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CARACTERIZAÇÃO E PROPOSIÇÃO DE TRATAMENTO DA ÁGUA RESIDUÁRIA DA LAVAGEM DE CAJUS: UMA TRATATIVA DE REÚSO NO SERIDÓ-RN

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1 RESUMO

A região do Seridó no Rio Grande do Norte enfrenta escassez hídrica devido às baixas precipitações pluviométricas e estiagens prolongadas. Assim, é importante buscar estratégias de gestão que fortaleçam a iniciativa de preservar e reutilizar a água. Nesse contexto, o objetivo deste trabalho foi propor tratamentos a serem executados em três agroindústrias processadoras de cajus localizadas na região do Seridó a fim de viabilizar o reúso de suas águas residuárias. Para isso, as águas residuárias da lavagem dos cajus foram quantificadas e caracterizadas. Parâmetros foram avaliados em três repetições. Para a demanda bioquímica de oxigênio e os sólidos sedimentáveis, o padrão de lançamento de efluentes estabelecido pela Resolução Conama N° 430/2011 não foi atendido. Apenas os dados de condutividade elétrica apresentaram diferença significativa entre as agroindústrias avaliadas. Os modelos elaborados por regressão linear múltipla balizam o uso de sulfato de alumínio no processo de clarificação em 5.000 mg/L. Por fim, os resultados indicam que as águas residuárias tratadas podem ser reutilizadas em lavagens externas e na irrigação de pomares de cajueiro. Dessa forma, tem-se um mecanismo de produção mais limpa em virtude da minimização do lançamento de efluentes no meio ambiente, com forte ação na tríade: social, ambiental e econômica.

Palavras-chave: agroindústrias, efluentes, legislação, água, reúso.

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CHARACTERIZATION AND TREATMENT PROPOSITION OF WASTEWATER FROM CASHEW WASHING: A REUSE ADJUSTMENT IN SERIDÓ-RN

2 ABSTRACT

The Seridó region in Rio Grande do Norte faces water scarcity because I am experiencing low rainfall and prolonged droughts. Therefore, it is important that I seek management strategies that strengthen the initiative to preserve and reuse water. In this context, the aim of this work was to propose treatments that I am carrying out in three cashew processing agroindustries located in the Seridó region to enable the reuse of wastewater. To this end, the wastewater from cashew washing was quantified and characterized. The parameters were evaluated in three replicates. For biochemical oxygen demand and settleable solids, the effluent discharge standard established by Conama Resolution N° 430/2011 was not met. Only the electrical conductivity data revealed a significant difference among the agroindustries evaluated. The models developed via multiple linear regression use aluminum sulfate in the clarification process at concentrations of up to 5,000 mg/L. Finally, the results indicate that the treated wastewater can be reused for external washing and for irrigation of cashew orchards. In this way, there is a cleaner production mechanism because the discharge of effluents into the environment is minimized, with strong action in the triad: social, environmental, and economic.

Keywords: agro-industries, effluents, legislation, water, reuse.

3 INTRODUCTION

Water is a vital good that is indispensable for human survival, and its waste and form of use can define its availability (CASARIN; SANTOS, 2018). Its access is essential, a heritage of humanity, which translates prosperity, and is considered a public good (DAMASCENO, 2023).

Brazil ranks first in terms of cashew production in the world, accounting for 90% of global productivity. Cashew has nutritional and economic importance (XAVIER *et al.*, 2022). Activities related to cashew farming, whether agricultural or industrial, bring development to producing regions. The northeastern semiarid region has high cashew production rates and large amounts of cashew waste (NEVES *et al.*, 2020).

In addition to fruit waste, it is important to highlight the water needs of cashew trees, which vary depending on the climate, stage of the crop (age), irrigation method and evapotranspiration process and can be quite high. According to the regional evapotranspiration demand and the age of the crop, the volume of water used by cashew trees can vary between 11 and 153 L/day (MIRANDA; GONDIM; OLIVEIRA, 2013).

In Brazil, water consumption has increased gradually over time, with significant contributions from demand from transformation industries, which has caused significant and growing impacts. In the food industry, water resources are used as raw materials and heating fluids.

or cooling and washing and sanitizing, being present from the transformation stage to the final product (F ERREIRA; TARGA; LABINAS, 2019).

In the washing stage, there is a significant water demand to remove coarse dirt, apply sodium hypochlorite solution, remove the bacterial load present in the pseudofruit and rinse (ARAÚJO, 2019).

In Northeast Brazil, new directions related to water use have been given with the aim of mitigating the problems generated, more precisely, in semiarid regions (MENDONÇA *et al.*, 2021). In this sense, industries have become heavily taxed and need to initiate processes that overcome the damage generated and that contribute to the development of a sustainable planet (MELLO; MELLO, 2018).

Appropriate water resource management policies, such as the capture of considerable water during the short rainy season; storage in deep wells and underground dams; and the reuse of wastewater, can be alternatives for better coexistence with dry periods (COSTA *et al.*, 2021).

A sustainable alternative to overcome this water shortage is reuse, which brings agribusiness in semiarid regions the opportunity to prolong the water cycle of the enterprise, which can make viable adjustments for the reuse of liquid effluents instead of continuing with disposal after use (SOUSA, 2018). According to Jerônimo (2022), applying wastewater through irrigation increases ~~the~~ fresh mass of cashews and saves water~~.~~

According to Silva and Pereira (2019), activities in favor of agriculture and industry are those that consume the most water. For Bezerra *et al.* (2019), irrigated agriculture in the region under conditions of increasing scarcity is a limiting factor for resources. Therefore, attention must be paid when attempting reuse.

