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Short Review

Potency of Bioflocculants Based on Onggok Cassava Starch Modified by Graft Copolymerization with Polyacrylamide (PAM) and Its Application in Textile Waste Treatment

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Abstract

The textile industry is a major source of environmental pollution due to the discharge of highly colored and chemically complex wastewater containing toxic, mutagenic, and carcinogenic compounds that are often resistant to conventional treatment. Although conventional chemical coagulants and flocculants such as alum and synthetic polymers are effective, their application raises concerns about excessive sludge generation, residual toxicity, and long-term environmental impacts. This short review critically evaluates the potential of cassava pulp (onggok) starch modified by graft copolymerization with polyacrylamide (PAM) as a bioflocculant for textile wastewater treatment. The review synthesizes current knowledge on textile wastewater characteristics, coagulation-flocculation principles, and the development of starch-based bioflocculants, with particular emphasis on cassava-derived starch and starch-g-PAM systems. Special attention is given to the underlying flocculation mechanisms, including charge neutralization and polymer bridging, as well as to reported performance in turbidity, color, and chemical oxygen demand removal. Furthermore, the environmental and economic advantages of valorizing cassava pulp waste into high-value bioflocculants are discussed in relation to sustainable wastewater management and relevant Sustainable Development Goals (SDGs). Overall, this review provides a focused scientific framework and identifies key research directions to advance graft-modified cassava pulp starch as a low-cost and environmentally friendly alternative to conventional flocculants for textile wastewater treatment.

Keywords

Textile waste; onggok starch; flocculant; starch modification; graft copolymerization; polyacrilamide

1. Introduction

The textile industry is one of the fastest-growing manufacturing sectors worldwide and plays a strategic role in national economic development through employment generation and export earnings [1-3]. However, this rapid growth is accompanied by serious environmental challenges, particularly the generation of large volumes of wastewater containing dyes, surfactants, salts, heavy metals, and various toxic organic compounds [4-6]. Textile effluents are typically characterized by high color, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS), and variable pH. They are often resistant to biodegradation, making their treatment technically and economically challenging [2, 3]. If discharged untreated, this wastewater can reduce light penetration, disrupt photosynthesis in aquatic ecosystems, bioaccumulate in the food chain, and pose mutagenic and carcinogenic risks to humans and other organisms [3, 4].

Conventional wastewater treatment in the textile industry commonly relies on physicochemical methods, including coagulation-flocculation, adsorption, oxidation, and membrane processes, either as standalone systems or in combination [4]. Among these methods, coagulation-flocculation is widely applied because it is relatively simple, effective, and cost-efficient for removing color and suspended solids [5]. Aluminum sulfate, ferric salts, and synthetic polymeric flocculants such as polyacrylamide (PAM) are frequently used to destabilize colloids and promote the formation of larger flocs that can be separated by sedimentation or filtration [5, 6]. Nevertheless, the use of inorganic coagulants and fully synthetic polymers has been associated with several drawbacks, including the generation of large amounts of chemical sludge, potential toxicity of residual metals or monomers, pH reduction, and concerns about long-term impacts on ecosystems and human health [6, 7]. These issues have driven growing interest in developing alternative coagulants and flocculants based on renewable, biodegradable, and less toxic materials.

Natural polymers such as chitosan, tannins, plant gums, and starch have gained attention as promising bioflocculants due to their biodegradability, low toxicity, and abundant availability [4, 7-9]. Starch, in particular, is an attractive candidate because it is inexpensive, derived from various agricultural commodities, and contains hydroxyl groups that can participate in hydrogen bonding and adsorption processes during coagulation-flocculation [8-10]. However, native starches often exhibit limitations such as low charge density, limited solubility under certain conditions, and insufficient flocculation efficiency when used alone to treat highly contaminated industrial effluents [9, 10]. To overcome these limitations, chemical modification—especially graft copolymerization with synthetic monomers such as acrylamide—has been widely explored to enhance the performance of starch-based flocculants [11-13].

