

# Efficiency of *Cassia fistula* Seed as a Natural Coagulant in Raw Water Treatment from Sinú River, Colombia

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## Abstract

**Objective:** To evaluate coagulant activity of *Cassia fistula* seeds in turbidity removal of raw water from the Sinú River and its influence on pH of treated water. **Methods/Statistical Analysis:** Saline extracts of *Cassia fistula* seeds were tested in raw water samples with 10 different turbidity levels and different coagulant doses in a jar test, according to standardized techniques. ANOVA blanks and tables with a 95% confidence level were used to verify if there were statistically significant differences in pH after treatment. **Findings:** Turbidity removals in raw water reached up to 70% for highly turbid samples (500 to 800 NTU), with a 50 mg L<sup>-1</sup> optimum dose. Coagulant activity reached up to 50% for samples with turbidity levels between 250 to 492 NTU, and it was less than 30% for levels from 158 to 241 NTU. No statistically significant change evidence was found in pH of water treated with *Cassia fistula* seeds as a coagulant. **Application/Improvements:** This work proved that use of *Cassia fistula* for raw water treatment from Sinú River could serve as a coagulation aid and not as a primary coagulant.

**Keywords:** *Cassia fistula*, Coagulant Activity, pH, Raw Water, Sinú River, Turbidity

## 1. Introduction

Raw water purification includes physical and chemical processes such as sedimentation, coagulation, flocculation, filtration, and disinfection.<sup>1</sup> Coagulation/flocculation is a common technique widely used in many industrial applications for promoting solid/liquid separation processes due to profitability and easy operation.<sup>2-4</sup>

The coagulation stage is very important in the purification treatment (drinking water) because colloids presence lowers efficiency of the disinfection process; offering protection to pathogenic microorganisms.<sup>5</sup> Turbidity removal of raw water is done traditionally by using coagulants such as synthetic salts (aluminum sulfate or ferric chloride). Large doses of these inorganic coagulants are required for efficient flocculation, though, leading to the

production of large volumes of metal hydroxide sludges.<sup>1</sup> Another drawback for using synthetic coagulants is their high sensitivity to pH, low efficiency in the removal of very fine particles and that they are only applicable to a few dispersed systems.<sup>6,7</sup>

Nowadays, use of natural products is being widely studied due to their advantages over chemical products. Fruit husk residues of coconut tree have been used as wastewater coagulant with high removals of total suspended solids, biochemical oxygen demand, and chemical oxygen demand.<sup>8</sup> Agricultural waste can be used as absorbent material in heavy metal removal and many plant extracts have shown to have fungicidal activity.<sup>9,10</sup>

Natural coagulants have been used for more than 4000 years in India, China, and Africa, where their effectiveness as primary coagulants and coagulation aids in

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highly turbid waters have been proven.<sup>11</sup> Natural coagulants are a viable, economical and safe alternative for raw water treatment in rural and remote areas of developing countries. Among plant coagulants, *Moringa oleifera* seed extracts stand out, due to their high efficiency in turbidity removal in lotic waters, and for not producing significant changes in pH and alkalinity of treated water.<sup>11,12</sup>

Similarly, other coagulants coming from *Hylocereus cf. trigonus* stems, *Albizia saman* gummy exudates and *Guazuma ulmifolia* barks, have been evaluated to measure their coagulating activity efficiency in turbidity removal of raw water from the Sinú River in Colombia. Removal rates varied between 50% and 70% for these coagulant extracts, with relatively low applied optimal doses [between 20 mg L<sup>-1</sup> and 30 mg L<sup>-1</sup>].<sup>13</sup> Other authors report good efficiencies for *Opuntia ficus-indica* extracts [83.66%] and *Cassia fistula* seeds [95%] in turbidity removal for raw water from Magdalena River, another main river in Colombia.<sup>14,15</sup>

The *Cassia fistula* is an exotic tree coming from the *Fabaceae-Caesalpinaceae* family, commonly known as *canafistula*, golden rain or cassia golden rain. Native to India, it is distributed and cultivated in tropical and subtropical America in the dry Pacific regions.<sup>16</sup> It is a low height (5m), very branched tree, with abundant yellow flowers grouped in raceme form and their seeds, are in elongated brown pods.

