"EFFECTUATION OF JACKFRUIT (ARTOCARPUS HETEROPHYLLUS) PEEL COAGULANT IN TURBIDITY REDUCTION UNDER DIFFERENT PH OF WASTEWATER"

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Abstract - Presently, wastewater treatment using chemical coagulants has been major concern due to production of sludge in large volume, high costs and health effects. Thus, the use of plant-based coagulants has captivated researchers to overcome these problems. This study describes the effect of pH on coagulation process by using of jackfruit (Artocarpus heterophyllus) peel as coagulant. The coagulant from jackfruit peel was prepared by extraction method using distilled water. Synthetic sewage was used in this study to imitate medium strength domestic wastewater. Jar test experiment was carried out and the pH of wastewater was varied using hydrochloric acid and sodium hydroxide. After treated, the turbidity of the wastewater was measured to determine the percentage of reduction. The coagulant extracts were characterized using FTIR and zeta potential. It was observed that the jackfruit peel extract works the best as a coagulant at pH 2. Jackfruit peel coagulant can be used as primary water treatment of the wastewater and believed to be an environmentally friendly alternative.

KEYWORDS: wastewater, natural coagulant, water treatment, turbidity, pH

I. INTRODUCTION

A wide range of scientific technologies are used to minimize the contaminants and pollutants in wastewater such as membrane separation, flocculation, solvent extraction, oxidation and reduction, coagulation, ion exchange and electrolysis. Of these technologies, the coagulation process is one of the promising process in removing suspended solids, colloids, dissolved solids and organic matter present in wastewater. Basically, coagulation is a physico-chemical process where the repulsive potential of the electrical double layer of colloids gets reduced to form microparticles which collide with one another to create larger structures defined as flocs and the whole process termed as the flocculation process.

The application of this process includes removing dissolved chemical species and turbidity by adding chemical-based coagulants for instance, alum ($AlCl_3$), ferric chloride ($FeCl_3$) as well as polyaluminium chloride (PAC). The chemical coagulants are well known for their high ability to improve the quality of wastewater to be released to the mainstream [11]. Researchers have demonstrated the ability of aluminium coagulants like aluminium sulphate [$Al_2(SO_4)_3$], aluminium chloride ($AlCl_3$) and poly-aluminium chloride (PAC) as well as iron coagulants which include ferric sulphate [$Fe_2(SO_4)_3$] and ferric chloride ($FeCl_3$) to treat wastewater. However, several adverse health implications of chemical coagulants have been reported over the years, for instance, consumption of water with alum residues after coagulation process may cause accumulation of aluminium inside brain which leads to neurodegenerative diseases including Parkinson's disease and Alzheimer's dementia. In addition, the sludge produced after wastewater treatment using chemical coagulant often contain chemical residue such as alum that need to be treated prior disposal. Due to drawbacks of chemical coagulants, researchers have now developing and evaluating the performance of natural coagulants in the process of coagulation. Natural coagulants are workable substitute of chemical coagulants as they are biodegradable, safe and cheap means of wastewater treatment. Natural coagulants can be derived from plants and fruit waste. The use of natural coagulants predominantly polysaccharides and proteins contribute to vital development towards sustainable environmental technology as they are cost effective, biodegradable and are presumed to be safe for human health. The common plant-based coagulant well known within the scientific group are Moringa Oleifera, Nirmali seeds (Strychnos potatorum), tannin and cactus. It was reported that Moringa oleifera capable in reduction of turbidity up to 85%-94%, copper up to 98% and lead up to 78% from the river water sample. Despite its effectiveness, there are debate that plants are not considered as unwanted materials or waste. To address that issue, researchers made several attempts to utilize fruit waste as natural coagulant including jackfruit (Artocarpus heterophyllus) seeds, mango (Mangifera indica) seeds, apricot (Prunus armeniaca) seeds, orange (Citrus sinensis) peel, date (Phoenix dactylifera) seeds, avocado (Persea Americana) seeds and banana peel. The effectiveness of fruit seed and peel in water treatment varies depending on the fruit. Fruit waste is commonly rich in natural polymers such as polysaccharides, carbohydrates and pectin. The size of these polymers can be interpreted in terms of molecular weight. Larger molecular weight of a polymer corresponds to a longer chain of polymeric. This attribute is greatly advantageous for process of coagulation to occur and number of active sites available will be increased for particle adsorption. There are many factors that influence the efficiency of coagulation in a treatment process. One of the variables is pH or alkalinity of raw water which is important to determine the efficiency of this process. Alkalinity is related to the buffering potential of the water and its ability to neutralize acid contaminants. Alkalinity and pH are closely related where waters with high alkalinity have high pH. The water pH affects the chemistry of the coagulant in terms of solubility and charge on the natural organic matter particles during coagulation process. Coagulants such as alum and ferric chloride are more acidic as compared to polyaluminium chloride. The pH must be controlled as the coagulation process occurs in a specific range for respective coagulant. Higher alkalinity water may need more coagulant addition to decrease the pH to a favorable value for effective coagulation. In this work, the effectiveness of jackfruit peel that has been transformed into liquid coagulant was investigated in terms of turbidity reduction of synthetic sewage. Although it was studied the application of starch from jackfruit seed as coagulant aid for treatment of synthetic turbid water, there is no characterization analysis or performance study on the peel part of the fruit. On the contrary, this study was carried out by using the jackfruit peel and the coagulant solution was tested using synthetic sewage under different pH of wastewater. Several characterizations were carried out to determine the biomass composition, functional group, and surface charge.

