



Tannins from cashew tree (*Anacardium occidentale*) bark as a flocculant for water clarification

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ABSTRACT

Concern about the overexploitation of natural resources has increased in recent decades, especially involving water and its treatment. Paradoxically, one of the sources of water pollution is the treatment itself, due to the use of chemical flocculants, which end up generating sludge that may be highly aggressive to the environment. One of the ways to solve this problem is to use natural flocculants for this purpose, since they are biodegradable and do not harm nature. This study evaluated the efficiency of a natural flocculant produced from tannins extracted from the bark of the cashew tree (*Anacardium occidentale*) and compared it with two commercial coagulants, Tanfloc® and iron chloride. The water for treatment was collected from a weir. The cashew trees' bark was collected, ground, and submitted to hot-water extraction to yield the tannins, and the extraction product was cationized. The flocculation tests were carried out using the jar test with solutions having concentrations of 33.3, 66.7, and 100 mg L⁻¹. Turbidity and pH were analyzed before and after flocculation. Among the assessed flocculants, the cationized tannins produced the best responses both for removal of turbidity and final pH of the treated water. Tanfloc® also produced satisfactory results regarding turbidity removal. The iron chloride, besides not properly clarifying the water, left it very acidic. Since the cationized tannins practically did not change the pH and were effective in the removal of turbidity, they represent an interesting, sustainable alternative product to treat the water.

Keywords: cationized tannins, natural flocculating agente, removal of turbidity, water treatment.

Uso de taninos da casca de cajueiro (*Anacardium occidentale*) como floculante para remoção de turbidez de água

RESUMO

A preocupação com a exploração desenfreada dos recursos naturais tem aumentado nas



últimas décadas, principalmente envolvendo a água e seu tratamento. Paradoxalmente, uma das fontes de poluição da água é justamente o seu tratamento, devido ao uso de floculantes químicos, que acabam gerando lodos que podem ser altamente agressivos ao meio ambiente. Uma das formas de resolver este problema é utilizar floculantes naturais para esta finalidade, uma vez que são biodegradáveis e não agredem a natureza. O objetivo deste trabalho foi avaliar a eficiência de um floculante natural produzido com taninos extraídos da casca do cajueiro (*Anacardium occidentale*) e compará-lo com dois coagulantes comerciais, Tanfloc® e cloreto de ferro. A água para tratamento foi coletada de um açude. A casca do cajueiro foi coletada, moída e submetida à extração em água quente para obtenção dos taninos, e o produto da extração foi cationizado. Os testes de floculação foram realizados utilizando-se o jar test com soluções nas concentrações de 33,3, 66,7 e 100 mg L⁻¹. A turbidez e o pH foram analisados antes e após a floculação. Dentre os floculantes avaliados, os taninos cationizados produziram as melhores respostas tanto para remoção de turbidez quanto para pH final da água tratada. O Tanfloc® também apresentou resultados satisfatórios quanto à remoção de turbidez. O cloreto de ferro, além de não clarificar adequadamente a água, a deixou muito ácida. Como os taninos cationizados praticamente não alteraram o pH e foram eficazes na remoção da turbidez, consistem em um produto interessante para o tratamento da água.

Palavras-chave: floculante natural, remoção de turbidez, taninos cationizados, tratamento de água.

1. INTRODUCTION

The high level of urbanization in the world is negatively affecting the quantity and quality of water supplies, making it increasingly difficult to satisfy societal needs. The treatment of water for human consumption, irrigation, and industrial use, among other activities, has prompted studies related to the reuse and/or recycling of water. However, this alternative requires a considerable increase in the use of flocculants for the removal of turbidity before the water is returned to the population (Sousa, 2018). The main water resources available to public supply are from the surface, whose quality is often degraded. In this respect, the employment of the traditional flocculants based on inorganic metallic salts, such as aluminum salts, is not always effective, and above all requires strict control of the residual aluminum in the water treated for human consumption. The presence of aluminum in treated water is undesirable because this element can damage the nervous system, as demonstrated by Kawamura (1991), among other researchers.

