Heliyon 10 (2024) e27584

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Coagulation process for the removal of color and turbidity from wet coffee processing industry wastewater using bio-coagulant: Optimization through central composite design

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A R T I C L E I N F O

Keywords:
Coffee processing wastewater
Natural coagulants
Optimization
Color and turbidity removal
Sustainable environment

A B S T R A C T

The growing problem of industrial pollution in developing countries, especially Ethiopia, has sparked serious issues about the quality of the water, particularly when it comes to the effluent from wet coffee processing industries. In response, this study investigates the potential of utilizing natural coagulants, Acanthus sennii C., Moringa stenopetala B., and Aloe vera L., either individually or in combination, for the treatment of coffee effluent. Methodologically, the study systematically varies operational parameters, including coagulant dose, pH levels, stirring speed, and stirring time, to evaluate their impact on coagulation efficiency. Experimental data undergo statistical analysis, employing ANOVA, while computational optimization techniques are employed using Design Expert software to determine optimal conditions. Notably, the blended form of the three coagulants emerges as particularly promising, yielding optimal conditions of 0.750 g/L coagulant dosage, pH 8.76, agitation speed of 80.73 rpm, and agitation time of 19.23 min. Under these optimized conditions, the blended coagulant achieves remarkable removal efficiencies, approximately 99.99% for color and 98.7% for turbidity. These findings underscore the efficiency of natural coagulants, particularly in blended form, for sustainable wastewater treatment in wet coffee processing.

1. Introduction

Water pollution resulting from coffee processing poses significant environmental and public health challenges, particularly in developing countries where the majority of coffee production occurs [1]. The inefficiencies in processing methods lead to the discharge of wastewater containing organic residues and pollutants into water bodies, necessitating effective treatment solutions [[2,3]]. Precipitation coagulation, a fundamental process in wastewater treatment, involves the addition of coagulants to destabilize colloidal particles and facilitate their aggregation for subsequent removal [4]. This process plays a crucial role in reducing turbidity and removing contaminants from wastewater, thereby improving water quality [5].

Recent studies have highlighted the potential of natural coagulants derived from plant materials as sustainable alternatives to

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https://doi.org/10.1016/j.heliyon.2024.e27584
Received 11 December 2023; Received in revised form 16 February 2024; Accepted 4 March 2024
Available online 19 March 2024

conventional chemical coagulants like alum [6,7]. These natural coagulants offer advantages such as renewability, biodegradability, and cost-effectiveness, making them promising candidates for coffee processing wastewater treatment [5].To optimize the efficacy of natural coagulants, it is essential to understand the principles and mechanisms underlying precipitation coagulation [6]. Insights from references [2–6] provide valuable perspectives on various aspects of coagulation processes, including coagulant selection, dosage optimization, and treatment efficiency assessment. By integrating knowledge from these sources, this study aims to advance our understanding of precipitation coagulation mechanisms and contribute to the development of sustainable wastewater treatment solutions for coffee processing industries.

Water, land, and human health are all negatively impacted by the excessive pollution that occurs in coffee-growing and coffee-exporting nations due to the large amount of effluent from wet coffee processing plant [8]. Due to a lack of technological and economic viability, the processing industries use either no technology at all or very inefficient technologies for management [1]. Data from the United States Department of Agriculture (USDA, 2011) indicates that more than 8.2 million tons of coffee were produced worldwide in 2010./2011. Worldwide, more than 2.25 billion cups of coffee are drank each day [9]. While most coffee is consumed in advanced economies, over 90% of coffee production occurs in developing countries [9]. This coffee tree species, the only native coffee in the world, has historically been cultivated and harvested in the highland woods of southwest Ethiopia (mostly in the former Kaffa Province) [10]. In Ethiopia, the majority of wet coffee processing facilities are situated near water bodies [9]. This is due to the fact that large amounts of water are required not only for cleaning the beans and eliminating the pulp and mucilage but also for directly disposing of the wastewater that is discharged from the wet coffee processing facilities into water bodies [11].

Because pollutants are transported into human systems and wastewater effluent enters the environment uncontrollably, environmental protection necessitates the deployment of appropriate purification/treatment systems with high removal efficiency for contaminants, [12,13]. One of the major environmental risks is water pollution, which is a result of numerous industrial operations. Because of this effluent's direct release into the nearby water bodies, residents in the area suffer from a number of serious health problems, such as nausea, breathing difficulties, dizziness, and irritation of the eyes, ears, and skin [[1,14]].

As reported by Ref. [15], Every year, millions of tons of coffee wastes rich in organic residues are produced from the wet pulping method of processing coffee cherries, which is the way that farmers most choose to use to isolate their fine coffee beans [15]. When waste is disposed of, it produces an offensive odor, insect reproduction, and vectors [16]. Because these particles contain fermentable carbohydrates, neutral wastewater frequently becomes acidic. Typically, the effluent is a recognizable shade of dark brown [1]. This results in a degradation of the dissolved oxygen molecules in the entering freshwater zones. These discharges pose a threat to the environment because they lower the dissolved oxygen content of the water, which has a significant effect on the biotic environment, can kill fish and other aquatic life, and produce odorous products [17].

Reliable wastewater treatment systems are a good indicator of a municipality's level of development and the health of the local population because the volume and quality of wastewater treated determines how these treatment facilities affect the nearby water sources into which it is discharged. [[18,19]]. The Jimma Zone in particular lacks monitoring facilities, thus wastewater from coffee processing is frequently dumped untreated into Ethiopia's river system [1]. As a result, the declining water quality poses risks to public health as well as the environment, necessitating further research. So effluent from coffee production needs to be treated before it can be put into a river system. These days, it's normal practice to use plant materials as natural coagulants for wastewater purification, and the quest is on for the best wastewater treatment system using sustainable technology [20].

Numerous scientific studies have been conducted on the treatment of contaminated water by the use of different techniques such solvent extraction, ion exchange, chemical precipitation, lime coagulation, and reverse osmosis [[21,22]]. Despite being the most popular and successful method, a shift from chemical to natural coagulants has been seen because of the limits that chemical-based coagulants have [1]. Although expensive, alum is highly neurotoxic and may contribute to the onset of Alzheimer's disease [[23, 24]]. Coagulation is a frequently used technique for treating water and wastewater because of how well it works. The quantity and fate of sludge produced during coffee processing wastewater treatment are contingent on various factors, including treatment methods employed and wastewater characteristics. Typically, processes like coagulation-flocculation, sedimentation, and filtration lead to sludge accumulation, comprising removed contaminants and suspended solids. This sludge necessitates proper management to adhere to environmental regulations and minimize impact [25]. Various inorganic salts are commonly employed as coagulants; however, there are drawbacks to this approach as well, such as costly costs, substantial sludge production, and even some health risks [26]. These consist of non-toxic substances such starch, cellulose derivatives, gelatin, galactomannans, chitosan, alginate, glues, and microbial polysaccharides. The processes involved in using natural coagulants are molecule bridging, adsorption, and charge neutralization [21]. The main advantages of using natural coagulants for waste water purification are their ability to effectively remove turbidity and their renewable, non-toxic, biodegradable, and economical nature [27] Research has been done on natural-based coagulants as a possible long-term substitute for chemical coagulants that address these issues [28].

Since coagulants are made from plant materials, their use is environmentally benign because their byproducts are organic and biodegradable [29]. Azadirachta indica A. Juss, a natural coagulant, is less expensive to operate ($USD 0.56/m3) for treating urban wastewater than alum ($USD 1.73/m3), according to a study done in India by Ref. [30]. In summary, plant-based coagulant treatment offers potential cost savings and environmental benefits compared to other methods, but a thorough evaluation is crucial for decision-making [31]. Natural coagulants have not been widely accepted for use in water and wastewater treatment facilities, despite their benefits [32]. This is mostly due to a lack of industry confidence in the adoption of natural coagulants due to uncertainties over these coagulants' consistency and efficiency when employed extensively in water treatment. Thus, the purpose of this study was to examine the advantages and disadvantages of treating water with natural plant extracts instead of commercial coagulants [[1,33]].

