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Investigating the Efficiency of Papaya and Date Dry Seeds as Natural Coagulants in the Wastewater Treatment Process

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ABSTRACT

Industrial effluent contaminants include insoluble substances, heavy metals and organic and inorganic compounds. The textile industry has a hard time dealing with its waste because it contains a lot of different colours and chemicals. To treat industrial effluent, coagulation-flocculation is frequently employed due to its efficacy in removing suspended particles organic matter, turbidity and colour. Conversely, employing a chemical coagulant may result in significant costs and the production of considerable quantities of non-biodegradable waste and metallic byproducts in the treated water, both of which face contamination risks by pollutants and diseases. An environmentally sustainable, non-toxic and biodegradable alternative method under consideration of utilising natural coagulants derived from plants, namely papaya seed and date seed. This study uses different NaCl concentrations to see how well papaya seed and date seed work as natural coagulants in treating textile industry wastewater. NaCl was the solvent and distilled water was used to extract the natural coagulant. Chemical Oxygen Demand (COD), turbidity, ammonia nitrogen and pH were assessed to evaluate the textile wastewater sample's response to papaya and date seed purification. The experiment's findings indicate that papaya and date seeds possess exceptional coagulation properties. The optimum turbidity reduction efficiency for papaya seed was 61.48% when 30 ml of a 1.0 NaCl concentration solvent was utilised. On the other hand, date seed removed turbidity with an efficiency of 83.96% when 10 ml of a 1.0 NaCl solvent was utilised. Aside from that, 1.0M NaCl was found to be the most effective COD reduction solution for the Carica papaya seed, while 2.0M NaCl resulted in a 56.19% reduction for the date seed. In addition, 30 ml Carica papaya seed coagulant dosage containing 2.0M NaCl produced the most significant reduction in ammonia nitrogen (82.84%). Also, the dosage of 20 ml date seed coagulant containing 2.0M NaCl eliminated 43.33% of ammonia nitrogen. The study's findings illustrated the potential advantages of utilising papaya and date seeds as organic coagulants in the remediation of effluents from the textile industry.

Keywords:
Coagulant; water treatment; papaya seed; date seed; textile wastewater

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1. Introduction

Industrial wastewater contains a variety of pollutants, such as organic and inorganic compounds, heavy metals and insoluble substances. Industrial effluent types are diverse and many depend on the industry. Industries such as mineral refinement, paper production, iron and metal shaping and beer brewing are known to produce wastewater. In many scenarios, industrial wastewater often requires cost-effective treatment technologies [1]. The textile industry faces environmental challenges in managing its waste output due to the abundance of colours and chemical additives. The main contributors to textile wastewater pollution are the dying procedures, which produce significant amounts of chemical oxygen demand, heat, highly suspended particles and colour. The chemical composition of textile wastewater is complex due to various contributing elements [2]. The textile industry is a rapidly growing sector contributing to Malaysia's economic expansion. The increased value of textile manufacturing has raised concerns about wastewater treatment due to the industry's growth [3]. According to Abu Bakar *et al.,* [4], typical textile concentrations in Malaysia for COD, TSS and dyes range from 55-299 mg/L, 69-205 mg/L and 17-140 ADMI, respectively.

Water treatment eliminates harmful chemicals from water to render it appropriate for human and domestic utilisation. The comprehensive treatment procedure includes coagulation, flocculation, sedimentation, filtration and disinfection [5]. The coagulation-flocculation process is widely employed in water and wastewater treatment because it eliminates organic matter, suspended particles, turbidity and colouring. Usually, flocculation occurs after coagulation, which helps particles clump together, making them easier to remove through sedimentation or filtering [6]. Aluminium sulphate and poly-aluminium chloride are two examples of divalently positively charged chemical compounds that are commonly used in the conventional coagulation process for coagulation purposes [7].

The utilisation of chemical coagulants in wastewater treatment processes has several drawbacks. First, the expense of chemical coagulants might raise the production costs associated with treating wastewater [8]. Spending on effluent treatment might be particularly difficult for certain industries and areas. Chemical coagulants can also be harmful to the environment. Significant amounts of non-biodegradable silt and metallic residues can be produced in treated water by chemical purification techniques like coagulation. These materials can be sources of illness and environmental damage [9]. Chemical coagulants may also harm the environment and human health [10]. Chemical coagulants can produce highly toxic chemical precipitates that pose hazards to both human health and the environment. The head of the Malaysian Water Engineers Action Committee (MyWAC), Ishak Hasnan, says that the cost of the chemicals used in water treatment makes up 20 to 30 percent of the total costs related to the water treatment procedure. In turn, an increase in the price of these chemicals results in a corresponding rise in the expenses related to water treatment. These issues may result in low water quality, possible health hazards and financial hardships [11].

Concerns arise with the environment, health and prolonged usage when employing chemical coagulants for the treatment of water. Therefore, natural coagulants are being investigated as a potential substitute. To address these issues, one potential solution is the utilisation of natural coagulants such as plants or microbial substances. By substituting chemical coagulants with natural alternatives, the production of waste and the associated health hazards from residual chemicals are reduced, leading to a more sustainable approach to water treatment. Owodunni *et al.,* [12] state that natural coagulants required reduced concentrations and produce less sedimentation. This reduces the expenses associated with coagulants and sediment. The decreased dose requirement can be attributed to the efficacy of natural coagulants in charge neutralisation and polymer bridging, which are the main processes for eliminating pollutants.