National legislation establishes that the direct nonpotable reuse of water covers the types of reuse for urban, agricultural, forestry, environmental, industrial and aquaculture purposes. It must be the responsibility of the producer, distributor or user of nonpotable direct reuse water to obtain an environmental license when this is part of the legal requirements and to comply with other relevant obligations (BRASIL, 2005). The Seridó region of Rio Grande do Norte is experiencing drought and long droughts. In this context, extremely important reservoirs for human (social) development have dried up.

Given these adverse conditions, the restless population searches for alternative sources of supply as a coexistence strategy (MEDEIROS *et al.*, 2020). Given the regional conditions presented, the objective of this work was to propose treatments to be carried out in three cashew processing agroindustries located in the Seridó region, RN, to enable the reuse of wastewater, thus promoting sustainable production systems and social, environmental and economic improvements.

4 MATERIALS AND METHODS

4.1 Characterization of the research and sample collection locations

The research was carried out in partnership with the Federal Institute Sudeste de Minas Gerais, Rio Pomba campus, the institution proposing the project, the Federal Institute of Rio Grande do Norte (IFRN), Currais Novos campus, and agribusinesses located in Seridó, RN. The characterization of wastewater and simulations of treatments to be applied later in agroindustries at larger scales were developed in the IFRN laboratory at the Currais Novos campus.

Sample collection was carried out from September 2021 to February 2023 in private or cooperative agribusinesses that functioned as study systems. The agroindustries were located in the interior of Rio Grande do Norte, more precisely, in the Seridó region. Three agribusinesses, A, B and C, were selected for the evaluations.

4.2 Measurement of cashew washing water in agribusinesses

To quantify the water used in the raw material washing process, a graduated volumetric bucket with a capacity of 18 liters was used. While the bucket was being filled, the time elapsed was checked with the aid of a stopwatch, and then the mass of cashews washed during the period was quantified via a precision electronic scale (Mars brand) with the capacity to measure up to 100 kg. With this information, the amount of water used per unit of time and per mass of cashew processed in each production unit was calculated.

4.3 Physicochemical characterization

The physicochemical analyses were carried out in accordance with the methodologies established by APHA, AWWA and WEF (2012) to preliminarily characterize the wastewater and subsequently verify (posttreatment) the improvement in its quality (Table 1).

Table 1. Physicochemical parameters evaluated and methods used

Parameter	Methodology
pH	Direct, Potentiometric, 4500 B
Temperature (°C)	Infrared Thermometer, SKILL-TEC
Turbidity (NTU)	Tubidimeter , Nephelometric Method , 2130 B
COD (mg/L)	Reflux Closed by colorimetry, 5220 D
BOD_5 (mg/L)	BOD Method $_5$, 5210B
Electrical conductivity	Direct method, conductivity meter, Method 2510 B
Apparent color	Spectrophotometric Method, 2120 B
Acidity (mg $CaCO_3$/L)	Titrimetric Method, 2310
Alkalinity (mg $CaCO_3$/L)	Titrimetric Method, 2320 B
Settleable Solids (SSed)	Volumetric Method, 2540F

Source: Own authorship (2021). COD = chemical oxygen demand; BOD_5 = biochemical oxygen demand.

4.4 Microbiological characterization

For microbiological determination, the conventional methods described in the manual by Silva *et al. were used.* (2017), which includes the multiple tube technique, was used to determine total coliforms at 35°C and thermotolerant coliforms at 44.5°C.

The technique identifies and quantifies bacteria from the coliform group in water. For coliforms at 35°C, the presumptive test was carried out in Lauryl sulfate-tryptose (LST) culture medium, which inhibits the growth of accompanying bacteria and enriches the medium that favors the development of microorganisms from the coliform group. After 48 hours of incubation at the ideal temperature, a confirmatory test was carried out. For the confirmatory test, portions of the positive tubes (presumptive test results) were transferred to Caldo Verde Brilhante Bile 2% (VB) for incubation for 24 h at 35.5°C. After this period, coliforms were quantified at 35°C.

In the confirmatory stage, for thermotolerant coliforms, tubes positive for total coliforms were selected at 35°C, from which they were transferred to tubes containing *E. coli broth* (EC), which were then incubated in a water bath for 24 hours at 44.5°C. After this period, coliforms were quantified at 44.5°C. Growth (positivity) in the three stages is observed through the turbidity of the medium present in the test tubes, as well as through the production of gas in more than two-thirds of the inverted Duhram tube contained in the test tubes. With the help of the most likelymost probable number (MPN) table, the MPN is determined in one hundred milliliters (100 mL), NPM/100 mL, on the basis of the number of positive tubes.

4.5 Wash water treatment

After the wastewater was characterized, treatment techniques were used according to each agro-industrial reality verified. For this purpose, a simulator called the Jar test, model JTC, with three tests was used (Figure 1).