II. Related Work:

1. **Proximate analysis of jackfruit peel…** Based on the proximate analysis of the jackfruit peel, it is found that the peel contained 6% of protein and 72% of carbohydrates. As shown in Table, the percentage of the experimental study is within the range of the results obtained from the literature. Carbohydrates in the jackfruit peel can be linked to the presence of polysaccharides and pectin which is known as natural high molecular compound present in middle lamella structure and cell wall of plants. Pectin is commonly regarded as a complex polysaccharide comprises of a-1,4-linked D-galacturonic acid, that is partly methyl esterified whereas the side chain comprises of various neutral sugars including, L-arabinose, L-rhamnose and D-galactose. It was postulated that the linear and smooth extended molecular chains of the pectin provide active sites for the attachment and settlement of suspended and dissolved particle.

2. **Functional group analysis of jackfruit peel coagulant**. The analysis of FTIR spectra to determine the main functional groups of jackfruit peel extracted using distilled water. It was reported that hydroxyl (O–H), carboxyl (C = O), and amino or amide (–NH2) groups as well as hydrogen bonding were the preferred groups for the coagulation-flocculation process. The major adsorption band obtained for this analysis for coagulant is shown in Fig. 3. It can be proved that the main functional groups existing in these coagulants extracts due to existence of carboxyl (C = O) and hydroxyl (O–H) group. This can be assumed that these main groups in jackfruit peel extracts functioned through bridging mechanism in order for coagulation to take place.

3. **Effect of pH of wastewater**. As for this experiment, the pH of the synthetic wastewater was altered as required before the coagulation test was performed with jackfruit peel extracted using distilled water. The pH of wastewater mainly affects the surface charge of coagulants and the stabilization of suspension. The results obtained from the coagulation test by using jackfruit peel extract is as shown in Fig. As can be seen, the coagulation performance of jackfruit peel in reducing turbidity favoured the acidic condition. It was observed that the jackfruit peel extract works the best as a coagulant at pH 2. Highest turbidity reduction can be obtained at this pH that is almost 70 ± 1% in reduction. The water appeared to be clearer and more flocs is formed at this pH. The effectiveness starts declining gradually when the pH is increased from 3 to 12. The water turns cloudier with percentage of turbidity reduction in the range of 67 ± 1% to 29 ± 1% and less flocs were found after the settling process due to pH incremental. The lowest turbidity reduction was found at pH 12 when the wastewater condition is most alkaline. The turbidity reduction was only 30 ± 1% which indicates the least effective pH for jackfruit peel to perform as coagulant. The coagulative behavior of jackfruit peel decreases when the alkalinity of the wastewater increases as within the range of pH 8 to pH 12. Thus, it clearly shows that jackfruit peel works well in acidic condition which supported with characterization analysis. Based on zeta potential study, the zeta potential measured was 25.2 mV at pH of 6.95 which indicates that the surface charge present in the coagulant is negative. The acidic condition of wastewater promotes the positive charges on molecules that may influence and enhance the performance of the molecules to function well as coagulant. Acidic condition of wastewater is highly present with hydrogen ions which also increases the positive charge of the wastewater. Thus, this phenomenon significantly affects the turbidity reduction of the synthetic wastewater.

The comparison of results obtained from this study with literature is illustrated as in Table.