Carica papaya is an herbaceous plant that is classified within the Caricaceae family. The vegetation grows in tropical regions and exhibits a maximum height of 10 metres [13]. The seeds contain a high concentration of unsaturated lipids, making them a potential substitute for essential oil. The papaya seeds and leaves are both rich sources of protein, dietary fibres, phytochemicals, antioxidants and minerals [13]. The coagulant properties of papaya seeds can be linked to the presence of proteins with positive charges [14]. These proteins can stick to things like silt, clay, bacteria and toxins that have a negative charge. This process of sticking together makes it easier for flocs to form, which then settle and clear the water. This process includes both binding and neutralisation of charges [14]. Additionally, papaya seed powder can bind to solid particles in water solutions, making them sink to the bottom [14].

Due to their widespread availability and popularity as a fruit, date seeds are favoured as natural coagulants for water treatment in Malaysia. They may be found in many sorts and varieties at local markets, supermarkets and fruit stands nationwide. The fruit known as dates, scientifically referred to as *Phoenix dactylifera L.*, is a type of perennial fruit tree belonging to the family *Arecaceae* [15]. The fruits of this plant are widely consumed worldwide because of their nutritional, economic and therapeutic advantages [16]. The date seed can be employed in wastewater treatment as a natural coagulant. Owodunni *et al.,* [17] discovered that employing date palm seed as a coagulant had a 62.54% efficiency in eliminating turbidity from wastewater. A further investigation extracted a bio-coagulant from date pits and determined that, when applied at a pH level of 13 and a dosage of 1ml per litre of solution, it achieved an efficacy of 86% in removing contaminants. According to the study by Mangi *et al.,* [18] date pits can be effectively used as waste materials for the coagulation-flocculation treatment of muddy water. It is important to acknowledge that the effectiveness of date seed as a coagulant can differ based on the specific conditions of the effluent being treated.

The utilization of solely the powder form of plant-based coagulants in research and domestic applications to replicate traditional local methods presents a notable challenge due to the inclusion of the coagulating active agents and plant tissues in the prepared powder. Plant tissue in the coagulant powder results in an elevated organic loading in the treated water due to its high concentration of organic constituents [19]. So, using NaCl solvent to extract coagulant agents will be utilised to overcome organic loading in wastewater issues. The presence of contaminants has hindered the effectiveness of natural coagulants. The pulverised seeds include active coagulating agents, which, along with plant tissues rich in organic contents, contribute to the organic load of the treated water. Furthermore, other substances, such as oil and fats, hinder their capacity to coagulate. Researchers have explored the extraction of active coagulation agents to improve turbidity reduction and enhance coagulation efficacy. Nonetheless, the efficacy of these bio-coagulants in water and wastewater treatment relies on the specific techniques employed for their extraction [12]. Distilled water is the primary and cost-effective solvent used for extraction. Nevertheless, it lacks the same level of effectiveness as a salt solution, such as sodium chloride (NaCl) and sodium hydroxide (NaOH), in breaking the protein-protein bonds found in coagulant sources. These salt solutions demonstrate exceptional coagulation efficiency through the salting-out effect and continue interacting with hydrophobic substances in the extracts [20].

Other studies use the extract as a coagulant. The study from Zedan *et al.,* [21] used walnut seeds as a natural coagulant with NaCl as a solvent to remove turbidity from synthetic turbid wastewater. The optimal dose of walnut seed extract may be 3ml/L and the highest turbidity removal efficiency was observed at a pH greater than 7 [21]. Another study by Lek *et al.,* [22] removed turbidity, TSS and COD from palm oil mill effluent (POME) using chickpea powder. The study findings reduced effluent turbidity by 86%, TSS by 87% and COD by 56%, respectively. Moreover, Fourier transform infrared (FTIR) analysis of chickpea powder revealed the presence of OH, CH, NH, CC, CO and CN groups, which assist in the bridging flocculation mechanism during the coagulation process [22].

Using papaya and date seed powders as natural coagulants in wastewater treatment offers theoretical and practical benefits. Theoretically, it promotes green chemistry by providing sustainable alternatives to conventional coagulants, deepens our understanding of coagulation mechanisms and combines insights from multiple scientific disciplines. Practically, these coagulants are cost-effective, reduce reliance on synthetic chemicals and support safer environmental practices. They have been shown to effectively lower turbidity, COD and TSS in wastewater while being biodegradable and non-toxic [14]. Addressing scalability and implementation challenges is critical for their more comprehensive industrial application, presenting them as a viable option for sustainable wastewater management.

The objective of this study is to utilise a naturally occurring coagulant derived from papaya and date seeds as an effective substitute for a chemical coagulant. This study investigates the effectiveness of papaya and date seeds as a natural coagulant in water treatment procedures. According to the existing literature, there is a scarcity of studies on the utilisation of the selected seeds for coagulation in wastewater treatment. Despite the existence of studies utilising specific seeds as natural coagulants, there is a dearth of research on the impact of varying amounts of solvent extraction on the effectiveness of date seed and papaya seed as a natural coagulant in water treatment procedures, particularly in the context of textile wastewater. This study has a few limitations. Firstly, it only focuses on textile wastewater, which may limit the generalisability of the findings to other types of wastewaters. Secondly, the study does not consider the reduction of colour in textile wastewater with high colour content.

2. Methodology

2.1 Preparation of Papaya and Date Seed Powder

The papaya and date seed were rinsed with distilled water and dried for six hours at 60 ° C to remove moisture. Using an electric blender, the seeds were ground into a fine powder and then sieved to ensure particles of uniform size, as shown in Figure 1.

