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Assessment of chemically modified vegetable tannins as coagulants for water treatment

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ABSTRACT

This research assessed the efficiency of chemically modified tannins as coagulants for water treatment. Tannins from *Anacardium occidentale* (cashew tree) and *Mimosa caesalpiniifolia* ('sabiá') barks and seedless fruits of *Anadenanthera colubrina* ('angico') and *Pityrocarpa moniliformis* ('angico de bezerro') were evaluated after cationization to remove turbidity from water. After extraction, the total solids content (TSC), Stiasny index (SI), and total condensed tannins content (TCC) of the tannins extracts were determined. Extracted tannins were converted into powders and cationized. Then, the cationized tannins' effectiveness on water turbidity removal, sedimentation time, and effect on pH were assessed. Three concentrations of each type of tannin were used to evaluate flocculant efficiency: 50, 100, and 150 mg L^{-1}. Although the *P. moniliformis* extract had a higher TSC value (56.06%), it presented the lowest SI (0.42%) and TTC (0.23%) values. *M. caesalpiniifolia* had the lowest TSC (9.18%) and the highest SI (91.27%), while *Ac occidentale* stood out with the highest TCC (19.83%). All species have shown potential for tannin production and efficiently removed turbidity at all concentrations. However, only *A. occidentale*, at a concentration of 100 mg L^{-1}, presented a nephelometric turbidity unit of 2.4, reaching the potability standards required by international specifications and, therefore, being indicated for water treatment.

Keywords: condensed tannins, forest species, natural flocculants, turbidity removal.

Avaliação de taninos vegetais modificados quimicamente como coagulantes para tratamento de água

RESUMO

O presente trabalho teve como objetivo avaliar a eficiência de taninos quimicamente modificados como coagulantes para tratamento de água. Os taninos das cascas de *Anacardium occidentale* (cajueiro) e *Mimosa caesalpiniifolia* (sabiá) e dos frutos sem sementes de *Anadenanthera colubrina* (angico) e *Pityrocarpa moniliformis* (angico de bezerro) foram avaliados após cationização para remover a turbidez da água. Após a extração, os extratos de

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taninos tiveram o teor de sólidos totais (TST), o índice de Stiasny (IS) e o teor de taninos totais condensados (TCT). Os taninos extraídos foram convertidos em pó e cationizados. Em seguida, avaliou-se a eficácia dos taninos cationizados na remoção da turbidez e o tempo de sedimentação além do efeito no pH da água. Para avaliar a eficiência dos taninos cationizados como floculantes foram utilizadas três concentrações de cada tipo de material: 50, 100 e 150 mg L^{-1}. Embora o extrato de *P. moniliformis* tenha apresentado maior valor de TST (56,06%), apresentou os menores valores de IS (0,42%) e TCT (0,23%). Os taninos da casca de *M. caesalpiniifolia* apresentou o menor TST (9,18%) e o maior IS (91,27%), enquanto os derivados de *A. occidentale* se destacaram pelo maior TCT (19,83%). Todas as espécies demonstraram potencial para produção de taninos e foram eficientes em remover a turbidez da água em todas as concentrações. Porém, apenas o *A. occidentale*, na concentração de 100 mg L^{-1}, apresentou unidade de turbidez nefelométrica de 2,4, atingindo os padrões de potabilidade exigidos pelas especificações internacionais e, portanto, sendo indicado para tratamento de água.

Palavras-chave: espécies florestais, floculantes naturais, remoção de turbidez, taninos condensados.

1. INTRODUCTION

The availability of treated water is necessary to the well-being of any society. Clean water is essential for improving health and hygiene conditions. However, as the population increases, combined with multiple industrial activities, the load of pollutants discharged to rivers, lakes, and other water collections also increases. Pollutant wastes consist of various dissolved and suspended substances, causing damage to natural bodies of water and consequently expanding the scarcity status of this resource (Zdarta *et al.*, 2022). Misuse, combined with high demand, has been worrying experts and authorities on the subject due to the evident decrease in the availability of clean water across the planet. Water scarcity must be seen as a determining factor for survival, and the estimates presented regarding availability for the future are not very optimistic (Roy *et al.*, 2022).