Type of wastewater	Natural Coagulant	Turbidity Reduction (%)
Kaolin synthetic wastewater	Jackfruit (Artocarpus heterophyllus) seeds	75.0
Raw surface water (Nile river)	Apricot (Prunus armeniaca) seeds Mango (Mangifera indica) seeds	54.0
Raw surface water	Orange (Citrus sinensis) peel	85.0
Synthetic water (bentonite)	Date (Phoenix dactylifera) seeds	90.0
Raw surface water (storm water)	Avocado (Persea Americana) seeds	64.2
Synthetic domestic wastewater	Banana (Musa Acuminata) peel	73

As shown in the table, various natural coagulant has been explored in determining the effectiveness in turbidity reduction of wastewater. Research on jackfruit peel has not been carried out up to date. It can be described that turbidity reduction using jackfruit peel was higher comparable to apricot and mango seeds. Date seed and papaya seed performed better but they were examined using different types of wastewater. This finding demonstrated the potential of jackfruit peel as alternative solution to chemical coagulant as well as an added value to the abundant jackfruit peel waste available.

Materials

Jackfruit peels were collected from local farm house located in Nashik, (MH) India. Analytical-grade hydrochloric acid (HCl with purity 37%), sodium hydroxide (NaOH with purity 99.5%) and sodium chloride (NaCl) were purchased from Vision Chemicals. Pvt. Ltd. **Apparatus and Measurements**

Turbidity was measured using a turbidity meter (ELICO CL 52D NEPHELOMETER) and it was expressed in nephelometric turbidity units (NTU). pH is measured using a pH meter (ELICO LI 120 pH meter). Analytical instrument (ELICO PE 135 DO Analyzer) was used to determine the dissolved oxygen. Conductivity meter (ELICO CM 180) was used to measure the water conductivity, sulfate and chloride concentration was determined according to standard titrimetric methods (APHA-2012), using (ELICO SL 159) UV–V is spectrophotometer. JLT6 VELP Jar Test 6 Paddle instrument for flocculation method.

Preparation of kaolin synthetic wastewater

In this study, synthetic turbid water was prepared by adding kaolin a stock kaolin suspension to distilled water for all coagulation experiments. The stock kaolin suspension was prepared by dissolving 10 g of kaolin powder in 1 L of distilled water. The suspension was stirred slowly at 20 rpm for 1 h to achieve uniform dispersion of the kaolin particles. The suspension was then permitted to stand for 24 h to allow for complete hydration of the kaolin.
This suspension was used as a stock solution for the preparation of water samples of varying turbidity for the coagulation's tests. The initial pH was adjusted with 0.1 M NaOH (or) 0.1 M HCl to obtain desired values of turbidity and pH for the synthetic turbid water.

Collection of waste-water:

-Add kaolin suspension to distilled water 20 RPM for 1 hr.
-Adjust initial pH with 0.1 M NaOH or 0.1 M HCl to obtain desired value of turbidity.

Preparation of Natural Coagulant:

1) Extraction of active components from Jackfruit peels:

-Grind dry peels by using laboratory mill and sieved through 0.4mm.
-The fraction with particle size less than 0.4 mm can be used for experiment.
-10gm. of peels powder is suspended in 1 ltr of NaCl water solution (0.5 mol/ltr).
-Then stir the suspension using glass rod to accomplish extraction and then filter with muslin cotton cloth to obtain crude extract of active components.

2) Precipitation of active components:

-Process the coagulation active components from peels powder by precipitation and dialysis.
-Saturate the crude extracts to 80% by addition of (NH4)2SO4 and centrifuge
for 10 min.
-Then redissolve precipitate in 10 Mmol/L appropriate buffer and dialyze overnight at 4°C against Millipore water in dialysis bag with molecular cut-off 12–14 kDa.

3) Purification of active component:

-Load dialysate extract onto column (10 mm * 150 mm glass column) packed with 10 mL of Amberlite IRA-900 Cl previously equilibrated with 50 mol/L phosphate buffer, pH 7.5.
-Then elute the active components from resin by linear gradient of ionic strength of NaCl solution from 0 to 1 mol/L at a flow rate 1 mL/min.
-Then protein content and coagulation activity of fractions (2 mL) can be determined.