The most common technique for evaluating and improving the coagulation-flocculation processes is the jar test. The test comprises of three batch tests (sedimentation, fast, and slow mixing) that are conducted simultaneously and consecutively [[1,34]]. The jar test is a pilot-scale assessment of the treatment chemicals utilized in a particular water plant. It mimics the mechanisms of flocculation and coagulation found in water treatment facilities. By assisting operators in determining whether they are utilizing the proper dosage of treatment chemicals, jar testing increases the efficiency of the plant [[1,35]]. The ability to save money is a significant justification for carrying out the jar tests. Overfeeding or overdosing is a significant problem in water treatment, particularly with coagulants []. Although this may not have an adverse effect on water quality, it is very expensive.

The composition of the samples used in this study includes various parameters such as salinity, pH, turbidity, color, and chemical oxygen demand (COD). Salinity, specifically, refers to the concentration of dissolved salts in the water sample [36]. In the context of coffee processing wastewater, salinity levels may vary depending on factors such as the source of water used in processing and the specific processing methods employed [37]. Salinity can have a significant impact on the effectiveness of coagulation processes and overall treatment efficiency. High salinity levels can interfere with the coagulation process by affecting the charge characteristics of colloidal particles and coagulants, potentially reducing treatment efficacy [38]. Therefore, it is important to consider salinity levels when optimizing coagulation processes for coffee processing wastewater treatment.

In this study, salinity levels of the wastewater samples was measured and recorded as part of the initial raw wastewater characterization process to understand their influence on coagulation efficiency. Additionally, adjustments to coagulant dosage and process parameters ware made based on salinity levels to optimize treatment performance … …

Response surface methodology (RSM) aims to maximize the response surface and determine the correlation between the response variable and the input parameters [39]. Central Composite Design (CCD) and Box Behnken Design (BBD) are the two main forms of RSM. There are more tests in CCD than in BOX BEHNKEN because BBD has fewer design points than axial points in CCD. Since CCD tests under harsh circumstances as well, it provides superior results for quadratic models [40]. In contrast to CCD, where $N = 2^k + 2K + C_0$, where k is the number of factors and C_0 is the number of central points, BBD requires $N = 2K(K-1) + C_0$ experiments [39]. In this research the Central composite design type was used for optimization purpose.

This study's revolutionary technique to treating wastewater in the coffee processing sector makes it unique. The study ventures into uncharted terrain in the search for environmentally acceptable solutions by looking into the usage of natural coagulants and using a central composite design (CCD) method for process optimization. The utilization of a blend and individual form of Acanthus sennii C., Moringa stenopetala B., and Aloe vera L. as coagulants represents a novel strategy for enhancing the removal of color and turbidity from coffee processing wastewater. Furthermore, the determination of optimal conditions for coagulant dosage, pH, mixing speed, and time adds a novel dimension to the research, providing valuable insights into effective treatment methodologies. Overall, this research breaks new ground in the field of wastewater management, offering fresh perspectives and potential solutions for addressing environmental challenges in the coffee industry.

This study examined the potential use of locally accessible Acanthus sennii C., Moringa stenopetala B., and Aloe vera L. as low-cost coagulant for the treatment of the physicochemical properties of wet coffee processing wastewater in an effort to lessen the problems with synthetic coagulant that have been previously mentioned. Functional groups present in Acanthus sennii C., Moringa stenopetala B., and Aloe vera L. include phenols, flavonoids, terpenoids, alkaloids, carboxylic acids, polysaccharides, enzymes, amino acids, and sulfur-containing compounds [41]. These groups contribute to the plants' diverse bioactivity and potential coagulation properties in water treatment processes [41].This experiment examined the amount of coagulant dose, stirring time, stirring speed, and pH for the best color reduction because the turbidity level was the main issue. This kind of treatment is agitating the water to be treated vigorously after swiftly spreading the coagulating ingredient (also known as rapid mixing) [42]. This study looked into the possible removal efficiency of a selected natural coagulant for treating wastewater from the wet coffee processing process. Along with examining its limitations, the ideal dosage and application were established.

2. Materials and methods

2.1. Materials, equipment and reagents

This set of equipment includes jar testing apparatus, refrigerator, oven dry, measuring cylinder, beakers, magnetic stirrer, weight balance, pipette, vacuum hood, crucible, COD kit, conductivity meter, domestic mill, sieve, desiccator, filter paper, pH meter, digital Nephelo turbidity meter, HANNA Instrument (HI-93703), COD digester, UV Spectrophotometer (model-6700), heater, vacuum pump, multimeter, polyethylene bottle, thermometer, burette, Erlenmeyer flasks and standard flasks, spoons. To accomplish the study's goal, a pestle and mortar were the instruments and equipment employed in the trials. Potassium hydroxide (NaOH), silver sulfate (Ag_2SO_4), mercury sulfate ($HgSO_4$), potassium hydroxide (KOH), potassium dichromate reagent, ferrous ammonium sulfate (FAS) reagent, and ferrrion red were the chemicals and reagents used. Concentrated sulfuric acid (H_2SO_4) was used for pH adjustment.

2.2. Sample collection

Using the grap/hand sampling approach, wet coffee processing effluent samples from Jimma zone, Mana wereda, were collected for this study by filling the container directly. The sample size was 108 L, which is the same as the number of runs in the coagulation-flocculation method utilized in this study. Samples are collected using plastic containers that have been washed with detergent, rinsed with tap water, submerged in 10% concentrated nitric acid, and then rinsed with deionized water. The sample that was obtained was then brought to the Jimma University Environmental Engineering (JUEE) laboratory and refrigerated for two days at 4 °C to minimize the chance that its features would change before evaluation [43].

2.3. Preparation of coagulants

When selecting the plant material, which has advantageous characteristics including coagulation activity, availability, and nutritional composition—particularly the quantity of protein and carbohydrates [[44,45]]. In this study, matured Moringa stenopetala B. seed, denoted by white and dried fruits, and moist Acanthus sennii C stems were used as a natural coagulant. The Moringa stenopetala B seeds from Wolayta Sodo that are obtained locally. It dried in the sun for six to seven days. After removing the seed kernels from the surrounding chaff, they are ground into a fine powder with a pestle and mortar and sieved to a 600 μm size [46]. The coagulant made from Moringa seeds was this one.

A sample of mature fresh Aloe vera L. measuring 30–40 cm in length was obtained from the Jimma zone in the Seka district and placed in a polyethylene plastic bag. The thick, slimy gel was then washed and split in half with a knife before being recovered in a 1-Liter beaker. For 30 min, 50 mL of the recovered gel were mixed with 500 mL of distilled water using a magnetic stirrer. After this, the solution was strained using a 25 mm sieve [47]. Ultimately, the filtrate was collected and refrigerated for a maximum of 48 h to inhibit microbial degradation [1].

Very immature, short stems of Acanthus sennii C and the softer tips of the mature stems were collected in Jimma Town, close to St. Gabriel church, and cut into many tiny pieces with a knife. The little Acanthus sennii C stem pieces are washed in distilled water to remove any excess pollutants before debarking. After the debarked stems were separated using a knife, they were put into a clean bucket for storage. After this procedure, the cleaned and dried mortar lab received the separated stem pieces. The stems were pounded into a paste in the properly cleaned pestle and mortar. When enough crushing had been done, the stem paste was scooped by spoon and put into a clean ampoule for use in the coagulation experiment. For Acanthus sennii C., this results in extracts containing phenols, flavonoids, terpenoids, alkaloids, and carboxylic acids [32]. Moringa stenopetala B. yields extracts containing phenols, flavonoids, terpenoids, alkaloids, carboxylic acids, polysaccharides, and amino acids [40]. Aloe vera L. extracts are rich in phenols, polysaccharides, enzymes, terpenoids, carboxylic acids, and sulfur-containing compounds [7]. These extracts are then ready for further evaluation and application as natural coagulants for wastewater treatment.

2.4. Raw wastewater characteristics

Table 1 presents an overview of the preliminary physiochemical parameters of an average untreated coffee effluent wastewater sample, which was collected from the Jimma zone Mana area.

