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Coagulation-Flocculation of Brewery Wastewater Using Chicken Intestine

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ABSTRACT

The study used biocoagulants for the improvement in the reduction rate of the brewery wastewater contaminants before safe discharge to the environment. The chicken intestine was converted to coagulant using different unit operational techniques including drying, blending, grinding and sieving. The morphology and functional groups present were analyzed using the scanning electron microscope and the Fourier transform infrared spectrophotometer respectively. The parameters studied on the coagulation-flocculation process of the brewery wastewater were pH (5-9), coagulant dosage (0.3g/l), temperature (40 -70 ^{0}C), settling time (10-70 min) and particle size (0.2 - 2 mm).. The results showed that as the pH increased, the colour intensity decreased from 89.88 – 89.28%, the total suspend solids (TSS) decreased from 83.18 – 78.9% and the turbidity increased from 40.19 – 42.07%. However, as the coagulant dosage value increased from 0.2 – 1.0 g, there was an increase in the reduction efficiency of the contaminants. Scanning electron microscopy (SEM) image showed uniform-sized particles cluster of dome-shaped cells with a bulk density of 1.83 g/cm^3 and particle size of 64.28 µm. The kinetic study showed second order reaction (R^2=1) with rate constant K_1 and K_2, 0.046 min^{-1} and 0.115 min^{-1} respectively.

Keywords: Brewery, chicken intestine, coagulation flocculation, properties, waste.

Graphical Abstract


Plate 1:Chicken intestine

→


Plate 2: Grounded chicken intestine

INTRODUCTION

Brewery products globally play important role in the markets of nations [1, 2]. Breweries in Nigeria are some of the global fastest growing companies [3] playing a game charger in the modern economy and has many benefits crucial for economic transformation [4]. Brewing entails many stages, which includes malting, milling, mashing, wort boiling and filtering, hopping, fermentation and maturation, stabilization, clarifying, and packaging [2] Boiling and clarifying of wort generates 3 - 10 litres of brewery wastewater (BWW) for every liter of beer produced [1, 2 5]This wastewater is subjected to analysis for organic matter, biological oxygen demand (BOD), and pH among others.

Primary treatments are necessary to reduce contaminants and improve the quality of the wastewater before discharge to the environment. Pre-treatment techniques used in removal of suspended particles in brewery wastewater were filtering, flow equalization, sedimentation, etc [2, 5], which overtime have shown to be very ineffective and limited to the removal of common particles. The introduction of coagulation and flocculation have been proven to be very efficient in delivery the objective of removing pollutants in both liquid and solid phases [5, 6] Coagulation-flocculation (CF) is extensively employed as a chemical process in the treatment of industrial and urban wastewater for solid-liquid separation due to its ease of application and control with minimal energy expenditure [7]. Chemical inorganic salts like aluminum and ferric sulfate and chloride were often used for CF. Aluminum chlorohydrate and polyamine have been tested as coagulants for the removal of particulate COD and turbidity in BWW [2,5]. The results showed that the use of aluminum chlorohydrate reduced by 37% and 54% of chemical oxygen demand and turbidity, respectively.

According to recent research, natural coagulants can function as chemical coagulants during the sedimentation process [8] As a result, their uses in the treatment of industrial wastewater are becoming increasingly common. Corn, okra mucilage, and *Moringa oleifera* are among the crops that can be used as natural coagulants. Chitosan, a co-polymer formed by the deacetylation of chitin, is one example of a substance that can also have an animal origin [9].

In Nigeria chicken intestines are waste obtained from the processing of chickens in the frozen foods market. The disposal of these waste in the environment is constituting a lot of pollution problems, hence the need for value addition to be processed as a sustainable and cost-effective coagulants for the treatment of brewery waste water. The use of chicken intestine as a sustainable possible coagulant has not been reported in literature.

The present study is aimed at investigating the effectiveness of chicken intestines as a sustainable cost-effective coagulant for the treatment of brewery wastewater.