Figure 1. Small-scale treatment simulator (Jar test)

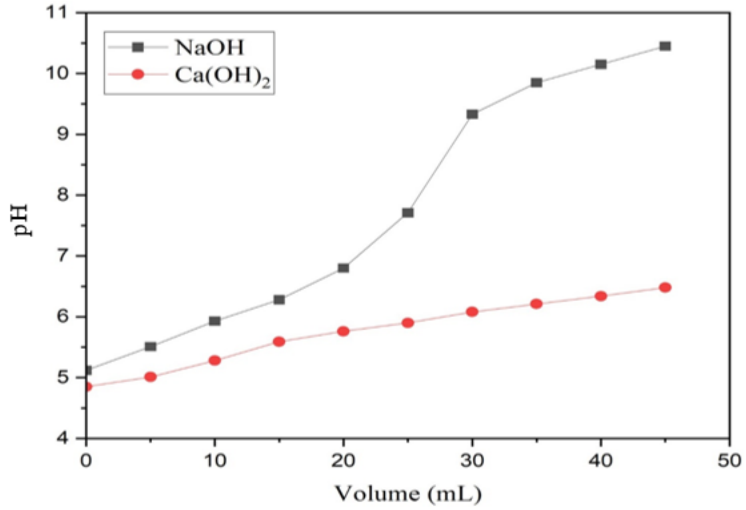
Source: Authors' own authorship (2023)

The experiments were carried out through sporadic collection on alternate days, which were tested in the jar test (Figure 1), with three tests per day of collection, using different concentrations of coagulant for each agribusiness. Following the recommendations of Silva (2021), the fast mixing time adopted was 2 (two) minutes, with a speed of 120 rpm, whereas for the slow mixing time, 20 minutes and a speed of 25 rpm were adopted. The time for sedimentation (rest) was 20 minutes.

Aluminum sulfate is effective when the pH is in the range of 6.0--8.5; therefore, when the pH is outside this range, a hydrated lime solution with a concentration of 10,000 mg/L is used for adjustment. Aluminum sulfate, a powerful coagulant, was used to clarify wastewater samples since, according to Eguchi and Arantes (2022), it is usual to use coagulants to destabilize dissolved suspended particles, as they promote the formation of flocs that can be removed through the sedimentation process.

To maintain the pH of the samples treated with aluminum sulfate between 5.0 and 8.0, a titration curve was constructed with NaOH (sodium hydroxide) and $Ca(OH)_2$ (hydrated lime) at 10,000 mg/L (Figure 2).

Figure 2. Alkalinizer titration curve



Source: Research data (2023). NaOH = solution concentration equal to 10000 mg/L; $Ca(OH)_2$ = solution concentration equal to 10000 mg/L.

The curve indicated the best option and that hydrated lime provides a linear and continuous increase in alkalinity, favoring pH control by companies. Furthermore, this is an alkalizing agent at an affordable price, making it financially applicable to agroindustries.

The proposed treatment was conventional because of its reduced costs and greater ease of implementation. For Ferreira Filho (2020), conventional treatment is a set of physical–chemical processes that require chemicals to speed up the treatment and adjust the pH. There is an application of coagulant in the coagulation/flocculation stages, after which the decantation stage continues, thus promoting water clarification. When necessary, the treatment process continues by adding filtration, disinfection and fluoridation steps.

In the clarification process for subsequent decantation, the application of products (chemical reagents) was carried out in quantities proportional to the wastewater evaluated. The use of the Jar test made it possible to execute the operations in a unitary manner, which allowed the determination of the most efficient treatment for each case, with the obtaining of multiple linear regression models for each agribusiness.

After each test, the supernatant was collected, and pH, turbidity and apparent color analyses were carried out to verify the efficiency of the treatment and improve the quality of the water in the three different concentrations of the coagulant.

4.6 Statistical analysis

Statistical analysis of the treatments was performed at a confidence level of 95% via the Statistica 13.0 program (TIBCO, 2017). First, the normality of the data was evaluated, namely, chemical oxygen demand (COD), biochemical oxygen demand (BOD), alkalinity, pH, settleable solids, conductivity, temperature, apparent color, turbidity and acidity. Data that presented normal distributions were subjected to the F test to compare means. Those that did not present a normal distribution were subjected to the Kruskal–Wallis test.

The results of the simulated treatments were treated statistically with a 95% confidence interval and then analyzed via multiple linear regression models, in which the amount of aluminum sulfate was correlated with the color and turbidity parameters and was equal to 5,000 mg/L, indicating greater industrial applicability. The models were generated via the Jamovi program, version 2.3.

5 RESULTS AND DISCUSSION

5.1 Water demand of fruits subjected to agribusiness

This work presents an estimate of the maximum production capacity feasible and desired by each agribusiness, resulting from a favorable scenario, with the presence of a good and continuous harvest for four consecutive months, perfect industrial operation capacity and a consumer market absorbing the production. This result also reflects the relationship between each agroindustry and the amount of water used when washing cashews.

Agribusiness A is small and processes cashews once a week. The present study indicated that 2.86 liters of water were used to wash each kilogram of processed cashew. As this company processes a maximum of 6.4 tons per harvest, it was estimated that it would use 18,286 m3 of water per harvest. Agribusiness B is medium-sized and processes cashews twice a week. It was found that 0.17 liters were used to wash each kilogram of processed cashew. Because it has a maximum production capacity of 100 tons per day, reaching 3,200 tons per harvest, it was estimated that it can use up to 5,486 × $^{104\ m3}$ of water per harvest. Finally, agribusiness C is an MEI; that is, it belongs to an individual microentrepreneur and occasionally processes cashews once a month. For her, 1 liter was used to wash each kilogram of processed cashew. Its maximum capacity per harvest is 0.8 tons. Therefore, its water demand was estimated to be 0.8 m3 per harvest. Agribusiness C is the smallest, whereas B is the largest. Agroindustry B has already greatly optimized its washing process and has the lowest water consumption per kg of processed fruit; however, there is a high consumption of water used, given its greater operation and processing capacity. Agroindustry A had the highest water consumption per kg of fruit processed.