One of the sources of water pollution may come precisely from its treatment. In the coagulation and flocculation stages of treatment, chemicals such as aluminum sulfate and ferric chloride can be used to achieve the best level of water clarification. When used in excess, these agents remain in the water in high concentrations, causing significant problems for human health. However, one of the main disadvantages of using them is the formation of sludge after decantation, which, in addition to colloid flakes, contains remaining amounts of aluminum, iron, sulfate, and chlorides, causing adverse effects to aquatic environments (Alves *et al.*, 2022; Sousa, 2015).

A feasible alternative to overcome the environmental impacts of chemicals in water treatment is using natural or organic substances instead of inorganic substances. New technologies are being used for it, such as substances extracted from tree species that have shown satisfactory results in the water clarification step. In this context, tannins appear as an option to replace metal-based inorganic coagulants, acting as a coagulating agent in wastewater and effluent treatment processes, being characterized by allowing the production of biodegradable sludge, in addition to being obtained from renewable sources, making them ecologically friendly and economically viable (Fraga-Corral *et al.*, 2020; Martins *et al.*, 2014).

The importance of using natural coagulants in the treatment of water and effluents is very relevant, as this profoundly affects the three pillars of sustainable development: environment, society, and economy. The situation is a matter of concern in Brazil, as in other countries, although the government has privileged water availability. In this scenario, fresh water becomes progressively scarce and increasingly valued, becoming an economic good (Lima *et al.*, 2020).

It is well-known that Brazil has one of the largest concentrations of forest species with the potential to produce tannins. Even though there are many species, the main barrier to a prompt transition to natural coagulants from trees is a change of mindset and overcoming resistance to replace traditional chemical agents. As an example, in the Brazilian dry forest (locally called Caatinga), several research studies have been identifying tree species with real potential to provide tannins in industrial amounts, such as *Anacardium occidentale*, *Mimosa tenuiflora*, *Mimosa arenosa*, *Mimosa caesalpiniifolia*, and *Anadenanthera colubrina*, among others (Azevedo *et al.*, 2017; Calegari *et al.*, 2016; Lopes *et al.*, 2015; Paes *et al.*, 2006a).

In this context, studies directed to the prospect of new natural substances to promote an efficiency equal to or higher than chemical coagulants in water treatment become essential not only for the added economic value but also concerning the population's health and conservation of the environment. This study extracted, quantified, and chemically modified tannins through cationization and evaluated their efficiency as natural coagulants. The tannin sources employed were the barks from *Anacardium occidentale* (cashew tree) and *Mimosa caesalpiniifolia* ('sabiá'), and the seedless fruits of *Anadenanthera colubrina* ('angico') and *Pityrocarpa moniliformis* ('angico de bezerro').

2. MATERIAL AND METHODS

2.1. Material collection and tannins extraction

To conduct the experiments, samples of five trees of each species with healthy phytosanitary characteristics were used, and those with no attack by pests and diseases were selected for each species: *M. caesalpiniifolia*, *A. occidentale*, *P. moniliformis*, and *A. colubrina*. The trees came from a natural forest at the Escola Agrícola de Jundiaí (EAJ), Universidade Federal do Rio Grande do Norte (UFRN), Macaíba, RN. The soil in the area is classified as a yellow latosol with a sandy texture and flat topography (Beltrão *et al.*, 1975). The local climate is a transition between types As and BSw, characterized as tropical rainy, according to the Köppen classification, with an average annual temperature of 27.1°C, annual relative humidity of 76%, and rainfall varying between 860 and 1070 mm (IDEMA, 2013).

Random trees were selected for the species P. moniliformis and A. colubrina, separating the fruits from the seeds so they could not interfere with the tannins quantification results. The barks of *M. caesalpinia folia* and *A. occidentale* were collected using a machete, removed from the trunks and branches, and weighed to determine their initial moisture content. The materials were then air-dried, ground in a hammer mill, and used to extract tannins in high quantities. To quantify condensed tannins, a sample of the material from each individual (approximately 200 g) had its particle size reduced using a Willey-type mill, then classified with particle size sieves of 16, 60, and 150 mesh.

