the wastewater. Although lower than the values reported by Yordanov (2010), the results still demonstrate significant solid loading.

Overall, the results confirm that the raw chicken slaughterhouse wastewater exceeds the discharge standards for both BOD_5 and TSS under DAO 2016-08. These findings align with previous studies reporting high organic and solid loads due to blood, fats, and processing residues (Yaakob et al., 2018; Yordanov (2010), emphasizing the need for effective treatment such as coagulation–flocculation using biocoagulants prior to discharge.

3.2 Jar Testing and Physical Observations

Jar testing was conducted to simulate the coagulation-flocculation process and to evaluate the effectiveness of durian peel powder as a natural biocoagulant for treating slaughterhouse wastewater.

Different dosages of durian peel powder were applied to the wastewater samples to determine the optimum dosage for pollutant removal. The dosages tested were 250 mg/L, 500 mg/L, 750 mg/L, 1000 mg/L, 1250 mg/L, and 1500 mg/L.

Figure 3.3. Using Jar Tester to Conduct the Coagulation of Different Dosages (Trial 1)

Figure 3.4. Using Jar Tester to Conduct the Coagulation of Different Dosages (Trial 2)

During the experiment, one liter of wastewater was placed in each beaker and subjected to rapid mixing at 100 rpm for 2 minutes, followed by slow mixing at 30 rpm for 15 minutes to allow floc formation as shown in figures 3.3 and 3.4. After mixing, the samples were allowed to settle for one hour to facilitate sedimentation of the formed flocs.

Visible changes in water clarity were observed during the mixing and settling stages. Suspended particles began to aggregate and form larger flocs which gradually settled at the bottom of the containers.

After the settling period, the treated samples were carefully transferred into one-liter containers for laboratory analysis of BOD5 and TSS concentrations.

Durian Peel Coagulation Observation

During the coagulation process, the addition of durian peel powder resulted in noticeable physical changes in the wastewater samples. The rapid mixing stage allowed the coagulant particles to disperse evenly in the water, initiating the neutralization of suspended particles.

At lower dosages (250–500 mg/L), the wastewater showed moderate clarification as some suspended particles began to aggregate into small flocs. However, the water still appeared slightly turbid after settling.

At medium dosages (750–1000 mg/L), larger flocs formed and settled more rapidly at the bottom of the beakers. The treated water appeared clearer compared to the lower dosage treatments.

At higher dosages (1250–1500 mg/L), the floc formation became more pronounced and sedimentation occurred more quickly. The wastewater became visibly clearer as more suspended particles were removed through coagulation and settling.

However, small traces of organic residues from the durian peel powder were occasionally observed at the highest dosage levels.

3.3 BOD5 Laboratory Results

Table 3.2 shows the laboratory results of Biochemical Oxygen Demand (BOD5) concentration for durian peel powder at varying dosages. The BOD5 concentration of raw wastewater was 380 mg/L. After treatment, BOD5 concentrations were 270 mg/L, 260 mg/L, 390 mg/L, 390 mg/L, 320 mg/L, and 280 mg/L for dosages of 250 mg/L, 500 mg/L, 750 mg/L, 1000 mg/L, 1250 mg/L, and 1500 mg/L, respectively.

TABLE 3.2. *Trial 1 BOD5 Results and Removal Efficiency*

Dosage (mg/L)	Lab Result (mg/L)	Removal Efficiency (%)
Raw	860	–
250	440	48.8%
500	1,480	-72.1%
750	580	32.6%
1,000	620	27.9%
1,250	800	7.0%
1,500	730	15.1%

Table 3.2 presents the BOD_5 results and removal efficiency of durian peel powder during Trial 1 using different dosages applied to slaughterhouse wastewater. The raw wastewater exhibited an initial BOD_5 concentration of 860 mg/L, indicating a high level of biodegradable organic pollution typical of slaughterhouse effluents.

The results show that the 250 mg/L dosage achieved the highest treatment performance, reducing the BOD_5 concentration to 440 mg/L with a removal efficiency of 48.8%. This suggests that at lower dosage levels, durian peel powder provided sufficient active adsorption and coagulation sites for the removal of organic matter without causing system instability. According to Mostafa et al. (2022), optimal adsorbent dosage enhances pollutant removal by maximizing available surface sites for contaminant binding.