In this context, the use of natural products for water treatment has some advantages, such as renewable sources, the biodegradability of the residual sludge, low consumption of alkalis, and no release of metals after the water is treated (Yin, 2010). In the flocculation stage, flakes are formed due to the aggregation of neutralized particles (Béltran-Heredia *et al.*, 2011). According to Paula (2004), the formation of flakes can occur spontaneously as a result of successive collisions among the suspended particles, but only if energy is available for this process. According to Ioshimura (2016), sedimentation occurs due to the differential speed of decantation of the flakes. In all these steps, the consumption of energy and sedimentation time is reduced when flocculants are added to the water treatment. The use of tannins is an option that provides all the advantages cited above due to their ability to neutralize surface electrical charges of colloidal particles, promoting flocculation and sedimentation (Coral *et al.*, 2009). However, tannins in their original state do not have the cationic characteristics that enable their use as flocculants for the clarification of water. Thus, they have to go through a cationization reaction, where the substance becomes ionized when it dissolves in water, acquiring a positive charge and acting as a cation. In this form, cationized tannins can destabilize the colloidal system by neutralizing the charges of the particles that keep them in suspension in the untreated

water (Mangrich *et al.*, 2014).

Present in all forest plant species, mainly in the bark, condensed tannins are the most important class of tannins and have a broad range of applications in the pharmaceutical and food industries, leather making, adhesive production, and water treatment (Pizzi, 1994; Marques *et al.*, 2021). However, only a few studies have examined species from the dry forest of Northeast Brazil concerning their potential as sources of tannins for water treatment, mainly because they produce large amounts of bark. Some species of this biome have gained prominence, as is the case of *Anadenanthera colubrina* ('angico-vermelho') and *Mimosa tenuiflora* ('jurema preta'), both from the Fabaceae family.

The cashew tree (*Anacardium occidentale*) is native to Northeast Brazil. Besides the use of its pseudofruit as food (nuts and juice from the fruits), extracts also have medicinal therapeutic applications (Novaes and Novaes, 2021). The species is cultivated mainly in India, Vietnam, Côte d'Ivoire, Guinea-Bissau, Tanzania, Benin, Brazil, and other countries in East and West Central Africa and Southeast Asia, but plantations have also been established in South Africa and Australia (Global Cashew Council, 2021). World production of cashew nuts currently ranges between 720,000 and 790,000 metric tons (kernel basis) per year (seasons 2015/16-2019/20). India, with yearly output of 170,000-195,000 MT, ranks first, followed by Côte d'Ivoire, Vietnam, and Tanzania, with figures of 149,000; 82,000 and 53,000 MT, respectively (Oliveira *et al.*, 2020; Global Cashew Council, 2021).

The trunk of the cashew tree produces a yellow resin, known as cashew gum, which can replace the gum arabic used in the paper and pharmaceutical industries. The cashew tree wood is durable and pink in color and can be used in civil construction, cabinet making, joinery, etc. (Ceará, 2019). Pruning is one of the main management procedures applied to cashew trees. According to Embrapa (2021), young cashew orchards should be managed to form a compact canopy, with a large productive surface, free from entanglements and weed competition, in particular, to facilitate mechanized harvesting. Liming and fertilization (manual or mechanical) should be used as required, as well as inspection of the irrigation system when the crop is irrigated. In general, pruning is limited to removing parts of the tree attacked by insects or diseases, along with dry and broken branches. Since the fruiting of the cashew tree is peripheral, especially in the lower two-thirds of the plant, the elimination of the lower branches should be limited. In some cases, the strategy of canopy substitution can be successfully applied to unproductive and tall trees, where the crowns are removed and replaced by grafts of early-fruiting clones with small size and high production, keeping the root system and part of the trunk (Montenegro and Parente, 2018).