2.2. Tannins extraction and quantification

Three portions of 25 g of homogenized and dried material from each species were used to quantify tannins. The samples were transferred to 500-mL flat-bottom flasks, to which 250 mL of distilled water was added and boiled under reflux for two hours. The weight/weight (w/w) ratio between solid material and water was 1:10. Subsequently, each sample was subjected to two extractions to remove the maximum quantity of extractives. Thus, the final w/w ratio became 1:20. After these steps, the aqueous extracts were passed through a 150 mesh sieve and a flannel cloth to retain and eliminate solid fine particles. Then, each extract was homogenized and filtered in a synthesized glass funnel with porosity Number 2. Then, each extract was concentrated to 250 mL by evaporating the water using a Soxhlet-type apparatus. After three 50-mL aliquots of each extract were collected, two of them were used to determine the condensed tannin content (CTC), and the remaining one was evaporated in oven-dried at 103 ± 2ºC for 48 hours until complete dryness to determine the percentage of total solids content

(TSC). The TSC was calculated using Equation 1.

$$TSC\ (\%) = \left(\frac{M1 - M2}{M2}\right) x100 \quad (1)$$

Where:

TSC = total solids content (%)

M1 = initial weight (g)

M2 = final weight (g)

The Stiasny method, described by Guangcheng *et al.* (1991), was used to determine the TTC present in each sample. To do so, 4 mL of formaldehyde (37% m/m) and 1 mL of concentrated hydrochloric acid were added to 50 mL of raw extract. Each mixture was boiled under reflux for 30 min. Under these conditions, tannins form insoluble complexes that could be separated by simple filtration as a precipitate. For this, a paper filter was placed in a Büchner funnel with a diameter of 10 cm and a depth of 4 cm. All analyses were performed in triplicate, using the methodologies cited by Trujillo *et al.* (1997) and Paes *et al.* (2006a; 2006b). The material retained in the filter was oven-dried at 103 ± 2°C for 24 hours, weighed, and the Stiasny index was calculated (Equation 2).

$$I(\%) = \left(\frac{M2}{M1}\right) x\ 100 \quad (2)$$

Where:

I = Stiasny index (%)

M_1 = initial weight of solids in 50 mL of extract (g)

M_2 = precipitate dry weight (g)

The total tannin content (TTC) in each sample was obtained using Equation 3.

$$TTC\ (\%) = \frac{TSC\ x\ I}{100} \quad (3)$$

2.3. Cationization of tannins and coagulation assays

The cationization of tannins was performed following the Mannich reaction reported by Konrath and Fava (2006). The reaction consists of three steps. Initially, 5.4 g of ammonium chloride and 24.4 g of formaldehyde were placed in a 250-mL reaction flask and reacted for 2 hours. The final liquid's light yellow to colorless pattern indicated that the reaction between the two reactants had occurred. The reaction's product was mixed with 28.0 g of an aqueous solution of tannins (50% w/w) and reacted for 30 min at temperatures ranging from 50 to 60°C. After this second step, 0.2 g of monoethanolamine was added to the mixture and left to react for 3 hours at temperatures from 50 to 60°C.

The water source to perform the coagulation tests came from a reservoir located at the Escola Agrícola de Jundiaí-EAJ, Macaíba, Rio Grande do Norte, Brazil. After collection, the water was stored in 5-liter glass flasks and refrigerated (4°C). A jar-test equipment was employed to assess the water coagulation/flocculation process, where 1.5 L of the collected water was added to each jar. Initially, water pH and turbidity measurements were checked. The coagulating agents were the cationized tannins from each species. For all coagulants, three concentrations were used, these being 50, 100, and 150 mg L^{-1}. Two stirring times were used for the four coagulants: 130 rpm for 2 min and 30 rpm for 30 min (fast and slow stirring). Those values came from the work of Beltrán-Heredia *et al.* (2009) and Sousa (2015), and after preliminary tests, they were adopted as standards. The initial turbidity and initial pH were checked. After 1 hour after the end of each test, each sample's pH and final turbidity were evaluated to find the optimal concentration and stirring times for each species.

2.4. Statistical analysis

The means of the parameters, total solids content, Stiasny index, and total condensed tannins content were compared using the T-test at a 95% probability. The experiment was set according to an entirely randomized design with a 4 x 3 factorial arrangement, corresponding to 4 types of tannins and three concentrations of cationized tannins. Experimental data were subjected to analysis of variance, and the means were compared by the Scott-Knott test at a 95% probability. All analyses were performed with the Sisvar® software, and all graphs were expressed as Pareto diagrams.