Moraes (2019), in an industrial unit that produces fruit pulp, reported that its water demand was 1,000 liters of water per day, and this volume included consumption related to production activities and environmental hygiene. These thousand liters represent the daily amount of wastewater generated, and through this, the production of 252 thousand liters of wastewater per year can be estimated, excluding weekends from the calculation.

Owing to the difference in consumption between the present study and that of Moraes (2019), the amount of water required for industrial operation and washing raw materials clearly depends on the routine of each agribusiness, its size and operating time.

5.2 Physicochemical characterization of wastewater

Table 2 presents the averages for the alkalinity, COD and BOD parameters. These data presented a normal distribution and were therefore compared via the F test, in which statistical analysis was performed via a parametric test. There were no statistically significant differences in these data between the agribusinesses evaluated ($p > 0.05$).

Table 2. Values (mean ± standard deviation) of the following parameters: alkalinity, chemical oxygen demand (COD) and biochemical oxygen demand (BOD) of wastewater from cashew washing in agribusinesses A, B and C

	Parameters		
Agroindustry	**Alkalinity ($CaCO_3$ /L)**	**COD (mg O_2 /L)**	**BOD (mg O_2 /L)**
THE	61.26 ± 24.55a	461.37 ± 68.45a	284.41 ± 44.19a
B	88.22 ± 58.94a	1,990.97 ± 1,049.67a	1,178.30 ± 628.33a
W	106.77 ± 60.86a	2,725.94 ± 1,235.94a	1,603.11 ± 727.04a

Source: Research data (2023). Means with the same letters in the same column do not differ from each other according to the F test ($p > 0.05$).

Alkalinity is an important variable in the characterization of effluents and must be quantified to propose appropriate treatment, as it directly influences the success of the clarification process through the action of the coagulant used (Silva, 2021).

For better action of aluminum sulfate in the formation of floccules to obtain good clarification, there must be an equivalence of 0.5 mg of alkalinity for 1.0 mg of aluminum sulfate (product active), since this relationship is considered ideal for achieving high efficiency values in the treatment of wastewater from the agroindustries studied (Table 2).

The present study revealed mean alkalinity values that varied from 61.26 mg $CaCO_3$/L (Agroindustry A) to 106.77 mg $CaCO_3$/L (Agroindustry C), with no statistically significant difference observed ($p > 0.05$) among the agribusinesses evaluated (Table 2). Notably, the current national legislation that defines quality standards for managing the discharge of effluents into receiving bodies of water, the resolution of the National Environmental Council (Conama) N° 430 of May 13, 2011, does not establish a limit value for this parameter (BRASIL, 2011).

Agroindustry C presented a greater average alkalinity parameter, which may have been the result of its addition of a sanitizing agent, which is alkaline, during the cashew washing process. Agroindustry B presented the second highest average, and agroindustry A presented the lowest average for this parameter (Table 2). Both agribusinesses A and B do not use sanitizers when washing cashews, with alkalinity resulting from the characteristics of the water supply used.

Regarding the quantification of the organic material present in the samples, represented by the COD parameter (Table 2), high data variability was observed (high standard deviation values), which was possibly influenced by the type of washing (immersion or spraying), the constitution of the fruit and its integrity (maturation stage and physical conditions), reception and management of cashews, method of harvesting (directly on the plant or on the ground), the supplying regions, cities in Seridó do RN and cities in Piauí, given the distances, the removal of nuts and even the addition of sanitizers. The COD data ranged from 461.37 mg O_2/L (Agroindustry A) to 2,725.94 mg O_2/L (Agroindustry C), which was probably due to the contact of water with the organic material inherent to the fruit itself and the acquisition during the procedures performed there.

Conama resolution No. 430 of 2011 also does not establish a limit value for the DQO parameter. Therefore, a comparison must be established with the quality standard set out at the aforementioned resolution. Therefore, on the basis of its analysis, wastewater from agroindustries A, B and C contains organic matter that can be degraded by chemical treatment processes, such as the one presented in the present study. Furthermore, the organic matter present in wastewater is interesting for agricultural reuse in the irrigation of cashew orchards, as it allows an increase in organic material in the soil.

For wastewater from açaí processing, Feio, Girard and Mendonça (2014) determined that the COD values were much higher than those reported in this work. The COD reached 7,720 mg O $_2$/L, which was attributed to the fact that the açai fruits were crushed during processing.

The average BOD ranged from 284.41 mg O $_2$/L (Agribusiness A) to 1,603.11 mg O $_2$/L (Agribusiness C) (Table 2). These values, compared with the maximum BOD value, equal to 120 mg O $_2$/L, established by Conama resolution No. 430 of 2011 as a standard for effluents from sanitary sewage treatment systems (Brazil, 2011), are greater; therefore, they are in disagreement with this standard of the aforementioned resolution. Notably, in general, the contact of water with cashews led to an increase in the content of organic material, mainly in agroindustries that work with fruit without nuts (Agroindustry B) and those that add sanitizer (Agroindustry B) and those that add sanitizer (Agroindustry C).