MATERIALS AND METHODS

A brewery in Ibadan, Southwest Nigeria, provided the effluent sample utilized in this investigation. Before and after treatment, the effluent was kept and subjected to established techniques of analysis for a variety of wastewater parameters. The chicken intestine was obtained from Auchi, Edo State, Nigeria.

Processing of the Chicken Intestine into a Coagulant

The intestines were cleaned with water, pulverized and sun dried for some weeks. After that, it was subjected to laboratory sieve and homogenized using an electric blender to create even finer granules, stored in an airtight polyethylene bottle. Particle size of the sieved samples ranged 0.2-2 mm.

Coagulation-Flocculation Experiment

Coagulation-flocculation studies were carried out in Unit operation laboratory. pH, coagulant dose, settling time, particle size, and temperature were the operational factors that were examined.

Physiochemical Properties of Brewery Water before and after Coagulation.

Effluents from three locations were combined and analyzed for their physico-chemical properties: pH using the pH meter, Color was measured calorimetrically with a colorimeter (Jenway PCO1 model), turbidity was done using the Hanna H198703 Turbidimeter, electrical conductivity was carried out using the portable conductimeter type MC METTLER TOLEDO, Total solids was analyzed by gravimetric analysis

$$\text{Total Solid (mg/L)} = \frac{(X_2 - X_1) \times 1000}{Y} \qquad (1)$$

Where X_1 = weight (g) of empty dish; X_2 = weight (g) of dish + sample; Y = volume (mL) of sample taken

Total dissolved solids were determined using portable TDS meter and Total suspended solids (TSS) were computed as the difference between total solids and total dissolved solids.

(Total Solids - Total Dissolved Solids) = Total Suspended Solids (mg/L).

Determination of the Biological and Chemical Oxygen Demand

Using mercurimetric titration, the amount of chloride in the water sample was determined. Sulphate in the sample was evaluated turbidimetrically by absorption spectrophotometry. Using the ammonium molybdate spectrophotometric technique, the amount of phosphate in the sample was ascertained. HANNA H19142 dissolved oxygen meter was used to measure the amount of dissolved oxygen (DO) in the sample. The sample's dissolved oxygen level on a particular day, was incubated for five days, to determine the biochemical oxygen demand.

$$\text{BOD (mg/L)} = DO_1 - DO_5 \qquad [2]$$

$$\text{Dilution factor (DF)} = \frac{\text{Volume of BOD bottle (mL)}}{\text{Initial volume of sample (mL)}} \qquad [3]$$

The following formula was used to determine the COD content in the water sample.

$$\text{COD (mg/L)} = \frac{(A - B) \times M \times 8000)}{\text{Volume of sample (mL)}} \qquad [4\,]$$

where A = volume (mL) of standard ferrous sulphate used for blank

B = volume (mL) of standard sulphate used for sample

M = molarity of standardized ferrous sulphate

Determination of Alkalinity, Total Hardness and Metals

Alkalinity was determined by titration and calculated using the formular:

$$\text{Alkalinity (mg/L)} = \frac{\text{Volume of acid used (mL)} \times \text{Molarity of acid} \times 50000}{\text{Volume of sample (mL)}} \qquad [5]$$

Total Hardness was determined by titration with standard 0.01M EDTA solution and calculated as:

$$\text{Total Hardness (mg/L)} = \frac{\text{Volume of 0.01M EDTA} \times 1000}{\text{Volume of sample (mL)}} \qquad [6]$$

Calcium was determined by titration with 0.01M EDTA and calculated as:

$$\text{Conc. of Calcium (mg/l)} = \frac{\text{volume of 0.01M EDTA} \times 1\,000}{\text{volume of sample (ml)}} \qquad [7]$$

The magnesium titre of the sample was determined by subtracting titre value obtained for calcium determination from the titre value for hardness determination.

$$\text{Conc. of Mg (mg/L)} = \frac{\text{Titre for hardness (mL)} - \text{Titre for Ca} \times 1\,000}{\text{Volume of sample (mL)}} \qquad [8]$$

The presence of heavy metals in water samples were examined using flame atomic absorption spectrophotometry. Flame photometer was used to analyze the samples for sodium and potassium.