3. RESULTS AND DISCUSSION

3.1. Tannin yields and other parameters

As shown in Table 1, for the TSC, the fruit of *Pityrocarpa moniliformis* presented the highest percentage at 57.06%, then the bark of *Anacardium occidentale* with 33.36%. The fruit of *Anadenanthera colubrina* reached 17.60%, and finally, the bark of Mimosa caesalpiniifolia, with 9.18%.

Table 1. Comparison of means for the total solids content (TSC), Stiasny index, and total condensed tannins content (TCT) of the four extracts from the different raw materials.

Raw Material	TSC (%)	SI (%)	TCT (%)
A. occidentale bark	33.36 b	59.45 b	19.83 a
M. caesalpinia folia bark	9.18 d	91.27 a	8.38 b
P. moniliformis fruit	57.06 a	0.42 c	0.23 c
A. colubrina fruit	17.60 c	60.93 b	10.70 b

Means followed by the same letters in the rows are statistically dissimilar by T-test at a 95% probability.

The quantification of condensed tannins is one of the most important variables for determining the potential for commercial extraction of a given species, and studies on the quantification of different parts of the plant strengthen its potential use for such. For Medeiros *et al.* (2019), the total solids content (TSC) can be understood as the gross yield of extracted powder from some plant parts. No values are cited in the literature regarding quantifying extracts from *P. moniliformis* fruits. In this study, the highest value was for TSC among the species analyzed. Azevedo *et al.* (2017) found lower values for *M. tenuiflora* between 24.25 and 30.80%, while Paes *et al.* (2006a) found the same value for *A. occidentale* at 33.36%. Paes *et al.* (2010), when analyzing tannic extracts from different parts of *A. colubrina*, obtained similar values for fruits with and without seeds to this research, with 18.20 and 17.60%, respectively.

The Stiasny index refers to flavanol-type tannins precipitated through condensation with formaldehyde in an acidic medium, which are of high molecular weight and difficult to dissolve (Medeiros *et al.*, 2019). For this parameter, *M. caesalpiniifolia* stood out with 91.27%. There was no significant difference between the species *A. colubrina* (60.93%) and *A. occidentale* (59.45%); the lowest value was observed for the fruit of *P. moniliformis* with only 0.42%. These values show promising results for these three species because the higher the Stiasny index, the higher the polyphenols content. It indicates a higher degree of purity of tannin extracts followed by a low content of other substances, such as sugars and gums (Ferreira, 2004). Paes *et al.* (2010) found similar values for the seedless fruit of *A. colubrina* with 60.93%, a higher value seen by the same author, but for the fruit with seeds presenting a percentage of 40.12%.

The TCT can be interpreted as the proportion of tannins effectively present in a given material. In this study, the highest value for this parameter was in the *A. occidentale* bark, reaching 19.83%, followed by *A. colubrina fruits* with 10.70% and *M. caesalpinia folia bark* with 8.38%. The *P. moniliformis* fruits had the lowest value for TCT, 0.23%. Nevertheless, both *A. colubrina* fruits and *M. caesalpinia folia* bark had the lowest values of 15.23%, as reported by Silva (2021), who assessed *Stryphnodendron adstringens* bark. The low values of SI and TCT for the fruits of *P. moniliformis* justify that this species has a high rate of insect predation, even when it is still attached to the mother plant, as observed by Correia *et al.* (2017). Low levels of condensed tannins in plants' compartments may bring about less protection, leaving the material more susceptible to attack by insects and diseases.

Gonçalves and Lelis (2001) found a value of 2% TCT for *M. caesalpinia folia* bark, which is lower than that obtained in the present study. Several factors affect the production of TCT in the plant, such as plant age, site, temperature, soil, and collection period, as it influences the total metabolites produced and their proportions in the plant (Azevedo *et al.*, 2017; Taiz *et al.*, 2017; Gobbo-Neto and Lopes, 2007). According to Paes *et al.* (2010), species with a percentage higher than 10% of TCT have the potential to be economically exploited, as observed in the bark of *M. caesalpinia folia* and *A. occidentale* barks and the fruits of *A. colubrina*.