2.5. Experimental setup

This investigation's experiment with natural coagulants was conducted in a typical jar test format. Four 1L beakers connected by four spindle stirrers were used in this batch test. Before the test was conducted, the material was well combined. This work compares the effects of sedimentation, slow mixing, and fast mixing using a batch experiment. Usually, the apparatus includes six rotating paddles, also known as stirrers, and beakers. But in this study, time, runs, sample water, and four 100 mL beakers were used for the three coagulants and the blended one. Finally, the best scenario was considered to evaluate the coagulants' effectiveness in eliminating pollutants throughout all of the experiment's runs.

The greatest speed at which the jar test apparatus can stir is 300 rpm. The device was programmed to run at 150 rpm for 2 min to ensure that the dosed coagulant and sample were evenly disseminated or mixed, 30–40 rpm for 15 min, and 60 min to allow the scattered, coagulated, and flocculated particles to settle or sediment to the bottom of the beaker [1]. This procedure was used for all experiments. In this investigation, coagulant dosages of 0.75g, 1.25g, and 1.75g, stirring speeds of 40 rpm, 80 rpm, and 120 rpm, stirring times of 15 min, 30 min, and 45 min, pH values of 3, 7, and 11, and the optimal condition chosen out of each factor were utilized, accordingly.

The experiment was carried out utilizing a sample of wet wastewater from the processing of coffee that had constant turbidity, color, and other components. For each batch of an experiment, there are four beakers containing the three coagulants and blended coagulants, each of which is filled with the same water sample and has the same adjusted pH, coagulant dosage, stirring speed, stirring time, and settling time. The dosage, pH, stirring rate, and time elements included in this investigation were taken into consideration for all trials, which were carried out in the sequence of treatment combinations.

According to [[1,48]] each beaker was filled with the proper amount of stock solution, the speed was reduced to 50 rpm, and the procedure was continued for 25 min. Afterwards, the paddles were turned off, and the water was allowed to settle for an additional

Table 1
Physiochemical characteristics of raw coffee processing wastewater.

Characteristics	Unit	Raw wet coffee wastewater before treatment	WHO (1995) permissible limits for irrigation
pH		4.75	6.5-8-5
Temperature	°C	26.89	20
Color	Abs	3.00	Clear
Turbidity	NTU	145	5–10
COD	mg L^{-1}	7603.2	300
Nitrate	mg L^{-1}	20.21	5
Phosphate	mg L^{-1}	9.10	5

hour. After 1 h, a clean water sample was collected and kept at $4^{O}C$ for further analysis in a conical flask. Speed was reduced to 50 rpm for the next 25 min. The pH trial interval are also chosen to test the effectiveness of the selected coagulants at 3 (extremely acidic), 7.0 (neutral), and 11 (the reference pH). The trial interval for the input variable in this study was chosen at random, but it takes into account or is based on trials that have already been examined by other researchers in order to avoid redundant experimental testing under the same conditions and to verify the efficacy of the chosen coagulants under the new (very basic) conditions [1].

2.6. Experimental design and data presentation

Response Surface Methodology (RSM) is an optimization technique that makes use of experimental design, analysis, modeling of the experimental variables, and partial regression fighting [[1,49]]. It has the ability to simultaneously integrate several variables and demonstrate how they reciprocally interact to influence a method's effectiveness. Additionally, it minimizes the quantity of experimental runs required to yield adequate data for outcomes that are appropriate from a statistical standpoint [1,50]. The central

Fig. 1. (a) coagulants used in coagulation flocculation process.
Fig. 1(b): Experimental setup, Photographic representation of wet coffee wastewater treatment using wet *Acanthus sennii* C., *Moringa stenopetala B.*, and *Aloe vera* L and blended form coagulants.

composite design (CCD) and the Box-Behnken design (BBD) are the two most often used designs in RSM. The operational parameters of current density, follow rate, and effluent concentration on COD removal and power consumption were optimized in the current work using a CCD with RSM [51,52]. CCD is employed in a face-centered experimental strategy. Face-centered CCD with = 1 was created. The star is oriented so that its points are facing the cube-shaped design element. The choice of a face-centered CCD was made due to the complexity of the design as well as the fact that it is an option in the CCD architecture. Additionally, by choosing the face-centered option, it is ensured that the factorial component was not more extreme than the axial runs [1]. The independent variables in the study were determined to be pH, coagulant dosage, stirring speed, and stirring time (A, B, C, and D, respectively). For each answer, a total of 27 experiments were run. The total number of runs is calculated mathematically using equation (1). With k factors, the total number of experiments, N, is:

$$N = 2^k + 2k + n \quad (1)$$

where N denotes the center points and K denotes the number of elements. Equation (1) states that 108 experimental runs were required for each of the four coagulants..

2.7. Analysis

2.7.1. Determination of color

The color of the treated and untreated samples was measured at a maximum wavelength of 450 nm using a UV Spectrophotometer (model-6700). Consequently, more color in the water is indicated by a higher absorbance reading. The percentage of color eliminated, as calculated by equation (2)

$$Percentage\ color\ removal = \frac{Absi\ \ - Abst}{Absi} \quad (2)$$

Where, Abs_i = initial color absorbance before treatment, Abs_f = final absorbance after treatment.

2.7.2. Turbidity determination

The primary objective of the coagulation/flocculation process is to remove turbidity from the wastewater [53]. Turbidity, the term used to describe the cloudiness of water, is caused by particles suspended in the liquid. The amount of light that is either absorbed or dispersed by suspended material in water is measured as turbidity. HANNA Instrument's digital Nephelo turbidity meter was used to measure the turbidity (HI-93703). Raw coffee wastewater sample and coagulated water are assessed for turbidity after this device is calibrated with distilled water. The values were established over a stable display period in NTU. According to equation (3), The turbidity reduction percentage is calculated using the sample's initial turbidity (Ti) and residual turbidity (Tf).

$$Percentage\ turbidity\ removal = \frac{T_i\ \ - T_f}{T_i} \quad (3)$$

Where, T_i = initial turbidity before treatment, T_f = final turbidity after treatment.

3. Results and Discussions

3.1. Impact of specific operation parameters on the effectiveness of turbidity and color removal

The coagulation and flocculation process was affected by design elements such as pH, coagulant dosage, stirring rate, and time [[1, 54]]. The impacts on coagulant efficiency, each response, and each other were the most evident when one parameter changed in relation to the other. As such, they may have a positive or negative impact on removal effectiveness. Consequently, the degree to which the selected natural coagulants were able to eliminate the color and turbidity percentage depended on the input factors used during the coagulation and flocculation process.

3.1.1. pH effect

The coagulation/flocculation process depended on the wastewater's original pH [[55,56]] The pH of the raw water sample was 4.75, but for this experimental study, it was adjusted to 3, 7, and 11 to assess the effectiveness of the coagulant under acidic, neutral, and alkaline settings. The experimental results showing that pH affects which natural coagulants work best at eliminating color and turbidity are shown in Fig. 1(a). As a result, as the sample's alkalinity rises, the coagulant's effectiveness climbs until pH 7 and then somewhat decreases to pH 11. However, it is essentially worthless in an acidic environment at pH 3. According to Ref. [27], When the pH was increased to 9, the efficiency of removing pollutants increased, and when the pH was increased further, the amount of pollutants reduced. The removal capacity steadily decreased as the pH felled below 3, and it has been demonstrated that the solubility of a few natural coagulants decreased as the pH became more acidic. Because the positive charges on a chosen coagulant surface greatly increased as pH decreased beyond the optimal level. The extra H^+ ions that compete with the active chemicals in the polymer chain under acidic circumstances and when pH is too low impair flocculation through a bridging mechanism. On the other hand, in alkaline conditions, too many OH ions cause the sweeping effect, which could explain why coffee processing wastewater utilizing coagulant treatment at higher pH results in larger nitrate reductions. As a result, the coagulant's contribution charge neutralizing responsibilities in particle destabilization decrease [57]. Also, the results at pH 7 demonstrated that the flocs formed by the chosen natural coagulant were quick to form large floc, which was essential for the settlement's ease. In order to enhance the effectiveness of removal, the pH value in the coagulation-flocculation process must be optimized [58].

