

SUSTAINABLE BIO-COAGULANT FROM MORINGA OLEIFERA SEED EXTRACT FOR WATER TREATMENT APPLICATION

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Abstract

This study focused on producing a natural bio-coagulant from moringa seeds. Moringa seed extract is a natural coagulants for the treatment of water containing suspended solids and colloids and is obtained through grinding, oil extraction, protein extraction from the solids using 2M NaCl solution, protein separation by centrifugation followed by filtration. This study investigated production and use of bio-coagulant. Parameters investigated when producing the bio-coagulant include effect of temperature on the removal of moisture content in the moringa seeds, effect of the type of solvent on the oil yield and effect of varying the volume of n-hexane for oil extraction. Parameters investigated when using the bio-coagulant include effect of dosage of bio-coagulant on pH and turbidity removal efficiency, and the performance of the bio-coagulant at low, medium and high turbidity levels. The optimum temperature obtained by drying the moringa seeds was at 100 °C and the highest oil yield obtained was 31 % when using n-hexane as the solvent. Turbidity removal efficiency went up to 96 % when using 40 mg/L of the bio-coagulant at a pH of 6.1. High turbidity removal was achieved at low bio-coagulant dosages which was regarded as a breakthrough finding for this research.

Keywords: Moringa Oleifera seeds, n-hexane, bio-coagulant, water treatment

Introduction

Background Information

Water availability for all is ultimate realisation of Sustainable Development Goal number 6 which thrusts upon member states the obligation to ensure availability and sustainable management of water by at least decreasing the number of people lacking access to safe potable water by half [1]. Before water is distributed to consumers, conventional methods such as coagulation, flocculation, adsorption and activated sludge are applied for water and wastewater treatment [2-4]. In addition, there is a high demand for using efficient and inexpensive methods from biomaterials, like biosorption and adsorption, and this is giving rise to use of inexpensive biosorbents to reduce the costs [1,3,5]. Despite the remarkable role of chemical and synthetic coagulants in water purification, they are associated with carcinogenic and neurotoxic effects due to their residues in treated water, such as aluminium [1,4-6]. Development of sustainable and eco-friendly coagulants as an alternative to chemical coagulants has been reported [7]. The presence of numerous bioactive compounds has associated Moringa plant with multiple nutritional and healthy benefits [1,2,8]. In addition, Moringa oleifera (MO) can also be used in water treatment plants as a coagulant since at high doses no effects are posed on public health. Unwanted particles from wastewater can be separated by the seed extract [6]. Over 90% of bacteria can sediment from raw water by using the unprocessed seed powder, thus they can be potentially used as an anti-microbial treatment. The seed extract acts as a coagulant and flocculent to clarify turbid water. Moringa seed extract destabilize colloidal particles thus have a good potential in lowering the E. coli count [8] and Moringa oleifera has been used to treat waste water from paper mills [6]. Therefore, this project focuses on the coagulation potential of moringa oleifera seed extract in treatment of water.

Coagulants Used in Water and Wastewater Treatment

Coagulants are either natural or inorganic based. Natural coagulants are economical since a variety of users can use them at lower dosages without losing their efficacy and they require far less sludge to be disposed of, which further lowers expenses [3,8]. Low turbidity raw water can be effectively treated with inorganic coagulants that are primarily based on aluminium or iron. Examples include polyaluminium chloride (PAC), sodium aluminate, aluminium sulphate (Alum), ferric sulphate and ferric chloride [2-4].

Aluminium-based coagulants are primarily used in water and wastewater treatment to: (i) remove heavy metals like cadmium (Cd), lead (Pb), arsenic (As) and iron (Fe), (ii) remove phosphorus (chemical precipitation), (iii) remove chemical and biological oxygen demands (COD) and BOD, (iv) remove colour pigments, and (v) for sludge conditioning and dewatering [9]. When using inorganic coagulants, a larger dosage is needed to cause coagulation, and a lot of sludge containing dangerous chemicals is produced as a result [2].