Furthermore, the Sinú River is the main source providing water to aqueduct systems in the Córdoba Department (Colombia); nonetheless, its turbidity levels are higher than 1,200 NTU, during the rainy season, and even higher than 40 NTU, during dry season.<sup>17</sup>

This study aims at determining the efficiency of *Cassia fistula* seeds in raw water treatment from the Sinú River and its influence on pH of treated water.

## 2. Materials and Methods

### 2.1 Raw Water Samples

Raw water samples were taken from the Sinú River alongside “*Ronda del Sinú*” linear park in Monteria city, Colombia. Ten simple samplings covering the region’s dry and rainy seasons were carried out from April to August 2017. Samples were stored in 20 Liter plastic containers and taken to Sucre University in Sincelejo city, where jar tests and measurement of physicochemical parameters were carried out.

### 2.2 Coagulant Extract Preparation

Seeds for coagulant extract preparation were obtained from dried fistulas of *Cassia fistula* tree. Peeled manually and then dried by placing them in sunlight for eight days at ambient temperature. The dried seeds were passed through a manual mill and sieved in a No. 100 mesh repeatedly until a very fine powder was obtained. Then 10.0 g of the powder was dissolved in a volumetric flask, up to 1.0 L with 1.0% sodium chloride saline solution (w/v). The solution was mixed with magnetic stirring for 1 hour and filtered under vacuum with cellulose filter paper. The filtrate was labeled as a salt coagulant extract with a concentration of 10,000 mg L<sup>-1</sup> and kept cooled at 4°C until application.<sup>18</sup>

### 2.3 Jar Test

Seeds extract of *Cassia fistula*, as a coagulant, was applied in 20, 25, 30, 35, 40, 45 and 50 mg L<sup>-1</sup> doses to each raw water sample. An EyQ F6-300-T jar test equipment was used, set up with six rotating blades and an equal number of 1000 mL beakers. The rapid mixture was 200 rpm for 1 minute (170 s<sup>-1</sup> speed gradient), followed by a slow mixture of 40 rpm for 20 minutes (22 s<sup>-1</sup> speed gradient) and a 30-minute sedimentation time.<sup>12,19</sup>

A blank was used to verify natural coagulant activity and turbidity removal in all jar tests. This was calculated using the following equation:<sup>2,13,18,20,21</sup>

$$\% \text{ Coagulant Activity} = \frac{\text{Residual Turbidity}_{\text{blank}} - \text{Residual Turbidity}_{\text{sample}}}{\text{Residual Turbidity}_{\text{blank}}} * 100 \quad \text{Equation 1.}$$

### 2.4 Equipment and Physicochemical Parameters

Turbidity and pH were measured in duplicate form for all water samples before and after jar tests. The turbidity was measured with a Thermo Orion AQ 3010 turbidimeter and the pH with an SI Analytics-Lab865 pH meter. Measurement protocols established in the standardized methods for the analysis of drinking and residual water according to the American Public Health Association were followed.<sup>22</sup>

### 2.5 Statistical Analysis

An R version Trial software was used for statistical and graphic analysis. A cubic model was generated and an

ANOVA with a 95% significance level was applied to visualize relationship between experimental variables and their answers through surface graphics.<sup>13,23</sup>

