PERIÓDICO TCHÊ QUÍMICA
ARTIGO ORIGINAL

EFEITO DO CACTO AMAZÔNICO (*Cereus jamacaru*) COMO COAGULANTE NATURAL PARA A REMOÇÃO DA TURBIDEZ DE ÁGUAS SUPERFICIAIS

EFFECT OF AMAZON CACTUS (*Cereus jamacaru*) AS A NATURAL COAGULANT FOR THE REMOVAL OF TURBIDITY FROM SURFACE WATER

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RESUMO

Introdução: O Brasil sofre com a falta de saneamento básico e esse fato se intensifica na região Amazônica quando pensamos nas populações vivendo em áreas de difícil acesso. A aplicação de coagulantes naturais surge como uma alternativa promissora, apresenta metodologia simples, de baixo custo, de fácil reprodução e acessível, promovendo a saúde e melhorias ambientais. O uso de coagulantes químicos pode acarretar malefícios ao ambiente e à saúde humana. **Objetivo:** Portanto, o objetivo desse estudo foi avaliar o efeito de coagulação de uma espécie de cacto amazônico aplicado ao tratamento de água para consumo humano. **Métodos:** Para o estudo, coletou-se cerca de 500 gramas da parte aérea do *Cereus jamacaru* às margens da BR 174 na região do lavrado de Roraima. No laboratório, foram retirados os espinhos, o material vegetal foi lavado, cortados a uma espessura de um centímetro, secos em estufa a 60 °C por 36 horas, triturados em liquidificador e peneirados até a obtenção de um pó, o qual foi testado como coagulante natural. A água utilizada no estudo foi coletada do Rio Branco no município de Boa Vista-RR e caracterizada quanto a sua turbidez inicial. **Resultados:** A dosagem de 0,2g do coagulante natural de cacto apresentou significativa redução na turbidez da água de estudo, deixando-a dentro dos padrões de potabilidade estabelecidos para as água subterrâneas. **Discussão:** A coagulação no contexto sanitário é evidenciada em razão da remoção de partículas microscópicas associadas aos microrganismos patogênicos, normalmente encontrados nas águas brutas e com velocidade de sedimentação muito reduzida. Substituir substâncias químicas poluidoras por coagulantes naturais no tratamento da água para consumo humano contribui para a qualidade de vida. **Conclusão:** O cacto amazônico *Cereus jamacaru* demonstrou eficácia de coagulação para a análise do parâmetro turbidez da água para consume humano.

Palavras-chave: *Qualidade da água, Saúde humana, Biocoagulante*

ABSTRACT

Background: Brazil suffers from a lack of basic sanitation in many regions, intensified in the Amazon region due to its difficult access. The application of natural coagulants is a promising alternative since it eliminates the use of chemicals, is a simple, low-cost method that is easy to reproduce, and is accessible to any community, thus promoting health and environmental improvements. On the other hand, the use of chemical coagulants can cause harm to the environment and human health. **Aim:** Therefore, the objective of this study was to evaluate the coagulation effect of a species of Amazonian cactus applied in the treatment of water for human consumption. **Methods:** For the study, about 500 grams of the aerial part of the *Cereus jamacaru* was collected on the banks of the BR 174 in the region of Roraima. The spines were removed in the laboratory, the plant material was washed, cut to a thickness, dried in an oven at 60 °C for 36 hours, then ground and sieved until obtaining a powder, which was tested as a natural coagulant. The water used in the study was collected from the Branco River in Boa Vista, Roraima, and characterized its initial turbidity. **Results:** The dosage of 0.2g of the natural cactus coagulant showed a significant reduction in the turbidity of the study water, leaving it within the potability standards established for groundwater. **Discussion**: Coagulation in the sanitary context is evidenced by the removal of

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microscopic particles associated with pathogenic microorganisms, normally found in raw water and with very low sedimentation speed. Replacing polluting chemical substances with natural coagulants in the treatment of water for human consumption contributes to the quality of life. **Conclusion:** The Amazonian cactus *Cereus jamacaru* demonstrated coagulation efficiency for analyzing the turbidity parameter of water for human consumption.