(a) (b) (c) (d)

Fig. 1. Date seed preparation (a) Date seed (b) Date seed powder (c) Papaya seed (d) Papaya seed powder

Two grams of papaya seed powder and date seed powder was mixed with 100 mL of distilled water and NaCl separately to generate a coagulant solution. The solutions were stirred for 45 min with a magnetic stirrer and filtered using 0.45 µm filter paper. Date seed powder was dissolved in distilled water and varied concentrations of NaCl to create a coagulant solution. This experiment used NaCl concentrations of 0.5M, 1M, 1.5M and 2.0M.

2.2 Preparation of Papaya and Date Seed Powder

The wastewater sample used in this study was obtained from an industrial area located in Tongkang Pechah, Batu Pahat, Johor. The industrial processes in the area that produce textile effluent were the source of this wastewater sample. The effluent utilised in this study was analysed to determine its initial properties. It is revealed that the initial turbidity of the water was 39.87 NTU. Initial COD levels were 1248 mg/L.

2.3 Jar Test

The ASTM D2035 was utilised to perform the Coagulation-Flocculation Jar Test for water. ASTM D2035 outlines the application of jar testing to evaluate the effectiveness of coagulation and flocculation methods in the treatment of water and wastewater. As shown in Figure 2, six 0.5L beakers were used in this jar test method. Before the stirring process started, the initial data was taken from wastewater samples which are pH, turbidity and COD. Experiments were conducted by setting the apparatus to a swift mixing speed of 100 rpm for two minutes, followed by a slower mixing speed of 25 rpm for 20 minutes and then allowing the mixture to settle for a 30-minute period [15].

Fig. 2. Jar test process

2.4 Data Collection

There are several parameters that were investigated in this study. Five types of characterization parameters from the Water Quality Index (WQI) will be taken once the water sampling from the mentioned wastewater sample is done. The research involved studying turbidity and pH using an Extech TB400 turbidity meter and an HQ440D Laboratory Dual Input and Multi-Parameter Meter, respectively. The COD test was conducted using a DR 6000 for high-range concentrations (1500 mg/L) with HACH's reagent. Prior to measurement, the COD vial was filled with 2 mL of sample and preheated on a reactor for 2 hours at 150 °C. Ammonia nitrogen was also tested with the DR 6000 using the Nessler method, which involved mixing a 25 ml sample with three drops of mineral stabilizer, three drops of Polyvinyl Alcohol Dispersing Agent and 1 mL Nessler reagent. Table 1 below shows the parameter data that is involved in this study.

Table 1
Methods and parameters of characterisation

Parameters	Method
Turbidity	Extech TB400 turbidity meter
Chemical Oxygen Demand (COD)	Reactor Digestion Method (Hach Method 8000)
pH	HQ440D Laboratory Dual Input, Multi-Parameter Meter
Settling Depth	Settling Rate Assessment
Ammonia Nitrogen	Nessler Method (Hach Method 8038)

2.4.1 Chemical oxygen demand (COD)

The data analysis of COD reduction percentages investigates how wastewater treatment procedures can effectively reduce COD levels over time. This analysis employs statistical techniques to improve treatment efficacy and expand the theoretical basis of sustainable water management. The effectiveness of the date seed in reducing the COD of the water was determined using Eq. (1).

$$\text{COD Reduction (\%)} = \frac{pre-post}{pre}\, x\ 100\% \quad (1)$$

Where, pre = Initial COD (mg/l) and post = Final COD (mg/l)

2.4.2 Turbidity removal

Examining turbidity removal data means figuring out how well natural coagulants reduce turbidity in effluent and figuring out how turbidity is related to different environmental factors. Eq. (2) was used to determine the effectiveness of the date seed coagulant in reducing the turbidity of the water.

$$\text{Turbidity Reduction (\%)} = \frac{T_1-T_2}{T_1}\, x\ 100\% \quad (2)$$

Where, T_1 = Initial turbidity (NTU) and T_2 = Final NTU

2.4.3 Ammonia nitrogen removal

Analysing Ammonia Nitrogen removal data involves determining how well natural coagulants reduce turbidity in effluent and how turbidity relates to various environmental factors. By analysing the data, it is possible to identify the most influential factors affecting ammonia nitrogen removal, satisfy regulatory requirements and safeguard the environment from the harmful effects of ammonia nitrogen pollution. This formula is a straightforward and effective optimisation tool for wastewater treatment procedures. Eq. (3) was utilised to ascertain the efficacy of the date seed coagulant in reducing the Ammonia Nitrogen content of the water.

$$\text{Ammonia Reduction (\%)} = \frac{AN_1-AN_2}{AN_1}\, x\ 100\% \quad (3)$$

Where, AN_1 = Initial Ammonia (mg/l) and AN_2 = Final Ammonia (mg/l)

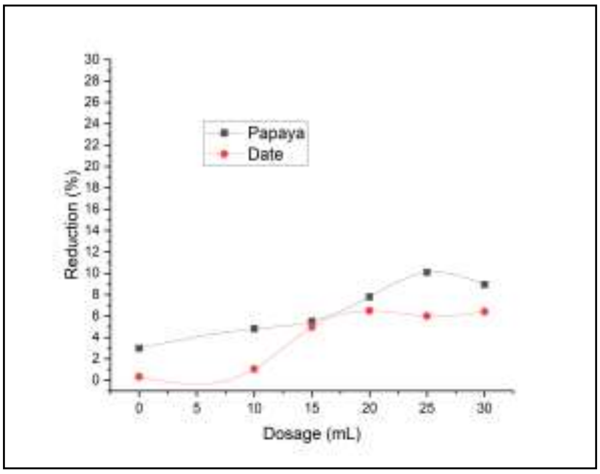
3. Results and Discussion

3.1 Papaya Seed and Date Seed Coagulant COD Removal Efficiency

As an indicator of the concentration of organic pollutants in the water, lowering the COD is an essential component of wastewater treatment. Figure 3 shows the effectiveness of papaya seed and date seed with different concentration solvents in removing COD. Mostly, papaya seeds do better-removing COD than date seeds. The most optimum removing COD for papaya seeds was at a coagulant concentration of 1.0 M NaCl of dosage 20 ml, which is 78.84% COD removal. Meanwhile, for date seed, a concentration of 2.0 M NaCl of dosage 25ml, which is 56.19 % COD removal.