However, increasing the dosage to 500 mg/L resulted in a sharp increase in BOD_5 concentration to 1,480 mg/L, corresponding to a negative removal efficiency of −72.1%. This unexpected increase indicates that overdosing negatively affected treatment performance. Since durian peel is a lignocellulosic organic material, excessive application may have introduced additional biodegradable organic compounds into the wastewater, thereby increasing oxygen demand. In addition, excessive solid loading may have disrupted adsorption equilibrium, leading to reduced pollutant uptake or possible release of previously attached organics. Mostafa et al. (2022) noted that excessive adsorbent dosage can reduce adsorption efficiency due to site saturation, particle interaction, and equilibrium disturbances.

At dosages of 750 mg/L and 1,000 mg/L, BOD_5 concentrations decreased to 580 mg/L and 620 mg/L, with removal efficiencies of 32.6% and 27.9%, respectively. Although these values indicate partial recovery of treatment performance, they remain lower than the optimum observed at 250 mg/L. This suggests that increasing adsorbent dosage beyond the optimal level does not necessarily improve organic matter removal. According to Mostafa et al. (2022), adsorption efficiency depends not only on dosage but also on surface area availability, particle dispersion, and mass transfer limitations. Higher dosages may also promote particle aggregation, reducing effective surface area for adsorption.

At higher dosages of 1,250 mg/L and 1,500 mg/L, removal efficiencies further declined to 7.0% and 15.1%, respectively. The reduced performance at these levels may be attributed to excessive solid accumulation in the system, which can increase turbidity and hinder contact between pollutants and active sites. This behavior is consistent with adsorption principles, where removal efficiency improves only up to an optimum dosage before plateauing or declining due to site overlap and reduced efficiency.

Overall, the results indicate that 250 mg/L is the optimum dosage for BOD_5 reduction using durian peel powder in Trial 1. Beyond this level, treatment efficiency decreases due to overdosing effects, organic leaching, and reduced adsorption effectiveness. Similar findings have been reported in adsorption studies where increasing adsorbent dosage improves removal only until an optimal point, after which efficiency declines due to aggregation and saturation of active sites (Jain et al., 2016).

Figure 3.5 illustrates a highly inconsistent and non-linear relationship between durian peel dosage and BOD_5 removal efficiency, with sharp fluctuations observed at lower concentrations. The raw wastewater in Trial 1 recorded a BOD_5 concentration of 860 mg/L. BOD levels in this range commonly exceed 1,000 mg/L in conventional poultry slaughterhouses, and values above 500 mg/L are already indicative of high-strength effluent. The highest removal efficiency of 48.8% at 250 mg/L indicates effective charge neutralization and floc formation, allowing partial removal of

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organic pollutants. This supports the findings of Ahmad et al. (2021), who emphasized that coagulation is most efficient within a controlled dosage range.