Keywords: *Quality water, Human health, Biocoagulant*

1. INTRODUCTION:

According to the National Information System on Basic Sanitation, 39.4 million Brazilians do not have access to treated water (BRASIL, 2018). The problem of lack of basic sanitation intensifies in the Amazon region of Brazil, principally due to its difficult access areas. In addition, economic viability and the complexity of the operation may make it impossible to implement specific water treatment methods in some locations (MELLO, 2018). To supply good quality water to the population for their daily activities, water intended for supply goes through a treatment process in water treatment plants (ETA). The conventional and most commonly used treatment in Brazilian ETAs consists of four stages: coagulation and flocculation, decantation, filtration, and finally, chlorination and fluoridation. Coagulation stands out as a process involving the application of chemicals that allow the removal of dissolved compounds in the water and the destabilization of colloidal suspensions and solids that cannot be removed by sedimentation or filtration. Closely linked to coagulation is flocculation, during which particles destabilized by the coagulant coalesce and form flakes amenable to decantation (LIMA JUNIOR, 2018; RICHTER, 2009).

Following the principles of green chemistry proposed in the 90s, Lima Junior and Abreu (2018) state that the development of coagulants and flocculants, based on biodegradable natural raw materials abundant in nature, called natural coagulants or biocoagulants, has been gaining more and more space in research focused on environmental technologies since natural coagulants follow the concept of eco-friendly material, those designed to cause the least harm to nature. Therefore, studies with cacti that can be used for water treatment have received great attention due to their chemical composition since they have nutrients with coagulation potential (ZARA; THOMAZINI; LENZ, 2012). Furthermore, during water treatment, the accumulation of residues of non-biodegradable metal hydroxides generated during coagulation and flocculation processes, the high concentration of sludge that presents ecotoxic potential (OLADOJA *et al*., 2017), and the relationship with pathologies that affect the central nervous system, such as dementia and Alzheimer's and Parkinson's diseases, are some of the results of the application of chemical coagulants to the treatment of water for human consumption (CHUA *et al*., 2019; FERMINO *et al*., 2017; WALTON, 2013). Such hazards make studies with natural coagulants advantageous as there is a high availability of raw materials, are often renewable, have low corrosiveness on the water distribution system, and there is a decrease of up to five times in the volume of sludge generated in the water treatment process. In addition, they do not present risks to human and animal health, and there is a significant reduction in costs and dangers in the treatment processes (TEIXEIRA *et al*., 2017).

Mandacaru (*C. jamacaru*) is a cactus native to Brazil, abundant in the northeast region of the country (ZARA; THOMAZINI; LENZ, 2012) and found in the Roraima field (OLIVEIRA, 2016; PASSOS, 2019). According to Cavalcante (2013), some metabolic and structural adaptations are necessary, so that species of the cactus family can survive in different environments, including adverse ones. Studies with cactus intended for water treatment have received significant attention due to their chemical and structural composition since they contain nutrients, proteins, amylose, malic acid, resin, vitamins, and cellulose (ZARA; THOMAZINI; LENZ, 2012). However, research on the application of cactus in water treatment is still scarce, and it is worth mentioning that no records were found about this application with species from the Amazon region of Brazil.

This study was developed in the context of the Brazilian Amazon and considered the environmental, spatial, temporal, and mainly social conjuncture. The state of Roraima is located in the northwest of the northern region of Brazil and is predominated by rainforest vegetation; however, in the central-eastern region, there is a huge strip of farmland known as "lavrado", a local name given to the savanna region. The farmland of Roraima is highly important for conserving biodiversity and water resources; therefore, the cactus *Cereus jamacaru* De Candolle (popularly

known as Mandacaru) was studied for treating water. Furthermore, due to its polymers, which have coagulating and flocculating action, it is believed that the cactus is not only effective but also safer in the treatment of water, thus promoting lower impacts on the environment and human health. Therefore, the objective of this study was to evaluate the coagulation effect of a species of Amazonian cactus applied to water treatment for human consumption.