In all cases mentioned above, regular pruning and canopy substitution produce significant amounts of lignocellulosic material that is sold as firewood. Brazil has 439,200 ha cultivated with cashew trees (Novaes and Novaes, 2020), of which 99.5% are located in the country's Northeast region. Thus, every year thousands of tons of wood from cashew trees are used as firewood, mainly by brickyards. The bark is also burned as a source of energy. Nevertheless, despite these uses, a large amount of wood and bark waste is produced, so the development of other uses of these wastes has the potential to generate additional profits for growers. One option would be to find more uses of the condensed tannins from the bark and waste wood of cashew trees. The use of tannins for water clarification would achieve this goal.

To this aim, the present work assessed the technical viability of using tannins from cashew tree bark as flocculants for the clarification of water by coagulation and compared their performance with a commercial product and iron chloride. The novel aspect of this work is the employment of new raw material, more specifically, tannins from cashew tree bark, as a flocculant for water clarification.

2. MATERIAL AND METHODS

2.1. Tree selection and bark collection

For the experiments, 10 cashew trees (*Anacardium occidentale*) (around 15 years old) in good phytosanitary conditions were selected, considering the absence of pest attacks and diseases. The trees were located at the Forest Experimentation Unit (5°51'36" S and 35°20'59" W), Forest Engineering Department, Rio Grande do Norte Federal University (UFRN), in the municipality of Macaíba, Rio Grande do Norte State, Brazil. The local soil is classified as a sandy-textured yellow oxisol and the topography is flat (Beltrão *et al.*, 1975). The local climate is a transition between As and BSw, characterized as tropical rainy, according to the Köppen classification, with an annual average temperature of 27.1°C, average relative humidity of 76%, and total precipitation ranging from 863.7 to 1.070.7 mm (IDEMA, 2013).

After harvesting the trees, the bark was collected from the trunk and branches using a machete. The collected material was promptly packed in plastic bags to prevent moisture loss and stored for further processing. The bark was weighed and its natural moisture content was determined. The material was then dried outdoors in a sheltered shed. After the natural drying, the bark was chopped in a forage chopper (TRP-400 model, TRAPP, São Paulo-SP, Brazil). After this, the granulometry of the material was reduced by grinding in a Wiley mill (TE-650/1 model, CASALAB, Belo Horizonte-MG, Brazil).

2.2. Tannin extraction and quantification

For the tannin extraction and quantification, five 25 g dry samples were employed. The samples were transferred to 500 mL flat-bottomed glass flasks and 250 mL of deionized water was added to each one (1:10 weight/weight ratio). The samples were heated until boiling and kept under reflux for 2 hours. Each sample was double extracted to ensure the complete removal of the hot-water fraction. This way, the final bark/water ratio became 1:20 (w/w). After extraction, the solutions were filtered through flannel and a 150-mesh sieve to remove the fine particles. Then the extracts were filtered through a number-2 sintered glass filter. The extracts were concentrated by evaporation using a Soxhlet apparatus until a final volume of 50 mL. Two samples were employed for the determination of the total condensed tannins content (TTC) and one was evaporated until dry at $103 \pm 2^\circ\text{C}$ for 48 hours to determine the total solids content (TSC). The TSC was calculated using Equation 1.

$$TSC (\%) = \left(\frac{M_1 - M_2}{M_2} \right) \times 100 \quad (1)$$

Where:

TSC = total solids content (%);

M_1 = Initial mass (g);

M_2 = Final mass (g).

For the determination of TTC, the Stiasny method was employed as described by Guangcheng *et al.* (1991) with three replicates. For this, 4 mL of formaldehyde (37% w/w) and 1 mL of hydrochloric acid were added to 50 mL of the raw extract. Each replicate was boiled under reflux for 30 min. After cooling, the precipitated tannins were separated by simple filtering through filter paper (Whatman Number 1) by using a 10 cm diameter Büchner funnel. The solids retained in the filter paper were oven-dried at $103 \pm 2^\circ\text{C}$ for 24 hours, weighed and the Stiasny number was calculated.