3.1.2. Coagulant dosage effect

Optimizing coagulant dose is important in in wastewater treatment [[59,60]]. One of the most important factors to take into account when assessing the efficacy of coagulants in coagulation and flocculation is coagulant dosage. In essence, poor process performance would arise from either an inadequate dosage or an excessive dosage [61]. In order to limit dosing costs and sludge formation and still achieve peak treatment efficiency, it is crucial to choose the ideal dose. As shown Fig. 2 (b) and 3 (b), tests carried out to determine the effects of coagulant dosages between 0.75 and 1.75g. With increases in coagulant dosages up to 1.25g, there was continuous elimination of color and turbidity, which may be attributed to the inter-particle bridging and charge neutralization process brought on by the poly-cationic nature of the coagulant dose. The coffee processing wastewater particles get destabilized and flocculate as a result of the negatively charged colloidal particles' adsorption attachment to positively charged functional groups of the natural polymer. Then, color and turbidity removal efficiencies dropped with further increases of 1.25–1.75g, respectively. The over dosage of flocculants in wastewater from the processing of coffee, which resulted in electrostatic repulsive forces and a poor separation of color and turbidity, had a detrimental impact on the efficiency of color and turbidity removal. However, the additional coagulant injected causes the aggregated particles to scatter and impairs particle settling when the coagulant dose surpasses 1.25g. According to [[1,62]] each experiment demonstrated that the sample water became turbid and colored as the dose was increased.

3.1.3. Stirring time effect

The flocculation time must be a crucial operating parameter in any water treatment facility that performs coagulation-flocculation operations [[63,64]]. The results of the present study showed that stirring time could have a direct and positive effect on coffee processing wastewater treatment by using coagulants. Fig. 2(c) and 3(c) illustrates how changing the flocculation period from 15 to 45 min while maintaining other parameters shows how color and turbidity are removed. According to the experimental findings, color and turbidity were continuously eliminated as mixing time was increased from 15 to 30 min. According to [[1,65]] at the optimum dose, the impact of contact time on the efficiency of COD and turbidity removal was studied in the 15–150 min range. Collisions between coagulants and colloids are unsuccessful at precipitating suspended solids in wastewater when the mixing Period is short 30 min [1]. On the other hand, a prolonged mixing time more than 30 min causes more flocs to break apart and reduces the size of the floc that forms, which reduces the effectiveness of removal. Hence, optimum time allows the formed flocs to settle, however, continuing experiments beyond optimum settling time showed little effect on color and turbidity removals as most of the flocs were already settled.

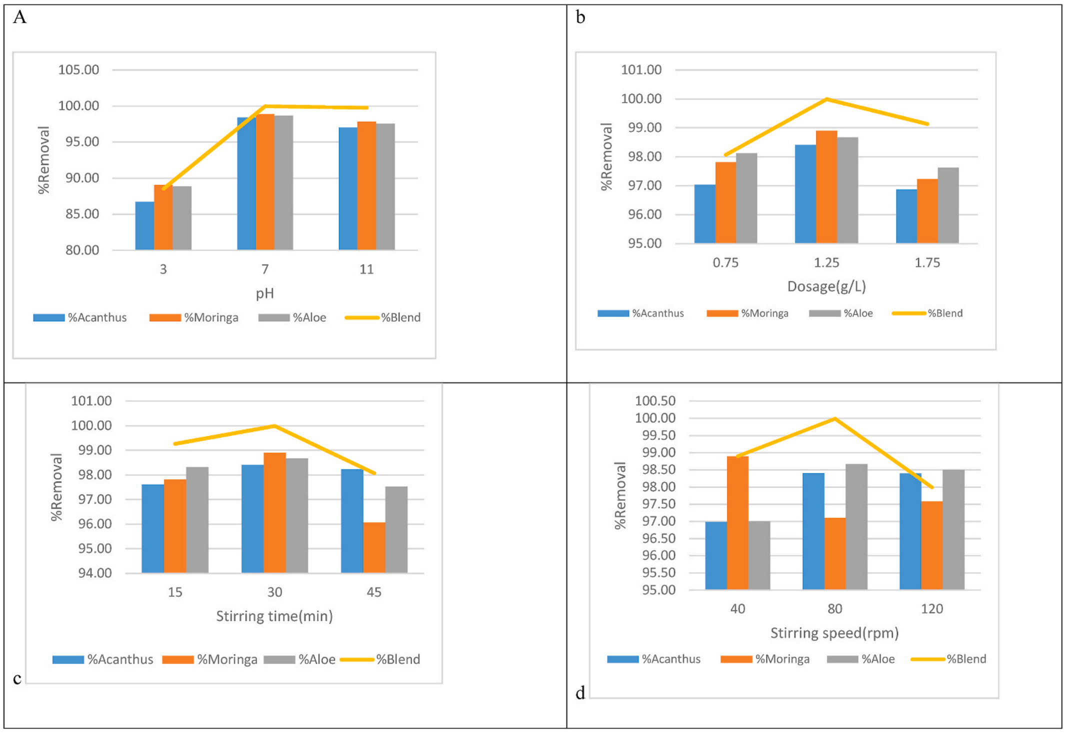

Fig. 2. Percent removal of Color versus affecting parameters.

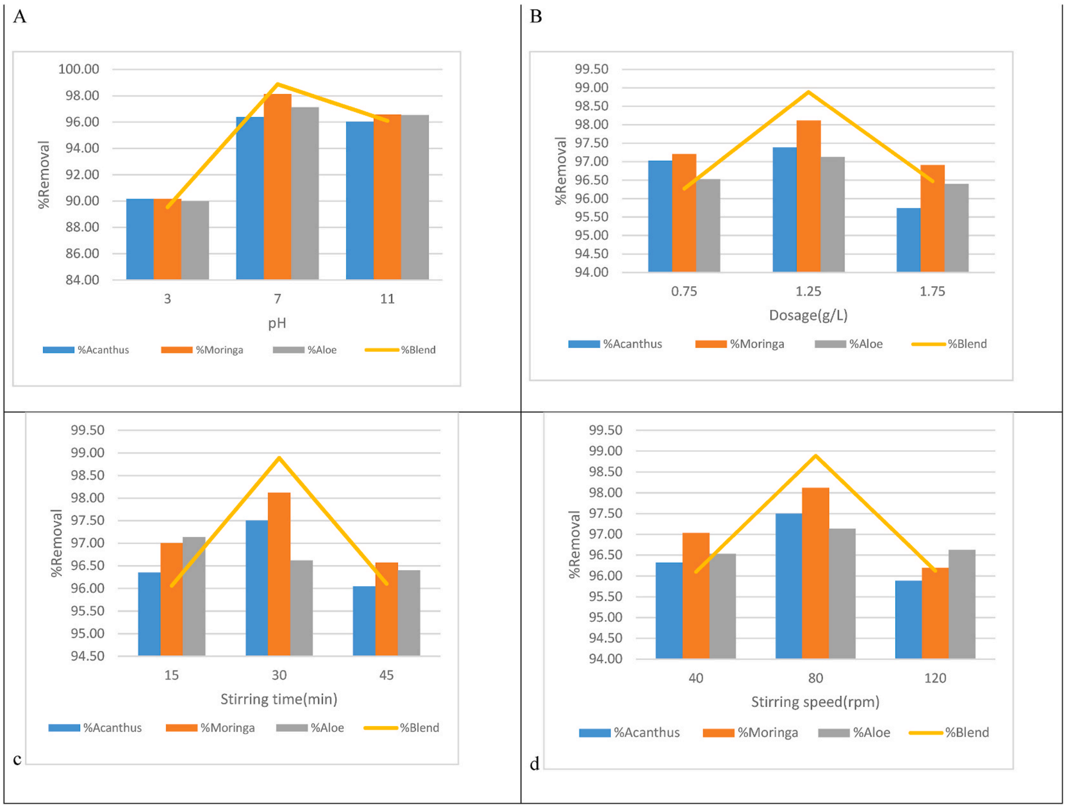

Fig. 3. Percent removal of Turbidity versus affecting parameters.