2. MATERIALS AND METHODS:

Raw water samples from the Branco River were collected near the extraction point used by the Water and Sewage Company of Roraima (CAER), located in the city of Boa Vista, state of Roraima, Brazil, under geographic coordinates 760511 E, 312928 N. The collection was carried out in March 2021 in a period of drought in the State of Roraima. 12 liters of water were collected, stored in amber glasses, placed in a styrofoam box containing ice for cooling and transported to the laboratory of the Federal University of Roraima. Coagulation assays were performed on the same day of collection. Water characterization before and after treatment was performed by measuring turbidity (Akso TU430) based on the 20th Standard Methods for the Examination of Water and Wastewater (APHA; AWWA; WEF, 2017).

2.1. Preparation of the natural coagulant

The natural coagulant (NC) was prepared with 500 grams (g) of the aerial part of *C. jamacaru*, which was collected in the agricultural region of Roraima. First, the spines of the plant material were removed and discarded, and then the cactus was washed under running water, cut into pieces of about 1 centimeter (cm), and placed on trays (Figure 1a). These were then placed in an oven at 60 ºC for drying (MILLER *et al*., 2008; OTHMANI *et al*., 2020).

After drying, the cactus pieces were ground in a household blender and sieved to provide a powder (Figure 1b) with particles of about 300 micrometers (µm) in diameter. This powder was stored in a sealed container, dated and identified, and kept in a refrigerator until the tests were performed using the jar test equipment.

2.2. Coagulation test

The coagulation assay was performed using jar test equipment (Afakit AT-700) with six jars with a blade speed regulated for two mixing regimes: fast (150 rpm for three minutes); slow (60 rpm for 17 minutes); plus a sedimentation time of 30 minutes with the equipment turned off (Table 1). In the jars, 400 milliliters (mL) of raw water were used according to the adapted methodology of Zara *et al*. (2012).

The dosages of the natural coagulant of cactus and the aluminum sulfate (control) were determined according to values obtained in the literature and in the pre-assays of this study. They were 0.032 g of aluminum sulfate (Zara *et al*., 2012) and 0.01, 0.02, 0.04, 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 g of natural cactus coagulant (ORTIZ; ASTUDILLO; MARTÍNEZ, 2013; FEDALA *et al*., 2015), which were applied directly to the 400 mL of water contained in individual jars. At the end of the coagulation assay, samples of the treated water were collected from each jar with a 20 mL graduated pipette, and a new turbidity measurement was performed.

Table 1. *Stages and rotation speeds and duration for each step of the coagulation assay.*

Stages	Rotation/Duration
Rapid mixing	150 rpm/3 minutes
Slow mixing	60 rpm/17 minutes
Sedimentation	0/30 minutes

3. RESULTS AND DISCUSSION:

3.1. Results

The raw water used in the coagulation test showed initial turbidity of 23 turbidity units (NTUs). After this test, a new turbidity measurement was performed (Table 2). The potability standard for human consumption water is established by Ordinance No. 888, of May 4, 2021, by the Brazilian Ministry of Health (BRASIL, 2021) and has a maximum limit of 5 NTUs established as a standard in the turbidity parameter of the distribution network.

The decreased efficacy of turbidity removal with increased dosage of the natural coagulant (Figure 2) demonstrated in this study corroborates the results of Pichler *et al*. (2012), who used the mucilage of cacti *Opuntia ficus-indica* in water treatment and observed that, by increasing the dose of mucilage, after sedimentation of the flakes, the turbidity of the supernatant also increased.