All the analyses were carried out in triplicate according to the methods recommended by Paes *et al.* (2006a; 2006b). The Stiasny number was obtained by Equation 2.

$$I (\%) = \left(\frac{M_2}{M_1} \right) \times 100 \quad (2)$$

Where:

I = Stiasny number (%);

M₁ = Mass of solids in 50 mL of hot-water extract;

M₂ = Mass of precipitated tannins.

The total condensed tannins content of each sample was calculated by Equation 3.

$$TCT (\%) = \frac{TSC \times I}{100} \quad (3)$$

2.3. Cationization and flocculation assays

Before use as a flocculating agent, the tannins' structure was modified by cationization. This process was carried out in three steps based on the reaction of Mannich reported by Konrath and Fava (2006). Initially, 5.4 g of aluminum chloride and 24.4 g of formaldehyde were placed in a reaction flask. The mixture was heated to 80 – 90°C for 2 hours. The effectiveness of the reaction between the reactants was checked until the mixture reached a pale-yellow color. Then the reaction product was stirred together with 28.0 g of an aqueous solution of tannins (50% weight/weight) for 30 min at 50 – 60°C. Next, the product of this second step was mixed with 0.2 g of monoethanolamine and left to react for 3 hours at 50 – 60°C.

The water employed in the flocculation assays was collected from a reservoir located at the Jundiá School of Agriculture, Rio Grande do Norte Federal University (UFRN). Ten samples of 5 L were collected and stored under refrigeration until further use. For the flocculation assays, the jar test was used, with 1.5 L of water in each jar. Before the assays, the pH (HI9813-6N Grochek pH/EC/TDS/C Portable Meter w/ Cal Check, Hanna Instruments) and turbidity (portable turbidimeter, LaMotte model LTC-3000 we/wi) were determined. The performance of the cationized tannins as flocculating agents was compared with two commercial products: ferric chloride (iron-III chloride, Sigma-Aldrich) and Tanfloc® powder (Tanac, Montenegro, RS, Brazil). Tanfloc® is an organic flocculant produced with tannins from the bark of black wattle (*Acacia mearnsii*). As defined in preliminary tests and based on the study of Silva (2021), for all three flocculation agents we employed concentrations of 33.3, 66.7, and 100 mg L⁻¹, with two stirring speeds/times: 30 rpm for 30 min and 130 rpm for 2 min (slow and fast mixing). Those values were established based on the works of Beltrán-Heredia *et al.* (2009) and Sousa (2015). One hour after stirring, the final pH and turbidity of the water were determined. After each flocculant was applied in the water, the values of turbidity were determined in NTUs (nephelometric turbidity units) at intervals of 10 min until 60 min. The initial turbidity of the water samples was 150 NTUs. All assays were performed with this turbidity value as a starting point.

2.4. FTIR analysis

The tannins were analyzed by FTIR before and after cationization. The samples were oven-dried at 60°C for three hours. Then they were immobilized in KBr pellets and analyzed with a Shimadzu model IRA Affinity-1 spectrophotometer. The FTIR spectra were acquired by attenuated total reflectance (ATR). Each spectrum was acquired with 32 scans with a resolution of 4 cm⁻¹ from 4,000 to 500 cm⁻¹.

3. RESULTS AND DISCUSSION

3.1. Tannin extraction and quantification

Table 1 reports the mean values found for total solids content (TSC), Stiasny number (I), and total condensed tannins content (TCT) in the hot-water extracts of cashew tree bark. The results found for the hot-water extraction and the tannin parameters were similar to those

determined in previous research works (Paes *et al.*, 2006a; 2006b).

Table 1. Means of total solids content (TSC), Stiasny number (I), and the total condensed tannins content (TCT) found in the hot-water extracts of cashew tree bark.

Source	TSC (%)	I (%)	TTC (%)
Cashew tree bark	33.4	59.5	19.8

3.2. Flocculation assays

Table 2 compares the performance of the three flocculants for the reduction of water turbidity. Mean values (from three replicates) of each assessed flocculant for the removal of turbidity are presented according to the time of sedimentation.

Table 2. Means of final turbidity obtained with increasing sedimentation times as a function of flocculant concentration.

