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Reduction of Total Dissolved Solids (TDS) in Tapioca Industrial Wastewater Using the Fine-Bubble Aerator Method

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Abstract. Indonesia, the world's largest cassava producer, has substantial potential in the tapioca industry, with major production centers in Lampung, South Sumatra, and Central Java. However, the industry also generates acidic wastewater with high Total Dissolved Solids (TDS), posing environmental risks. This study evaluates the effectiveness of fine-bubble aeration in reducing TDS and stabilizing pH in tapioca industrial wastewater. Aeration was carried out at airflow rates of 2 and 5 L/min for up to 60 minutes. Results showed a significant TDS reduction from ~1650 mg/L to 1000–1100 mg/L and a pH increase from 1.8 to 6.0–6.4. The 5 L/min rate achieved faster improvements. The findings suggest that fine-bubble aeration enhanced flocculation, oxidation of organic compounds , and the release of dissolved gases, providing an efficient, economical, and environmentally friendly approach for tapioca wastewater treatment.

Keywords: aeration, fine-bubble aerator, tapioca industrial wastewater, total dissolved solids

1. Introduction

The tapioca processing industry plays a crucial role in Indonesia’s national economy, serving as a key supplier of raw materials for downstream sectors such as food, pharmaceuticals, and textiles. The production process involves multiple stages, including washing, peeling, grating, starch extraction, sedimentation, and drying. Despite its substantial economic contribution, the industry’s expansion poses significant environmental challenges, particularly related to the volume and characteristics of the resulting wastewater. Effluents, primarily generated during the washing and starch separation stages, are known to contain high concentrations of dissolved and suspended organic matter (Septira & Prayitno, 2020).

Tapioca industrial wastewater is often characterized by high Total Dissolved Solids (TDS) and unsuitable pH levels for direct discharge into the environment. Typically, it has a pH of 6.0–

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6.5, Chemical Oxygen Demand (COD) of 7,000-30,000 mg/L, and TDS ranging from 638 to 2,836 mg/L (Septira & Prayitno, 2020). However, these values can fluctuate significantly due to residual starch fermentation post-processing. Extreme pH deviations, either acidic or alkaline, can disrupt aquatic ecosystems by impairing the survival of aquatic organisms, interfering with natural biological processes, and altering the toxicity of other compounds; for example, heavy metals tend to become more toxic under low pH conditions. Elevated TDS concentrations, primarily composed of inorganic salts (Vitricia et al., 2022) and minor amounts of dissolved organic matter, can affect water conductivity, reduce clarity, and pose ecological risks to both aquatic and surrounding environments. In addition, this wastewater may contain hazardous compounds such as cyanide and can promote the formation of methane (CH_4), a greenhouse gas with a global warming potential significantly greater than carbon dioxide (CO_2) (Septira & Prayitno, 2020). Physically, the wastewater appears whitish-yellow with a distinct cassava odor; without proper treatment, it darkens to gray and emits foul smells that degrade environmental quality (Wijayanti & Rahmadhia, 2021). These conditions may pose health risks, disturb ecological balance, lead to aquatic organism mortality, and inhibit growth in disposal areas. Therefore, appropriate wastewater treatment prior to discharge into natural water bodies is imperative.

To address these environmental challenges, various approaches have been developed to mitigate the impact of industrial wastewater, including physical, chemical, and biological treatments such as BOD reduction (Farahdiba, 2022). Among these, aeration technology has emerged as a relatively cost-effective and efficient option. The fundamental principle involves increasing the dissolved oxygen (DO) content in wastewater (Alkhalidi & Amano, 2012), a key factor for supporting aerobic microbial activity essential for organic matter degradation (Efendi et al., 2023). Elevated DO levels may also influence pH balance through oxidation of specific compounds and the release of dissolved gases such as carbon dioxide (CO_2). Moreover, aeration facilitates flocculation and sedimentation of suspended solids, which, although distinct from Total Dissolved Solids (TDS), are often correlated and can impact the overall solids content of the effluent. Fine-bubble aeration systems have gained considerable attention due to their ability to generate microbubbles (typically 1-3 mm) via porous diffusers (Akli et al., 2022). The small bubble size significantly increases the surface area-to-volume ratio, thereby enhancing oxygen transfer efficiency from air to water (Farahdiba, 2022). Additionally, the slower rise velocity of smaller bubbles prolongs gas–liquid contact time, which may contribute to the reduction of TDS. Research by Akli et al. (2022) on palm oil mill effluent (POME) demonstrated that fine-bubble aeration directly impacted pH, total nitrogen content, and monthly reductions in total suspended solids (TSS). Similarly, Vitricia et al. (2022) reported the effectiveness of aeration in treating laundry wastewater, achieving 90% and 95% removal of BOD and COD, respectively, after 72 hours of operation. A comprehensive review by Simbolon et al. (2019) and Vitricia et al. (2022) further highlights the practicality, affordability, and environmental sustainability of wastewater treatment using fine-bubble aerator technology.