3.1.4. Stirring speed effect

According to the experimental study of the scholars, stirring speed is important for the coagulation and flocculation water treatment processes [1,66]. It has an appealing physical characteristic on the suspended flocs during each experimental session at the designated speed range in addition to its effect on the reactions. Therefore, the purpose of this study was to examine how stirring speed affected the coagulation process at 40, 80, and 120 rpm for the treatment of wastewater from coffee processing using coagulants. The findings displayed in Fig. 2(d) and 3(d) demonstrate that at 40 rpm, the suspended small size flocs were distributed throughout the surface of the sample water in a beaker, and sedimentation time was obtained at this slow stirring speed. However, suspended small size flocs gathered close to the sample water's center when the stirrer was rotated at 80 and 120 rpm, showing the creation of an agglomeration of those small size flocs that quickly and easily settled [1]. Therefore, proper mixing is necessary for both the coagulant's addition and the floc's growth and extension [52]. Extremely slow mixing and long mixing durations can slow down the floc formation rate, whereas excessively quick mixing and short mixing times can break up the flocs, which will result in inefficient settling [1].

3.2. Examining the experimental results statistically

Table 2 shows that the levels are provided according to the factorial design, which is a 2k factorial design. Each control variable in a *2K* factorial design was assessed at two levels, each programmed to take the values −1, 1, which represent the variable's "low" and "high" levels, respectively. All possible pairings of these *K* component levels are included in this design. Design expert® 11.1.2.0. software was used to analyze all the data and determine the effects of operating parameters such pH, mixing duration, and coagulant dosage. The percentage of removal was the dependent variable used as a response parameter [1]. To reduce unexpected variability in the observed response caused by unrelated variables, all trials were conducted in a random order. Using Design expert® 11.1.2.0 software, the trials' quadratic polynomial design model has five as its center point for each block.

Using central composite design (CCD), a part of response surface methodology (RSM), the usefulness of Acanthus sennii C., Moringa stenopetala B., and Aloe vera L. as color and turbidity removers for the treatment of wet coffee wastewater samples was experimentally determined and statistically analyzed in this study. Table 2, shows that the quadratic model type has been suggested for further study based on the model summary statistics from the ANOVA results. Furthermore, because the difference between the *adjusted* R^2 and the *predicted* R^2 is less than 0.2, there is a good agreement. To ascertain the interaction between the process factors and the responses, graphical analyses of the data were conducted using analysis of variances (ANOVA). The statistical significance of the coefficient of determination (R^2) and the fit of the quadratic model were assessed using the F-test. Model terms were chosen or disqualified using a

Table 2
Result obtained from the experiment for *A.Sennii* (A) *Moringa*(B), *Aloe vera*(C) and blended(D) coagulant.

Run	Factor 1 coagulant dosage g	Factor 2 pH –	Factor 3 stirring speed rpm	Factor 4 stirring time minute	Response 1 Color removal efficiency A	(%) B	(%) C	(%) D	Response 2 Turbidity removal efficiency (%) A	(%) B	(%) C	(%) D
1	1.25	11	80	30	96.25	94.53	97.57	97.7	95.46	96.5	95.42	95.54
2	0.75	11	120	45	95.75	95.81	96.62	96.75	95.35	96.19	94.56	95.33
3	1.75	7	80	30	96.76	97.1	97.62	99.13	96.42	96.91	95.67	96.47
4	0.75	7	80	30	98.01	96.73	98.12	98.07	97.03	97.21	96.21	96.27
5	1.75	3	40	15	84.56	84.63	86.7	88.53	88.99	90.12	87.81	87.76
6	1.75	11	40	15	96.43	97.23	96.57	98.9	95.76	96.29	94.44	95.69
7	1.25	7	80	30	98.41	97.52	98.67	99.99	97.5	97.3	96.67	97.02
8	0.75	3	40	45	83.67	88.47	85.43	85.63	88.74	89.27	88.78	85.32
9	0.75	3	40	15	84.93	89.07	86.5	85.83	89.75	90.16	89.63	89.53
10	1.25	7	120	30	97.98	97.36	98.5	97.99	95.59	96.04	96.62	96.12
11	1.25	7	80	30	98.35	96.63	98.23	98.68	96.38	97.13	96.21	98.89
12	1.75	11	120	45	96.23	93.67	96.43	95.67	94.78	95.84	94.48	91.14
13	1.25	3	80	30	85.3	85.47	87.6	86.83	90.16	88.78	88.71	88.52
14	0.75	3	120	15	86.73	84.91	88.87	86.6	89.65	88.47	89.99	87.38
15	1.75	11	120	15	96.87	97.01	96.97	97.73	95.88	95.67	95.01	94.23
16	0.75	11	40	45	95.87	92.21	95.99	97.87	96.04	96.57	94.98	96.1
17	1.75	3	120	15	84.37	80.57	86.1	86.7	88.65	89.09	85.12	84.57
18	1.25	7	80	45	98.23	96.07	97.53	97.97	95.77	95.1	96.31	95.37
19	0.75	3	120	45	85.83	83.77	87.81	82.62	88.56	89.1	86.78	87.28
20	1.25	7	80	15	97.61	96.32	98.32	99.27	96.35	97	96.6	96.7
21	1.75	3	40	45	83.49	84.37	84.9	86.6	87.92	87.28	86.96	85.45
22	1.25	7	40	30	96.98	97.4	97	96.33	96.32	97.03	95.06	94.14
23	1.25	7	80	30	97.4	96.54	97.5	97.9	96.34	98.12	96.61	97.01
24	0.75	11	120	15	97.03	97.82	97.13	96.3	95.55	95.86	96.24	95.87
25	1.75	11	40	45	95.89	95.77	96.24	98.07	95.75	96.17	96.4	96.03
26	1.75	3	120	45	83.32	83.33	83.5	85.27	86.82	84.81	84.79	80.48
27	0.75	11	40	15	95.93	97.53	96.33	97.57	95.85	96.53	96.53	96.06

95% confidence level and the P-value (probability). The influence of the four component levels was used to construct three-dimensional (3D) surface plots. To determine the interaction between the process variables and the responses, graphical analyses of the data were performed using analysis of variances (ANOVA)(Tables 6–8) (see Table 9).

Design expert® 11.1.2.0 software was used to assess the data obtained in Table 2 and determine the effects of the operating parameters, which include coagulant dose, pH, agitation time, and agitation speed. The percentage of removal was the dependent variable used as a response parameter. In order to mitigate the impact of unexpected variability in the observed response resulting from external factors, the trials were conducted in a randomized order. Four-level Design Synopsis for Percentage Removal. Using Design Expert® 11 software, the trials' quadratic polynomial design model has five centers each block [1].

It was crucial to perform an analysis of variance (ANOVA), Table 4, in order to determine the significance of the quadratic model. In order to determine the significance of each coefficient and to show the degree of interaction between each parameter, the probability (P-values) values were utilized. The corresponding coefficient's importance increases with decreasing P-values [68].

Design parameters for a successful treatment of effluent from the coffee-processing process. (The following are the conclusions of the research in terms of color and turbidity removal rate for Acanthus sennii C., Moringa stenopetala B., and Aloe vera L and blended coagulant. Estimation methods were employed to improve the solutions for generating suitable areas for operational circumstances and attaining the highest removal efficiency [52]. To get the optimum removal performance under operating conditions, color and turbidity removal were set to their maximum values. The ideal circumstances for independent variables were a coagulant dosage of 1.25 g/L, a stirring speed of 80 rpm, a reaction period of 30 min, and parameters maintained at pH 7. In these circumstances, the attractiveness of the model was equal to 1. The analysis of the variance test is shown in Tables 6 and 8 A parameter is considered significant if its p-value is less than 0.05; if it is more than 0.05, the parameter is considered insignificant, meaning it has no effect on the outcome [69]. Several parameters influence the effectiveness of coagulation process, including coagulant dosage, pH, agitation time, agitation speed and settling time. To reduce pollution comparatively using the desired amount of dosage, these operational

Table 3
Experimental and levels of the independent variables.