### 3. Results and Discussion

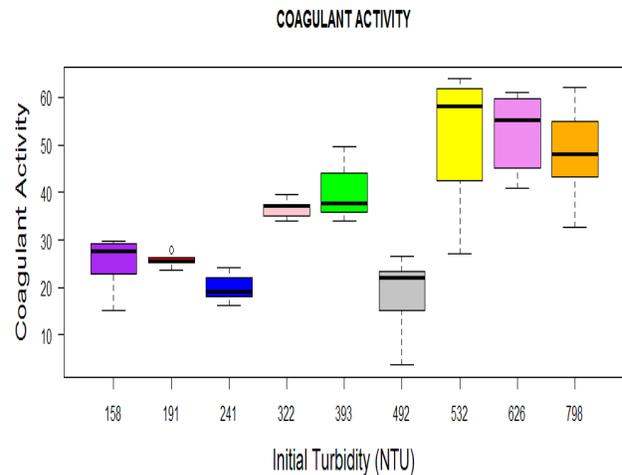
Physicochemical characteristics of raw water samples taken from the Sinú River are shown in Table 1. Although samples turbidity varied over a wide range, due to the different seasons took and analyzed; pH remained in a very narrow range, with a 6.30 average value, a 0.15 standard deviation and a 2.4% variation coefficient, i.e., there is no evidence of sudden changes in water pH regarding the basin dry or rainy season. Nevertheless, a slight acid tendency of samples could be evidenced. These pH values are in line with values reported in the technical literature for the Sinú River<sup>24</sup>, however, its average value is slightly outside the range established in the Colombian regulation for drinking water (6.5 to 9.0 pH units).<sup>24</sup> Figure 1 shows the behavior of the coagulant activity of the *Cassia fistula* seed as a function of turbidity of raw water from Sinú River.

**Table 1.** Turbidity and pH of raw water samples from the Sinú River

Sample	Initial Turbidity (NTU)	pH
1	73.5	6.26
2	158.0	6.28
3	191.0	6.32
4	241.0	6.32
5	322.0	6.39
6	393.0	6.40
7	492.0	6.20
8	532.0	6.62
9	626.0	6.08
10	798.0	6.16

According to Figure 1, coagulant activity of the *Cassia fistula* seed depends on the initial turbidity of raw water, i.e., the greater the turbidity, the greater removal efficiency. For turbidity levels between 158 NTU and 241 NTU, little removal was obtained, according to low coagulant activity observed (between 15% and 30%).<sup>25</sup> For the turbidity range from 250 NTU to 492 NTU, the coagulating activity varied between 15% and 50%, and finally, the best turbidity removals were achieved for very turbid raw

waters (between 500 NTU and 800 NTU), with coagulant activity between 40% and 65%.

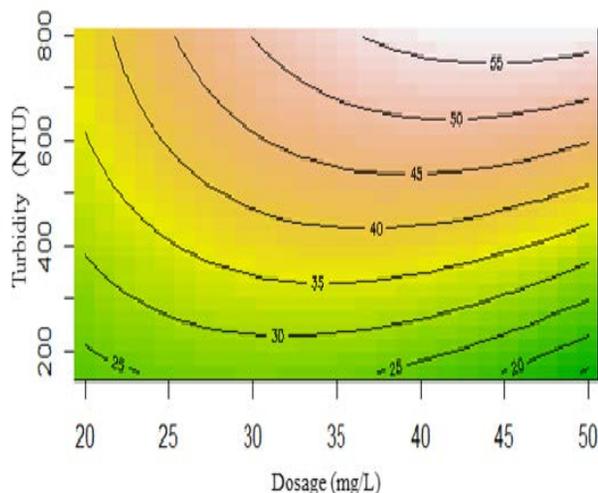


**Figure 1.** Coagulating activity (CA%) of *Cassia fistula* for raw water from the Sinú River.

These results are different from those found by other authors for raw water from rivers, where they report removal efficiencies reaching up to 90% by applying doses of *Cassia fistula* seeds of 20 and 25 mg L<sup>-1</sup> in samples taken from the Magdalena River, with a 120 NTU initial turbidity<sup>15</sup>. In contrast, turbidity removal efficiencies similar to those found in this work (between 50% and 70%) have been reported for raw water from the Sinú River, using coagulants from saline extracts of *Hylocereus trigonous*, *Albizia saman* and *Guazuma ulmifolia*, regardless of the applied dose of coagulant and initial turbidity of raw water.<sup>18</sup> Figure 2 shows a diagram of the coagulant activity based on the turbidity of raw water from the Sinú River and the applied doses of a saline extract from *Cassia fistula*.

