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# Coagulation/flocculation of slaughterhouse wastewater using cottonseed as coagulant

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**ABSTRACT:** The objective of this study was to evaluate the influence of a natural product (cottonseed) when used as a coagulant agent in the turbidity removal from a swine slaughterhouse wastewater. The cottonseed was used as a coagulant in three preparation ways, in aqueous solution using distilled water, saline solution (NaCl - 1M) and in a solid phase. The aqueous solutions were prepared at the time of the test. Coagulation/flocculation/sedimentation tests were performed to evaluate the wastewater coagulant effect using Jar-test device, evaluating the dosages effects of 50, 100, 200, 500, 1000, 1500, 2500 and 5000 mg $L^{-1}$ cottonseed solution (aqueous and saline) and 50, 100, 200, 500, 1000 and 1500 mg $L^{-1}$ of solid phase cottonseed. According to the results obtained, the turbidity removals were observed when using saline solution (41.1%) with a great dosage of 1000 mg $L^{-1}$ and mainly when using solid phase cottonseed (43.5%) with a great dosage of 100 mg $L^{-1}$, since there is a larger contact surface, which may be considered a potential coagulant in the treatment of agro-industrial wastewater.

**Keywords:** natural coagulant, wastewater treatment, turbidity.

## Coagulação/floculação de efluente de abatedouro utilizando torta de algodão como coagulante

**RESUMO:** No presente trabalho, teve-se como objetivo avaliar a influência de um produto natural (torta de algodão), quando utilizado como agente coagulante, na remoção de turbidez de efluente proveniente de um abatedouro de suínos. A torta de algodão foi utilizada como coagulante em três formas de preparação, em solução aquosa utilizando-se água destilada, solução salina (NaCl – 1M) e em fase sólida. As soluções aquosas foram preparadas no momento do ensaio. Para avaliação do efeito do coagulante no efluente, foram realizados ensaios de coagulação/floculação/sedimentação utilizando o aparelho Jar- test, sendo avaliados os efeitos das dosagens de50, 100, 200, 500, 1000, 1500, 2500 e 5000 mg $L^{-1}$ de torta de algodão em solução (aquosa e salina) e 50, 100, 200, 500, 1000 e 1500 mg $L^{-1}$ de torta de algodão em fase sólida. De acordo com os resultados obtidos, observou-se remoções de turbidez quando da utilização da solução salina (41,1%) com dosagem ótima de 1000 mg $L^{-1}$ e principalmente quando se utiliza a torta de algodão em fase sólida (43,5%) com dosagem ótima de 100 mg $L^{-1}$, já que há uma maior superfície de contato, podendo este ser considerado um coagulante potencial no tratamento de efluentes agroindustriais.

**Palavras-chave:** coagulante natural, tratamento de efluentes, turbidez.

## 1. INTRODUCTION

Since the early twentieth century, the environment has become one of the biggest concerns of citizens and essential in government policy both in industrialized countries or not (LAYRARGUES, 2000). This is causing agribusinesses increasingly concern to achieve a correct environmental performance, coherent with the policy adopted by the company and its environmental objectives, through the control of environmental impacts caused due to their activities, generated products, and services. These companies seek to act within the context of the legislation, which is increasingly demanding, seeking to adopt the protection of the environment, and the growing concern of the interested people related to environmental issues and sustainable development. The sector must comply with the health and environmental laws to ensure the protection of the environment and its product demand by the buyers (ROSA, 2012).

The control of water pollution is one of the most important environmental activities in agribusiness considered essential for the preservation of human life.

Water is widely used in agribusiness, especially in slaughterhouses where it is used in cleaning and sanitation processes, in pigsty washing, in animal watering and truck washing, in the slaughtering and bleeding, in the evisceration and division, in the processing of guts and in the scalding operations and hair removal (KRIEGER, 2007; BAZRAFSHAN et al., 2012.). About 85% of the water used in the agribusiness process of a slaughterhouse is discarded as effluent, also known as wastewater. This wastewater is composed of large amounts of blood, fat, excreta, tissue fragments, among others, generating a large amount of organic matter, in addition to the high concentration of suspended solids and high biochemical oxygen demand (BOD) (AMUDA and ALADE, 2006; BAZRAFSHAN et al., 2012).