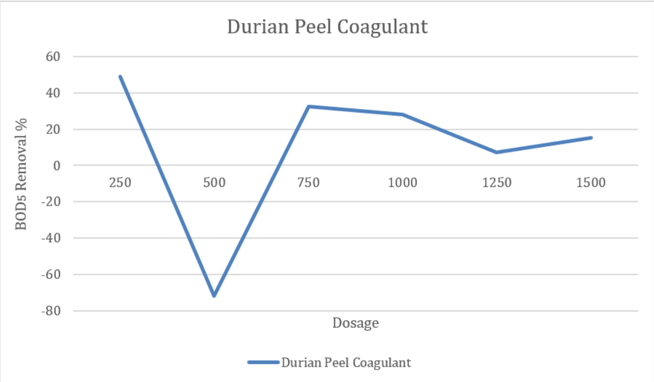

Figure 3.5. BOD5 Removal Efficiency Using Durian Peel Powder

However, this peak is immediately followed by a drastic decline to −72.1% at 500 mg/L, indicating overdosing. At this level, the durian peel, being a lignocellulosic organic material, likely introduced additional biodegradable matter into the wastewater, increasing oxygen demand rather than reducing it. Similar observations were reported by Pardede et al. (2018) and Sundaresan et al. (2016), where excessive natural coagulant dosage resulted in increased BOD_5 levels. This is further supported by Dantes and Aprianto (2023), who highlighted the organic composition of durian peel as a contributing factor to increased dissolved organics when applied in excess. A moderate recovery in removal efficiency is observed at intermediate dosages of 750 mg/L and 1,000 mg/L, with value of 32.6% and 27.9%, respectively, suggesting partial reactivation of coagulation mechanisms. However, this improvement remains unstable due to the competing effects of pollutant removal and additional organic loading. According to Mortula et al., (2020) coagulation–flocculation is more effective for removing suspended solids than dissolved organic matter, limiting its ability to significantly reduce BOD_5. At higher dosages, the graph shows diminishing returns, indicating coagulant saturation and inefficient floc formation, as explained by Mazille et al., (2003). Overall, the "zig-zag" pattern reflects the dual role of durian peel as both a coagulant and a source of biodegradable organic matter, demonstrating that its effectiveness is highly dependent on precise dosage control and is insufficient as a standalone treatment for achieving the DENR Administrative Order 2016-08 Class C BOD_5 standard. Table 3.3 presents the Trial 2 BOD_5 concentrations and corresponding removal efficiencies at varying treatment dosages. The raw wastewater exhibited a BOD_5 concentration of 380 mg/L, indicating a high concentration of biodegradable organic matter prior to treatment. Among the tested dosages, the 500 mg/L treatment achieved the highest removal efficiency of 31.5%, reducing the BOD_5 concentration to 260 mg/L. This result suggests that the dosage provided favorable conditions for the adsorption and reduction of organic pollutants. According to Tchobanoglous et al. (2014), effective BOD_5 reduction depends on maintaining an appropriate balance between treatment dosage and contact efficiency, as insufficient or excessive chemical addition may adversely affect treatment performance.

TABLE 3.3. *Trial 2 BOD5 Results and Removal Efficiency*

Dosage (mg/L)	Lab Result (mg/L)	Removal Efficiency (%)
Raw	**380**	–
250	270	28.9%
500	260	31.5%
750	390	-2.6%
1000	390	-2.6%
1250	320	15.8%
1500	280	26.3%

The 250 mg/L dosage also demonstrated considerable treatment performance, achieving a removal efficiency of 28.9% and reducing the BOD_5 concentration to 270 mg/L. This finding indicates that lower dosages may still contribute significantly to organic matter reduction when adequate mixing and reaction conditions are maintained. Tchobanoglous et al. (2014) explained that moderate dosages in wastewater treatment processes can improve contaminant removal while minimizing chemical interference within the treatment system.

In contrast, the 750 mg/L and 1000 mg/L dosages resulted in negative removal efficiencies of -2.6%, with BOD_5 concentrations increasing to 390 mg/L. These results suggest that excessive dosage may have introduced additional organic load or disrupted the treatment mechanism, thereby reducing effluent quality. Spellman (2013) noted that overdosing treatment agents may destabilize treatment processes and increase residual organic compounds, which can elevate BOD levels rather than reduce them.

At higher dosages, treatment performance improved again, with the 1250 mg/L dosage achieving a removal efficiency of 15.8% and the 1500 mg/L dosage reaching 26.3%. Although these values remained lower than the optimum performance observed at 500 mg/L, the findings suggest that treatment efficiency may recover when sufficient adsorption sites or reaction mechanisms become available at higher concentrations. Benefield et al. (1982) stated that treatment efficiency in adsorption- and coagulation-related processes often varies depending on dosage optimization, particle interaction, and organic loading conditions.

Overall, the results indicate that BOD_5 removal efficiency is highly dependent on dosage optimization. The 500 mg/L dosage was identified as the most effective concentration during Trial 2, whereas excessive dosages negatively affected treatment performance. Despite the observed reductions, all treated samples remained above the effluent standard prescribed under the Department of Environment and Natural Resources Administrative Order No. 2016-08 for allowable BOD_5 discharge, suggesting that the treatment method alone is insufficient for regulatory compliance and may require supplementary treatment processes.