Scanning Electron Microscopy

To ascertain the form of the product samples, scanning electron microscopy (SEM; Hitachi SU 3500 scanning microscope, Tokyo, Japan) was used. To examine the element compositions and the physical shape of sample surfaces, energy dispersive X-ray spectroscopy (SEM-EDX) analysis was used, functional groups by Fourier Transform Infrared Spectrophotometer (FTIR) (Perkin-Elmer model RX1) [10].

RESULTS AND DISCUSSION

SEM/EDX characterization

SEM/EDX image was used to depict the morphology and texture at x 500 magnification of the chicken intestine coagulant as shown in Fig. 1.

A cluster of dome-shaped cells with uniformly sized particles and a bulk density of 1.83 g/cm^3 were found in the SEM picture (Figure. 1), with a particle size of 64.28 µm. The elemental makeup of the coagulant was displayed by EDX in Figure 1. The coagulant's capacity to coagulate was further supported by the EDX's confirmation of the preponderance of carbon, calcium, and sulfur. The surface morphology structure revealed that the biocoagulant produced has a rough, compact, and regular pattern. This configuration in the shape of the biocoagulant may be responsible for its efficient flocculation. As a result of the interaction between both the biocoagulant and the wastewater, flocs formed eventually aggregated to produce bigger sized flocs. This observation corroborates the documented reports on biocoagulants in literature [11]. The EDX analysis affirmed the presence of metals; copper, calcium magnesium and iron as well as chlorine, sulphur carbon and oxygen (Figure 1). Similar elements were also observed in the work of Singh, et al. [12, 13].