If disposed untreated into the environment, this wastewater becomes a focus of insects and pathogens, having a rapid decomposition (a few hours), polluting the air, causing odor, and high power of soil contamination and surface and ground waters.

The treatment of this wastewater from agribusiness activities has been extensively studied in conventional biological treatment systems (ESCOBAR et al., 2005) due to being effective and economical. In most cases, the substrates are not easily biodegradable and high concentrations of biomass and hydraulic retention times are required for degradation (LUCAS et al., 2007). That is, these processes are sometimes less attractive than physical treatments - chemicals, requiring less retention time, as coagulation/flocculation (DROGUI et al., 2008), searching for natural coagulants, being the subject of many studies when performing this type of treatment (BELTRÁN-HEREDIA et al., 2010; SÁNCHEZ-MARTÍN et al., 2010).

There are several reports in the literature concerning the treatment of slaughterhouse wastewater (MITTAL, 2006; AMUDA and ALADE, 2006) using chemical coagulants in the coagulation/flocculation process, such as aluminum sulfate and aluminum chloride. However, because of many problems caused by residual aluminum, such as the difficulty in disposal and treatment of the generated sludge, natural treatment processes have been increasingly stimulated as protecting the environment, and have low operating cost, satisfactorily efficient, such as the use of the *Moringa oleifera* Lam seeds (GARCÍA-FAYOS et al., 2010; BINA et al., 2010; SÁNCHEZ-MARTÍN et al., 2010). Furthermore, they have demonstrated advantages over chemicals, specifically regarding biodegradability, low toxicity and low residual sludge production rate (OKUDA et al., 2001).

The growing awareness that the wastewater treatment comes from agribusiness is fundamental for the control of environmental pollution, guiding us to the need of seeking alternative and low-cost ways to carry out the treatment of these water. Thus, this research aimed to evaluate the performance of a natural alternative coagulant (cottonseed), in the turbidity removal, using the process of coagulation/flocculation/sedimentation in an agribusiness wastewater coming from a swine slaughterhouse.

## 2. MATERIAL AND METHODS

The wastewater used in the study came from a swine slaughterhouse, located in the municipality of Sinop/Mato Grosso, named as a raw wastewater because it was not subjected to any preliminary treatment. The sample was packed in a container and kept chilled. Then, it was referred to the analysis in the laboratory to an initial characterization. The analyses were turbidity, pH, $UV_{254nm}$, COD, BOD and TSS, performed by Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

For coagulation/flocculation/sedimentation tests, the cottonseed (CS) was used as a natural coagulant, originated from a local company that produces cottonseed oil. The cottonseed was used as a coagulant in three preparation ways, in aqueous solution using distilled water (DW), brine (NaCl - 1M) (TAS) and solid phase (TAFs). All coagulant solutions were prepared at the time of the assay because studies have shown that the storage of the solution for several days, especially the aqueous, can lead to process inefficiency, for example, *M. oleifera* (YARAHMADI et al., 2009).

For cottonseed solution, there were 20 grams weighed and crushed together with 100 mL of distilled water or NaCl (1M) in a blender, with subsequent agitation of 30 minutes on a magnetic stirrer, obtaining a 20% seed solution (seed concentration in the solution = 200,000 mg $L^{-1}$). For the use of the cottonseed in a solid phase, it was only shredded in a blender as a powder.

Coagulation/flocculation/sedimentation tests were carried out in the Jar-test device of six tests with speed controller for the solutions mixing. The experimental tests were simultaneously performed with six samples of wastewater in containers of 500 mL capacity, 250 mL of raw wastewater to determine the optimal dosages of coagulants. The pH of the samples was constant throughout the experiment. During the tests, different speed conditions were used (fast mixing speed (FMS) and slow mixing speed (SMS)) and time (rapid mix time (RMT), slow mixing time (SMT) and settling time (ST)) in Jar-test device, shown in Table 1.

The dosages used in different coagulant preparations are presented in Table 2. In percentage terms, the great dosage value contained the most significant reduction of the turbidity value. The great value of dosages removal was determined by statistical analysis.