Indonesia is one of the largest producers of cassava, and cassava-processing industries generate substantial quantities of solid by-products such as cassava pulp (onggok) [4, 14, 15]. Onggok typically contains a high residual starch content, making it a potential raw material for value-added bioproducts [14-16]. At present, onggok is mostly used as low-value animal feed or fertilizer, or discarded as waste, which can contribute to environmental problems if not properly managed [14]. Valorizing onggok into bioflocculants for wastewater treatment represents an opportunity to address two issues simultaneously: the need for more sustainable flocculants and the management of agro-industrial solid waste. Previous studies have demonstrated that cassava-derived starch can effectively reduce turbidity and color in water and wastewater, either as a primary coagulant or as a coagulant aid in combination with inorganic salts [8-10].

Graft copolymerization of cassava starch with polyacrylamide (starch-g-PAM) has emerged as a promising strategy to combine the environmental advantages of starch with the high flocculation efficiency of PAM [11-13]. In such systems, starch provides a biodegradable backbone. It contributes to bridging and adsorption, while the grafted PAM chains increase charge density, water solubility, and interaction with suspended particles and dissolved pollutants [11, 12]. Several experimental studies have reported that starch-g-PAM-based flocculants can significantly enhance the removal of turbidity, dyes, and heavy metals from synthetic and real wastewater, often at lower dosages than conventional coagulants [9-13]. However, the specific potential of starch derived from cassava pulp (onggok) modified by graft copolymerization with PAM for textile wastewater treatment has not been extensively reviewed in a structured manner.

Therefore, this short review aims to summarize and critically discuss the potential of cassava pulp starch modified through graft copolymerization with polyacrylamide as a bioflocculant for textile wastewater treatment. The review first outlines the characteristics and environmental impacts of textile wastewater, then discusses the principles of coagulation-flocculation and the role of starch-based bioflocculants, with emphasis on cassava-derived starch. Subsequently, the synthesis, mechanisms, and performance of starch-g-PAM systems are examined, including their relevance to Sustainable Development Goals (SDGs) related to clean water, sustainable industry, and environmental protection. By integrating available findings, this review provides a scientific basis for the development and application of onggok-based starch-g-PAM as an environmentally friendly, cost-effective alternative to conventional flocculants in textile wastewater management.

2. Methodology of the Review

This short review synthesized literature on cassava pulp (onggok) starch modified via graft copolymerization with polyacrylamide (PAM) for textile wastewater treatment. Searches were performed in Scopus, Web of Science, ScienceDirect, and Google Scholar using combinations of keywords such as “textile wastewater”, “bioflocculant”, “cassava starch”, “onggok”, “starch-based flocculant”, “graft copolymerization”, and “polyacrylamide”. Boolean operators (AND/OR) refined the queries. The initial search covered publications from approximately 2000 to 2024, with emphasis on studies since 2015.

Peer-reviewed articles, reviews, conference papers, and selected book chapters in English were considered. Studies were included if they (i) addressed textile or related industrial effluents, (ii) investigated natural or starch-based flocculants, (iii) described synthesis/characterization/application of starch-g-PAM systems, or (iv) provided relevant coagulation-flocculation background. Excluded were studies focused solely on unrelated treatment processes (e.g., stand-alone AOPs or membranes without coagulants), inaccessible full texts, or insufficient methodological detail. Priority was given to works reporting quantitative performance metrics (turbidity, color, COD, BOD, heavy-metal removal) and key operational parameters (pH, dosage, contact time).

After screening titles, abstracts, and full texts, selected studies were organized into the review's thematic sections and synthesized narratively; quantitative results were summarized in tables where available. The aim was a focused, structured synthesis to support the development of onggok-based starch-g-PAM as an environmentally friendly and cost-effective alternative to conventional flocculants.