Due to the presence of glutathione (GSH), papaya seeds can lower COD values [17,23]. GSH has been linked to the immune response to biotic stress [12]. GSH can collaborate with the antioxidant enzyme superoxide dismutase (SOD) to neutralise reactive oxygen species (ROS) [24]. As a result, papaya seeds can lower COD indirectly by eliminating contaminants that cause oxidative stress and ROS generation.

Aal-Hamad [25] stated that date seed powder can remove contaminants from wastewater because it includes natural polyphenols that absorb mineral ions and dissolved organic debris. When COD is eliminated, the removal efficiency drops and becomes imbalanced due to coagulant aggregation and congestion. Alternatively, Abujazar *et al.,* [26] found that encapsulating the topmost layer of the natural coagulant limits the number of potential parts of adsorption for particle bridging, resulting in saturation or equilibrium at a dose of 25 ml for most concentration solvents.



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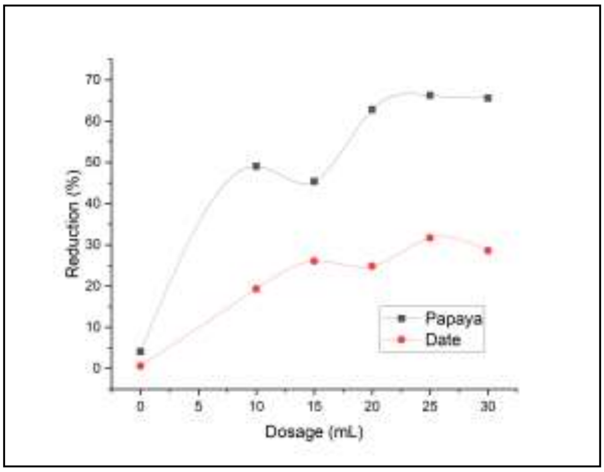

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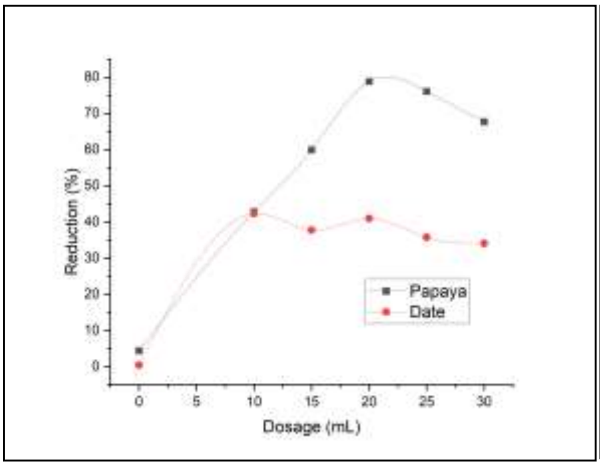

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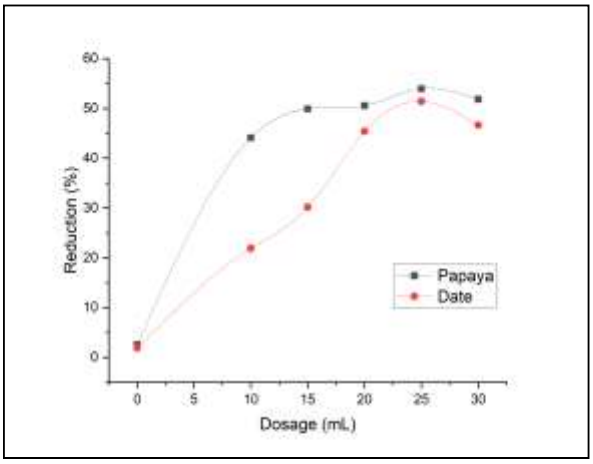

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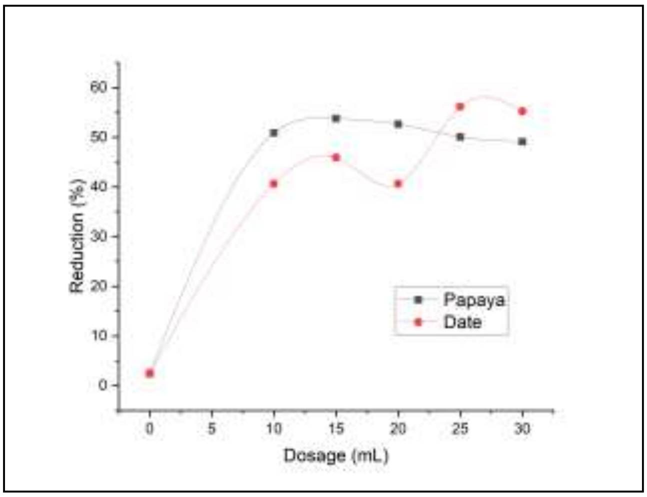


(e)

Fig. 3. Percentage of COD reduction vs coagulant dosage for coagulant concentration of (a) DW (b) 0.5M NaCl (c) 1.0M NaCl (d) 1.5M NaCl (e) 2.0M NaCl

3.2 Papaya Seed and Date Seed Coagulant Turbidity Removal Efficiency

The coagulation dosage is a critical factor that impacts the effectiveness of natural coagulants in the process of coagulation. The graphical representation of the impact of natural coagulant dosage and concentration on turbidity removal is depicted in Figure 4. Distilled water as a solvent demonstrates that papaya seed coagulant is more effective at removing turbidity than date seed. Conversely, extractive concentrations in all salt solutions indicate that date seed coagulant is superior to papaya seed coagulant at removing particles.