A completely randomized design (CRD) was used for the coagulant solution in a factorial design in the 2x8 arrangement, with the following factors: treatment (two forms of preparation of cottonseed as a coagulant - TAA and TAS) and dosages (eight dosages for both preparations), with three repetitions, totaling 24 experimental units for each coagulant. A completely randomized

Table 1. Different rotation conditions and device time Jar-test.
Tabela 1. Diferentes condições de rotação e tempo do aparelho Jar-test.

| Parameters | Coagulants |
|---|---|
| | TAA/TAS/TAFs |
| FMS (rpm) | 100 |
| RMT (min) | 2 |
| SMS (rpm) | 20 |
| SMT (min) | 20 |
| ST (min) | 60 |

Source: AMUDA & ALADE (2006).

Table 2. The dosage ranges of different coagulant preparations.
Tabela 2. Faixa de dosagem das diferentes preparações do coagulante.

| TAA/TAS | TAFs |
|---|---|
| mg $L^{-1}$ | |
| 50 | 50 |
| 100 | 100 |
| 200 | 200 |
| 500 | 500 |
| 1000 | 1000 |
| 1500 | 1500 |
| 2500 | - |
| 5000 | - |

design (CRD) was used for TAFs coagulant, consisting of six doses with three replications.

## 3. RESULTS AND DISCUSSION

### 3.1. Wastewater characterization

The characterization of the wastewater, regarding parameters, turbidity, pH, $UV_{254nm}$, COD, BOD, and TSS is shown in Table 3.

High values of BOD and COD and suspended solids were observed, demonstrating that the raw wastewater of the experiments showed high organic load.

According to Pacheco and Yamanaka (2008), the COD values for swine and bovine slaughter wastewater are in the range of 2500-4000 mg $L^{-1}$ per slaughtered animal. The concentration of suspended solids in raw wastewater was within the range expected in the literature; that is from 1600-2700 mg $L^{-1}$ (PACHECO and YAMANAKA, 2008; MASSE et al., 2000).

In the tests without the addition of a coagulant, also called blank test, it was observed a decrease of turbidity levels (418 NTU) when compared to the raw wastewater, due to the presence of settleable solids. The calculation of the turbidity removal percentage (% R) of all the tests with the addition of coagulant was using this blank test as a reference (Eq. 1).

$$\%R = \frac{C_0 - C_e}{C_0}(100) \quad (1)$$

where $C_0$ and $C_e$ are the initial turbidity (white) and final (treated) of the wastewater (NTU), respectively.



Table 3. Wastewater characterization.
Tabela 3. Caracterização do efluente.

| Parameters | Values |
|---|---|
| Turbidity (NTU[1]) | 1065 ± 7.3 |
| pH | 6.1 ± 0.01 |
| $UV_{254nm}$ ($cm^{-1}$) | 3.0 ± 0.0 |
| COD (mg $L^{-1}$) | 9217 ± 0.02 |
| BOD (mg $L^{-1}$) | 505 ± 0.06 |
| TSS (mg $L^{-1}$) | 8400 ± 2.71 |

[1] NTU: Nephelometric turbidity units

### 3.2. Determining the optimal dosage of the tested coagulants

#### *3.2.1 Coagulation/flocculation with coagulant cottonseed solution*

Figure 1 shows the graph of the residual turbidity of different coagulant solution preparations (TAA and TAS). Assays of each coagulant preparation are represented by different colors of the columns, and the dosages are arranged along the X-axis.

Analyzing the parameter, smaller residual turbidity were observed in the dose range of 50-100 mg $L^{-1}$ for TAA (<300 NTU) and 1000-5000 mg $L^{-1}$ to TAS (<270 NTU). They are not by CONAMA 357/2005 legislation; that defines the release of wastewater into the water body as ideal turbidity, equal and/or fewer values than 40 NTU.

Figure 2 shows the turbidity removal chart of the different preparations of the coagulant. Assays of each coagulant preparation are represented by different colors of the columns; the dosages are arranged along the X-axis.