3. Results and Discussion

3.1 Environmental Issue of Textile Wastewater

The textile industry is widely recognized as one of the most polluting industrial sectors due to its intensive use of water and chemicals during preparation, dyeing, printing, and finishing processes [13, 17]. Textile wastewater typically contains a complex mixture of dyes, surfactants, salts, heavy metals, and auxiliary chemicals, resulting in high levels of color, turbidity, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and total suspended solids (TSS) [18, 19]. Reported values for textile effluents often range from several hundred to more than 10,000 mg/L for COD, 800-6000 mg/L for BOD, and 15-8000 mg/L for TSS, with pH values varying between 6 and 10 depending on the specific processes and chemicals used [17, 19]. Such characteristics make textile wastewater difficult to treat using conventional biological processes alone, especially when highly stable synthetic dyes and non-biodegradable organic compounds are present [20].

If discharged untreated, textile wastewater can severely affect aquatic ecosystems and human health. High color and turbidity reduce light penetration and inhibit photosynthesis in aquatic plants, while elevated organic loads can lead to oxygen depletion and eutrophication [20]. Many dyes and auxiliary chemicals used in textile processing have been reported to exhibit mutagenic, carcinogenic, or endocrine-disrupting properties, and can bioaccumulate in the food chain [3, 20]. In addition, the presence of heavy metals such as Cr, Cu, Zn, Pb, Cd, and As in some textile effluents further increases the toxicity and persistence of these waste streams [18]. These environmental and health concerns have led to stricter regulatory standards for textile effluent discharge in many countries, including maximum permissible limits for BOD, COD, TSS, and color [21]. Consequently, there is an urgent need for effective and sustainable treatment technologies capable of removing both organic and inorganic pollutants from textile wastewater [22].

Coagulation-flocculation remains one of the most widely applied primary or secondary treatment steps for textile effluents due to its simplicity, relatively low cost, and ability to rapidly remove color and suspended solids [19]. Aluminum and iron salts, as well as synthetic polymeric flocculants such as polyacrylamide (PAM), are commonly used to destabilize colloidal particles and promote floc formation [5, 19]. However, their use has raised concerns about the generation of large volumes of chemical sludge, potential residual toxicity (for example, from aluminum or acrylamide monomers), and the need for pH adjustment and subsequent sludge handling [6, 7]. These limitations have stimulated the exploration of natural and bio-based flocculants, particularly those derived from renewable agricultural resources such as starch, as more environmentally benign alternatives or coagulant aids in textile wastewater treatment [7-9, 23, 24].

3.2 Starch-Based Bioflocculants

Starch is a renewable, biodegradable, and widely available polysaccharide that has attracted considerable attention as a base material for environmentally friendly flocculants [8-10, 24]. It consists mainly of two components, amylose and amylopectin, whose relative proportions typically range from about 20-30% for amylose and 70-80% for amylopectin, depending on the starch source [25]. These structural features influence its physicochemical properties, including solubility, gelatinization behavior, and interaction with contaminants in aqueous systems. The presence of numerous hydroxyl groups along the starch chains enables hydrogen bonding and adsorption onto particle surfaces, which can contribute to charge neutralization and bridging mechanisms during coagulation-flocculation [26, 27]. Owing to these characteristics, starch and starch-derived materials have been investigated as primary coagulants, coagulant aids, or flocculant backbones in the treatment of various wastewaters, including textile effluents.

Several studies have reported promising performance of starch-based flocculants for turbidity, color, and pollutant removal. Cassava-derived starch and related materials, in particular, have been used as natural coagulants or flocculants to reduce turbidity in water and wastewater, with removal efficiencies often exceeding 70-80% under optimized conditions [9, 10]. Research on cassava starch flocculants for textile wastewater treatment has further shown that, at appropriate dosages and pH, turbidity reductions above 80-90% can be achieved, indicating that starch can effectively neutralize colloidal charges and promote particle aggregation [9, 10, 26]. Moreover, biopolymer-based flocculants such as starch are generally associated with lower sludge toxicity, better biodegradability, and reduced risk of harmful residuals compared with purely inorganic or fully synthetic systems [28]. These advantages align well with current trends in green chemistry and sustainable wastewater management.