Cashew Bark Tannins			
Time of sedimentation (min)	Final turbidity (NTU) (with 33.3 mg L ⁻¹)	Final turbidity (NTU) (with 66.7 mg L ⁻¹)	Final turbidity (NTU) (with 100 mg L ⁻¹)
10	40.33	22.66	19.00
20	26.33	8.13	3.10
30	22.00	6.50	2.53
40	21.90	6.40	2.25
50	21.06	6.03	2.25
60	21.06	5.60	2.23
Tanfloc®			
10	11.53	25.00	34.66
20	3.66	7.93	22.00
30	2.73	7.76	20.00
40	2.43	7.73	19.33
50	2.43	7.73	18.33
60	2.36	7.43	18.00
Iron chloride			
10	39.66	51.66	63.33
20	30.33	41.33	41.33
30	30.00	40.33	39.66
40	28.66	40.33	39.33
50	28.33	40.00	39.00
60	28.33	39.66	39.00

*For each sedimentation time, the values of turbidity are the means of three replicates

As displayed in Table 2, the cationized cashew bark tannins presented the best removal of turbidity when the concentration of 100 mg L⁻¹ was employed, since this parameter decreased from the initial value to 2.23 NTUs. For this flocculant, the best sedimentation time was 60 min with a concentration of 100 mg L⁻¹. Different behavior was observed for Tanfloc®, since the best removal of turbidity (18.00 NTUs) was achieved at the lowest concentration (33.3 mg L⁻¹), but also at 60 min of sedimentation. The iron chloride had behavior similar to Tanfloc®, with the best performance at the same concentration but after sedimentation for 40

min. However, it is important to highlight that the final turbidity value achieved for Tanfloc® was 8 times greater than the value found for the cashew bark tannins. For iron chloride, the value of this parameter was 17.4 times higher. These results indicate the good performance of the cationized cashew bark tannins for the removal of water turbidity. The products Tanfloc® and iron chloride had the advantage of requiring lower concentration to produce their best results, only 33.3 mg L⁻¹. Iron chloride did not present satisfactory results, since the final turbidity for all concentrations was higher than that achieved with the organic flocculants (cashew bark tannins and Tanfloc®). As mentioned before, Tanfloc® is a commercial product derived from tannins from the bark of *Acacia mearnsii* trees.

Table 3 reports the final pH of the treated water samples of the three flocculants. As can be observed, only slight alterations between the initial and the final values of pH were found in the water treated with the cashew bark tannins and Tanfloc®, while for iron chloride, a significant change was determined, with the pH becoming less acidic with increased concentration.

Table 3. Effect of the type of flocculant on the final pH of the treated water.

Type of Flocculant	Concentration (mg L ⁻¹)	Initial pH	Final pH
Cashew bark tannins	33.3	6.80	7.14
	66.7	6.79	7.01
	100	7.02	6.88
Tanfloc®	33.3	7.84	7.10
	66.7	6.76	6.80
	100	6.97	6.70
Iron chloride	33.3	7.34	4.10
	66.7	7.05	3.20
	100	6.89	3.00

Good results with high concentrations of a flocculant based on cationized black wattle tannins to remove water turbidity were reported by Béltran-Heredia *et al.* (2011). Also, Silva (2021), employing a concentration of 33.3 mg L⁻¹ of tannins from the bark of *Stryphnodendron adstringens* ('barbatimão') trees, achieved 75% turbidity reduction, while with the concentration of 100 mg L⁻¹, that parameter increased to 96%. Concerning the alteration of the pH of water after flocculation, Sousa (2018) studied the employment of tannins from *Anadenanthera peregrina* and *Tachigali aurea*, comparing them with iron chloride and aluminum sulfate. They reported only slight changes in pH after their use, and good efficiency even when mixed with the chemical flocculants, corroborating the relevance of natural products. As previously noted, the cationized cashew tannins assessed in this work promoted only a small change in pH of the treated water after the product was applied.