Factor	Name	Units	Type	Minimum	Maximum	Coded Low	Coded High	Mean	Std. Dev.
A	coagulant dosage	G	Numeric	0.7500	1.75	−1 ↔ 0.75	+1 ↔ 1.75	1.25	0.4160
B	PH	–	Numeric	3.00	11.00	−1 ↔ 3.00	+1 ↔ 11.00	7.00	3.33
C	stirring speed	rpm	Numeric	40.00	120.00	−1 ↔ 40.00	+1 ↔ 120.00	80.00	33.28
D	stirring Time	minute	Numeric	15.00	45.00	−1 ↔ 15.00	+1 ↔ 45.00	30.00	12.48

Table 4
Design Summary of factorial designs.

File Version	11.1.2.0		
Study Type	Response Surface	Subtype	Randomized
Design Type	Central Composite	Runs	27
Design Model	Quadratic	Blocks	No Blocks
Build time (ms)	2.00		

Table 5
Comparison of the optimum experimental results obtained with previously investigated researches [[65,67]].

Characteristics	Unit	Raw wet coffee wastewater before treatment	wet coffee processing wastewater after treatment	Removal efficiency (blended)	Previous investigations	WHO (1995) permissible limits for irrigation
Color	Abs	3.00	0.0001	99.99%	99.02%	Clear
Turbidity	NTU	145	1.6095	98.89%	99.43%	5-10 NTU

Table 6
ANOVA for %removal of Color using blended coagulant.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	867.73	14	61.98	66.73	<0.0001	Highly significant
A-coagulant dosage	4.87	1	4.87	5.24	0.0410	significant
B-pH	577.43	1	577.43	621.68	<0.0001	Highly significant
C-stirring speed	5.23	1	5.23	5.63	0.0353	significant
D-stirring time	6.70	1	6.70	7.21	0.0198	significant
AB	1.29	1	1.29	1.39	0.2618	
AC	0.2756	1	0.2756	0.2967	0.5959	
AD	0.4970	1	0.4970	0.5351	0.4785	
BC	0.0196	1	0.0196	0.0211	0.8869	
BD	1.82	1	1.82	1.96	0.1866	
CD	1.19	1	1.19	1.28	0.2802	
A^2	0.1183	1	0.1183	0.1273	0.7274	
B^2	96.33	1	96.33	103.71	<0.0001	Highly significant
C^2	3.86	1	3.86	4.16	0.0641	
D^2	0.1413	1	0.1413	0.1522	0.7033	
Residual	11.15	12	0.9288			
Lack of Fit	8.92	10	0.8915	0.7992	0.6726	not significant
Pure Error	2.23	2	1.12			
Cor Total	878.88	26				

Table 7
Fit statistics.

Std. Dev.	0.9638	R^2	0.9873
Mean	93.94	**Adjusted R^2**	0.9725
C.V. %	1.03	**Predicted R^2**	0.9326
		Adeq Precision	21.7524

factors must be optimized. As per the investigation of this study pH value effects considerably the removal effectiveness of the coagulant, At pH 3 the removal efficiency were very small and at pH 7 and the removal efficiency was high and slightly declines after PH 7. Previous research has also demonstrated that the highest catalytic activity is found in coffee processing effluent at pH 6.8 [65].

The Model F-value of 66.73 suggests that the model is probably significant. The likelihood that an F-value this large may be the result of noise is only 0.01%. Model terms are considered significant when P-values are less than 0.0500. The model terms A, B, C, D, and B^2 are important in this situation. Values higher than 0.1000 suggest that there is no significance for the model terms [70]. It is fine for the model to not fit, even if we would prefer it to. At a 95% confidence level, the models' significance was investigated. The fit quality is shown by the coefficient of determination (R^2), while the significance and appropriateness of the models are indicated by the F-value and p-value [[1,51]].

A reasonable agreement is reached when the difference between the Adjusted R^2 of 0.9725 and the Expected R^2 of 0.9326 is less than 0.2. The signal to noise ratio is assessed by Appropriate Precision; a ratio larger than 4 is ideal. Your ratio of 21.752 indicates that your signal strength is sufficient. Use this model to navigate the design space. Thus, the design space can be explored using this paradigm [69]. Equations (3) and (4) illustrate the quadratic polynomial model for the percent elimination of color and turbidity,

Table 8
ANOVA for %removal of turbidity using Blend.

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	618.91	14	44.21	21.23	<0.0001	Highly significant
A-coagulant dosage	16.67	1	16.67	8.00	0.0152	Significant
B-pH	352.89	1	352.89	169.50	<0.0001	Highly significant
C-stirring speed	10.40	1	10.40	4.99	0.0452	Significant
D-stirring time	12.99	1	12.99	6.24	0.0280	Significant
AB	1.55	1	1.55	0.7445	0.4051	
AC	11.16	1	11.16	5.36	0.0391	Significant
AD	1.18	1	1.18	0.5655	0.4666	
BC	0.0676	1	0.0676	0.0325	0.8600	
BD	3.48	1	3.48	1.67	0.2205	
CD	0.1764	1	0.1764	0.0847	0.7760	
A^2	0.0393	1	0.0393	0.0189	0.8929	
B^2	51.23	1	51.23	24.61	0.0003	Significant
C^2	4.78	1	4.78	2.30	0.1555	
D^2	0.5411	1	0.5411	0.2599	0.6194	
Residual	24.98	12	2.08			
Lack of Fit	22.64	10	2.26	1.93	0.3889	not significant
Pure Error	2.34	2	1.17			
Cor Total	643.90	26				

Table 9
Best conditions derived from numerical optimization for both response variables and process factors.

coagulants	Process factors (optimum values)				Responses	
	Dose (g/L)	pH	Stirring speed (rpm)	Stirring time (min)	%Color	Turbidity
Acanthus	0.98	8.76	76.67	21.69	99.19	97.52
Moringa	0.82	8.6	73.68	28.00	98.53	98.37
Aloe vera	1.65	8.94	70.96	32.64	98.87	96.74
Blended	0.75	8.76	80.73	19.23	99.99	98.70

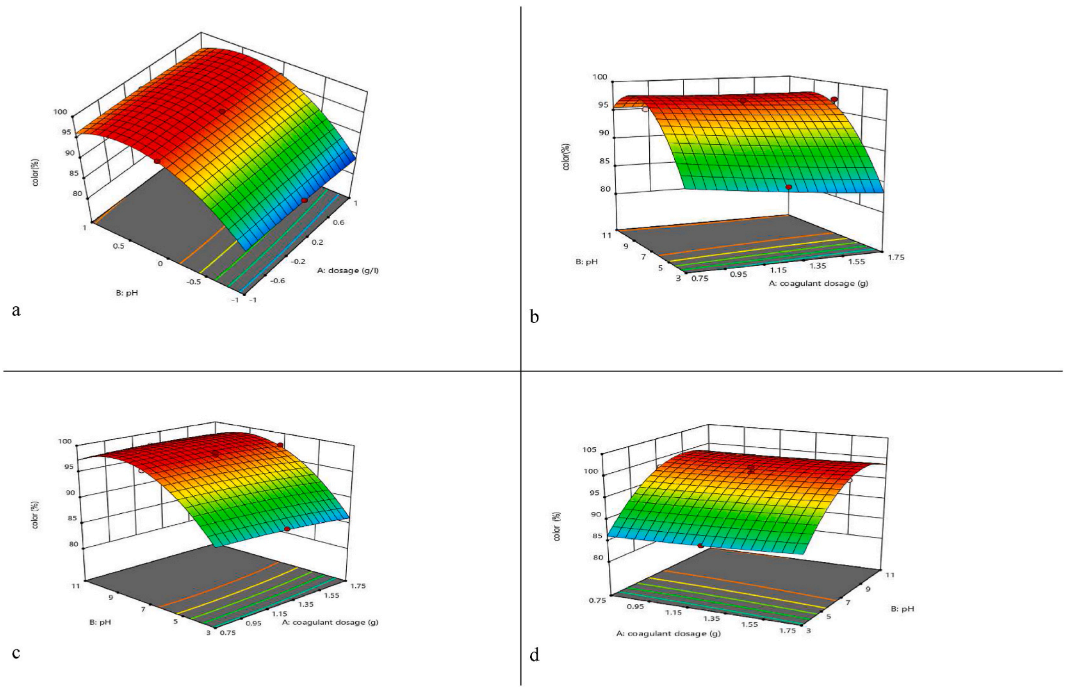

Fig. 4. 3D plot of the interaction effect of **Color** removal for *Acanthus sennii* (a), *Moringa*(b), *Aloe Vera*(c) and Blended form of the three coagulant(d) versus pH, coagulant dosage,stirring time, and stirring speed.

which was derived using the planned experimental data from Table 3.