Feio and Mendonça (2021) reported a high average BOD value, equal to 3,022 mg O $_2$/L, for raw effluent from açaí processing, with this value being much greater than the average value obtained for wastewater from washing cashews in agribusinesses A, B and C (Table 2). This finding may be related to the fact that during the processing of açaí, the fruit in crushed form is in contact with the water used in the process, consequently increasing the organic load.

The data on the COD/BOD ratio, pH, turbidity and color (Table 3) did not present a normal distribution, and their means, according to the Kruskal–Wallis test (p > 0.05), did not differ significantly among the agribusinesses.

Table 3. Chemical oxygen demand (COD)/biochemical oxygen demand (BOD) relationships and the pH, turbidity and color (mean ± standard deviation) parameters of wastewater from washing cashews in agribusinesses A, B and C

Agroindustry	Parameters			
	DQO/BOD ratio	**pH**	**Turbidity (NTU)**	**Color (mg/L of Pt -Co)**
THE	1.65 ± 0.04a	7.43 ± 0.29a	7.40 ± 3.64a	178.21 ± 15.17a
B	1.70 ± 0.01a	6.24 ± 0.24a	39.89 ± 19.14a	416.00 ± 44.74a
W	1.70 ± 0.00a	6.41 ± 1.29a	23.46 ± 24.46a	352.44 ± 194.02a

Source: Research data (2023). Means with the same letters in the same column do not differ from each other according to the Kruskal–Wallis test (p > 0.05). NTU = nephelometric turbidity unit; Pt -Co = Platinum–Cobalt scale.

The average COD/BOD ratios for agroindustries A, B and C were low (< 2.5), ranging from 1.65 (Agroindustry A) to 1.70 (Agroindustries B and C), which, according to Von Sperling (2014), suggests the use of biological treatment due to the high biodegradable fraction of wastewater. Although the analysis of this relationship indicates that biological treatment should be adopted, it was decided to remain with the proposed physical–chemical treatment, as it presents business viability (financial and economic), mainly because it has lower implementation costs.

The average pH, which was measured *in situ*, varied between 6.24 (Agroindustry B) and 7.43 (Agroindustry A) (Table 3). Its variation (reduction) over time is most likely due to the presence of juice and pulp residues, which have a natural tendency to acidify. Feio and Mendonça (2021) reported a variation of 5.3--5.8 in the pH of raw effluent from açaí processing, whereas Machado (2023), when evaluating effluent from coffee fruit processing, reported an average pH of 4,27. In this context, it is clear that pH values vary depending on the fruit to be processed and that the aforementioned studies presented lower values than the average results reported in the present work. Importantly, national legislation for the discharge of effluents (Conama N° 430/2011) recommends a pH standard in the range of 5.0--9.0; thus, the average pH values found in the present study for wastewater from washing cashews in agribusinesses A, B and C comply with legal requirements.

The average turbidity ranged from 7.40 NTU (Agribusiness A) to 39.89 NTU (Agribusiness B) (Table 3). These results can be considered low in comparison with the turbidity of wastewater originating from the processing of other fruits, for example, Machado (2023) and Gardiman Júnior (2018), when evaluating wastewater originating from the processing of coffee fruits, the average turbidity values were 1,629.50 and 1,008.00 NTU, respectively. When samples of wastewater originating from the processing of açai fruits were analyzed by Feio and Mendonça (2021), an average turbidity of 7900 NTU was observed. The cause of this difference is that the wastewater evaluated in the present study was produced only from the process of washing the fruits, whereas in the studies mentioned above, the wastewater was produced from the processes of washing, peeling or pulping the fruits.

With respect to turbidity and color (Table 3), which are associated with the presence of suspended solids and dissolved solids, respectively, agribusiness A presented the lowest average values, which were 7.40 NTU for turbidity and 178 and 21 mg/L Pt-Co for color. This agro-industry washes the fruits by spraying, and among the agro-industries evaluated, it requires the greatest amount of water in the washing process for each kilo of cashew processed. This behavior may have contributed to the dilution of solids from the processing process. washing. Furthermore, the fact that the cashew is intact and harvested by hand justifies less passage of juice and pulp into the wastewater, as well as less adhesion of dirt to the fruit, such factors also contribute to the nonincrease in turbidity. and color in wastewater originating from the washing process.

For agribusinesses B and C, the average color corresponded to 416.00 and 352.44 mg/L Pt-Co, respectively. These values are relatively close to those reported by Machado (2023) in the analyses of wastewater originating from the washing, peeling or pulping processes of coffee fruits, whose average value was equal to 1,404.00 mg/L Pt-Co. This difference in the means of the color parameters among the studies may be related to the fact that, in the present study, the wastewater analyzed came only from the cashew fruit washing process.

The data for the parameters acidity, temperature, settleable solids and conductivity did not present a normal distribution, and when the means of agribusinesses A, B and C were compared via the Kruskal–Wallis test, they did not differ significantly from each other ($p > 0.05$), except for the conductivity parameter (Table 4).