3.2. Discussion

Although the use of natural coagulants is a sustainable alternative for treating water for human consumption, the application of forms, such as powders, mucilage, or unpurified extracts, directly in the water to be treated leads to an increase in organic matter, thus leaving the water more turbid.

Choy *et al*. (2014) attribute the increase in organic matter to the presence of lipids, biomolecules that do not participate in the coagulation process. Although it was not possible to perform quantification tests of organic matter, this effect can be observed when verifying the initial turbidity of 23 NTUs of the water used in this study with the highest coagulant dosage of 0.5 g of cactus powder that presented the lowest efficiency for removal and left the water with a greenish appearance. However, it is possible to improve the treated water quality using filters, considering that the flakes formed by biomolecules are usually large and easily retained and do not require more advanced filtration systems (PICHLER *et al*., 2012).

Unlike some studies, which demonstrated that the higher the turbidity of the water to be treated, the better the efficiency of natural coagulants, the effect observed in the present study was satisfactory for the sample of water with low turbidity (23 NTUs). In a comparative study with aluminum sulfate, Pichler, Young, and Alcantar (2012) obtained excellent results with the cactus of the genus *Opuntia* by demonstrating that the same turbidity removal efficiency could be obtained with the cactus using a dosage 300 times lower than that of the chemical coagulant.

Pritchard *et al*. (2010) used a natural coagulant based on *Moringa oleifera* seed to treat water with a turbidity of 40 NTUs and 200 NTUs, and the removal efficiency at the end of treatment was 50% and 90%, respectively. A possible justification for this behavior lies in the fact that both *Moringa oleifera* and cacti are considered polyelectrolytes, i.e., they are flocculating polymers with different ionic charges that act in the formation of flakes and assist in coagulation.

For Baghvand *et al*. (2010), low turbidity waters have a small amount of colloidal matter, i.e., this lower concentration of colloids suspended in water limits the contact rate between particles and flocculating polymers, thus hindering the coagulation process and consequently the performance of the coagulant. Therefore, an alternative for treating low turbidity waters is the addition of synthetic turbidity in order to create the formation of heavier flakes, which settle more easily.

4. CONCLUSIONS:

The Amazonian cactus *C. jamacaru* demonstrated coagulation efficacy in the analysis of the turbidity of the sampled water. Replacing polluting chemicals with natural coagulants in water treatment for human consumption contributes to the quality of life by helping communities that do not have access to clean water and protecting the environment. It is possible to suggest the execution of new studies that seek to perform other tests of the physicochemical parameters and the zeta potential to guarantee the effectiveness and safety of cactus application as a natural coagulant for the treatment of water for human consumption.

5. DECLARATIONS

5.1. Study Limitations

The study is limited to the sample size and the period of the collection of the samples.

5.2. Acknowledgements

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5.3. Funding source

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5.4. Competing Interests

There are no potential conflict of interest in this publication.

5.5. Open Access

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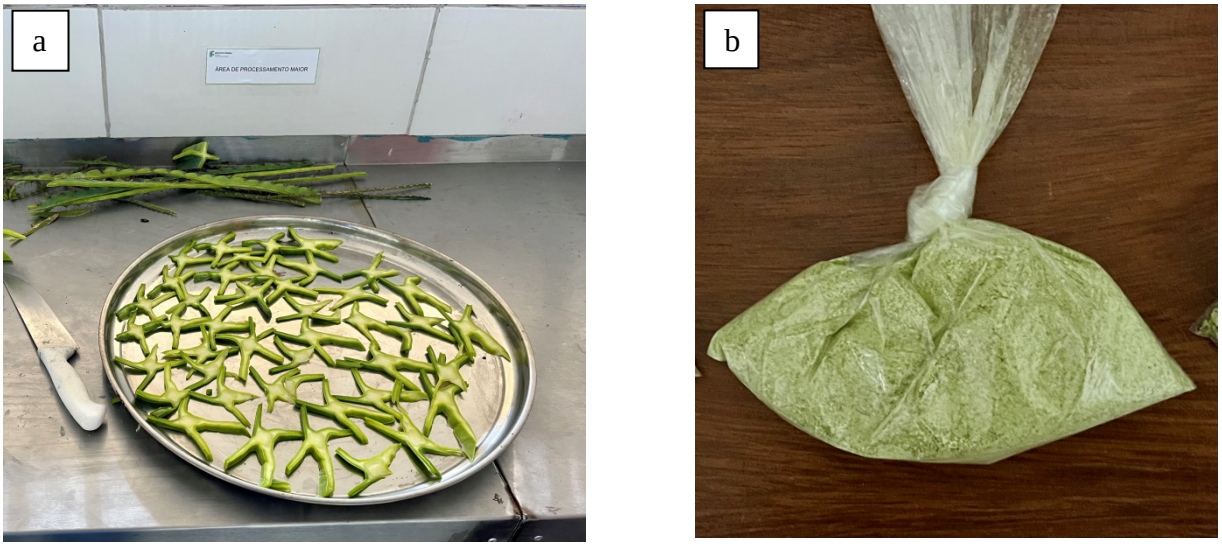