Final Equation in Terms of Coded Factors

$$\textbf{Color removal efficiency}, \% = 98.54 + 0.5200A + 5.66B - 0.5389C - 0.6100D - 0.2838AB - 0.1313AC + 0.3375AD - 0.0350BC + 0.3375BD - 0.2725CD + 0.2144A^2 - 6.12B^2 - 1.23C^2 + 0.2344D^2 \quad (4)$$

$$\textbf{Turbidity removal efficiency}, \% = 96.88 - 0.9622A + 4.43B - 0.7600C - 0.8494D + 0.3112AB - 0.8350AC - 0.2713AD + 0.0650BC + 0.4662BD - 0.1050CD - 0.1237A^2 - 4.46B^2 - 1.36C^2 - 0.1237D^2 \quad (5)$$

Where, A-coagulant dose, B- pH, C-stirring speed, and D-stirring time. When anything has a negative sign for the amount of color lost, the coefficient of variables shows whether it will be affected negatively or positively. With the equation represented in terms of coded factors, the response for particular levels of each element may be predicted. The high values of the factors are coded as +1 and the low levels as −1 by default. The relative relevance of the elements can be ascertained by utilizing the coded equation to compare the factor coefficients [1].

The Model F-value of 21.23 indicates that the model may be significant. Only 0.01% of the time may an F-value this high occur due to noise. Model terms with a P-value of less than 0.0500 are deemed significant. In this case, significant model terms are A, B, C, D, AC, and B^2. Only 0.01% of the time may an F-value this high occur due to noise. Significant model terms are those with -values smaller than 0.0500. In this case, key model terms are A, B, C, D, and B^2. If the value is higher than 0.1000, model terms are not significant [1]. The F-value for lack of fit, 1.93, suggests that even with many unimportant model terms (not including those required to maintain hierarchy), the lack of fit is not as substantial as the pure mistake. An enormous "Lack of Fit F-value" like this could have a 38.9% possibility of being due to noise. It is fine for the model to not fit, even if we would prefer it to. According to the study of [71], fisher's exact test and *adjusted* R^2 and R^2 were used to evaluate the model's goodness-of-fit. Statistics of importance (F test) [1].

Interactions of different operating parameters and responses by *Acanthus sennii* C., *Moringa stenopetala B.*, and *Aloe vera* L.

By maintaining the other variable value in the center, interactions between any two variables can result in contour or three-dimensional response surfaces, as seen in Fig. 4a,b, 4c, and 4d. Which of the coagulants listed can remove color and turbidity depends on a number of factors, including pH, coagulant dose, stirring time, and stirring rate. When the dosage and pH are suitable, the elimination efficiency rises as a result. Red and blue, correspondingly, indicate the highest and lowest points on a 3D surface. As seen in

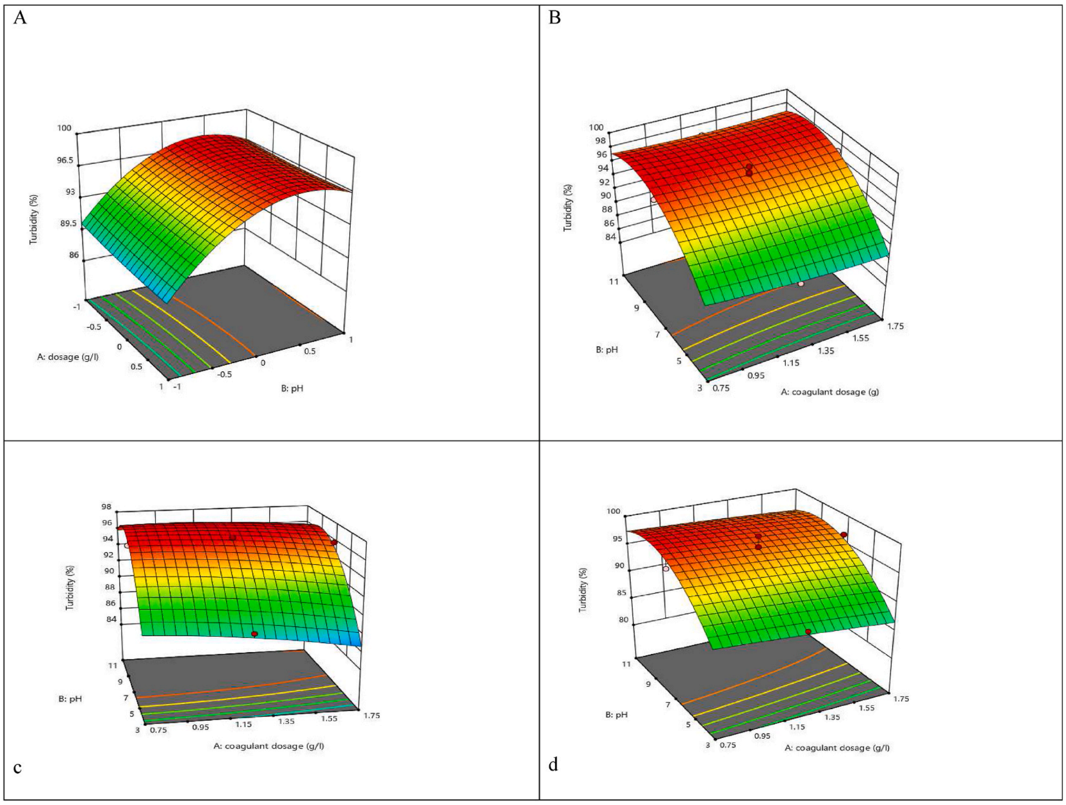

Fig. 5. 3D plot of the interaction effect of **Turbidity** removal for Acanthus sennii C, Moringa stenopetala B. and Aloe vera L. and Blended form of the three coagulant (D) versus pH, coagulant dosage, stirring time, and stirring speed.

the subfigures, the way pH interacts with the other operational parameters greatly influences the proportion of the coagulant eliminated. While all coagulants function effectively in neutral and alkaline environments, they are essentially ineffective at pH 3 for eliminating color and turbidity. As a result, raising the percentage of coagulants eliminated will come from improving the operating conditions. The outcomes demonstrated that there was no statistically significant difference ($P > 0.05$) between the experimental removal efficiency results and the expected values [51]. Thus, Tables 5–8 indicates that the established model makes sense and is appropriate for this investigation.

Interactions between any two variables may produce contour or 3D response surfaces, as shown in Fig. 5(a), b, 5c, and 5d, by keeping the other value of the variable in the center. The pH, coagulant dose, stirring time, and stirring rate all affect which of the coagulants described can remove color and turbidity. As a result, the elimination efficiency is increased when the dose and pH are appropriate. The highest and lowest points on a 3D surface are shown by the colors red and blue, respectively. The percentage of the coagulant removed depends significantly on how pH interacts with the other operational factors, as illustrated in the subfigures. All coagulants are practically useless for removing Color and turbidity at pH 3, although they work well in neutral and alkaline conditions. Consequently, optimizing the operating conditions will increase the percentage of coagulants removed. The results showed that the experimental removal efficiency results and the predicted values did not differ statistically significantly ($P > 0.05$). Tables 5–8 so suggests that the developed model is reasonable and suitable for this inquiry [51] (see Fig. 6).