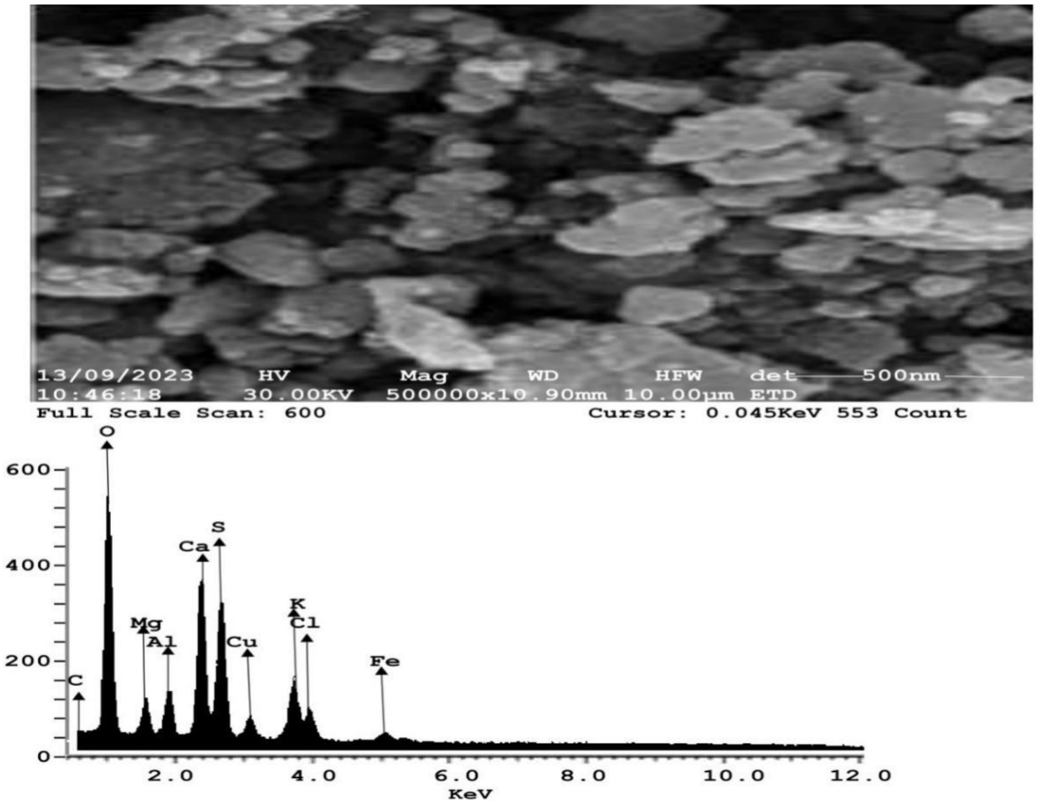

Figure 1: SEM/EDX image of chicken intestine coagulant at 500× magnification

FTIR Characterization of the Chicken Intestine Coagulant

The surface chemistry (surface functional groups) of the chicken intestinal coagulant sample was revealed by the FTIR spectra, which covered a frequency range of 500 to 4000 cm^{-1}. As seen in Figure. 2, the FTIR spectra revealed several absorption peaks that point to the existence of various kinds of functional groups on the material.

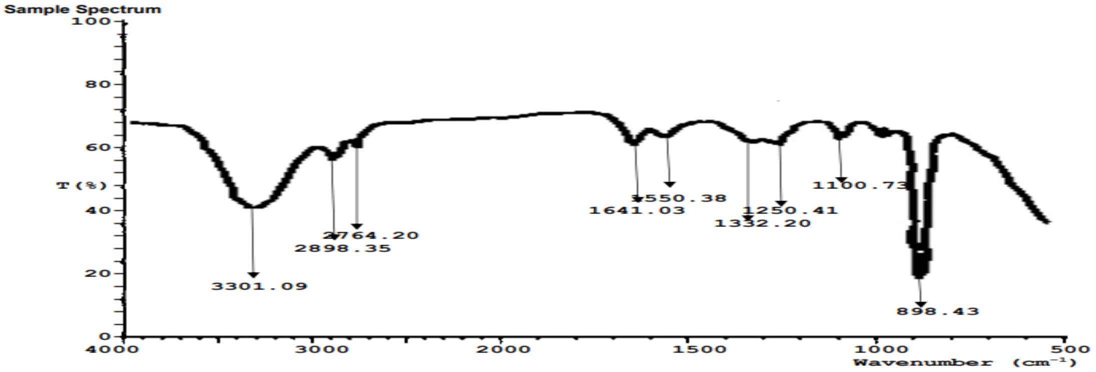

Figure 2: FTIR spectrum on chicken intestine coagulant

The standard signature in the FTIR library was compared with the FTIR results [14,15]. But there were several noticeable peaks in the sample photos, the most common of which was discovered to be at 3301.09 cm^{-1}, which is the O-H Stretching of the Hydroxyl group. Additionally, the carboxylic acid's C=O stretching vibration was ascribed at 2764.20 cm^{-1}. Moreover, the wavenumber of the C-O stretching vibration of ethers is 898.43 cm^{-1}, whereas the –O–C stretching vibration of the Carbonyl group is assigned 1100.73 cm^{-1} [16,17] The coagulant's ability to bind was verified by the existence of these functional groups. This observation is consistent with the report of Yang et al. [9]and Agunbiade, et al. [11]

Characterization of Brewery Wastewater for Coagulation

The characteristics of the brewery wastewater before and after coagulation process are presented in Table 1.