Figure 1. *a.Plant material processing. b. Coagulant powder.* ***Source:*** *the authors*

Table 2. *Turbidity removal values for each dosage and coagulants used.*

Initial turbidity of water sample (NTUs)	Dosage of coagulants (g)	Turbidity after application of coagulants (NTUs)
23	0.032 g aluminum sulphate (control)	2.5
	0.01 g of cactus NC	5.24
	0.02 g of cactus NC	4.91
	0.04 g of cactus NC	4.5
	0.05 g of cactus NC	4.43
	0.1 g of cactus NC	3.49
	0.2 g of cactus NC	2.49
	0.3 g of cactus NC	2.80
	0.4 g of cactus NC	3.99
	0.5 g of cactus NC	7

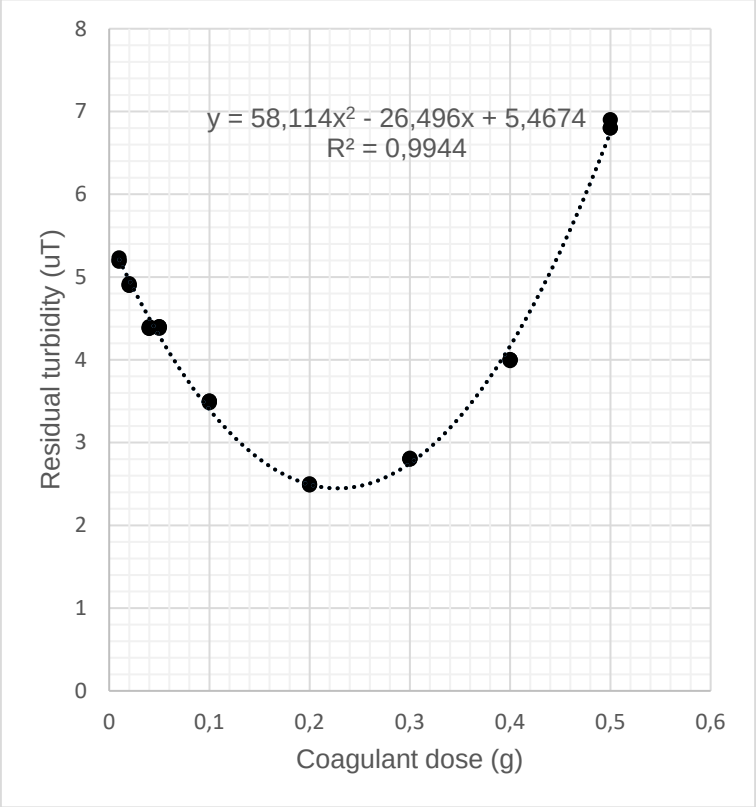

Figure 2. *Removal of turbidity vs. the dosage of coagulants.* ***Source:*** *the authors*