Despite these benefits, native starches still present some limitations when used directly as flocculants in complex industrial effluents such as textile wastewater. Their relatively low charge density, limited solubility under certain conditions, and sometimes insufficient mechanical strength of the formed flocs can restrict their performance compared with high-molecular-weight synthetic polymers such as PAM [29]. As a result, starch often requires modification to enhance its effectiveness as a bioflocculant. Various physical, chemical, and biological modification techniques have been developed to tailor the structure and functionality of starch, including isolation and purification, oxidation, cationization, crosslinking, and graft copolymerization with vinyl monomers [27-30]. Among these strategies, grafting starch with acrylamide to produce starch-g-PAM has been particularly attractive because it combines the biodegradability and renewable nature of starch with the high flocculation efficiency, strong particle-bridging ability, and tunable properties of PAM [11-13, 31]. The following sections discuss the potential of tapioca waste (cassava pulp or onggok) as a source of starch for bioflocculant production and the role of graft copolymerization with PAM in enhancing its performance in textile wastewater treatment.

3.3 Tapioca Waste Starch as a Bioflocculant

Tapioca processing industries generate substantial amounts of solid waste known as cassava pulp or onggok, which is typically produced in large volumes and often underutilized or disposed of as low-value animal feed [4, 14, 15]. Onggok still contains a considerable amount of residual starch, with reported starch contents ranging from approximately 50 to more than 70%, depending on processing conditions and scale of operation [14-16, 24]. In countries such as Indonesia, where cassava production and tapioca processing are concentrated in specific regions, the accumulation of onggok can pose environmental challenges if not properly managed, including odor generation, leachate formation, and pest attraction [24]. At the same time, the high starch content, continuous availability, and renewable nature of onggok make it a promising raw material for value-added applications, particularly in the development of bio-based materials and water treatment agents.

Several studies have explored the use of cassava-derived starch, including starch obtained from cassava residues such as onggok, as a natural coagulant or coagulant aid in water and wastewater treatment [9, 10, 32, 33]. Cassava starch has been reported to effectively reduce turbidity in model and real wastewater systems, often achieving turbidity removal efficiencies above 70-80% under optimized pH and dosage conditions [9, 32]. For textile wastewater treatment, cassava-based flocculants have demonstrated high turbidity and color removal efficiencies, in some cases exceeding 85-90%, while simultaneously reducing the required dosage of inorganic coagulants when applied in hybrid coagulation-flocculation systems [10, 23, 33]. These results indicate that starch from tapioca waste streams, such as cassava pulp, can be harnessed as a bioflocculant with performance comparable to, or complementary with, conventional chemical flocculants.

The flocculation performance of tapioca waste starch has been attributed to its physicochemical structure and interaction mechanisms in aqueous systems. Characterization studies using FTIR, SEM, and XRD have shown that the double-helix structure formed by the amorphous crystalline regions of cassava and onggok starch plays an important role in floc formation and subsequent sedimentation behavior [9]. Cassava onggok starch can neutralize anionic charges on colloidal particles, facilitate adsorption of suspended impurities, and promote particle bridging through hydrogen bonding and polymer chain interactions [10, 23]. In addition, the presence of cellulose and high-molecular-weight polysaccharide fractions in onggok starch contributes to the formation of larger and denser flocs, thereby enhancing turbidity reduction [34].