Regarding the turbidity, the statistical analysis indicates that different preparations of coagulants are statistically different between individual dosages (uppercase), showing

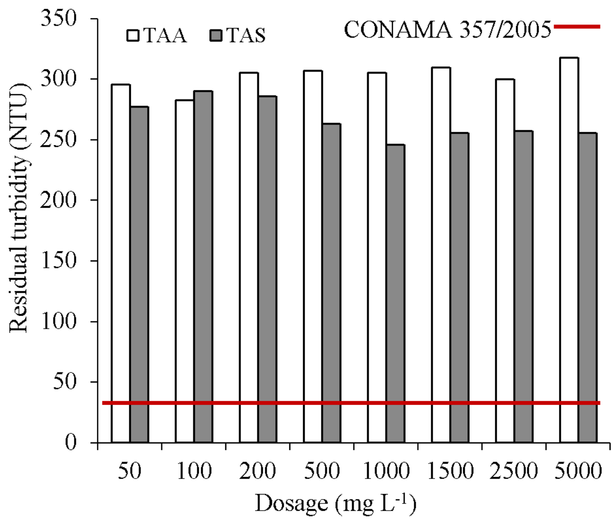
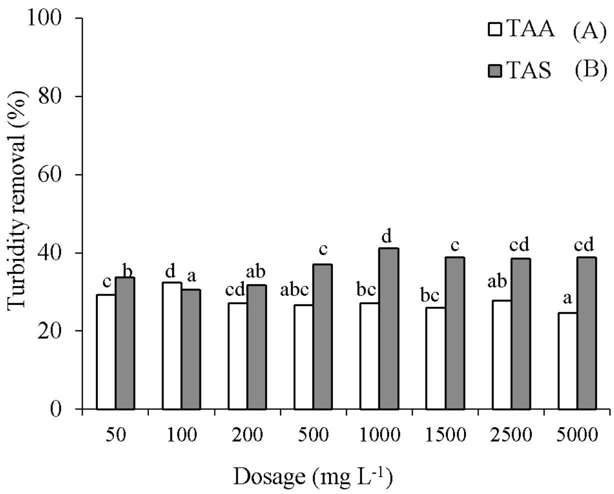



Figure 1. Turbidity residual analysis using different solution preparations (TAA and TAS) coagulant cottonseed.
Figura 1. Análise do residual de turbidez utilizando diferentes preparações de solução (TAA e TAS) do coagulante torta de algodão.




Lowercase letters assess separate treatment is checking differences in dosages and case letters evaluate the best treatment within each dosing (Tukey Test, $p < 0.05$).

Figure 2. Turbidity removal analysis using different solution preparations (TAA and TAS) of the cottonseed coagulant.
Figura 2. Análise de remoção de turbidez utilizando diferentes preparações de solução (TAA e TAS) do coagulante torta de algodão.

that compared to an aqueous solution the salt solution shows much more advantageous when used in preparing the coagulant. This improvement in the saline extraction efficiency could be described by a mechanism of salting-out, which increases the ionic strength and the solubility of the active components (OKUDA et al., 2001).

Several studies have shown that the use of saline as a solvent is more efficient than the aqueous solution prepared only with the coagulant and distilled water, for example, Okuda et al. (1999) showed that compared with the aqueous solution the seed coagulation ability of *M. oleifera* was up to 7.4 times higher when the preparation of the coagulant was performed with saline. One possible reason is that the protein in the coagulant is more soluble in water with high concentration of ions (OKUDA et al., 2001).

Evaluating each preparation of the coagulant separately and at different dosages (lowercase letters), it is verified that the best dosage for TAA and TAS were 100 mg $L^{-1}$ (33% removal) and 1000 mg $L^{-1}$ (41% removal), respectively.

There are no studies in literature reporting coagulation/flocculation/sedimentation processes using cottonseed as a coagulant, but as the cottonseed shows high protein content, it was decided to perform tests with this coagulant since there are natural products with coagulant action, as *Moringa oleifera*, with high protein content (NKHATA, 2001).

### *3.2.2 Coagulation/flocculation with cottonseed coagulant in a solid phase*

Figure 3 shows the residual turbidity chart of cottonseed in the solid phase (TAFs) at different dosages.