Moringa Oleifera

Moringa plant is classified as an organic coagulant (bio-coagulant) and it has a variety of bioactive chemicals, which have been linked to several health and nutritional advantages [1,8,9]. Moringa oleifera offers no risks to public health, even at greater concentrations, so it can be used in water treatment facilities as a coagulant [4,9]. In Zimbabwe, the Moringa oleifera tree grows quickly and is commonly grown, especially in tropical areas like the Binga district. Moringa seeds contain quality edible oil of up to 40 % by weight and yield proteins which act as effective coagulants in treatment of water and wastewater [1]. The seed extract can separate unwanted particles from wastewater sedimenting impurities [4,9]. The raw seed powder has the ability to filter out over 90 % of microorganisms from raw water, making it a viable anti-microbial treatment [8]. To clear turbid water, the seed extract works as a flocculent and coagulant [3,4,9].

Material and Methods

Materials Used

The wastewater samples used for testing the bio-coagulant were collected from Harare Institute of Technology's municipality water, laundry and canteen water. Moringa seeds used were sourced locally in Zimbabwe and it was utilised as the primary ingredient in the study (Figure 1).

Experimental Method

The study was carried out at the Harare Institute of Technology, Zimbabwe. The raw material used was Moringa seeds and the bio-coagulant extract can be obtained through processes of washing, drying, grinding and drying, oil extraction, protein extraction, centrifugation and filtration. The methodology (Figure 2) is similar to the one adapted from [2,8,9].

Drying and Grinding

The moringa seeds were dried at 100 °C for 20 min then ground using a mortar and pestle until a fine powder was obtained.

Afterwards, the moisture content can be determined as:

$$\text{Moisture content} = \frac{\text{difference in weight of seeds}}{\text{weight of seeds before drying}} \times 100 \% \quad [1] \quad (1)$$

Oil Extraction

Solvent used for oil extraction was n-hexane with a ratio of moringa solids to hexane of 1:5 w/v for 24 hr. The oil was separated by precipitation then filtration.

Protein Extraction and Centrifugation

The protein in moringa seeds was extracted by 2 M NaCl solvent. The solid residue was removed by filtration and the remaining supernatant was centrifuged at 4000 rpm for 30 min so as to remove the sediment and remain with the moringa liquid extract. NaCl present in Moringa oleifera solution improves coagulation efficiency because it helps to release the coagulant protein fraction present in the solution. This is because, coagulation process enhances this extraction by about 7 times higher than that extracted by distilled water [6].

Coagulation Tests

To determine optimum turbidity removal percentages and dosage, standard sedimentation jar test equipment was used in this study which comprised of six 1000 ml jars that can simultaneously test each sample as in [5]. The procedure involved using a 1000 ml graduate and pouring the necessary amount of well-mixed raw water into one of the transparent jars. Afterwards, identical paddles were placed in each beaker followed by setting the filled jars on the gang stirrer. For 30 seconds, beakers were agitated at 40 to 50 rpm until all dosages of the bio-coagulant (mg/L) have been added. For 30 seconds, the mixing was accelerated to a quick mix of 100–125 rpm and the slow mix time was increased to twice as long as the rapid mix, and then lowered the mixing speed to 40 rpm. The mixer was turned off for the mixture to settle. After 15 minutes of settling, the relative speeds of settling and the appearance of the supernatant was noted. Afterwards,

turbidity and/or absorption measurement of each sample was performed in triplicate and turbidity was measured using a hand-held turbidimeter with accuracy of $\pm 2\%$.

Coagulation Efficiency

The efficiency of using MO as a bio-coagulant was determined using turbidity (which was measured without any dilution) and it was calculated using the following expression:

$$\text{Turbidity removal} = \frac{\text{Turbidity}_{\text{before/raw}} - \text{Turbidity}_{\text{after/treated}}}{\text{Turbidity}_{\text{before/raw}}} = 100\% \quad (2)$$

Experimental Results and Discussion

Production of Bio-coagulant

Drying of Moringa seeds for Moisture removal

The mass change was monitored as the temperature was changed and the results are shown in Figure 3. The mass of moringa seeds decreased rapidly with increase in temperature until there was slight decrease at 100 °C to 120 °C hence this means that the moisture content in the seeds was removed and the optimum temperature was 100 °C. The Moringa seeds moisture content was determined as 6.8 %. Moisture content has a huge effect on the storage life of the seeds. Therefore, it is important to note the moisture content in order to predict a reasonable possible life storage of each accession.