To evaluate the reliability of the theoretical model prediction, five verification experiments were conducted under optimal conditions. The experiment's elimination efficiency results mostly matched the values that were anticipated, and the variations were not statistically significant ($p > 0.05$). Consequently, it was determined that the model used for this study was appropriate and legitimate [52]. The models' accuracy in predicting the removal of these two pollutants is demonstrated by the strong correlations between the actual and predicted color and turbidity removal values shown in Figs. 3–5. Regression model equations and aligned diagrams illustrating the interactive relationships between the four independent components and the dependent variable may be used to illustrate the interactive reaction between them and the response variable [51]. The model's suitability can be assessed using the diagnostic diagrams of predicted values vs. real values and the residuals' normal probability distribution diagram [72]. The fact that the points on these diagrams are all very straight lines indicates that the variance and the normal distribution are both constant. The graphic representing the residual normal probability distribution displays the points distributed mostly along a straight line. As seen in Fig. 6, some of the dispersed points are even consistent with a normal distribution of the data.

3.3. Optimization

RSM's main objectives are to identify the best control variable settings that produce the largest (or minimum) response over a particular region of interest, R2 [[1,73]]. The practice of modifying a process to make the best or most efficient use of a given set of parameters while abiding by all limitations is known as process optimization. The most frequent goals are to lower expenses while raising throughput and/or efficiency. The optimal option determined by balancing energy carrying, economy, and removal %. Due to the fact that the value of the optimum is determined by a "good" fitting model that adequately represents the mean response, this calls for having one. RSM optimization methods are dependent on the type of fitted model. Using the responses surface methodology, an optimization analysis of the experimental outcomes was carried out by keeping responses within desirable ranges [[52,74]]. Moreover, the response color and turbidity removal in this investigation were both maximized, and other design parameters were maintained within a range.

Thus, the response surfaces (3D) of the quadratic model in this investigation with the elimination of color and turbidity as the response for both coagulants are shown in Fig. 5, where two variables are fluctuating within the experimental ranges and one is maintained at a central level. The large dip in the response surfaces indicates that the optimal conditions were exactly inside the design boundary [1]. The results showed that four criteria that were looked at in this study had a substantial impact on how well color and turbidity are removed. The optimal circumstances and responses for coagulant dose, pH, agitation speed, and agitation time as well as their corresponding response color and turbidity removal efficiencies as determined by the experimentally examined results are shown in Table (9) below. Although though all coagulants are ideal, the blended type of coagulant was shown to have the best results when treating coffee wastewater. It could be as a result of parallel pathways being formed to successfully produce enough coagulants from the acanthus senii stem, moringa powder and aloe-vera gel to effectively remove color and turbidity from coffee processing wastewater. For model fitting, model validation, and model optimization, the RSM is a particular set of mathematical and statistical methods [[1,75]].

4. Conclusions

In this study, the treatment of raw wet coffee processing wastewater using various natural coagulants, including Acanthus sennii C., Moringa stenopetala B., Aloe vera L., and a combination of these coagulants was explored. Our findings underscore the importance of cleaning effluent from wet coffee processing to safeguard the environment. Coagulation emerged as an effective method for remediating contaminants in coffee production wastewater. The study addressed four main goals through various experimental designs. The initial characteristics of the coffee processing effluent revealed significant pollution, with suspended solids, color, organic and inorganic pollutants, and an acidic pH. Through coagulation experiments using a combination of Acanthus sennii C., Moringa stenopetala B., and Aloe vera L., we identified critical design parameters such as coagulant dose, pH, stirring speed, and mixing time for the removal of color and turbidity from the wastewater. Optimal conditions for utilizing the blended coagulant were determined to be 0.750g, pH 8.76, stirring speed of 80.73 rpm, and mixing time of 19.23 min, resulting in significant removal efficiencies of 99.99% for

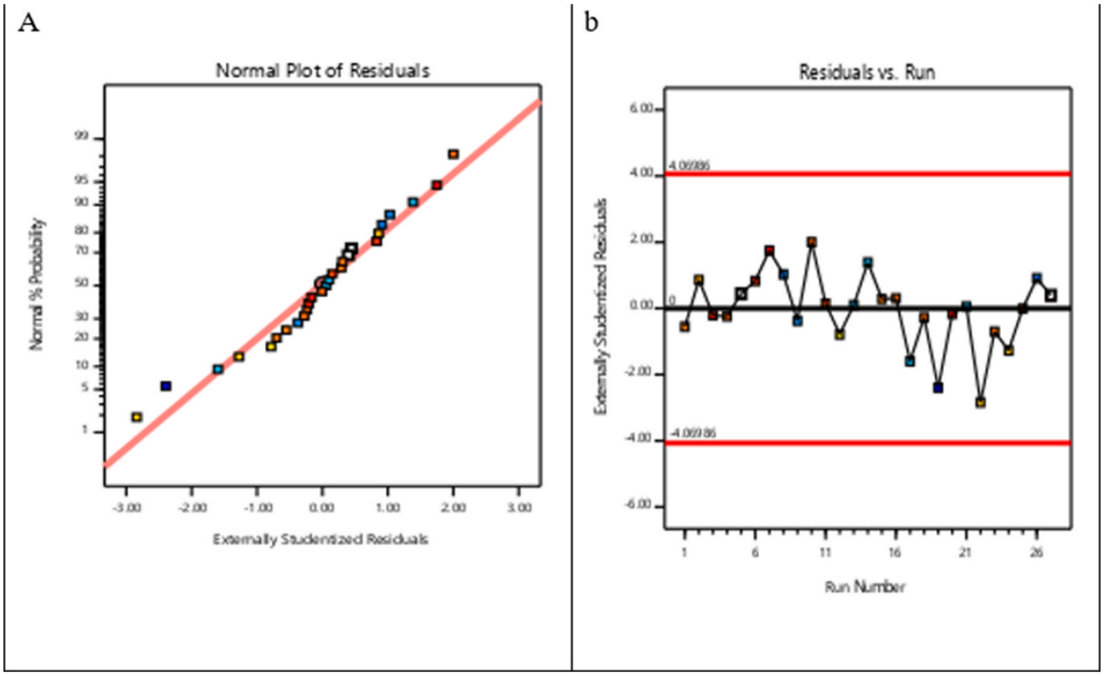

Fig. 6. diagnostic diagram.

color and 98.70% for turbidity. These findings were validated through Central Composite Design (CCD), demonstrating close agreement between experimental results and model predictions. The study highlights the effectiveness of using natural coagulants, both individually and in combination, for treating wet coffee processing wastewater. Particularly, the blended coagulant showed remarkable performance in removing color and turbidity compared to individual coagulants.

Based on the study's findings, a proposed treatment system for real effluent from wet coffee processing involves several key steps. Initially, the effluent undergoes pre-treatment, including screening to remove large solids and pH adjustment to optimize coagulation. Next, the optimized blended coagulant (Acanthus sennii C., Moringa stenopetala B., and Aloe vera L.) is added to facilitate particle aggregation. Rapid mixing ensures uniform dispersion, followed by gentle flocculation to promote larger floc formation. Subsequently, the effluent is allowed to settle in a basin, clarifying the supernatant, which is then filtered to remove finer solids. Disinfection treatments ensure pathogen removal, while pH adjustment post-treatment ensures regulatory compliance. Continuous monitoring of parameters and automated control systems maintain treatment efficacy. Proper sludge management completes the process, ensuring environmentally responsible disposal. This systematic approach ensures efficient and compliant treatment of coffee processing wastewater.

Ethical approval

This article does not contain any study with human and animals performed by any of the author.

Availability of data and materials

Data will be made available on request form corresponding author.

Funding

There is no external funds granted to this specific work.

CRediT authorship contribution statement

Moltot Getahun: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Adisu Befekadu:** Supervision, Methodology, Conceptualization. **Esayas Alemayehu:** Supervision, Resources, Methodology, 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.

Acknowledgment

We would like to say advanced thanks to Jimma University, Jimma Institute of Technology for its 334 support during experimental work.

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