3.2. Coagulation assays

The initial pH value for the water sample collected in the reservoir was 7.2. After using natural coagulants from the species under study, no change was observed after 60 minutes for any tested concentrations, as shown in Table 2. Concerning efficiency, when using the tannins as coagulants, none of the materials affected the pH of the water sample from the reservoir after 60 min of natural coagulant activity since there were no statistical differences among means.

Table 2. Values of water pH before and 60 min after the addition of different concentrations of cationized tannins from *P. moniliformis*, *A. colubrina*, *M. caesalpinia folia*, and *A. Occidentale*.

Raw Material	Concentration (mg L^{-1})	Initial pH	Final pH
Pityrocarpa moniliformis Fruto	50	7.75 a	7.72 a
	100	6.76 a	6.77 a
	150	6.97 a	6.88 a
Anadenanthera colubrina Fruto	50	6.83 a	7.07 a
	100	6.76 a	6.87 a
	150	7.04 a	7.05 a
Mimosa caesalpiniifolia Casca	50	7.22 a	7.04 a
	100	7.40 a	7.03 a
	150	7.29 a	7.05 a
Anacardium occidentale Casca	50	6.80 a	7.14 a
	100	6.79 a	7.01 a
	150	7.02 a	6.88 a

*The same letters in columns indicate they were not statistically different from each other.

According to the potability standard in Ordinance GM/MS 888/2021 (Ministry of Health, Brazilian Government), all pH values are from 6.0 to 9.0 (Brasil, 2021). When water has high acidic pH values, agents may act to remove neutralized microorganisms, resulting in serious health risks (Araújo and Andrade, 2020). The use of coagulants in the present research did not affect the pH at any of the concentrations evaluated, demonstrating that they are suitable from this standpoint.

The initial turbidity value for all assays was 150 NTU (nephelometric turbidity unit). Regarding the time required for sedimentation, it was observed that in just 30 minutes it was possible to observe a decrease in the water turbidity by more than 50% for all species, as displayed in Table 3.

Table 3. Sedimentation times and final water turbidity as a function of experimental treatments (type of cationized tannins x concentration).

Treatment	Concentration (mg L^{-1})	Sed. Time (min)	Final Turbidity (NTU)
P. moniliformis fruits	50	60	32
	100	30	60
	150	50	45
A. colubrina fruits	50	40	40
	100	50	36
	150	50	36
	50	60	35
M. caesalpinia folia bark	100	40	45
	150	40	45
	50	50	8.2
A. occidentale bark	100	40	2.4
	150	40	0.80

For all assays, the initial turbidity was 150 NTU.

Under the effect of cationized tannins from *P. moniliformis* fruits, turbidity removal stands out at a concentration of 50 mg L^{-1}. In contrast, for the *A. colubrina* fruits, it was observed that the best time for sedimentation was 40 minutes at a concentration of 50 mg L^{-1}. Nevertheless, for this type of cationized tannins at 100 and 150 mg L^{-1} concentrations, a good removal was attained after 50 minutes (Table 3). For the *P. moniliformis* fruits, good sedimentation was achieved at a concentration of 100 mg L^{-1}; however, the removal of turbidity reached the best point at 50 mg L^{-1} with a value of 32 NTU. The best sedimentation time for the *A. colubrina* fruits was 40 minutes, reaching a turbidity of 40 NTU. At 100 and 150 mg L^{-1}, the final turbidity reached 36 NTU after 50 minutes (Table 3). The *M. caesalpinia folia* bard had the same values in the sedimentation time, with 40 minutes, and the best value concerning water turbidity was 35 NTU.

Regarding *A. occidentale* bark, when compared to the other species, good results were reached for all concentrations, reaching the lowest values for turbidity. Nevertheless, the best sedimentation time was 40 minutes at 100 and 150 mg L^{-1} concentrations. At these concentrations, the NTU values were 2.4 and 0.8, respectively, within the range required by the Brazilian Ministry of Health ordinance (Brasil, 2021). Chapter V of Ordinance GM/MS Nº 888 addresses potability standards, in which to guarantee the microbiological quality of water, in addition to the requirements related to microbiological indicators, the turbidity standard must be met throughout the entire extension of the water system. Distribution (reservoir and network) or consumption points must meet the maximum value of 5.0 NTU for turbidity.