Effect of the Type of Solvent on oil extraction from Moringa seeds

The effects of using different solvents for oil extraction can be seen in Figure 4. Based on Figure 4, the oil in moringa seeds is highly soluble in n-hexane compared to other solvents such as ethanol. From the results, the oil yield obtained from hexane is 31 % slightly higher than that of ethanol 28.1 %. In a study, petroleum ether was determined as the best solvent (33.9 %) followed by n-hexane at 27.1 % [2]. Methanol was also tested and it was at 26.3 % extraction.

Effects of varying volume of n-Hexane on oil extraction

n-Hexane was used to extract the oil and the effect of changing its volume was investigated at constant Moringa seeds powder mass. This was done so as to determine the ratio of seed solid to n-hexane to be used (Figure 5). The results for the change of n-Hexane against the oil extracted

are presented in Figure 6. As the volume of n-hexane increased, the amount of oil extracted also increased as seen by the mass of oil extracted of n-Hexane. Change in mass of oil extracted increased slowly after 450 ml giving a ratio of seed solid to hexane of 1:5 w/v.

Validation of Bio-coagulant

Effect of bio-coagulant dosage on turbidity reduction efficiency

The effects of bio-coagulant dosage on turbidity reduction efficiency can be seen in Figure 7a. From Figure 7a, turbidity removal percentage increases from a dosage of 20 mg/L to 50 mg/L and then decreases slightly from 60 mg/L and 80 mg/L where the graph plateaus. The optimum dosage is determined as 50 mg/L. When the *Moringa oleifera* dosage goes above the optimum of 40 mg/L, the turbidity removal efficiency decreased. This is attributed to the increased turbidity because of neutralisation and precipitation of all colloids with an optimum dosage; therefore, turbidity in water is caused by the excess coagulants as they did not interact with colloidal particles which are oppositely charged [6]. *Moringa oleifera* was used to treat paper mill effluent at different coagulant dosage rates (50–300 mg/L) and the optimum dosage rate of 150 mg/L was determined when it had a turbidity removal efficiency of 96 % [6]. *Moringa oleifera* was also used to treat synthetic water and high residual nephelometric turbidity units (NTU) was determined at lower dosages (0 – 10 ml/L) of *Moringa oleifera* [2]. This was in contrast to our results.

Moringa oleifera and alum were used to treat two different natural waters (Santa Helena brook and Picacha brook) at different concentrations (mg/L) [5]. The performance for the Santa Helena brook natural water was: highest turbidity removal of 90 % at three different concentrations of 63, 94 and 125 mg/L for *Moringa oleifera* and the lowest dosage rate of 63 mg/L was taken as the optimum in this instance, and this was slightly higher than what was determined in this study. Of note, is that *Moringa oleifera* performed better than alum in this study as highest turbidity removal for alum was 80 % at 18.8 mg/L dosage rate. The performance for the Picacha brook natural water was: highest turbidity removal of 100 % at five different concentrations of 250, 281, 312, 344 and 375 mg/L for *Moringa oleifera* where the lowest dosage rate of 250 mg/L was taken as the optimum in this instance. This was higher than what was determined in this study. Of note, is that *Moringa oleifera* performed similar to alum in this study as highest turbidity removal for alum was also 100 % at 219, 250 and 281 mg/L dosage rate. *Moringa oleifera* was

investigated as a bio-coagulant on synthetic water at different dosages from 0 to 200 mg/L [10]. They determined that the highest turbidity removal of ~79 % was reached at 50 mg/L just as was observed in this study.

Effect of bio-coagulant dosage on pH

The effects of bio-coagulant dosage on pH can be seen in Figure 7b. From Figure 7b, the highest turbidity removal of 96 % was at pH 4.5 while the least turbidity removal of 75 % was at pH 6.2. Based on the experiments, the optimum pH obtained using moringa bio-coagulant is 6.1 with 89 % turbidity removal efficiency. This lies within WHO (2006) recommended pH range for water which is between 6.0 and 8.0. However, the pH of 4.4 can be used to remove the turbidity and adjust the pH afterwards. This will help to remove additional turbidity up to 96 %. Moringa oleifera was used to treat paper mill effluent at different pH values (4–9) and the optimum pH range was determined to be 6–8 [6]. The result from our study fell within the same range as for the authors.