Table 4. Values of acidity, temperature, settleable solids and conductivity (mean ± standard deviation) of wastewater from washing cashews in agribusinesses A, B and C

Agroindustry	Parameters			
	Acidity (mg $CaCO_3$/L)	Temperature (°C)	Settable solids (mL/L)	Conductivity (Sm^{-1})
THE	21.11 ± 24.30 a	14.15 ± 1.69 a	0.93 ± 0.15 a	474.86 ± 60.14 ab
B	149.38 ± 139.50 a	27.08 ± 0.54 a	0.31 ± 2.10 a	375.72 ± 44.54 a
W	58.88 ± 12.79 a	25.93 ± 2.12 a	5.06 ± 3.70 a	992.83 ± 274.33b

Source: Research data (2023). Means with the same letters in the same column do not differ from each other according to the Kruskal–Wallis test ($p > 0.05$). Sm^{-1} = Siemens per meter.

For acidity, agroindustry B presented the highest average value, equal to 149.38 mg of $CaCO_3$/L, whereas agroindustry A presented the lowest average value, equal to 21.11 mg of $CaCO_3$/L (Table 4). This can be explained by the distances covered, since in agribusiness B, the cashew takes longer to be processed than do agribusinesses A and C, which allows natural acidification of the fruit. Furthermore, agribusiness B receives cashew without the provision of nuts, whereas agribusinesses A and C receive cashews provided with nuts, which can contribute to obtaining lower acidity values.

With respect to temperature, all agroindustries had an average temperature of less than 40°C, which was equal to 14.15°C, 25.93°C and 27.08°C for agroindustries A, C and B, respectively (Table 4). In this way, they met the quality standard recommended by Conama Resolution No. 430/2011 for the discharge of effluents. Notably, temperature is a factor that influences the growth and reproduction of aquatic organisms, which is why monitoring it is important.

For settleable solids, agribusinesses A and B presented averages below 1 mL/L, which were equal to 0.93 and 0.31 mL/L, respectively. Agribusiness C had an average value of more than 1 mL/L, which was equal to 5.06 mL/L (Table 4). Conama Resolution No. 430/2011 provides a maximum value of 1 mL/L for this parameter; therefore, agribusiness C was the only one that did not comply with the aforementioned standard. In agribusinesses A and B, washing cashew fruits occurs by spraying, whereas in C, it occurs by immersion. The amount of processed fruit immersed in water can affect the concentration of solids, increasing the amount of settleable solids in wastewater. For açaí effluent, Feio and Mendonça (2021) determined an average of 4.75 mL/L for settleable solids; this value corroborates the result found for agroindustry C.

The average conductivities of agribusinesses A, B and C were 474.86, 375.72 and 992.83 Sm^{-1}, respectively. The average of agroindustry A did not differ significantly from the averages of agroindustries B and C; on the other hand, the average of agroindustry B differed significantly from the average of agroindustry C ($p < 0.05$) (Table 4). The differences observed for this parameter may be the result of the way in which the cashews are washed and sanitized and the presence or absence of nuts. Agribusinesses A and B carry out washing by spraying, whereas agroindustry C performs washing by immersion. Agribusinesses A and C receive cashews with nuts, whereas agribusinesses B receive them without nuts. The absence of nuts favors a greater release of solids and electrolytes. Finally, agribusinesses A and B do not use disinfectants, whereas agribusiness C uses the disinfectant sodium hypochlorite. Gardiman Júnior (2018) reported that, for wastewater from coffee, the average conductivity was equal to 1. 430

ds.cm $^{-1}$, which is equivalent to 0.143 Sm $^{-1}$. This value is much lower than those reported in the present work for the agribusinesses evaluated (Table 4) and may be a result of the handling of the fruits, which are different, in the washing process. Notably, conductivity is a quality parameter that reflects the capacity of wastewater to conduct electrical current, and the dissolution of electrolytes contributes to increased conductivity.

5.3 Microbiological parameters

For coliform bacteria at 35°C (Table 5), no agricultural industry had a negative result. Agribusinesses A and B presented high counts, with averages of 20.66 and 23.00 MPN/100 mL, respectively. Agribusiness C had a low count, with an average of 2.30 MPN/100 mL.

Table 5. Values for microbiological parameters (mean ± standard deviation) of wastewater from washing cashews in agribusinesses A, B and C

Agroindustry	Parameters	
	Coliforms at 35°C (MPN/100 mL)	**Coliforms at 45°C (MPN/100 mL)**
THE	20.66 ± 4.04	Absent
B	23.00 ± 0.00	14.67 ± 2.31
W	2.30 ± 3.98	Absent

Source: Survey data (2023)

Although there is no standard for total coliforms specifically defined for wastewater originating from the fruit washing process in agroindustries, according to Ceará (2016), the simple presence of total coliforms may not be related to contamination of fecal origin; however, this fact should serve as a warning and should never be neglected.

For coliforms at 45°C, there was an absence of agribusinesses A and C, with only agribusiness B having a count, with an average of 14.67 MPN/100 mL (Table 5). Notably, when cashew fruits from agribusinesses A and B are washed, there is no addition of a disinfectant agent. However, agribusiness C applies a sanitizing agent during the washing process. In view of the above, the absence of coliforms at 45°C in agroindustry A may be related to the fact that cashew fruits are less manipulated and because they are not picked from the ground, as they are harvested directly from the cashew tree.