In the distilled water solution, both papaya seed and date seed natural have optimum dosage at 25ml coagulant. Papaya seed yielded the highest turbidity in distilled water solution at 38.27% compared to date seed, which is 17.39% turbidity removal. In contrast to the coagulation efficacy of coagulants that were extracted using NaCl solution, Date seed coagulant exhibited the highest turbidity removal of 83.96 % at 10 ml dosage of 1.0 NaCl concentration followed by papaya seed coagulant (61.48%) at 30 ml dosage of 1.0 NaCl. The outcomes demonstrated that the extracted coagulants enhanced the removal of turbidity, supporting the hypothesis that the protein content of the extracts contributed to their coagulation activity [27]. This finding was also supported by Owodunni *et al.,* [17], who stated that salt solution extractives outperformed the distilled water-extracted coagulants in terms of turbidity reduction, which could be attributable to the seeds' increased protein solubility.

Based on the data presented in Figure 4, the turbidity removal percentage for date seed coagulant increased from 81.98% to 83.96% when the concentration of NaCl was raised from 0.5 M to 1.0 M. Nevertheless, the percentage decreased to 61.60% when the concentration reached to 2.0 M. Other than that, the turbidity removal percentage for papaya seed coagulant also increased from 35.93% to 61.48% when the concentration of NaCl was raised from 0.5 M to 1.0 M and decreased when reached 2.0 M with percentages removal of 32.87%. Tiruneh *et al.,* [28] mentioned that the enhancement in coagulation activity is attributed to the salting-in effect, which leads to an increase in solvating power. By dissolving a greater number of active components, the solvent will enhance the efficiency of coagulation. However, protein solvation is inhibited because of the salting-out effect when the salt concentration is increased beyond 1.0M, which causes water molecules to become sequestered.

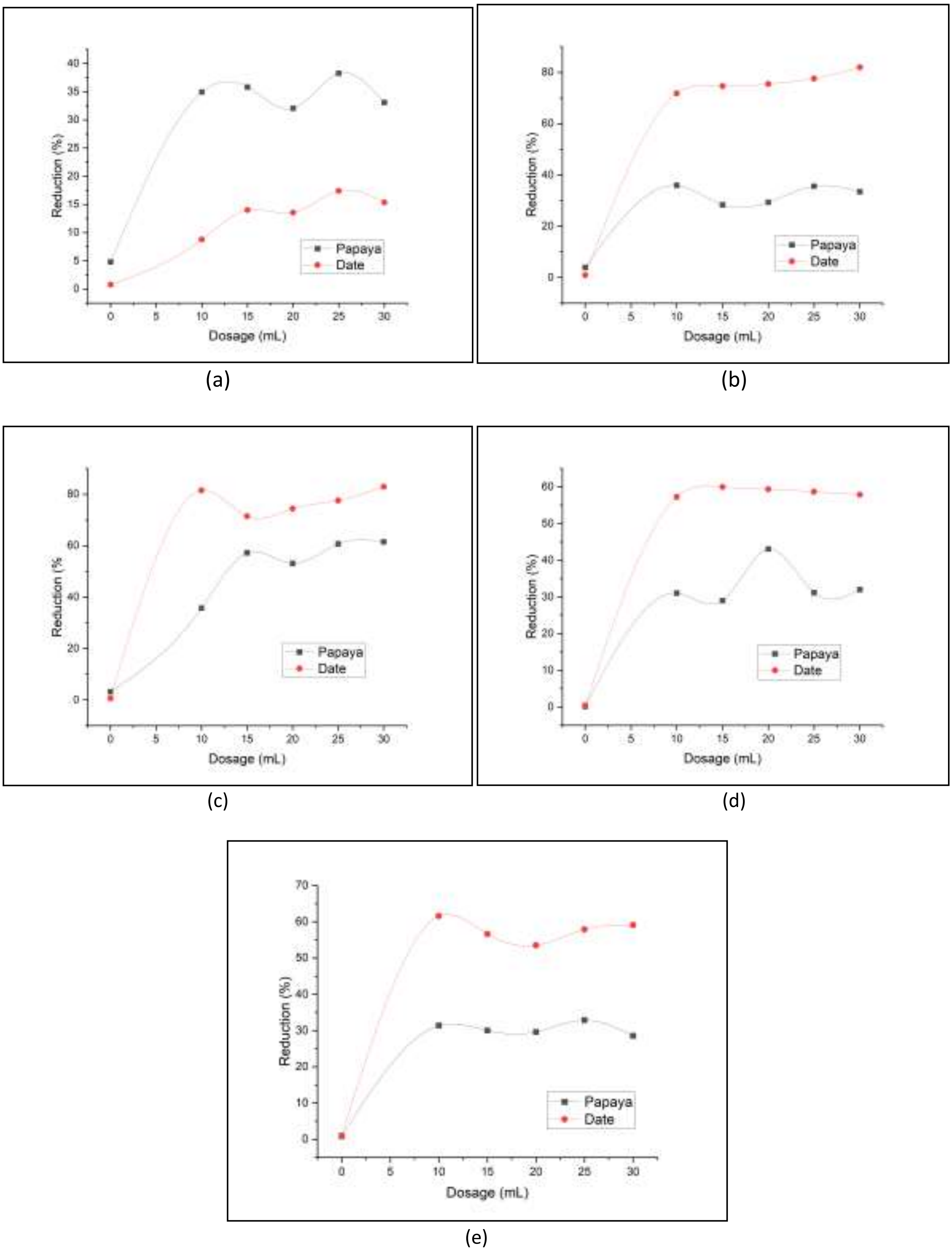
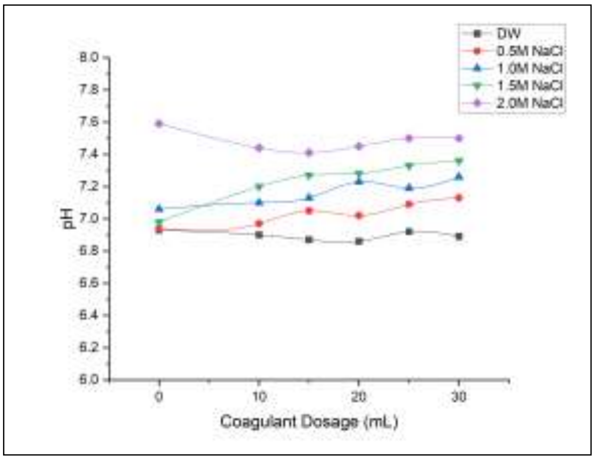