Effect of Different Turbidity Levels

The bio-coagulant was tested in water at different turbidity levels: low (5 NTU), medium (15 NTU) and high (40 NTU). The results are summarised in Figure 7c. Moringa oleifera bio-coagulant was found to be more effective in water of high turbidity. This is due to more frequent contact of the ions in the bio-coagulant which form heavy flocs hence providing high efficiency. The results can be seen in Figure 7c. Moringa oleifera was investigated as a bio-coagulant on synthetic water at different dosages from 0 to 200 mg/L from initial turbidity of 25 NTU and the highest turbidity removal of ~79 % was reached at 50 mg/L [10]. The synthetic waters used in the study had higher turbidity showing similar results as in our study. The Moringa oleifera dose can handle higher turbidity as is in this study and still achieves good removal efficiencies.

Conclusion

The protein in moringa seeds can potentially be used as a bio-coagulant. The optimum temperature for drying the moringa seeds was at 100 °C for 30 min. The results showed that the highest oil yield of 31 % was obtained from n-hexane since it is a more non polar solvent hence highly recommended for seed oil extraction compared to ethanol which had a yield of 28.1 %. Highest turbidity removal efficiency of 93.6 % was at low dosages of 40 mg/L where all the colloids have been neutralised and precipitated. A high turbidity removal of 88.6 % was also

obtained at an optimum pH of 6.1. *Moringa oleifera* bio-coagulant was found to be more effective in water of high turbidity. This is due to more frequent contact of the ions in the bio-coagulant and form heavy flocs, hence providing high efficiency.

Recommendations

Further studies on performance of the bio-coagulant in powder form for turbidity reduction efficiency must be carried out. Vacuum drying method or freeze-drying method can be used.

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Figure captions

Figure 1: (a) Moringa shells (b) Moringa seeds (c) Ground Moringa seeds

Figure 2: Graphical methodology for the process

Figure 3: Determination of moisture content in moringa seed

Figure 4: Oil yield against solvent type

Figure 5: Mixture of Moringa seed powder with n-Hexane before (a) and after (b) oil extraction

Figure 6: Effects of varying of moles of n-Hexane for oil extraction

Figure 7: (a) Effects of bio-coagulant dosage on turbidity removal efficiency, (b) effect of bio-coagulant dosage on pH and (c) performance of bio-coagulant dosage on different turbidity