Table 1: Characteristics of brewery wastewater

Parameters	Pre-coagulation	Post-coagulation
pH	7.140	8.240
Colour (Pt Co scale)	9.690	2.880
Turbidity (NTU)	357.0	40.02
Elect conductivity (µs/cm)	540.5	38.13
Total solid (TS) (mg/L)	544.1	107.1
Total dissolved solid (TDS) (mg/L)	211.6	30.47
Total suspended solid (TSS) (mg/L)	332.2	76.60
Total hardness (mg/L)	90.63	40.75
Total alkalinity (mg/L)	367.0	120.4
Dissolved oxygen (DO) (mg/L)	4.210	2.130
Biochemical oxygen demand (BOD) (mg/L)	431.0	76.30
Chemical oxygen demand (COD) (mg/L)	674.5	48.24
Lead (mg/L)	0.02000	0.01000
Copper (mg/L)	0.04100	0.01000
Chromium (mg/L)	0.02200	Nill
Manganese (mg/L)	0.05300	0.01000
Nickel (mg/L)	0.01400	Nill
Zinc (mg/L)	0.02500	0.0100
Iron (mg/L)	2.186	0.3900

Comparing the results with samples before treatment showed significant reduction in the major suspended particles and heavy metals, it showed the effectiveness of the chicken coagulation agents used to achieve the highest level of effectiveness in eliminating organic pollutants, the use of the agent allowed the removal of 92.87% of COD as shown in Table 1. It is important to note that the concentration of COD at the intake in the study was 674.5 mg L^{-1} compared to 48.24 mg L^{-1} reduction in the present work, which shows the influenced of the chicken coagulant in the removal of organic matter. In other studies, Fosso-Kankeu et al. [18] estimated the effectiveness of the use of a non-ionic flocculant for BWW pre-treatment highlighting that almost 4–26 mg of COD was removed per mg of coagulant used, a value lower than the 1–3 mg of COD removed per mg of coagulant obtained in this work. Results about heavy metals removal confirm near complete removal and in some cases more than 75% removal efficiency was obtained as shown in Table 1 for nickel, zinc, iron, and others. This shows the effectiveness of the chicken coagulant in the removal of heavy metals in brewery wastewater.

As shown in the results, coagulation treatment significantly decreased the pre-treatment values of the pollution parameters, including color, BOD, turbidity, and TSS, among others. This indicated that the treatment method was effective.

Effects of the Process Variables on the Reduction Efficiency

Effect of pH on the Reduction Efficiency

By varying the pH of the brewery wastewater from 5 to 9 over the course of a 70-minute settling period and using a coagulant dose of 0.3 g/l, as indicated in Fig. 3, the effectiveness of chicken intestine coagulant for color, turbidity, and the reduction of total suspended solids (TSS) in wastewater was examined.

With a rise in pH, the color intensity falls by 89.88 to 83.28%. A rise in pH causes the TSS to drop from 83.18 to 78.9%. But from 40.19 to 42.07%, the turbidity rises. Consequently, due to charges with increased availability of OH-, raising the pH increased the electrostatic repulsion of the coagulant and the particles in the brewery wastewater, which decreased the stability of the suspended pollutants [19].

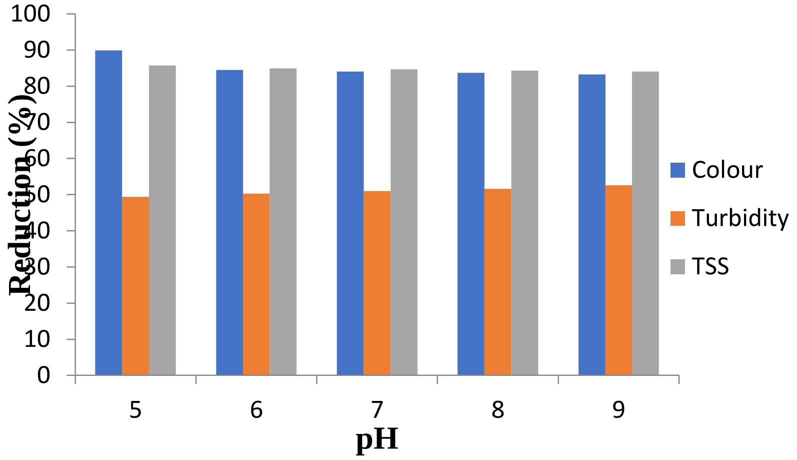

Fig. 3: Effect of pH on the Reduction Efficiency

Effect of Coagulant Dosage

The test trials were carried out by varying the dosage in concentration (0.2–1.0 mg/L) as shown in Fig. 4.