The use of tapioca waste starch as a bioflocculant offers several environmental and economic advantages. From an environmental perspective, it supports the valorization of agro-industrial waste, reduces reliance on non-renewable chemical coagulants, and may lower sludge toxicity while improving biodegradability of treatment residues [32]. Economically, onggok is inexpensive, abundantly available, and locally sourced in cassava-producing regions, which can reduce material costs and strengthen local value chains. However, similar to other native starches, tapioca waste starch may still exhibit limitations related to its native molecular structure, solubility, and relatively low charge density, which can constrain its flocculation performance in highly contaminated textile effluents [28, 29]. Consequently, modification strategies are required to enhance its functionality and flocculation efficiency. Among these, graft copolymerization with polyacrylamide has emerged as a promising approach to upgrade onggok starch into a high-performance bioflocculant suitable for textile wastewater treatment.

3.4 Application of Bioflocculants from Cassava Pulp Starch Modified by Graft Copolymerization with Polyacrylamide (PAM)

Graft copolymerization is a versatile and widely applied technique for modifying natural polymers by covalently attaching synthetic polymer chains onto their backbone, thereby integrating the advantageous properties of both components [11-13, 30]. In the case of starch, grafting with acrylamide to form starch-g-polyacrylamide (starch-g-PAM) has been shown to substantially enhance water solubility, charge density, and interaction with suspended particles and dissolved pollutants. Cassava-derived starch, including starch obtained from cassava pulp (onggok), provides an attractive backbone for graft copolymerization due to its high abundance of hydroxyl (-OH) functional groups and its availability as a low-cost agro-industrial by-product. Through PAM-assisted grafting, onggok starch can be transformed from a low-value waste stream into a functional bioflocculant specifically tailored for textile wastewater treatment.

Polyacrylamide (PAM) is one of the most commonly used synthetic polymers in wastewater treatment because of its linear chain structure, high molecular weight, and hydrophilic functional groups (-OH and -$CONH_2$), which confer strong adsorption capacity, effective particle bridging, and good water solubility [31]. In starch-g-PAM systems, the PAM chains play a crucial role in increasing the number of active sites and enhancing electrostatic interactions with negatively charged colloids, dyes, and metal ions. At the same time, the starch backbone contributes to polymer bridging and floc growth. This synergistic mechanism enables more efficient destabilization and aggregation of complex dye-surfactant-metal colloids, which are typically present in textile effluents.

Various approaches have been developed to synthesize starch-g-PAM, including physical, chemical, enzymatic, and hybrid methods. Physical techniques such as gamma irradiation, electron beam exposure, ultraviolet (UV) irradiation, and microwave-assisted polymerization can generate free radicals on the starch backbone, creating active sites for grafting [35]. Chemical methods rely on free-radical initiators (e.g., persulfates, peroxides, or azo compounds) or backbone oxidants such as ceric (IV) or manganese (III/IV) salts, which directly activate hydroxyl groups on the biopolymer chain [35, 36]. Enzymatic graft copolymerization has also gained attention as a greener alternative, as enzymes can selectively modify functional groups under mild reaction conditions, reducing energy consumption and minimizing the use of hazardous chemicals. Enzyme-assisted synthesis preserves the native polymer backbone while improving grafting efficiency and environmental compatibility [35].

An illustrative example of enzymatic graft copolymerization of cassava starch with PAM was reported by Kaavessina et al. [37]. In this approach, non-terminated polyacrylamide chains were first synthesized using a redox-initiation system, followed by grafting onto pre-gelatinized cassava starch under controlled temperature and inert-atmosphere conditions. The resulting starch-g-PAM exhibited improved interaction with suspended particles and superior flocculation performance compared with native starch, confirming that graft copolymerization is more effective than linear starch modification for wastewater treatment applications [12].

Numerous experimental studies have demonstrated that starch-g-PAM bioflocculants exhibit excellent performance in removing turbidity, color, chemical oxygen demand (COD), and heavy metals from aqueous systems. Reported turbidity removal efficiencies commonly exceed 80-90%, often at lower dosages than those required for native starch or conventional inorganic coagulants [11-13, 38-40]. For example, cassava-based starch-g-PAM has been shown to reduce turbidity in artificial and textile wastewater by more than 85%. At the same time, cellulose- and starch-based graft copolymers have demonstrated strong adsorption capacities for heavy metals, including Fe, Cu, Pb, and Cd [12, 38, 39]. These results highlight the versatility of graft-modified biopolymers in treating complex industrial wastewaters.