According to the results of Figure 3 for residual turbidity, it is also observed that any of the residual doses tested were in agreement with the CONAMA 357/2005 legislation (<40 NTU).

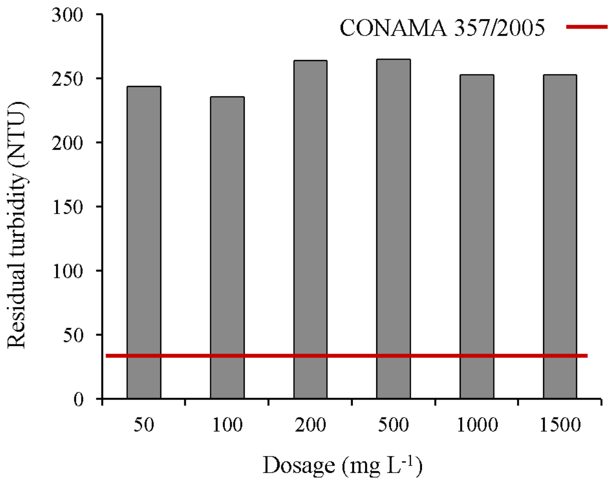
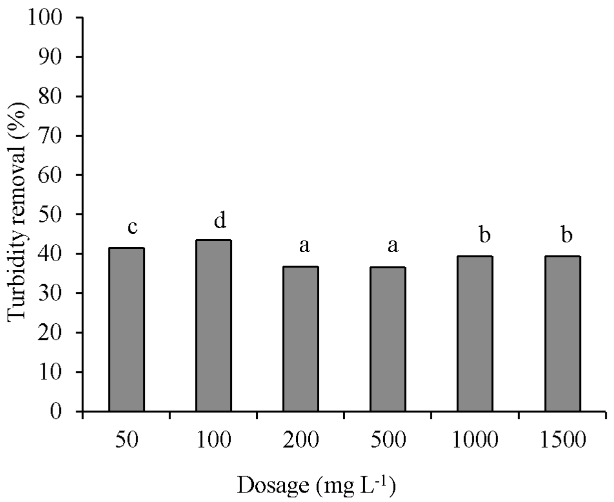



Figure 3. Residual turbidity analysis using cottonseed coagulant in a solid phase.
Figura 3. Análise do residual de turbidez utilizando o coagulante torta de algodão em fase sólida.




Letters (a, b, c, and d) in the chart identified different statistical groups (Tukey Test, $p < 0.05$).
Figure 4. Turbidity removal analysis using cottonseed coagulant in a solid phase.
Figura 4. Análise de remoção de turbidez utilizando o coagulante torta de algodão em fase sólida.

Figure 4 shows the turbidity removal chart of cottonseed in a solid phase (TAFs) at different dosages.

According to the results of Figure 4, about turbidity, the Tukey Test for multiple comparisons showed that there were differences between the doses of the coagulant TAFs with a great dose of 100 mg $L^{-1}$.

The summary of the results of the different forms of the cottonseed coagulant used is presented in Table 4.

Among the three forms of cottonseed as a coagulant useD, the cottonseed in the solid phase presented the highest turbidity removal using lower dose (100 mg $L^{-1}$), which may be due to a larger contact surface of the solid with the wastewater as compared to aqueous and saline solutions.

Table 4. Great dosages of the different ways of using cottonseed coagulant.
Tabela 4. Dosagens ótimas das diferentes formas de utilização do coagulante torta de algodão.

| Coagulant | Dosage (mg $L^{-1}$) | Removal average turbidity (%) |
|---|---|---|
| TAA | 100 | 32.5 ± 0.4 |
| TAS | 1000 | 41.1 ± 0.5 |
| TAFs | 100 | 43.5 ± 0.2 |

The removals results are represented by mean ± standard deviation.

## 4. CONCLUSIONS

Among the preparations of coagulant cottonseed, TAFs showed the greater turbidity removal using lower dose (100 mg $L^{-1}$).

Although the turbidity waste of the treated wastewater is not by the current legislation, cottonseed has a potential coagulant, requiring further studies to assess whether there is any component with coagulant potential that is masked in the cottonseed and could be isolated and increase its efficiency in coagulation/flocculation.



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