According to the coagulation diagram for *Cassia fistula*, coagulant activity depended on the dose applied and, it increased proportionally in accordance with the rise of the raw water turbidity. This behavior is typical of coagulation by adsorption and load neutralization<sup>13,26</sup>. It is possible that active cationic agents of *Cassia fistula* are globular proteins soluble in water and saline solution, capable of absorbing and neutralizing negatively charged impurity particles, and inducing coagulation<sup>27</sup>. The application range of optimum dose to achieve the highest efficiencies of coagulating activity for raw water of high

turbidity was between 30 and 50 mg L<sup>-1</sup>. To check coagulant influence on pH, a pH ANOVA was performed on raw and treated water samples. Table 2 shows the ANOVA result.



**Figure 2.** Diagram of *Cassia fistula* coagulant activity.

**Table 2.** ANOVA P Values for pH

Source	Sume of Squares	Degrees of Freedom	Average Squared	F-Ratio	P-Value
Between Groups	1.122	6	0.187	9.832	2.26
Inside the Groups	1.065	56.00	0.019		
Total	2.187	62.00			

Once assumptions compliance of normality, variances homogeneity and independence of ANOVA residues were verified, it was found that the P-value in Table 2 is equal to 2.26, per thus greater than 0.05, indicating that there is no statistically significant difference between average pH found for each sample tested, with a 95% confidence level.<sup>28,29</sup> Namely, the use of natural coagulant extracts such as *Cassia fistula* does not provide substances that can alter pH of raw water from the Sinú River, so adding substances to buffer acidity is not necessary, normally caused by iron or aluminum salts in the purification process.<sup>30</sup> Authors such as it is also showed that the dry powder of *Cassia fistula* seeds does not significantly alter pH or alkalinity of treated water, concluding that it can be used

as a primary coagulant in the treatment of raw water.<sup>15</sup> However, based on this research results, it is preferable to use *Cassia fistula* seed extracts as coagulation aids and not as a primary coagulant, particularly for raw water of low turbidity.

The combined use of synthetic coagulants with natural coagulants as coagulation aids allows to produce more biodegradable sludge at the end of the treatment process and would reduce production costs of drinking water, particularly, by decreasing the amount of chemical coagulant needed for coagulation/flocculation without altering efficiencies of turbidity removal in the process.<sup>31</sup> It has even been reported that use of coagulation aids in wastewater treatment with ferric chloride can promote additional COD removals of approximately 10-15% to that obtained with only iron chloride.<sup>32</sup>

## 4. Conclusion

It is possible to use *Cassia fistula* seeds in raw water treatment from the Sinú River as long as water turbidity is high (greater than 500 NTU), with doses between 30 and 50 mg L<sup>-1</sup>. Coagulant activity of *Cassia fistula* seeds is lower compared with the performance of other natural coagulants, with expected turbidity removals of less than 70%. Therefore, this natural coagulant is not recommended to be considered as a primary and only coagulant in water treatment process, but rather as a complementary coagulation aid.

There were no statistically significant changes in water pH after treatment with *Cassia fistula* seeds as a coagulant. This represents an economic advantage over synthetic coagulants since it is unnecessary to apply buffer substances to regulate pH. Nevertheless, none of the doses applied to raw water samples allowed to achieve the level of residual turbidity required by the Colombian drinking water quality standard (2 NTU). Like other natural coagulants, saline extracts of *Cassia fistula* seeds are environmentally sustainable and represent an economical and feasible alternative for the treatment of raw water from the Sinú River.

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