Coagulation test experiments:

Coagulation test experiments were performed by jar floc test method as shown in Fig.
with six-paddle rotor jar test equipment (JLT6 Velp Scientifica, Italy). Beakers comprised of 500 ml synthetic sewage and the desired amount of coagulant were prepared for the coagulation test. The jar test was conducted at room temperature of 25 C.
In this experiment, different pH of wastewater was tested in the range of pH 1 to pH 12.
The pH of wastewater was controlled by adding 1.0 M HCl and 1.0 M NaOH and the analyses were done in triplicate. The dosage of the coagulant used in this experiment was set at 100 mg/L and initial turbidity was recorded for each sample. The suspension was stirred at 100 rpm for 4 min of rapid mixing and followed by 25 min of slow mixing at 40 rpm. The mixture was left for one hour to allow settling and the supernatant was used in the analysis of water quality. The turbidity reduction was calculated for each sample.
Characteristics of waste water sample: Table 1

Parameter	Value (mg/L)	Value of domestic wastewater (mg/L)
BOD	300	190
COD	1500	430
TSS	216	210
NH_3-N	15	25
NO_3-N	27	40
Phosphorus	42	7

Characterization of coagulant

The powdered jackfruit peel was initially examined by proximate analysis to determine the composition of the peel itself using. Proximate analysis was performed based on the Association of Official Analytical Chemists (AOAC, 1984) method. The infrared spectra of the jackfruit peel extracted

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with distilled water was recorded using Fourier Transform Infrared (FTIR) (Perkin Elmer Spectrum 100, US) from 400 cm^1 to 4000 cm^1 to study on the functional group existing in the coagulant extract. Zeta potential was measured at a constant temperature of 25 C using zeta analyzer which is a light scattering equipment to identify the surface charges of the coagulant extract.

Table 2

Parameter (%)	Experimental (this work)	[37]	[38]
Total Carbohydrate	70.1	65.0	79.1
Total Fat	2.2	N/A	2.5
Moisture	13.0	13.0	8.2
Protein	6.4	6.3	6.5
Ash	5.5	7.0	3.7

Comparison of proximate analysis of jackfruit peel.

N/A: Not Available

Results and discussion

Proximate analysis of jackfruit peel

Based on the proximate analysis of the jackfruit peel, it is found that the peel contained 6.4% of protein and 70% of carbohydrates. As shown in Table 2, the percentage of the experimental study is within the range of the results obtained from the literature. Carbohydrates in the jackfruit peel can be linked to the presence of polysaccharides and pectin which is known as natural high molecular compound present in middle lamella structure and cell wall of plants. Pectin is commonly regarded as a complex polysaccharide comprises of a-1,4-linked D-galacturonic acid, that is partly methyl esterified whereas the side chain comprises of various neutral sugars including, L-arabinose, L-rhamnose and D-galactose. It was postulated that the linear and smooth extended molecular chains of the pectin provide active sites for the attachment and settlement of suspended and dissolved particles.

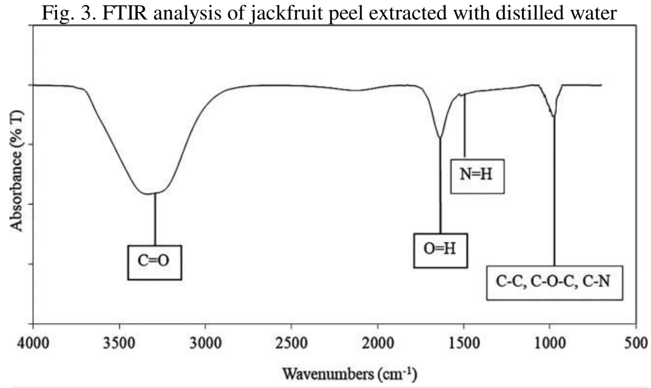
Functional group analysis of jackfruit peel coagulant

The analysis of FTIR spectra to determine the main functional groups of jackfruit peel extracted using distilled water. Reported that hydroxyl (O–H), carboxyl (C = O), and amino or amide (–NH2) groups as well as hydrogen bonding were the preferred groups for the coagulation-flocculation process. The major adsorption band obtained for this analysis for coagulant is shown in Fig. 3. It can be proved that the main functional groups existing in these coagulants extracts due to existence of carboxyl (C = O) and hydroxyl (O–H) group. This can be assumed that these main groups in jackfruit peel extracts functioned through bridging mechanism in order for coagulation to take place.