Comparison of the pH values showed that iron chloride did not comply with the regulations of the Brazilian National Environmental Council (CONAMA, 2011), which establishes that the value of this parameter must be in the range of 5 to 9. Coral *et al.* (2009), working with natural and chemical flocculant agents, also found results similar to ours, since the pH remained constant for Tanfloc® and decreased strongly with the use of aluminum sulfate. The same pattern was observed in our work for iron chloride.

3.3. FTIR analyses

The FTIR spectra of the cashew tree bark tannins in their pristine state and after cationization are presented in Figure 1.

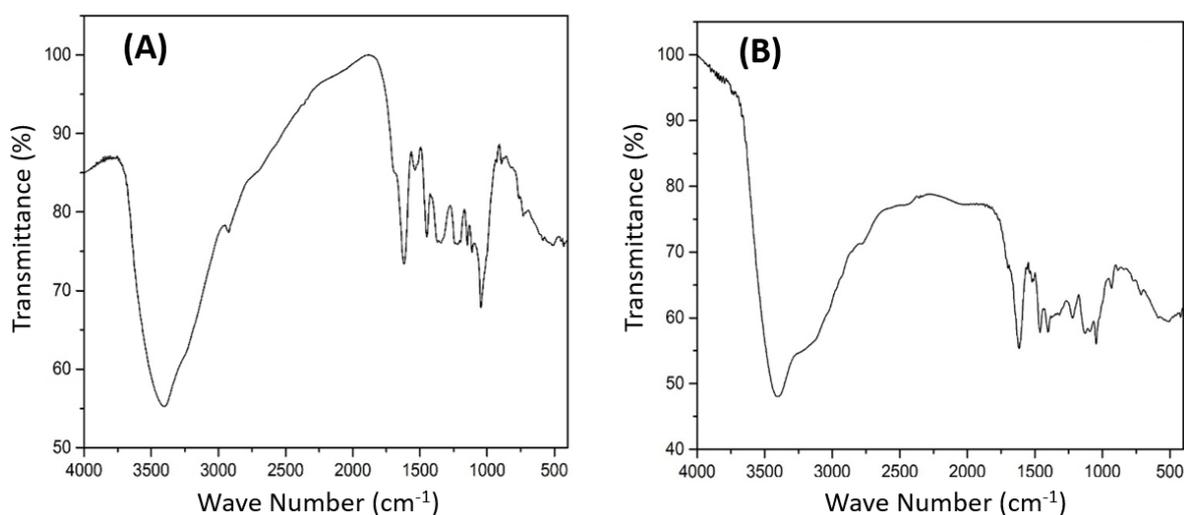


Figure 1. FTIR spectra of the cashew tree bark tannins, (A) original state and (B) after cationization.

Regarding the alterations in the chemical structure of the cashew bark tannins achieved after cationization, the spectra of the original product contained stretching bands related to hydroxyl groups (-OH) bonded to phenolic units and aliphatic chains at $3,400\text{ cm}^{-1}$, with a transmittance of 85%, while for the cationized tannins, the transmittance was 100%. This result is in the same range as found by Marques *et al.* (2021), who determined the same responses for tannins from the bark of *Acacia mangium* ($3,418\text{ cm}^{-1}$), *Azadirachta indica* ($3,452\text{ cm}^{-1}$), *Mimosa tenuiflora* ($3,418\text{ cm}^{-1}$), and *Mimosa caesalpiniiifolia* ($3,429\text{ cm}^{-1}$). Also, Silva (2021) found the same stretching band at $3,199\text{ cm}^{-1}$ for *Stryphnodendron adstringens* ('barbatimão'). The stretchings at $3,100\text{ cm}^{-1}$ found here for the cationized tannins can be attributed to primary amines (Silverstein *et al.*, 2019), indicating that N-H bonds were formed after the chemical modification of the tannins since they were not present in the product in its pristine form. The higher content of hydroxyl groups in the modified tannins is due to the reaction with formaldehyde (Ramires and Frollini, 2012).