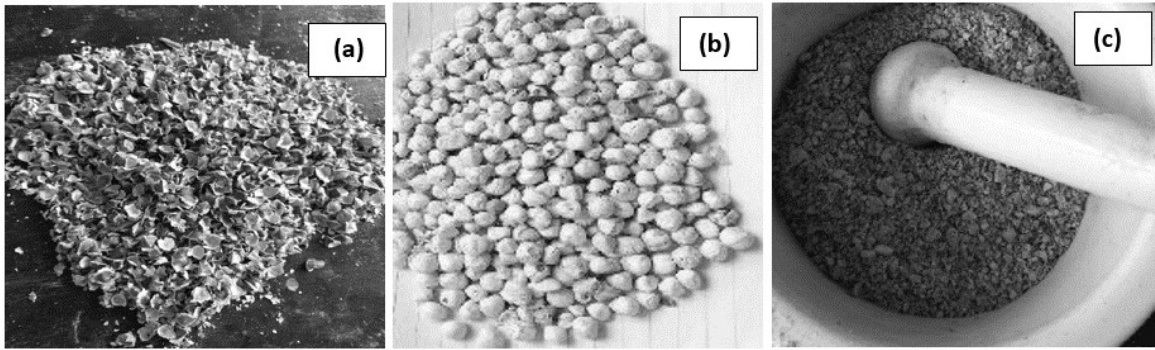


Figure 1

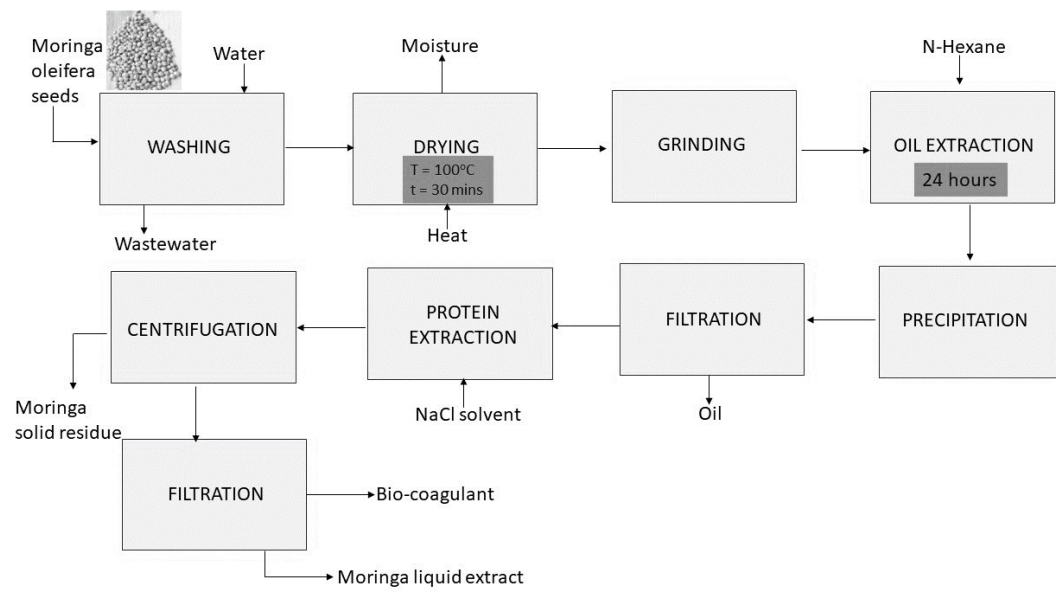


Figure 2

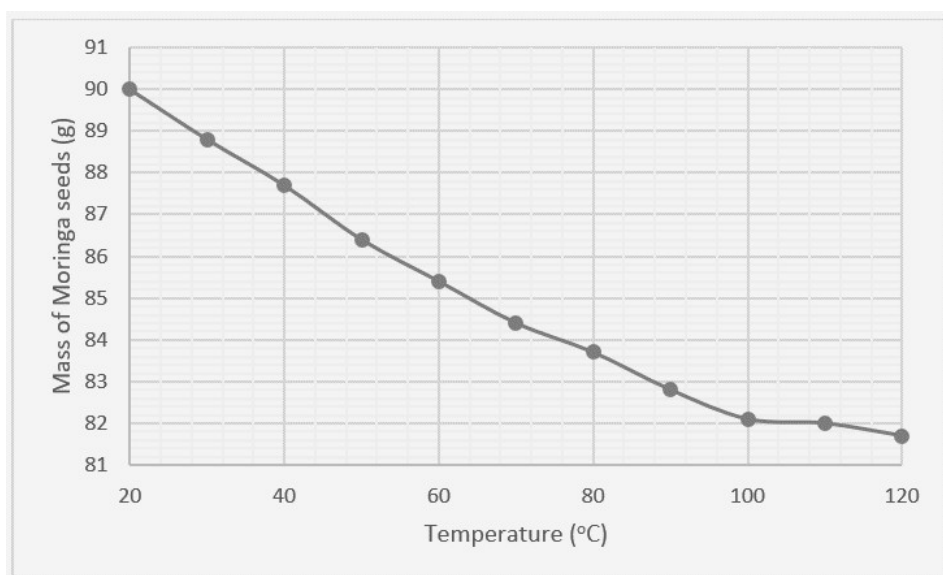