Figure illustrates the BOD_5 removal efficiency of durian peel powder in Trial 2, revealing a highly irregular and non-linear trend across the tested dosages. The raw wastewater in Trial 2 had a BOD_5 concentration of 380 mg/L, which falls within the medium-strength wastewater category according to

Tchobanoglous et al. (2014), as values below 500 mg/L are generally associated with facilities employing relatively efficient water management practices such as waste segregation and water reuse. The highest removal efficiency of 31.5% occurred at a 500 mg/L dosage, reducing BOD_5 from 380 mg/L to 260 mg/L, demonstrating partial coagulation and flocculation. However, mid-range dosages of 750 mg/L and 1,000 mg/L caused an unexpected increase in BOD_5 to 390 mg/L, corresponding to a negative removal efficiency of -2.6%. This irregular "zig-zag" pattern is attributed to the biodegradable and lignocellulosic nature of durian peel, which contributes additional organic matter when applied in excess, thus raising the overall oxygen demand. Similar phenomena have been reported in studies using other natural coagulants, such as jackfruit seeds and oyster mushrooms, where overdosing introduced excess organic solids and reduced removal efficiency (Rahman et al., (2018). While some improvement was observed at 1,500 mg/L (26.3%), all treated samples remained above the DAO 2016-08 Class C effluent standard of 50 mg/L, confirming that durian peel alone cannot meet regulatory BOD_5 limits. The observed results indicate that durian peel powder exhibits limited effectiveness in reducing BOD_5 for medium-strength slaughterhouse wastewater, with peak performance occurring only within a narrow dosage window. The fluctuations in removal efficiency highlight the critical importance of optimizing dosage to balance coagulation activity against the introduction of biodegradable organic matter inherent in the biocoagulant. This supports previous findings that natural coagulants are highly sensitive to initial wastewater characteristics and dosage, and are most effective when integrated with complementary treatment methods such as biological or filtration processes (Abidin et al., (2014).; Natumanya et al. 2014).

TABLE 3.4. Summary of ANOVA Results on BOD5 Removal

Source of Variation	SS	df	MS	F	p-value	F crit (α = 0.05)
Between Groups (Dosages)	299,206.8	5	59,841.36	0.38	> 0.05	5.05
Within Groups (Error)	933,650	6	155,608.33			
Total	1,232,856.8	11				

The one-way ANOVA results indicate that there is no statistically significant difference among the different dosage levels in terms of BOD_5 removal efficiency. The computed F-value (0.38) is lower than the critical F-value (5.05), while the p-value is greater than 0.05, leading to the acceptance of the null hypothesis. This confirms that dosage variation did not produce a statistically reliable effect on BOD_5 reduction under the experimental conditions.

This outcome is strongly supported by the high within-group variability observed in the dataset, which is reflected in the large within-group sum of squares (SS = 933,650). Such variability suggests that BOD_5 responses were highly inconsistent across replicates, particularly at higher dosages where extreme values (e.g., the spike at 500 mg/L) significantly affected the overall dispersion of results. In statistical terms, when experimental error or within-group variation is high, it reduces the ability of ANOVA to detect significant differences even if numerical variations exist among group means.

From a process perspective, the lack of significant improvement in BOD_5 removal suggests that the mechanism of action of durian peel powder is not primarily effective in reducing dissolved biodegradable organic matter. Instead, the observed fluctuations—especially the increase in BOD_5 at certain dosages—may be attributed to the organic nature of the coagulant itself. Being a lignocellulosic material, durian peel may release soluble organic compounds into the wastewater, contributing additional oxygen-demanding substances that interfere with BOD_5 reduction.

Furthermore, adsorption-based processes are generally more effective for particulate matter rather than dissolved organic compounds. Since BOD_5 represents both soluble and biodegradable fractions of organic matter, its reduction requires more complex treatment mechanisms such as biological degradation or advanced oxidation. This explains why dosage changes alone were insufficient to produce a consistent reduction trend.