From an environmental and health perspective, the use of starch-g-PAM offers important advantages over the direct application of synthetic PAM. Textile wastewater often contains non-biodegradable and hazardous compounds, including dyes, flame retardants, formaldehyde, biocides, and heavy metals, which pose risks through bioaccumulation and potential carcinogenicity [37]. Although PAM is effective as a flocculant, concerns remain regarding residual acrylamide monomers. Graft copolymerization with starch typically requires a lower PAM content than that required for pure synthetic flocculants, thereby reducing potential acrylamide exposure while maintaining high treatment efficiency [41]. In this sense, starch-g-PAM systems represent a safer and more sustainable compromise between performance and environmental impact.

The bioflocculation process using starch-g-PAM generally involves two main stages. Initially, starch segments promote pre-flocculation by adsorbing and aggregating suspended particles to form small flocs. Subsequently, PAM chains facilitate floc maturation through enhanced polymer bridging, leading to the formation of larger, denser, and more settleable flocs that can be readily removed by sedimentation or filtration [42]. This synergistic dual-polymer mechanism is schematically illustrated in Figure 1, which depicts the transition from particle suspension to mature floc formation through the combined action of starch and PAM.

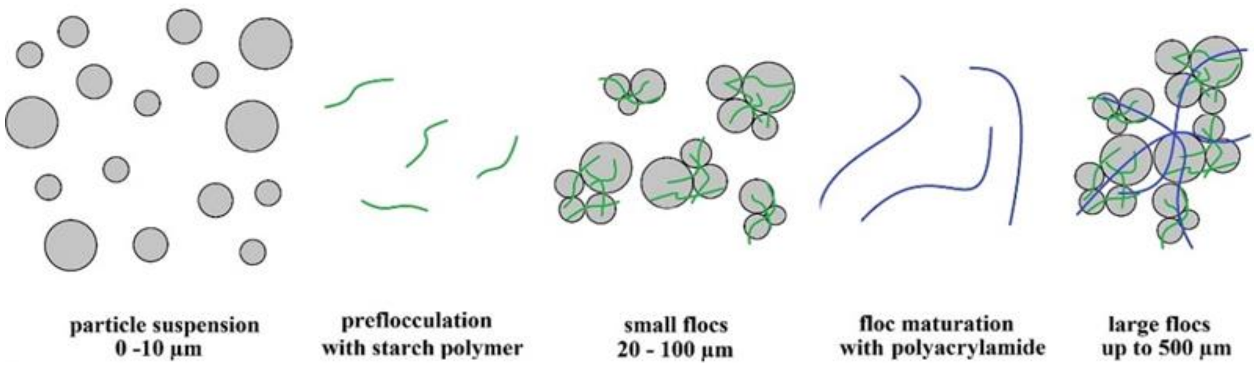

Figure 1 Illustration of the synergistic reaction of starch-g-PAM bioflocculant from cassava pulp starch [42].

From a broader sustainability perspective, the development and application of starch-g-PAM bioflocculants derived from cassava pulp contribute to several Sustainable Development Goals (SDGs). These include SDG 6 (Clean Water and Sanitation) through improved removal of hazardous pollutants from textile effluents; SDG 9 (Industry, Innovation and Infrastructure) by promoting innovative and sustainable wastewater treatment technologies; and SDG 12 (Responsible Consumption and Production) by valorizing agro-industrial waste into high-value functional materials. In addition, by preventing the release of toxic substances into aquatic environments, this approach indirectly supports SDG 14 (Life Below Water) [43]. Nevertheless, further research is required to optimize synthesis parameters, validate performance at pilot and full-scale levels, and conduct comprehensive techno-economic and life-cycle assessments to fully evaluate the feasibility and long-term benefits of onggok-based starch-g-PAM bioflocculants for textile wastewater treatment.