Effect of pH of Wastewater:

As for this experiment, the pH of the synthetic wastewater was altered as required before the coagulation test was performed with

Fig. 3. FTIR analysis of jackfruit peel extracted with distilled water



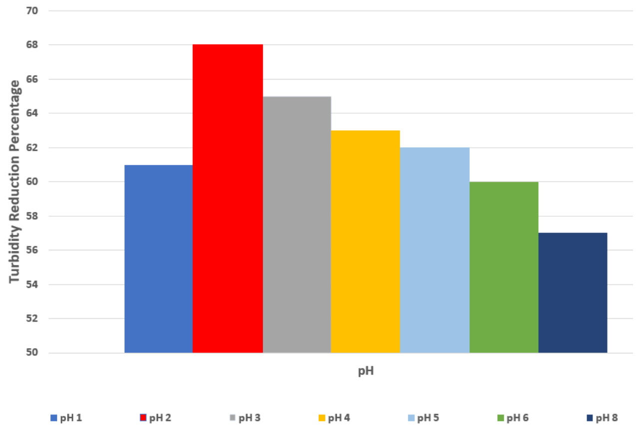


Fig. 4. The percentage of turbidity reduction against pH of wastewater range from 1 to 12 using jackfruit peel extract.

Table 3
Comparison of results obtained from current study with literature.

Type of wastewater	Natural Coagulant	Turbidity Reduction (%)	Ref.
Kaolin synthetic wastewater	Jackfruit (Artocarpus heterophyllus) seeds	75.0	[26]
Raw surface water (Nile river)	Apricot (Prunus armeniaca) seeds Mango (Mangifera indica) seeds	54.0	[27]
Raw surface water	Orange (Citrus sinensis) peel	85.0	[28]
Synthetic water (bentonite)	Date (Phoenix dactylifera) seeds	90.0	[29]
Raw surface water (storm water)	Avocado (Persea Americana) seeds	64.2	[30]
Synthetic domestic wastewater	Banana (Musa Acuminata) peel	73	[31]

jackfruit peel extracted using distilled water. The pH of wastewater mainly affects the surface charge of coagulants and the stabilization of suspension. The results obtained from the coagulation test by using jackfruit peel extract is as shown in Fig. 4. As can be seen, the coagulation performance of jackfruit peel in reducing turbidity favored the acidic condition. It was observed that the jackfruit peel extract works the best as a coagulant at pH 2. Highest turbidity reduction can be obtained at this pH that is almost 70 ± 1% in reduction. The water appeared to be clearer and more flocs is formed at this pH. The effectiveness starts declining gradually when the pH is increased from 3 to 12. The water turns cloudier with percentage of turbidity reduction in the range of 67 ± 1% to 29 ± 1% and less flocs were found after the settling process due to pH incremental. The lowest turbidity reduction was found at pH 12 when the wastewater condition is most alkaline. The turbidity reduction was only 30 ± 1% which indicates the least effective pH for jackfruit peel to perform as coagulant. The coagulative behavior of jackfruit peel decreases when the alkalinity of the wastewater increases as within the range of pH 8 to pH 12. Thus, it clearly shows that jackfruit peel works well in acidic condition which supported with characterization analysis. Based on zeta potential study, the zeta potential measured was 25.2 mV at pH of 6.95 which indicates that the surface charge present in the coagulant is negative. The acidic condition of wastewater promotes the positive charges on molecules that may influence and enhance the performance of the molecules to function well as coagulant [41]. Acidic condition of wastewater is highly present with hydrogen ions which also increases the positive charge of the wastewater. Thus, this phenomenon significantly affects the turbidity reduction of the synthetic wastewater.

3.4. Comparison of current study with literature

The comparison of results obtained from this study with literature is illustrated as in Table 3. As shown in the table, various natural coagulant has been explored in determining the effectiveness in turbidity reduction of wastewater. Research on jackfruit peel has not been carried out up to date. It can be described that turbidity reduction using jackfruit peel was higher comparable to apricot and mango seeds. Date seed and papaya seed performed better but they were examined using different types of wastewater. This finding demonstrated the potential of jackfruit peel as alternative solution to chemical coagulant as well as an added value to the abundant jackfruit peel waste available.

4. Conclusion

The results obtained from the present study show the feasibility jackfruit peel as natural coagulant on the removal of turbidity. It was observed that the jackfruit peel extract works the best as a coagulant at pH 2. This natural coagulant is effective in reducing turbidity in which it reduces up to 68%. As from the proximate analysis, jackfruit peel comprises of 6.5% protein and 70% carbohydrate potentially to be the components which assist in coagulation process. The FTIR analysis proved that the existence of carboxyl, hydroxyl group and hydrogen bonding in the coagulant that assist in the mechanism of bridging and charge neutralization. Jackfruit peel coagulant can be used as primary treatment of the wastewater. This coagulant is believed to be an environmentally friendly alternative to existing chemical coagulants that are currently being practiced in wastewater treatment.

Credit authorship contribution statement

Durgesh Ozarkar: Investigation, Writing - original draft, Methodology, Validation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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