When the experimental data at the three concentrations of each material at different times of sedimentation (10, 20, 30, 40, 50, and 60 min) were subjected to the analysis of variance, a statistical significance was determined, indicating differences among treatments with a coefficient of variation lower than 20%. Therefore, a comparison of the turbidity means (Table 4) could be carried out. The cationized tannins from *A. occidentale* had the lowest values of turbidity after the water samples were treated, statistically different from the other types.

Table 4. Comparison of means of turbidity at the coagulants' concentration of 50, 100, and 150 mg L^{-1}.

	Concentrations (mg L^{-1})		
Treatment	**50**	**100**	**150**
	Final Turbidity (NTU)		
Pityrocarpa moniliformis fruit	42.66 b	63.61 d	53.33 c
Anadenanthera colubrina fruit	45.55 b	45.72 b	45.67 b
Mimosa caesalpiniifolia	44.00 b	51.94 c	56.05 c
Anacardium Occidentale bark	25.45 a	9.22 a	5.22 a

*Means followed by different letters are statistically dissimilar by the Scott-Knot test at 95% probability.

Figure 1 displays the efficiency of each cationized tannin in removing turbidity (%) and the final pH after the water treatment.

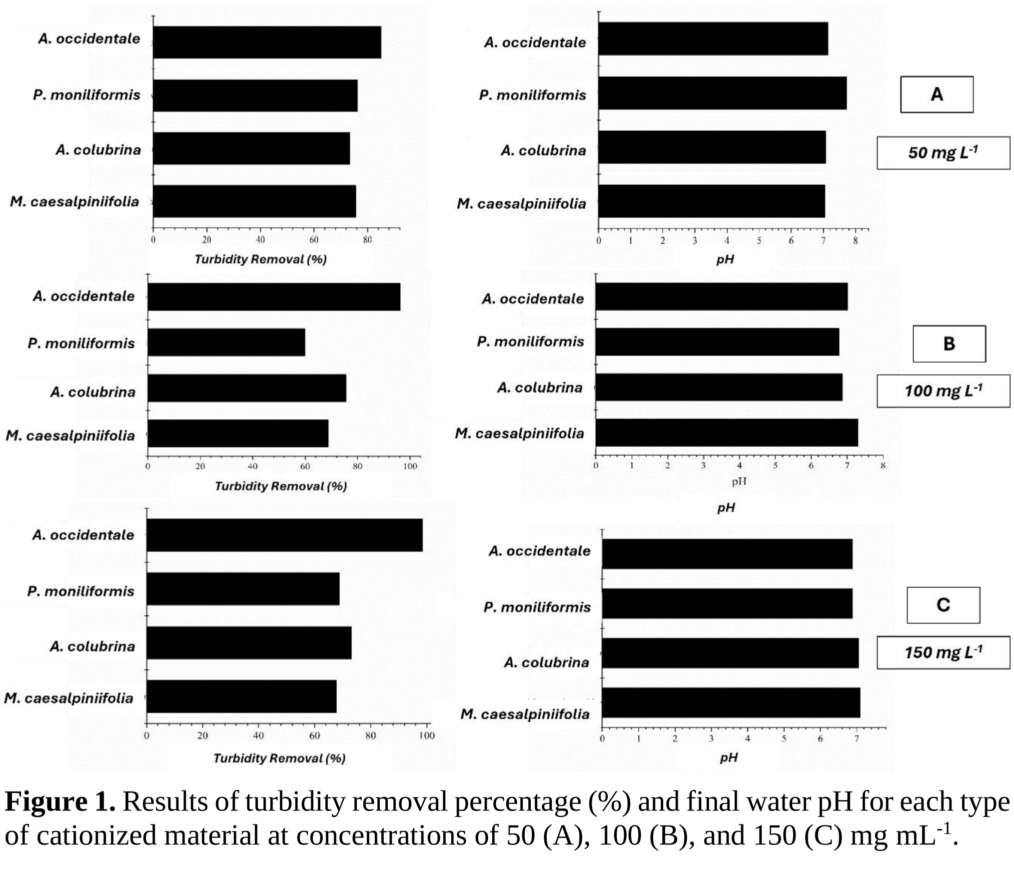

Figure 1. Results of turbidity removal percentage (%) and final water pH for each type of cationized material at concentrations of 50 (A), 100 (B), and 150 (C) mg mL^{-1}.