3.5 Further Implementation

The promising performance of starch-based bioflocculants, particularly starch-g-PAM derived from cassava pulp, indicates that these materials can be integrated into textile wastewater treatment schemes as either primary flocculants or coagulant aids. At the process level, such bioflocculants can be applied in conventional coagulation-flocculation units, for example, as a partial replacement for alum or other inorganic coagulants, to reduce chemical reagent dosage, decrease sludge toxicity, and improve the overall sustainability of the treatment system. In practice, implementation would require optimizing operational parameters such as pH, dosage, mixing conditions, and contact time to ensure stable and efficient removal of color, turbidity, COD, and heavy metals in real textile effluents. Pilot-scale and full-scale studies are therefore essential to validate laboratory findings and address issues related to process robustness, sludge handling, and regulatory compliance.

At the value-chain level, the utilization of cassava pulp for bioflocculant production offers an opportunity to establish closer collaboration among tapioca industries, wastewater treatment operators, and policymakers. Tapioca processors can supply onggok as a low-cost raw material, while chemical or bioproduct manufacturers can convert it into starch-g-PAM formulations tailored for industrial wastewater applications. Governmental and regulatory bodies may support this transition through incentives, guidelines, or demonstration projects that promote the use of bio-based flocculants in line with circular economy and green industry strategies. In the textile sector, such collaborations can enhance compliance with stringent environmental regulations and corporate sustainability commitments, while simultaneously adding value to agricultural byproducts and contributing to regional economic development.

4. Conclusions

Cassava pulp (onggok), a solid by-product of tapioca production, contains a high residual starch content and represents a promising raw material for the development of bioflocculants for textile wastewater treatment. As a natural polymer, starch offers advantages such as renewability, biodegradability, and functional groups that enable adsorption and bridging interactions with contaminants; however, native starch alone may not always provide sufficient flocculation efficiency for complex industrial effluents. Chemical modification via graft copolymerization with polyacrylamide (PAM) has emerged as an effective strategy to enhance the solubility, charge density, and flocculation performance of starch-based materials, yielding starch-g-PAM systems that achieve high removal efficiencies for turbidity, color, and organic pollutants in aqueous media.

The literature reviewed in this work indicates that starch-g-PAM derived from cassava-based starch can perform comparably to conventional synthetic flocculants and, in some cases, allows a reduction in the dosage of inorganic coagulants while maintaining or improving treatment efficiency. When the starch backbone is sourced from cassava pulp, the resulting bioflocculant not only supports the valorization of agro-industrial waste but also aligns with broader sustainability objectives by potentially lowering sludge toxicity and dependence on non-renewable chemical reagents. These attributes position onggok-based starch-g-PAM as a promising candidate for integration into textile wastewater treatment schemes that aim to meet increasingly stringent environmental regulations and Sustainable Development Goals (SDGs).

Despite these advantages, several research gaps remain. Further studies are needed to optimize grafting conditions and formulation parameters for cassava pulp starch-g-PAM, to systematically compare its performance with commercial flocculants under realistic textile effluent conditions, and to evaluate its long-term stability, regeneration, and sludge management. Comprehensive techno-economic and life-cycle assessments are also required to quantify the environmental and economic benefits of replacing or supplementing conventional flocculants with onggok-based starch-g-PAM at pilot and full scales. Addressing these gaps will be crucial for translating laboratory-scale success into practical, scalable, and sustainable solutions for textile wastewater management.

Author Contributions

Primasetya Ramadhan, Selvi, Putri Zhafira Azzahra, Naomi Azzahra, Gracela Natalie, Ocha Maharani, Kristina Alma Isadora, and Fransiska Dyah Ayu Cahyaningtyas wrote the manuscript in Bahasa and English. Esa Ghanim Fadhallah proofread the manuscript. All authors read and approved the final version of the manuscript.

Competing Interests

The authors have declared that no competing interests exist.

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