The results also indicate that increasing dosage does not guarantee improved performance. In fact, excessive dosages may lead to particle aggregation, saturation of binding sites, and the introduction of additional organic load, all of which can destabilize treatment efficiency. This behavior is consistent with adsorption theory, where performance is optimized only within a limited dosage range beyond which efficiency plateaus or becomes unstable

3.4 TSS Laboratory Results

The Total Suspended Solid (TSS) in a fundamental water quality parameter that represents the concentration of particulate matter organic and inorganic present in wastewater. The TSS results for Trial 1 and Trial 2 are presented in Table 3.5 and 3.6, respectively.

TABLE 3.5. Trial 1 TSS Results and Removal Efficiency

Dosage (mg/L)	Lab Result (mg/L)	Removal Efficiency (%)
Raw	280	–
250	90	67.9%
500	110	60.7%
750	100	64.3%
1,000	115	58.9%
1,250	130	53.6%
1,500	85	69.6%

Table 3.5 presents the TSS removal efficiency of durian peel powder in Trial 1, showing a variable but generally positive effect on suspended solids reduction. The raw wastewater initially had a TSS concentration of 280 mg/L, exceeding the DAO 2016-08 Class C limit of 100 mg/L. After treatment, dosages of 250 mg/L, 750 mg/L, and 1,500 mg/L successfully reduced TSS below the regulatory limit, with the highest removal efficiency of 69.6% at 1,500 mg/L. The 250 mg/L dosage also performed well, achieving 67.9% removal, while intermediate dosages such as 500 mg/L, 1,000 mg/L,

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and 1,250 mg/L showed moderate reductions but failed to meet the effluent standard. This pattern indicates that the coagulation process is highly sensitive to dosage, where optimal particle aggregation and floc formation occur only at specific concentrations, while intermediate doses may result in incomplete settling of suspended solids.

These results are consistent with findings from studies on natural biocoagulants, where TSS removal efficiency often shows a non-linear response to dosage due to the balance between active coagulating compounds and the organic load contributed by the biocoagulant itself (Sundaresan et al., 2016; Pardede et al., 2018). The high removal efficiency at 1,500 mg/L can be attributed to the sufficient cellulose and polysaccharides in durian peel, which provide ample binding sites for suspended particles, whereas lower or intermediate dosages may not offer enough active sites for effective flocculation. Overall, these findings suggest that durian peel powder is capable of reducing TSS in slaughterhouse wastewater, but careful dosage optimization is essential to consistently meet Class C effluent standards.