Therefore, this study aims to comprehensively investigate the effectiveness of fine-bubble aeration in stabilizing pH and reducing Total Dissolved Solids (TDS) concentrations in tapioca industrial wastewater. The research will identify the TDS reduction patterns, including aeration duration and the impact of two different airflow rates, to optimize treatment efficiency. The findings are expected to significantly contribute to the development of more efficient, sustainable, and cost-effective wastewater treatment strategies for the tapioca industry. Furthermore, this study aims to provide a robust scientific basis for industry practitioners, environmental policymakers, and academics in formulating more adaptive and effective waste management approaches, aligning with environmental conservation efforts and compliance with prevailing wastewater quality standards.

2. Methods

2.1. Materials

The material used in this study was wastewater from the tapioca industry . The equipment included a glass reactor (24 cm × 14 cm × 40 cm) with a capacity of 15 liters, a compressor, a diffuser, a stopwatch, a TDS meter, and a pH meter.

2.2. Aeration process

A volume of 3 liters of wastewater was introduced into the reactor and subjected to aeration for 60 minutes. The fine-bubble aerator was operated at flow rates of 2 L/min and 5 L/min. TDS and pH were measured at 0, 5, 10, 20, 30, 40, 50, and 60 minutes using a TDS meter and pH meter, respectively. All measurements were conducted in triplicate.

3. Result and Discussion

The treatment of tapioca industrial wastewater using a fine-bubble aerator was conducted, and the results are presented in Figures 1 and 2. Figure 1 illustrates the pH variation at an airflow rate of 2 L/min over 60 minutes of aeration. The initial pH ranged from approximately 1.78 to 1.9, indicating a strongly acidic condition typical of tapioca wastewater. During the first 10 minutes, the pH increased gradually to around 3.1, followed by a further rise to 3.5 after 20 minutes. This upward trend continued steadily, reaching near-neutral values of approximately 6.0 by the end of the 60-minute aeration period. The progressive increase in pH suggests effective neutralization of

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acidic components, likely facilitated by enhanced oxygen transfer and subsequent biochemical reactions during aeration.