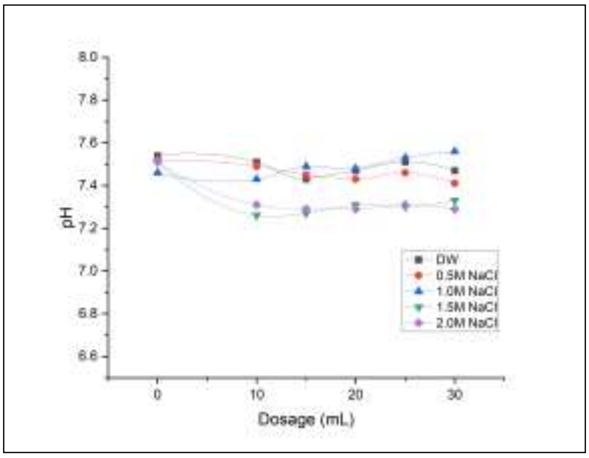
Fig. 4. Percentage of turbidity reduction vs Coagulant dosage for coagulant concentration of (a) DW (b) 0.5M NaCl (c) 1.0M NaCl (d) 1.5M NaCl (e) 2.0M NaCl

3.3 The Efficacy of Date Seed Coagulant as Measured by pH

As shown in Figure 5, the most drastic change in pH was the concentration of a coagulant solution of 1.5 M NaCl, which was from 6.98 to 7.36. However, this change in pH didn't change whether the wastewater was acidic or alkaline. The control sample has a neutral pH range from 6.98 to 7.06, blank sample is used. The date seed coagulant solution of NaCl concentration shows a slight increase in pH except for 2.0M NaCl solvent and distilled water. In conclusion, at varying dosages, there were no significant changes in pH for the water sample treated with date seed as a coagulant, but all other parameters of the water sample decreased significantly after treatment.

Likewise, papaya seed coagulant also didn't make any drastic change in wastewater to change the acid or basic in this wastewater. The most drastic change in pH is only 1.5M NaCl solvent, which is from 6.98 to 7.36. Thus, it was discovered that papaya seed powder has no discernible capacity to neutralise surface water samples [29]. This conclusion was supported by George *et al.,* [14] who found no significant pH changes in water treated with papaya seed as a coagulant.





(a) (b)

Fig. 5. pH vs Coagulant dosage of (a) Date seed and (b) Papaya seed

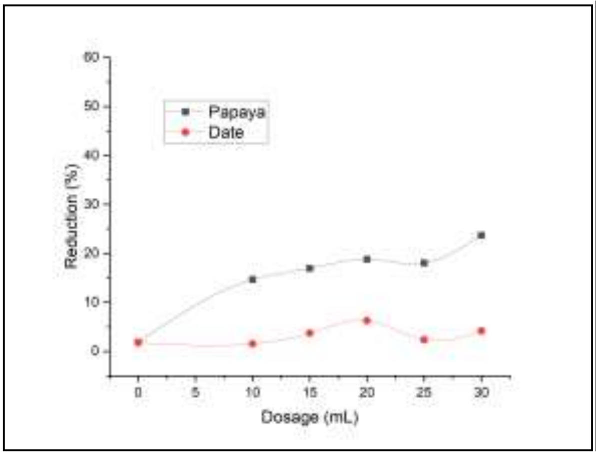
3.4 The Efficacy of Date Seed Coagulant in the Reduction of Ammonia Nitrogen

Figure 6 demonstrates the relationship between the percentage of ammonia nitrogen reduction and the dosage of date seed coagulant. Papaya seed seems to have a better reduction of Ammonia Nitrogen than date seed in every concentration of NaCl solvent and distilled water. When the dosage of date seed coagulant is increased, the graph depicts an ascending and then descending trend in the percentage of ammonia nitrogen reduction. The highest ammonia nitrogen reduction was at 20 ml date seed coagulant dosage of 2.0M NaCl at removal of 43.33%. For 2.0M NaCl and 1.0M NaCl, the decreasing trends begin at 25 ml coagulant dosage, whereas for 1.5M NaCl and distilled water, the decreasing trends begin at 20 ml coagulant dosage. Aside from this, only 0.5M NaCl has a decreasing point at 15 ml coagulant dosage but a minor increase at 25 ml coagulant dosage.