Figure 1 shows an efficient action in removing turbidity for the types of cationized material, four species, from a concentration of 50 mg L-1. Materials from *M. caesalpinia folia*, *P. moniliformis*, and *A. colubrina* presented a similar percentage of removal, higher than 75%, while *A. occidentale* stood out with a removal of 84% of turbidity (Figure 1A). Resolution No. 357, of March 17, 2005, on pages 58 and 59, replaces CONAMA resolution nº 20, establishing some parameters concerning water quality for domestic and industrial use. Thus, Resolution No. 357 provides for the classification of water bodies and environmental guidelines for their classification, establishes the conditions and standards for releasing effluents, and provides other measures (CONAMA, 2005).

In Section I of Freshwater Art. 4°, waters are classified for various purposes, including human consumption, after simplified treatment; protection of aquatic communities, the irrigation of edible vegetables and fruits that grow close to the ground and are eaten raw without removing the skin, and the protection of aquatic communities in Indigenous Lands. Among the conditions and standards of resolution No. 357, the turbidity value is up to 40 NTU, and pH values can vary from 6.0 to 9.0 (CONAMA, 2005). Those standards were met in the present work. The removal of turbidity was observed for the species studied, proving the product's suitability as a coagulant. For the final pH value, after carrying out the tests at each concentration, there was no significant change, which makes it a satisfactory result, as in addition to having a coagulating action, all cationized materials did not significantly change the water pH since the initial value for this parameter was 7.2 and turbidity 150 NTU (Figure 1B).

The best efficiency in water turbidity removal was achieved at the concentration of 100 mg L^{-1} using the c efficiency with the cationized tannins from *A. occidentale*, with more than 95% turbidity removal. The material from *A. colubrina* fruits followed it with 77% efficiency. For the same parameter, the other cationized coagulants from *M. caesalpinia folia* and *P. moniliformis* reached 65 and 60%, respectively, with the lowest values at 50 mg L^{-1}. However, at 100 mg L^{-1}, there was no improvement for either material (Figure 1C).

The lowest value for the fruit of *P. moniliformis* in removing turbidity can be compared to the quantification of tannins, which for the Stiasny Index was 0.42% and for the condensed tannin content was 0.23%, which can have influenced the result for this species, the result being similar to that found in the species *M. caesalpinia folia*, where the highest value of pure tannins is 91.27%. Silva (2021), when carrying out tests with forest species, obtained a similar result when using *M. tenuiflora* tannins, observing 99% removal of turbidity from the water, the same occurring in this study, at the relatively low concentration of the coagulant (50 mg L^{-1}). Most likely, it was because the tannins of this species have a high molecular weight, resulting in poorer coagulation. On the other hand, during the coagulation process using *A. occidentale* cationized tannins, they reacted quickly and formed larger flakes than the other coagulants.

It is essential to consider that, for each species and plant organ, there may be variations in the chemical composition of tannin, which may also influence its use. For *M. tenuiflora* tannins, Paes *et al.* (2006b) demonstrated their technical viability for tanning leather, which can replace *A. colubrina* bark tannins. This forest species is a reference in leather tanning in the Brazilian Northeast, but this activity could lead the species to its extinction due to predatory forest management. However, the fruits are discarded in the tanning process, and the species contains tannins in all parts of the plant (Paes *et al.*, 2010). Therefore, the raw material for this study was seedless fruits from this species so that economic value could be added in the case of good results. In this sense, the results for cationized tannins from the species fruits were satisfactory in this work. They can be compared to those found by Beltrán-Heredia *et al.* (2011) for commercial tannins from *Acacia mearnsii*. After carrying out the tests and applying the coagulants to the water, the final pH value did not change significantly, reaffirming the use of vegetable tannins for water treatment.

4. CONCLUSIONS

All types of cationized tannins assessed in this work presented coagulant activity at the three tested concentrations, reducing the turbidity of the reservoir water within 60 minutes of contact. The best results were obtained for the material from *A. occidentale*. After this type of cationized tannin was put in contact with water, it reached potability standards. Further studies should focus on a comparative economic analysis of cationized tannins with conventional coagulant agents. This way, tannins can be adequately recommended as a viable alternative, not only from a technical aspect but also from an economic justification.

5. ACKNOWLEDGMENTS

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