Figure 3

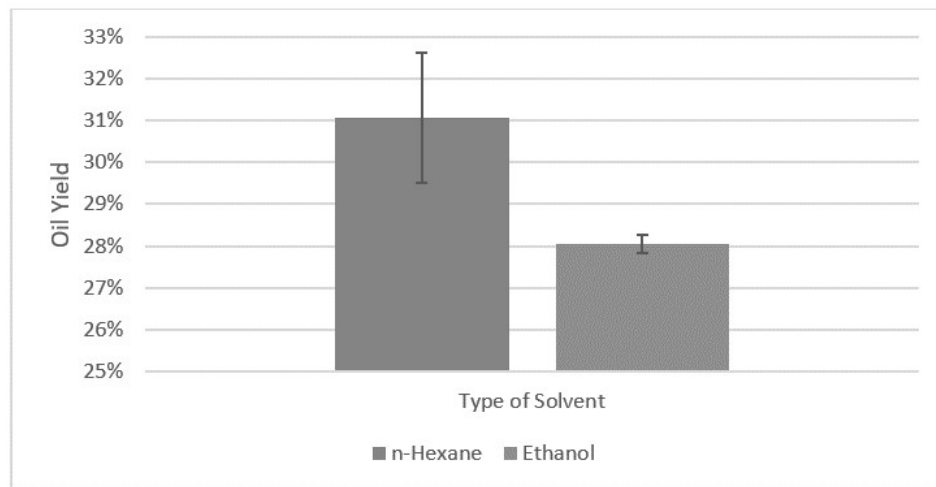


Figure 4

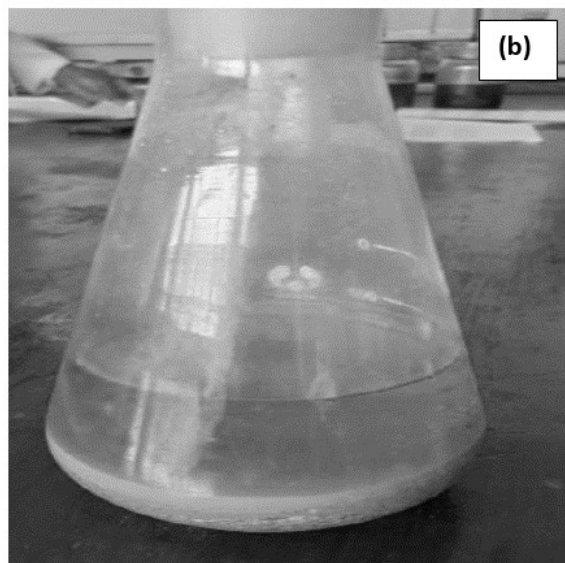
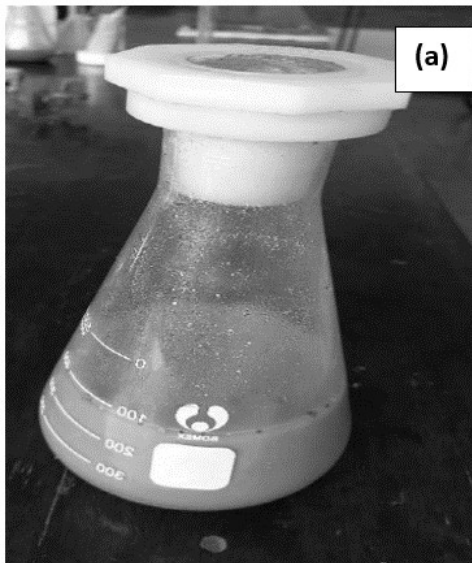