The increased efficacy of date seed powder in the treatment and removal of ammonia nitrogen is due to its molecular structure, which contains coagulants [25]. Moreover, Abu Amr *et al.,* [29] mentioned that the ability of date seed to reduce ammonia may be the result of the action of electric double layers generated by carboxylic, phenolic and amino groups. In fact, the wastewater contains solid particles that agglomerate, grow and then flow into the base of the support.

For papaya seed coagulant, percentage reduction shows increasing trends in every NaCl concentration solvent and distilled water except for 1.5M NaCl concentration. The highest reduction of ammonia nitrogen was at a dosage of 30ml with a NaCl concentration of 2.0M (82.84%). Textile wastewater typically exhibits a pH ranging from neutral to strongly alkaline [30]. According to Musa *et al.,* [31], alkaline solutions are more effective in removing ammoniacal nitrogen due to their ability to attract and adsorb positively charged ammonium ions through the presence of negative ions.

Other than that, the presence of NaCl also influences the reduction of ammonia nitrogen. According to Wu *et al.,* [32], the introduction of NaCl also benefits to enhance the ammonia nitrogen removal efficiency. In the process of ammonia nitrogen removal, NH^{4+} ion exchange with Na^{+} in vermiculite, to achieve the purpose of ammonia nitrogen removal. Therefore, sodium salts, such as NaCl, can be used to improve the ammonia removal capacity [33].



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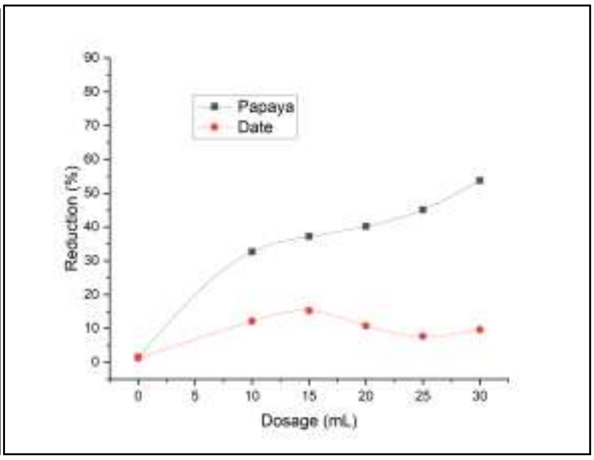

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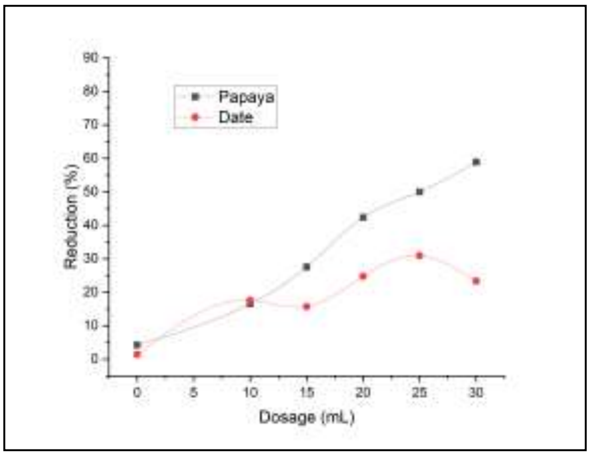

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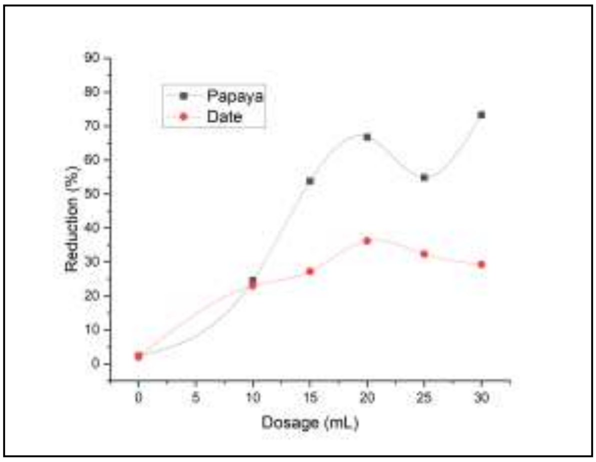

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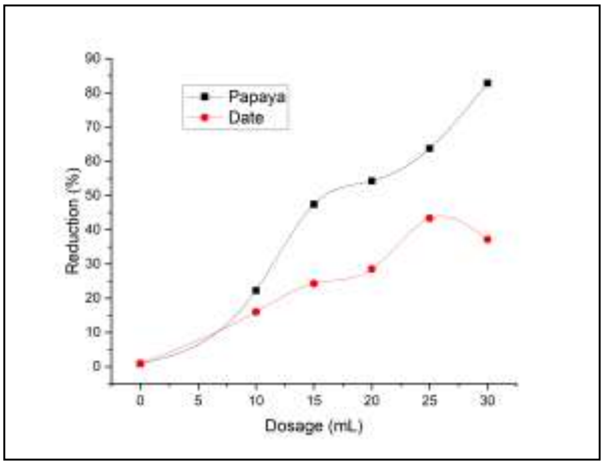

(e)