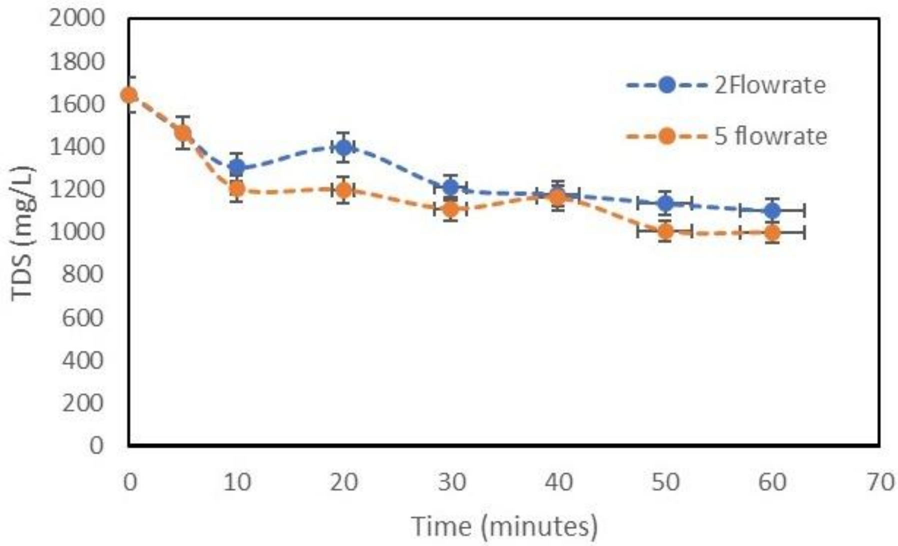

Figure 1. Effect of aeration time on TDS of wastewater

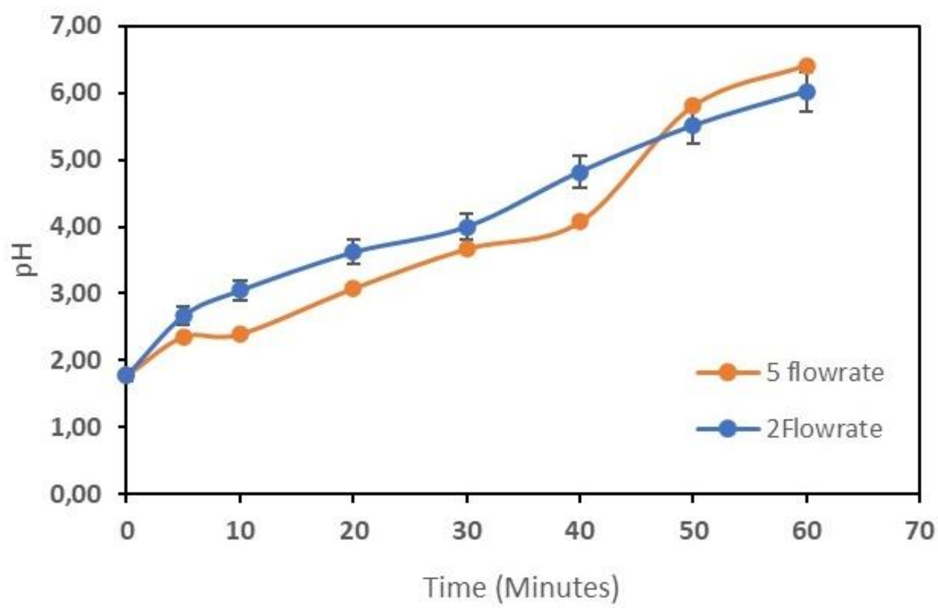

Figure 2. Effect of aeration time on pH of wastewater

In contrast, Figure 2 depicts the pH changes at a higher airflow rate of 5 L/min. The initial pH values were similar to those in the 2 L/min condition. However, the increase in pH was more rapid during the early stages, reaching approximately 2.4 after just 5 minutes and 3.1 by 20 minutes. The pH continued to rise steadily, achieving a slightly higher final pH value of about 6.4 at 60 minutes. The wastewater pH meets the quality standard of 6-9 as regulated by the Ministry of Environment and Forestry Regulation of Indonesia No. 68/2016. This comparison indicates that increasing the aeration intensity accelerates the pH stabilization process, presumably by promoting faster oxidation of acidic substances and enhanced release of dissolved carbon dioxide. The faster pH adjustment at 5 L/min demonstrates the advantage of higher airflow rates in improving the efficiency of wastewater neutralization, which is critical for mitigating the environmental impact of acidic effluents on aquatic ecosystems.

In addition to pH stabilization, the changes in Total Dissolved Solids (TDS) concentration during aeration at both airflow rates were monitored, as shown in the figures. The fine-bubble aeration process significantly reduced TDS levels, which are indicative of dissolved inorganic and organic contaminants in the wastewater. Although the detailed TDS data require further analysis, the overall trends suggest that aeration not only stabilizes pH but also contributes to the reduction of dissolved solids, possibly through mechanisms such as flocculation, oxidation of organic compounds, and the release of dissolved gases. These findings highlight the potential of fine-bubble aeration as an effective and economical method for treating tapioca industrial wastewater, balancing chemical parameters while minimizing environmental risks.

At both airflow rates, a decreasing trend in Total Dissolved Solids (TDS) concentration was observed as aeration time increased. At an airflow rate of 2 L/min, the initial TDS concentration of approximately 1650 mg/L decreased to around 1300 mg/L at the 10th minute, followed by a slight increase before stabilizing near 1100 mg/L at the 60th minute, representing an overall reduction of approximately 33.3%. For the 5 L/min airflow rate, the initial TDS concentration was similar (approximately 1650 mg/L), but exhibited a faster reduction during the early phase, reaching approximately 1200 mg/L at 10 minutes, and continuing to decline until stabilizing around 1000 mg/L at 60 minutes. This corresponds to a total reduction of approximately 39.4%, indicating a more effective TDS removal compared to the 2 L/min condition. Overall, fine-bubble aeration effectively reduced TDS concentrations, with the 5 L/min airflow showing slightly better efficiency, as indicated by the lower final TDS values. Minor fluctuations in the curves may reflect complex dynamics in the settling process or changes in the properties of dissolved solids during aeration (Harfadli, 2019).

Although aeration does not directly remove dissolved ions constituting TDS, the observed reduction can be attributed to several factors. Firstly, aeration may induce flocculation and coagulation of colloidal organic and inorganic particles (Munthe et al., 2018) or fine suspended solids previously dispersed in the wastewater and counted within TDS. Increased turbulence and particle collisions due to air bubbles facilitate the agglomeration of these particles into larger flocs, which subsequently settle. Secondly, oxidation of dissolved organic matter during aeration can alter the solubility of some organic components contributing to TDS, causing them to precipitate or convert into insoluble forms (Yuniarti, Dewi P, Komala, 2019). Thirdly, the release of other dissolved gases besides CO_2 may also contribute to the reduction of total dissolved solids. The efficiency of aeration in reducing TDS is also influenced by specific wastewater characteristics and the presence of substances that interact with oxidation or sedimentation processes.

4. Conclusion

This study shows that fine-bubble aeration effectively reduces Total Dissolved Solids (TDS) and increases pH in tapioca industrial wastewater. Using airflow rates of 2 and 5 L/min for 60 minutes decreased TDS to about 1000-1100 mg/L and increased pH from ~1.8 to 6.0-6.4. The higher airflow rate (5 L/min) achieved faster and more efficient results. The process effectiveness is attributed to oxidation, flocculation, and gas release. Therefore , fine-bubble aeration provides an efficient, sustainable, and environmentally friendly treatment method for tapioca wastewater.

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