5.4 Simulation of washing water treatment in the laboratory

Nine treatments were simulated and evaluated for agroindustry A (Table 6), nine for agroindustry B (Table 7) and six for agroindustry C (Table 8).

Table 6. Color and turbidity parameters evaluated before and after treatment with aluminum sulfate ($Al_2(SO_4)_3.14H_2O$ at 5,000 mg/L) in different volumes of wastewater generated by agribusiness A

	Parameters			
Volume (mL) of $Al_2(SO_4)_3.14H_2O$ at 5,000 mg/L	Initial color	Final color	Initial turbidity	Turbidity end
25.0	175	15	5.04	2.85
50.0	175	36	5.04	4.51
75.0	175	41	5.04	4.99
18.5	165	8	5.57	4.68
37.0	165	9	5.57	4.14
55.5	165	20	5.57	4.44
2.4	288	186	11.6	4.26
4.2	288	188	11.6	5.08
6.0	288	178	11.6	6.00

Source: Survey data (2023)

Table 7. Color and turbidity parameters evaluated before and after treatment with aluminum sulfate ($Al_2(SO_4)_3.14H_2O$ at 5,000 mg/L) in different volumes of wastewater generated by agribusiness B

	Parameters			
Volume (mL) of $Al_2(SO_4)_3.14H_2O$ at 5,000 mg/L	Initial color	Final color	Initial turbidity	Ultimate turbidity
1.5	163	70	4.63	5.0
3.3	163	80	4.63	5.21
5.1	163	87	4.63	5.43
6.2	403.6	250	54.13	8.04
12.6	403.6	275	54.13	8.79
18.6	403.6	373	54.13	12.3
32.0	385	31.6	16.9	5.95
77.6	385	59	16.9	4.81
123.0	385	55	16.9	4.47

Source: Research data, (2023)

Table 8. Color and turbidity parameters evaluated before and after treatment with aluminum sulfate ($Al_2(SO_4)_3.14H_2O$ at 5,000 mg/L) in different volumes of wastewater generated by agribusiness C

Volume (mL) of $Al_2(SO_3)_4.14H_2O$ at 5,000 mg/L	Parameters			
	Initial color	Final color	Initial turbidity	Ultimate turbidity
1.50	424.6	120	10.60	4.79
7.05	424.6	118.3	10.60	5.03
12.06	424.6	127	10.60	5.70
3.0	424	342	11.20	6.29
7.8	424	322	11.20	7.01
7.8	424	322	11.20	7.01
12.6	424	353	11.20	6.71

Source: Survey data (2023)

These simulations allowed the generation of equations through multiple linear regression to limit the amount of coagulant to be used in the physical–chemical treatment. The volume of wastewater used for each treatment was 1.5 L, which was the average capacity of the jar.

For all agroindustries (Tables 5, 6 and 7), there is a limitation regarding the use of an aluminum sulfate coagulant ($Al_2(SO_4)_3.14H_2O$)) in relation to its use in the treatment of wastewater with low turbidity, since when the concentration of the coagulant is increased, the turbidity remains practically unchanged. Pedretti and Medeiros (2022) verified this same limitation and noted that high concentrations of coagulant can even give color to the water to be treated.

Through treatment with the application of an aluminum sulfate coagulant, an improvement in the quality of wastewater from washing cashews was achieved in all agribusinesses evaluated (Tables 5, 6 and 7). The volume of coagulant capable of producing the best result varied among agribusinesses and among the parameters evaluated. For agribusiness A, a volume of 2.4 mL of aluminum sulfate at a concentration of 5,000 mg/L produced the best result for the turbidity parameter, whereas a volume of 18.5 mL produced the best result for the color parameter (Table 6). For agribusiness B, a volume of 6.2 mL of aluminum sulfate at a concentration of 5,000 mg/L produced the best result for the turbidity parameter, whereas a volume of 32 mL produced the best result for the color parameter (Table 7). For agroindustry C, a volume of 1.5 mL of aluminum sulfate at a concentration of 5,000 mg/L produced the best result for the turbidity parameter, whereas a volume of 7.05 mL produced the best result for the color parameter (Table 8).

Law No. 11,332 of December 30, 2022, of the state of Rio Grande do Norte establishes in its article 12 that the reuse of wastewater for nonpotable purposes, such as for washing external areas and irrigating cashew orchards, depends on prior characterization of the treated effluent, and it is defined in the sole paragraph of this article that the specific quality criteria and parameters for the nonpotable reuse modality must be detailed in regulation, observing the rules defined by the State Environmental Council (CONEMA) (Rio Grande do Norte, 2022). Therefore, the first step toward ensuring the reuse of wastewater from cashew washing in agribusinesses A, B and C, which is the prior characterization of the treated effluent, has already been carried out in the present study, which will collaborate with the decision regarding the viability of the practice of reuse.

For Schorr (2022), the treatment required strongly depends on the characteristics of the water or effluent and its intended use, as both direct the steps and actions necessary to achieve the desired quality.