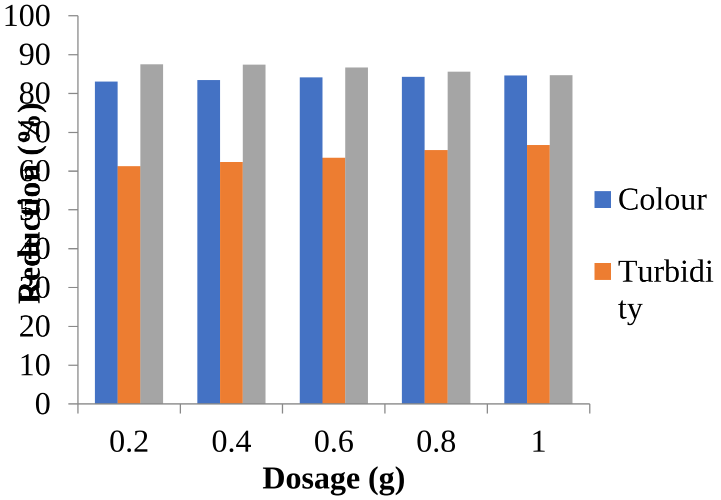

Fig. 4: Effect of Dosage on the Reduction Efficiency

After the supernatants were decanted, measurements were made of their TSS, turbidity, and color. The findings regarding the impact of coagulant dose on the removal of contaminants using pumpkin leaves are shown in Fig. 4. The flocculation and instability of colloids were shown to be improved with the dose increasing from 0.2–1.0 g. This is consistent with earlier research' findings that higher coagulant dosages enhance pollutants' ability to be reduced [20].

Effect of Temperature

The results from the investigation of the effect of brewery wastewater temperature in the range of 303^{0}C to 343^{0}C on the reduction efficiency are presented in Fig. 5.

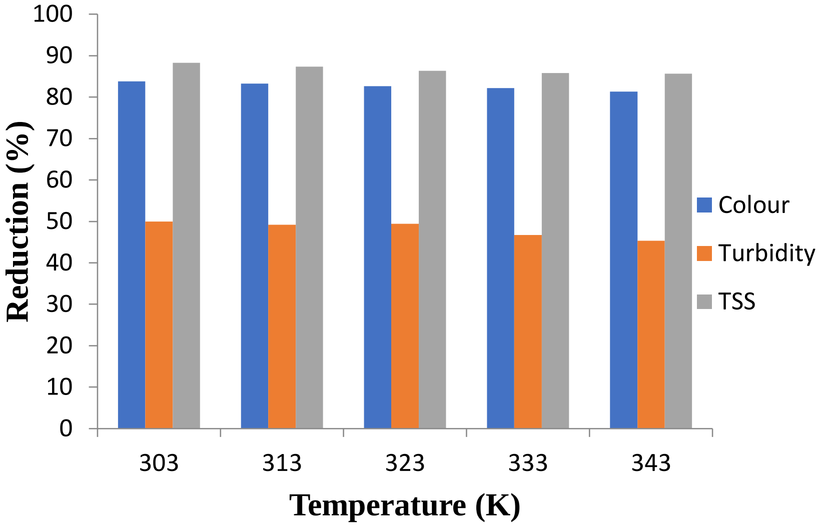

Fig. 5: Effect of Temperature on the Reduction Efficiency

As the temperature increased, Fig. 5 showed that the reduction efficiency of turbidity, color, and TSS decreased simultaneously. This is a result of the wastewater solution's molecules gaining greater kinetic energy at higher temperatures. As a result, the rate at which the coagulating agent and the colloidal particles collide will rise. These will lessen the wastewater's surface tension and viscosity, which will slow down the colloidal particles' settling kinetics.