Stretching related to C-H bonds from aromatic compounds was observed at $3,000\text{ cm}^{-1}$ for the original tannins. However, in the cationized versions, this stretching was not observed. For both types of tannins (before and after cationization), the spectral bands from $1,580$ to $1,615$; and $1,450$ to $1,510\text{ cm}^{-1}$ of aromatic stretching (C=C from aromatic rings) were observed with peaks of strong and medium intensities. According to Ntenga *et al.* (2017), intense peaks of aromatic C=C bonds combined with a high Stiasny number can be considered an indicator of the purity of tannic extracts. However, despite the presence of similar strong peaks in the spectra of the cashew tree bark observed in Figure 1, high purity was not detected, since the Stiasny number in the hot-water extracts was 59.5% (Table 1).

For the cationized tannins, the peaks at $1,520$ and $1,300\text{ cm}^{-1}$ disappeared, which was a result of the Mannich reaction. In the modified tannins, peaks appeared at 600 and 900 cm^{-1} . The first peak can be attributed to the out-of-plane stretching of the aromatic rings, most likely due to the action of the ammonium chloride employed in the cationization reaction, as stated by Faris *et al.* (2016). The same authors highlight that the second one can be attributed to the movements of -OH from aromatic alcohols and out-of-plane bending of aromatic CH.

Regarding the presence of formaldehyde in the water after treatment with the cationized tannins, the results of the analysis were negative, or at least when present, this compound was under the limits of detection of the method employed, of 0.001 mg L^{-1} . This quantification is important since several studies have proven the negative effects of formaldehyde on people exposed to it in water (Silva, 2021).

Concerning products for water clarification based on condensed tannins from the bark of

forest species, as cited above, several research works have been published. Tanfloc® is an example of a successful commercial product based on trees' bark tannins. Also, patents have been registered with innovative products. Still, Beltrán-Heredia *et al.* (2011) described in a scientific article a process to produce a flocculant based on trees' bark tannins. However, neither articles nor patents have been published or registered that employ tannins from the bark of cashew trees as raw material. The use of this material as a basis for producing a flocculant is therefore a clear novelty of the present work.

Brazilian patent BR 102015005684-2 A2 (Klein and Forte, 2015), titled "Process for obtaining a biodegradable flocculant from cashew tree gum and its use for the treatment of effluent waters", regards the obtention of a flocculant with the same end-use as the product whose application is depicted herein. However, in the cited patent, the flocculant is obtained from cashew tree gum. Such gum is mainly composed of polysaccharides and it is produced by the stem in a process named gummosis, partially as a natural phenomenon, partially in response to heat, drought stress, mechanical injuries, and fungal or bacterial attack (Cunha *et al.*, 2007; Pinto *et al.*, 2018). On the other hand, condensed tannins from cashew trees are polyphenolic products that are a constituent part of the bark. Therefore, the products cited above are rather different both in origin and chemical composition. The process described in this study is innovative in its entirety because it deals with the production of flocculant from a raw material derived from cashew bark, which has not been used in any previous process as a basis for the production of flocculant.

4. CONCLUSIONS

The flocculant agent produced through cationization of the cashew tree tannins presented better results for the removal of turbidity than the commercial products Tanfloc® and iron chloride. The use of Tanfloc®, for instance, brought about in final turbidity of 2.36 NTU, while after the application of the tannins this parameter reached 2.23 NTU. Similar to the Tanfloc®, the cashew tree tannins virtually did not modify the final pH of the treated water. On the other hand, the iron chloride made the water acidic after the removal of turbidity, reaching a final pH of 4.10 in the best condition of clarification (33.3 mg L⁻¹). Thus, the cationized tannins can be used as flocculant agents and their extraction from waste wood of cashew trees could be an interesting option to add value to the productive chain. The FTIR analyses showed the efficacy of the cationization of the tannins, since new bands of absorbance appeared in the spectra of the product after the chemical modification. The addition of new functional groups in the chemical structure of the cashew bark tannins explains the efficiency of the modified product for clarification of water.

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