5.5 Proposal for industrial treatment and destination of treated water

With the results of the treatments carried out on wastewater generated by agroindustries A and B, the models presented in Equations 1 and 2 were generated via multiple linear regression, according to Jamovi (2022), which represent the characteristics of agroindustries A and B, respectively. These models can help agribusinesses define the volume of aluminum sulfate at a concentration of 5,000 mg/L to be applied on the basis of the color and turbidity values they wish to achieve with the treatment.

$$Y = 0{,}26884\, X_1 + \; 10{,}05912\, X_2 + \; 4{,}973467 \tag{1}$$

where:
Y= volume of aluminum sulfate (5,000 mg/L concentration) in mL;
X $_1$ = final color; and
X $_2$ = final turbidity.

$$Y = \; -0{,}05081\, X_1 \; - \; 3{,}50667\, X_2 \; + \; 61{,}70745 \tag{2}$$

where:
Y= volume of aluminum sulfate (5,000 mg/L concentration) in mL;
X $_1$ = final color; and
X $_2$ = final turbidity.

For agroindustry C, a model was not generated to direct the treatment of wastewater with the addition of aluminum sulfate because of its low water demand for the process of washing cashew fruits (0.8 m3 per harvest). It is a small company managed by an individual microentrepreneur, uses the immersion washing process and has reduced infrastructure. Therefore, agroindustry C will continue to release a small amount of effluent into the public sewage network until a contract is signed with an outsourced company.

The results obtained showed variability; therefore, for the treatment of wastewater from washing cashew fruits, this prototype is proposed, whose specifications must be carefully followed:

$$Coagulação \rightarrow Floculação \rightarrow Decantação \rightarrow Filtração \rightarrow Desinfecção$$

Coagulation begins with the application of aluminum sulfate, and the proportion indicated in the multiple linear regression equation obtained from the correlation of color and turbidity must be followed to justify the amount of aluminum sulfate solution applied.

Flocculation/Sedimentation: After the aluminum sulfate coagulant is added, the flocs must wait 1 to 2 hours for them to form and settle.

Filtration: the supernatant (treated water) must be separated from the solids via a filter. This step takes place if necessary, as in laboratory tests, it does not need to be carried out.

Disinfection: First, 10 to 12% sodium hypochlorite must be applied to eliminate possible pathogenic microorganisms.

Importantly, the treatment is carried out on the same day as the generation of wastewater, thus avoiding a greater demand for work and the use of a greater quantity of chemical agent to alkalize the environment, since, within a period of 24 hours, the pH decreases significantly.

5.5.1 Wastewater destinations

Agribusinesses A and C have sent their industrial wastewater to the public sewage system, whereas agroindustry B has sent it to a stabilization pond. The reuse of this industrial wastewater in regions with a predominance of water scarcity, as is the case in the Seridó region of RN, is an action in favor of sustainable development capable of producing economic, social and environmental benefits. According to Bittencourt and Paula (2018), reused water can be a good source of water for less noble purposes, reducing pressure on water resources.

In this context, if wastewater treated in agroindustries is reused for washing external areas and irrigating cashew orchards, drinking water will not be used for these purposes. Magalhães, Martins and Medeiros (2019) reported that plants grown with treated wastewater exhibited improved growth due to the increase in organic matter as a source of nutrition for the plants. In view of the above, it is clear that the reuse of treated wastewater in agroindustries for irrigation, in addition to providing water savings, can also provide savings in the use of fertilizers.

Law 11,332 of December 2022, which provides for the policy of reuse of nonpotable water within the state of Rio Grande do Norte, defines the modality of reuse for industrial purposes as the use of treated wastewater in processes, activities and operations industry (RIO GRANDE DO NORTE, 2022). However, it is important to highlight that this law does not communicate the analytical standards to be met for each type of reuse.

On the basis of experimental observations and current legislation, agroindustry A, which has an orchard, perceives wastewater characteristics as an excellent alternative for irrigation, as it contains organic matter and is free from disinfectants. Agribusiness B will reuse it in different ways. Its treated wastewater must be used for agriculture, as the cooperative intends to plant it in 2023. It is also intended to be used for the first washing of cashew fruits, which is considered less critical due to the subsequent execution of two other washes. with drinking water.

In this way, there will be a reduction in the volume of wastewater destined for the stabilization pond, minimizing environmental impacts. As mentioned previously, agroindustry C, given the small amount of water used during harvest, was not feasible for reuse.

Lucena *et al.* (2018) noted that droughts and droughts are the most common types of disasters in Brazil, representing 54% of the total recorded disasters, with the Northeast Region being the most affected. Given this scenario, treatment to improve the quality of wastewater, to reuse it, needs to be a relevant sustainable action. With this, the agroindustries studied can be included among those that work successfully in the triad: economic, social and environmental.

6 CONCLUSION

The present work identified a prototype of conventional treatment for wastewater from washing cashews on the basis of the characterization of the wastewater and laboratory treatment simulations.

Physicochemical and microbiological analyses are relevant when conventional treatment is proposed since the characterization of wastewater directly influences the type of treatment indicated.

With respect to the feasibility of applying treatment technologies to remove and/or inactivate possible substances or contaminants, it was found that it is possible to make wastewater suitable for reuse for nonpotable purposes, thus reducing the pressure on water resources.

This study provides perspectives for water recycling given the potential for reusing wastewater treated by adding the coagulant aluminum sulfate to meet the demands of agroindustries, which include external washing and orchard irrigation.

For future studies, investigating whether the use of treated wastewater in the first washing of cashew fruits, when this is followed by washing with drinking water, is a viable reuse proposition is recommended.

It is important for the competent bodies of the state of Rio Grande do Norte to define the analytical standards to be met in each type of reuse, as provided by current state legislation.

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