Effect of Particle Size

As shown in Fig. 6, it was found that when the particle size increased from 0.212 to 2 mm, the wastewater's percentage reduction of color and TSS decreased while the percentage reduction of turbidity increased.

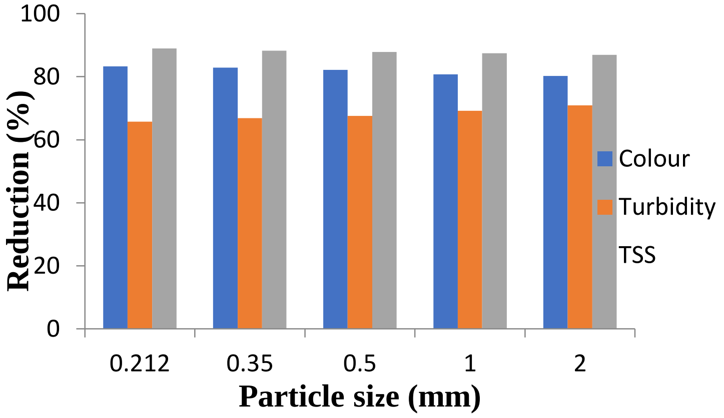

Fig.6: Effect of Particle Size on the Reduction Efficiency

This is attributed to the decrease in the surface areas of the coagulant available for flocs [21]

Effect of Settling Time

Time for the settling of the coagulated flocs, termed 'settling time', was analyzed at a constant pH, dosage, temperature, particle size, and the results are presented in Fig. 7.

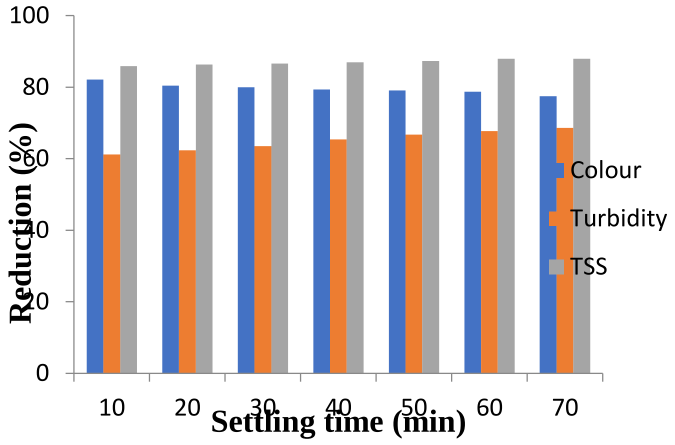

Fig. 7: Effect of Settling Time on the Reduction Efficiency

For every coagulant taken into consideration, it was discovered that turbidity and TSS reduction efficiency increased with settling time but color reduction effectiveness decreased. Smoluchowski's theory of coagulation states that longer settling times favor settleable particles with slower settling speeds for flocculation [22].

Coagulation-Adsorption Kinetics Studies

According to Balarak et al. [23] and Phalakornkule et al. [24], adsorption is known to be more efficient for reducing total suspended solids from effluents.The total suspended solid (TSS) was taken into consideration for the investigation of the adsorptive ingredient of the biocoagulation-flocculation process. According to Balarak et al. [23] coagulation events may be theoretically described as processes akin to adsorption. Pseudo-first order coagulation kinetics (PFO) and pseudo-second order coagulation kinetics (PSO) were the adsorption kinetic models into which the experimental data were fitted; the results are displayed in Figs. 8 and 9, respectively.