Fig. 6. Percentage of ammonia nitrogen reduction vs Coagulant dosage for coagulant concentration of (a) DW (b) 0.5M NaCl (c) 1.0M NaCl (d) 1.5M NaCl (e) 2.0M NaCl

3.5 Comparison of Results Obtained from the Current Study with Existing Literature

The summarised data in Table 2 compares the findings of this study with those of the existing literature. The table illustrates the efficacy of various natural coagulants in solvent distilled water and NaCl form with various concentrations in reducing turbidity and COD in wastewater. Date seed and Carica Papaya seed have been the subject of extensive research, especially in various concentrations of NaCl solvent form. In this study, COD reduction seems more influential on Carica Papaya seed with a reduction of 78.84% with 1.0M NaCl than date seed with a reduction of 56.19% with 2.0M NaCl when used in textile industrial wastewater, but when date seed in powder form was used in iron and steel industries, it was higher than Carica papaya in textile industrial wastewater. In another context, turbidity reduction significantly impacts date seed for optimum turbidity removal, with an 82.96% decrease using 1.0M NaCl, compared to Carica Papaya seed, which saw a 61.48% reduction with the same treatment used in textile industrial wastewater. The study by Bouchareb *et al.,* [34] and Fahmi *et al.,* [35] says that a solvent of 1.0M NaCl is the optimum concentration with turbidity removal of 88.98 % and 64.5 %, respectively by using Moringa Oleifra and Okra Seed as natural coagulant [31,32]. Meanwhile, the preliminary study by Praveena *et al.,* [36] stated that turbidity removal could reach 71.33 % and 65.58 % by using date seed and longan seed, respectively, in the solvent of 0.5M NaCl [33]. This study shows that this form of coagulant can remove turbidity without adding more sludge from the plant tissue itself because it only uses liquid form extraction. Based on the comparison with the previous study, it has been found that papaya seed and date seed in a saline solvent form are more effective coagulants for removing turbidity than several saline extractions from natural coagulants such as okra seed and longan seed. The possible justification for these results may be that the extracted protein content, a coagulant agent, was higher than in the previous study. Only a few previous studies have addressed COD reduction. Oghenekome *et al.,* [37] and Abujazar *et al.,* [26] are the only studies concluding COD reduction. The study shows that papaya and date seed in NaCl solvent form exhibit better COD reduction than papaya seed in carwash wastewater but lower reduction than in powder form when used in iron and steel industrial wastewater. Carica papaya was less effective for turbidity removal in textile industrial wastewater than carwash wastewater and raw river water samples. Still, they were studied using different types of natural coagulants and wastewater. The same goes for date seed, which was slightly less effective for turbidity removal in textile industrial wastewater than synthetic turbid wastewater.

Table 2
Comparison of results obtained from existing literature

Type of wastewater	Natural coagulant (Form)	Turbidity removal (%)	COD removal (%)	Reference
Raw Municipal wastewater	Moringa Oleifra (Solvent 1.0M NaCl)	88.98 %	-	[34]
Synthetic turbid water	Okra Seed (Solvent 1.0M NaCl)	64.5 %	-	[35]
Synthetic turbid water	Date Seed (Solvent 0.5M NaCl)	71.33 %	-	[36]
	Longan Seed (Solvent 0.5M NaCl)	65.58 %	-	
Carwash wastewater	Carica Papaya Seed (Powder)	97.00 %	35.91 %	[37]
Raw river water sample	Carica Papaya Seed (Powder)	89.14 %	-	[14]
Iron and steel industrial wastewater	Date seed (Powder)	-	96.50 %	[29]
Textile Industrial wastewater	Date seed (DW, 0.5M, 1.0M, 1.5M, 2.0M NaCl)	82.96 %	56.19 %	This Study

	Carica Papaya Seed (DW, 0.5M, 1.0M, 1.5M, 2.0M NaCl)	61.48 %	78.84 %

4. Conclusions

This study highlights the potential of utilising fruit seed leftovers as a source of natural coagulants. These coagulants can be easily obtained using distilled water or non-toxic inorganic salt, making them a sustainable and environmentally friendly option. The NaCl solution extracts of Carica papaya seed and date stone powder exhibited significant potential as a plant-based natural coagulant for textile industrial wastewater. These extracts demonstrated impressive removal percentages for chemical oxygen demand (COD), turbidity and ammonia nitrogen. The experiment showcased the remarkable coagulation properties of the Carica papaya seed and date stone. The turbidity removal efficiency of Carica papaya seed was found to be 61.48% when a dosage of 30 ml for 1.0 concentration NaCl solvent was used. On the other hand, date seed showed an optimum turbidity removal of 83.96% with a dosage of 10 ml for 1.0 NaCl concentration solvent. The optimal COD reduction was determined to be 1.0M NaCl for the Carica papaya seed and 2.0M NaCl for the date seed. These concentrations resulted in reductions of 78.84% and 56.19%, respectively. The Carica papaya seed coagulant dosage of 30 ml with a 2.0M NaCl concentration resulted in the greatest ammonia nitrogen reduction (82.84%). In a comparable manner, the 20 ml date seed coagulant dosage of 2.0M NaCl removed 43.33% of ammonia nitrogen. The addition of date seed and Carica papaya seed powder to textile industrial effluent did not result in a change in pH due to the organic composition of the substances. As a result, during the coagulation process, no pH adjustment was necessary when both powders were employed as the coagulant.

5. Recommendations for Future Research

Future research should focus on evaluating the effectiveness of papaya seed as a natural coagulant in various types of wastewaters and exploring the underlying mechanisms of contaminant removal to improve our comprehension and application of this environmentally friendly treatment method.

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