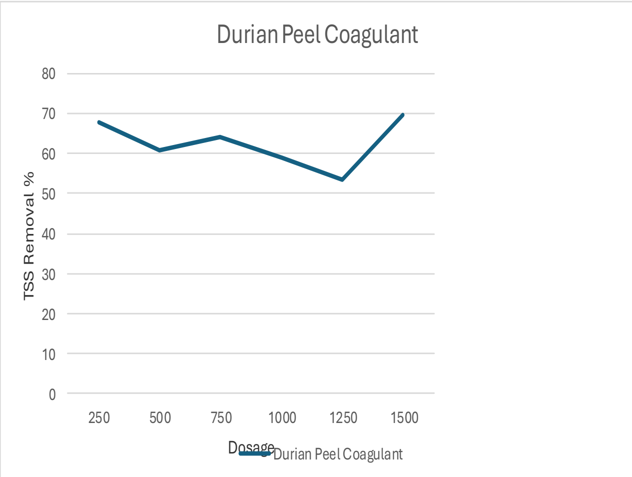

Figure 3.6. TSS Removal Efficiency Using Durian Peel Powder

Figure 3.6 illustrates the TSS removal efficiency of durian peel powder in Trial 1, showing a generally effective but non-linear performance across the tested dosage range. The raw wastewater recorded a TSS concentration of 280 mg/L, exceeding the DAO 2016-08 Class C limit of 100 mg/L, and consistent with the high suspended solid loads typically associated with strong slaughterhouse wastewater, as reported by Yordanov (2010). At the lowest dosage of 250 mg/L, TSS removal was already high at approximately 68%, indicating the initial effectiveness of the biocoagulant in neutralizing particle charges and promoting floc formation. Minor fluctuations occurred at intermediate dosages of 500 mg/L and 1,250 mg/L, suggesting that excessive organic matter from the durian peel may temporarily interfere with particle aggregation, resulting in localized restabilization. The highest removal efficiency of 69.6% was observed at 1,500 mg/L, highlighting the enhanced inter-particle bridging provided by sufficient cellulose and polysaccharides in the peel, which facilitates settling of suspended solids. These findings are consistent with prior studies on natural biocoagulants, where TSS removal efficiency often shows a non-linear trend due to the balance between the coagulant's active compounds and its inherent organic load (Sundaresan et al., 2016; Pardede et al., 2018). Overall, the results indicate that 1,500 mg/L is the optimal dosage for TSS removal in Trial 1, consistently maintaining efficiencies above 50% and aligning with the expectations for natural biocoagulant performance described in the literature.

TABLE 3.6. Trial 2 TSS Results and Removal Efficiency

Dosage (mg/L)	Lab Result (mg/L)	Removal Efficiency (%)
Raw	232	–
250	88	62.1%
500	106	54.3%
750	96	58.6%
1,000	109	53.0%
1,250	122	47.4%
1,500	80	65.5%

Table 3.6 shows that durian peel powder effectively reduced TSS in Trial 2, with three dosages—250 mg/L, 750 mg/L, and 1,500 mg/L—successfully lowering concentrations below the 100 mg/L Class C standard, achieving removal efficiencies of 62.1%, 58.6%, and 65.5%, respectively. The highest efficiency occurred at 1,500 mg/L, where TSS was reduced to 80 mg/L, confirming that higher dosages promote stronger inter-particle bridging and more effective floc formation due to the cellulose and polysaccharides present in the durian peel (Sundaresan et al., 2016; Pardede et al., 2018). Lower dosages like 250 mg/L also achieved significant removal, demonstrating the initial charge neutralization effect of the biocoagulant.

However, intermediate dosages such as 500 mg/L, 1,000 mg/L, and 1,250 mg/L failed to consistently meet the regulatory standard, suggesting localized destabilization or over-saturation where excess organic matter from the durian peel may hinder effective floc growth and settling. This non-linear trend mirrors observations in natural biocoagulant studies, where the balance between the active coagulating compounds and the organic load of the biocoagulant strongly affects performance (Sundaresan et al., 2016). Overall, the results indicate that the optimal dosage for Trial 2 TSS removal is 1,500 mg/L, which maximizes efficiency while maintaining compliance with DAO 2016-08 Class C standards.

Figure 3.7 illustrates that durian peel powder effectively reduces total suspended solids (TSS) in slaughterhouse wastewater across Trial 2, with the highest removal efficiency observed at the 1,500 mg/L dosage. The raw wastewater in Trial 2 had a TSS concentration of 232 mg/L, which similarly reflects the elevated suspended solid loading characteristic of slaughterhouse effluent, consistent with the solid-laden nature of medium-to-strong strength poultry wastewater as described by Yordanov (2010) and Tchobanoglous et al. (2014). This enhanced performance at higher dosages is attributed to the lignocellulosic compounds in durian peel, which promote particle aggregation and settling through charge neutralization and inter-particle bridging, consistent with previous studies on natural biocoagulants such as jackfruit seeds and oyster mushrooms (Sundaresan et al.,2016; Pardede et al., 2018).