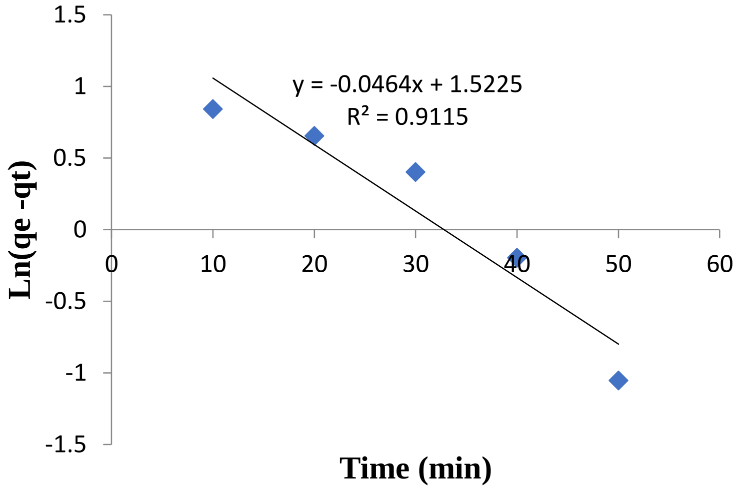

Fig. 8: Pseudo-first order (PFO) coagulation kinetics model fitting

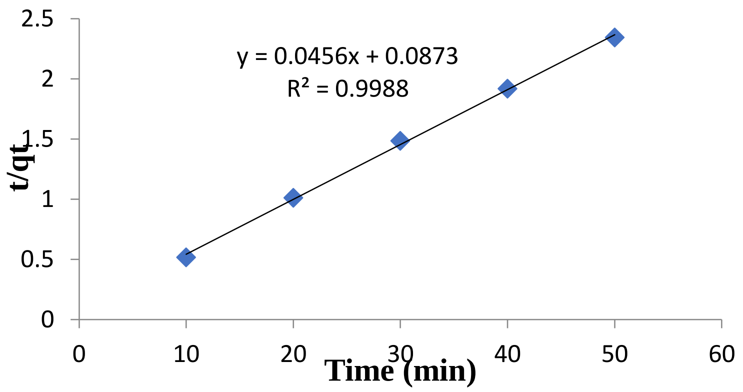

Fig. 9: Pseudo-second order (PSO) coagulation kinetics model fitting

The model that best matches the data was identified using the correlation coefficient, R^2. A model that fits the data the best is indicated by a higher R^2 value [21]. The kinetic data followed the second order kinetic model instead of the first-order kinetic model, as shown by the kinetic parameter (R^2), which was 0.911 for PFO and 0.998 for PSO. From the linearly regression model equations, the values of the rate constants, k_1 and k_2, were found to be 0.046 min^{-1} and 0.156 min^{-1} for PFO and PSO, respectively.

CONCLUSION

This work effectively tested the efficacy of chicken intestine in the coagulation treatment of wastewater. The findings demonstrated that the pH of the starting solution, the amount of coagulant used, the settling period, and the operating temperature all affect how well wastewater is coagulated using chicken intestine coagulant. The reactions fit into a pseudo second order kinetic model, according to the reaction kinetics analysis.

The results of the analysis demonstrated that, although the values of the pollution parameters, including color, BOD, turbidity, TSS, and others, were high prior to the treatment (coagulation), they significantly decreased following the coagulation treatment, indicating the efficacy of the treatment procedure.

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Appendix

Kinetics Equations

$$\frac{1}{C_t} - \frac{1}{C_0} = K_{C^t} \qquad [9]$$

(when α = 1)

$$LnC_1 = -K_{C^t} + LnC_0 \qquad [10]$$

(when α = 2), where C_0 and C are the initial TURB (in mg/L) and TURB (in mg/L) at any period, t, K_C is reaction rate constant and α is the reaction order. In general, the particle distribution graph for coagulation with time may be depicted as (4)

$$\frac{C_w}{C_o} = \frac{\left[\frac{1}{Ts}\right]^{w-1}}{\left[1 + \frac{t}{T_{1/2}}\right]^{w+1}} \qquad [11]$$

where w is 1, 2 or 3 for singlets, doublets and triplets respectively, and T_s is the swift coagulation period and swift coagulation half-life ($Ts_{1/2}$) evaluated using.

$$Ts = \frac{1}{C_0 K_c} \qquad [12]$$

$$Ts_{1/2} = \frac{1}{0.5 C_0 K_C} \qquad [13]$$