Figure 5

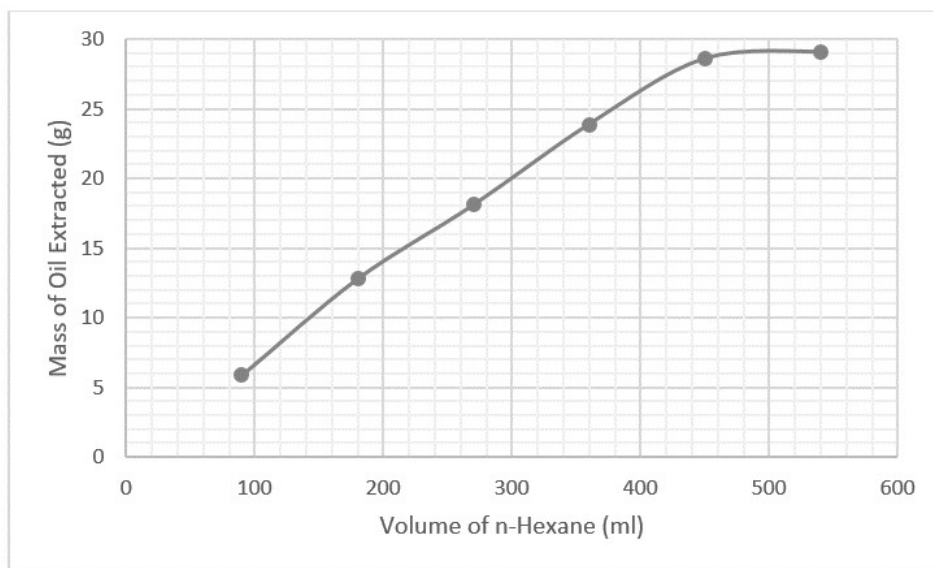


Figure 6

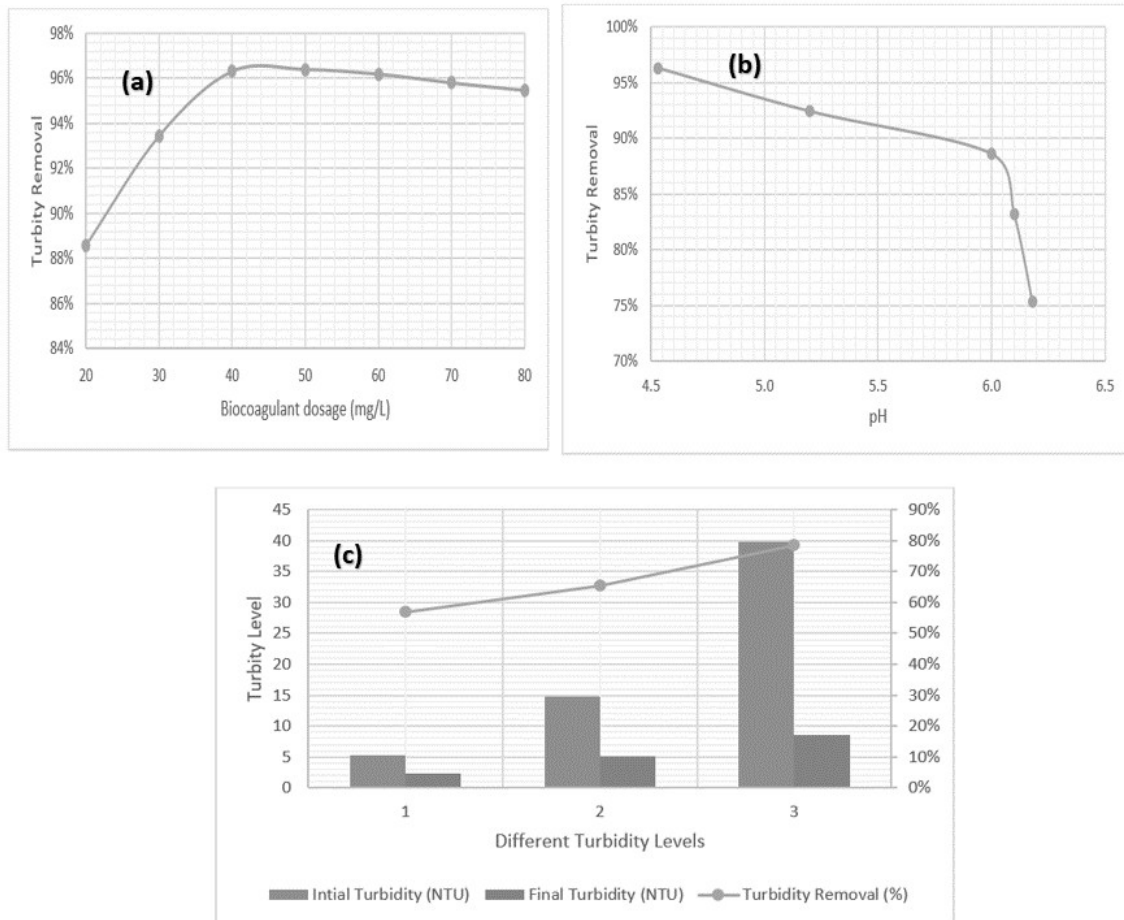


Figure 7