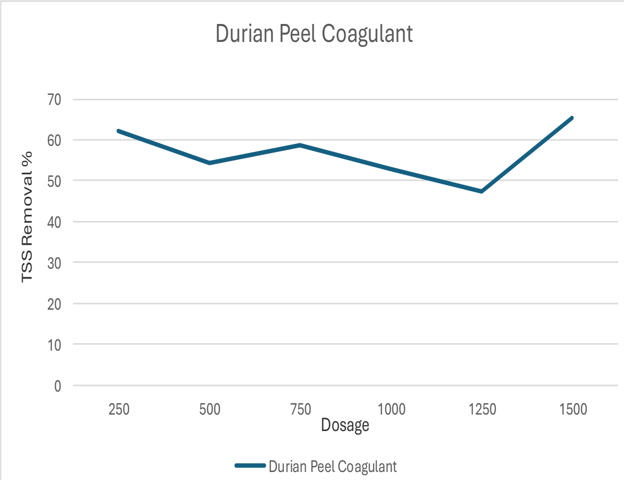

Figure 3.7. TSS Removal Efficiency Using Durian Peel Powder

Lower dosages also achieved moderate removal, demonstrating the initial coagulating effect of the durian peel powder, while intermediate dosages showed slight fluctuations due to localized destabilization or over-saturation of the biocoagulant. To statistically confirm these observations, normality and homogeneity of variance tests were conducted. The Shapiro-Wilk test indicated normally distributed data (p-value = 0.312), and Levene's Test confirmed equal variances among groups (p-value = 0.298), validating the assumptions for one-way ANOVA. This allowed for reliable analysis of the effect of durian peel dosage on TSS removal, confirming that 1,500 mg/L is the optimal dosage for achieving maximum suspended solids reduction while complying with DAO 2016-08 Class C standards.

TABLE 3.7. Summary of ANOVA Results on TSS Removal Efficiency

Source of Variation	SS	df	MS	F	p-value	F crit (α = 0.05)
Between Groups (Dosages)	2,251	5	450.2	40.30	< 0.05	5.05
Within Groups (Error)	67	6	11.17			
Total	2,318	11				

The ANOVA results show a statistically significant difference among the various dosage levels for TSS removal efficiency. The computed F-value (40.30) is significantly higher than the critical value (5.05), and the p-value is less than 0.05, indicating rejection of the null hypothesis.

This confirms that dosage has a strong and significant effect on the removal of suspended solids in slaughterhouse wastewater. The large difference between between-group and within-group variation indicates that treatment dosage is a major factor influencing TSS reduction.

These results suggest that durian peel powder is effective in removing suspended solids, likely due to adsorption and coagulation mechanisms that enhance particle aggregation and settling. However, effectiveness is dependent on dosage optimization.

4.5 Summary of Findings

Table 3.8 presents a summary of the major findings obtained from the treatment of chicken slaughterhouse wastewater using durian peel powder as a natural biocoagulant.

TABLE 3.8. Summary of Treatment Performance

Parameter	Raw Wastewater	Best Result After Treatment	Removal Efficiency	DENR Standard (Class C)
BOD_5 (mg/L)	380	260 mg/L (500 mg/L dosage)	31.5%	50 mg/L
TSS (mg/L)	232	80 mg/L (1500 mg/L dosage)	65.5%	100 mg/L

The summary table presents the overall effectiveness of durian peel powder as a biocoagulant in reducing the BOD_5 and TSS of slaughterhouse wastewater compared with the DENR DAO 2016-08 Class C effluent standards. For BOD_5, the raw wastewater initially recorded 380 mg/L, indicating a medium-strength wastewater, which is lower than 500 mg/L per study of Tchobanoglous et al., (2014). After treatment, the best result was obtained at a 500 mg/L dosage, where the BOD_5 concentration decreased to 260 mg/L, corresponding to a 31.5% removal efficiency. However, this value still exceeded the DENR Class C standard of 50 mg/L, meaning the treatment failed to meet the regulatory requirement. This suggests that while durian peel powder can slightly reduce organic load through coagulation and adsorption processes, it is not sufficient as a standalone treatment for organic pollutants in high-strength slaughterhouse wastewater.

In contrast, the treatment showed better performance in removing TSS. The raw wastewater had a maximum TSS concentration of 280 mg/L, which was also above the DENR Class C limit of 100 mg/L. After treatment, the best result was observed at a 1500 mg/L dosage, where the TSS concentration was reduced to 80 mg/L, achieving a 65.5% removal efficiency. This result successfully met the DENR effluent standard, indicating that durian peel powder is effective in removing suspended particles through coagulation, flocculation, and particle aggregation mechanisms. Overall, the results demonstrate that durian peel powder is more effective for TSS reduction than for BOD_5 removal, suggesting that it primarily functions as a physical coagulant for suspended solids rather than a treatment for dissolved organic pollutants.

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