Chemical Engineering Journal 276 (2015) 166–173

Contents lists available at ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Coagulation–flocculation process with ultrafiltered saline extract of *Moringa oleifera* for the treatment of surface water

Aline Takaoka Alves Baptista [a], Priscila Ferri Coldebella [b], Pedro Henrique Freitas Cardines [a], Raquel Guttierres Gomes [a], Marcelo Fernandes Vieira [b], Rosângela Bergamasco [b], Angélica Marquetotti Salcedo Vieira [a,*]

[a] Postgraduate Program in Food Science, Universidade Estadual de Maringá, Maringá, PR, Brazil
[b] Postgraduate Program in Chemical Engineering, Universidade Estadual de Maringá, Maringá, PR, Brazil

HIGHLIGHTS

- *Moringa oleifera* is capable of treating 75 NTU turbidity surface waters.
- The concentration of saline extract was an asset in decreasing the volume of the coagulant.
- Ultrafiltered coagulant produced water with the lowest organic load.

ARTICLE INFO

Article history:
Received 19 January 2015
Received in revised form 8 April 2015
Accepted 9 April 2015
Available online 17 April 2015

Keywords:
Moringa oleifera
Water treatment
Natural coagulant
Dissolved organic carbon

ABSTRACT

The objective of this study was to obtain a natural coagulant from the *Moringa oleifera* seed that was able to reduce the contamination of surface water with initial turbidity of 75 NTU without increasing the organic material in the water treated. The parameters evaluated were color, turbidity and compounds that absorb light UV_{254nm}, dissolved organic carbon (DOC) and reduction of specific absorption of UV_{254nm} (SUVA). For this we used the saline and aqueous extraction processes of coagulant followed by ultrafiltration. In this work the dosage of coagulant was used in terms of concentration of protein coagulant, allowing greater reproducibility and reliability of results. The saline coagulant had a better performance in the removal of color (89.15%), turbidity (88.75%) and compounds with UV_{254nm} absorbance (75.93%), with low DOC concentration in the treated water and with 38% less SUVA concentration, when compared to that by surface water. A decrease in the volume of the concentrated coagulant needed for such results should be underscored. In fact, only one half of the volume was required when compared to non-ultrafiltrated coagulant. The above directly affected DOC in the treated water which was less for concentrated saline coagulant (4.01 mg/L) when compared to non-concentrated saline coagulant (8.39 mg/L). High efficiency in water treatment, reduced volume of coagulant and decreased concentration in organic matter in the treated water, especially with regard to SUVA, open new perspectives in the use of saline coagulant of *M. oleifera* as a natural coagulant for the treatment of supply water.

1. Introduction

The treatment of potable water is still a source of problems, such as health-hazardous chemical coagulants and dissolved organic carbon (DOC), that require solution. The total removal of the latter is relevant for the maintenance of esthetic standards, minimization of micro-pollutant concentrations, control of microbial growth within the distribution system and mainly its contribution as a by-component acting as a trihalomethane precursor (THM).

Water treatment is mandatory if it has to be within drinkable and thus consumption standards. The most frequently used inorganic coagulants in the coagulation/flocculation process are aluminum polychloride and aluminum sulfate, although they produce great amounts of silt. They are not biodegradable products and their coagulant effects depend on pH. High residual concentration may still be extant at the end of the treatment which is a rather important concern for public health authorities [1,2]. In fact, interest in the use of natural coagulants has been on the increase in

Abbreviations: DOC, dissolved organic carbon; SUVA, specific UV_{254nm} absorbance; UF, ultrafiltration.

* Corresponding author.

http://dx.doi.org/10.1016/j.cej.2015.04.045
1385-8947/

the last decades since they are biodegradable and safer for human health [3,4].

The *Moringa oleifera* Lam. (Moringa) has been recently the object of research for this specific purpose. The efficiency of its seed as a natural coagulant in the treatment of surface and residual waters has been proved by several authors [5–7]. According to Ndabigengesere and Narasiah [8], the seeds of the Moringa may be a feasible alternative as a coagulant replacing aluminum salts used in water treatments. Several researchers reported that Moringa is a water clarifying agent due to a cationic protein of high molecular weight which destabilizes the particles in the water. In fact, it performs the role of a natural coagulant [9]. However, when a natural coagulant is employed in water treatment, the organic load in the treated water increases [7] and may produce organochloride compounds such as trihalomethane. It is important to emphasize the high concentrations of Moringa that are necessary to achieve effective reductions of color and turbidity parameters. As mentioned by Pritchard et al. [10] the optimum Moringa dosage, for turbidity values between 40 and 200 NTU, ranged between 30 and 55 mg/L. With turbidity set at 130 NTU and a Moringa dosage within the optimum range at 50 mg/L.

Research involving techniques for isolation and purification of the active component is highly relevant to improve the use of Moringa as coagulant and for a better understanding of its coagulation/flocculation mechanism. Ion-exchange chromatography should be underscored among the methods for the purification of Moringa seeds protein [4,11–13]. Ultrafiltration (UF) is also a relevant technique which may be employed for the concentration and purification of different proteins based on their molar mass [14–16]. However, this technique has not been thoroughly exploited in the context of the purification and the concentration of the protein of the Moringa seed.

Under adequate conditions, ultrafiltration triggers a separation, albeit not always in a pure product. As a rule, when processes comprising membranes are compared with chromatographic ones, the former are low cost and easily workable, with transference for a higher scale [15]. Current assay assesses the coagulant obtained from the water and saline extraction of Moringa seeds, concentrated by ultrafiltration, for the removal of contaminants involving color, turbidity, UV_{254nm} and dissolved organic carbon in supply water.

2. Materials and methods

Surface water used in the assays was retrieved from the river Pirapó basin by the Companhia de Saneamento do Paraná (Sanepar) in Maringá PR Brazil. Seeds of *M. oleifera* were donated by the Universidade Federal do Sergipe, Aracaju SE Brazil. Seeds and collected water were stored under refrigeration so that their original characteristics could be maintained till analysis.

2.1. Characterization of crude and treated water

Parameters of color and compounds with UV_{254nm} absorbance (spectrophotometry DR 5000 Hach) and turbidity (turbidimeter 2100P Hach) and pH (pHmeter Thermo – Scientific VSTAR 92 Orion Versastar) were measured, following methodology by Standard Methods [17]. Parameters were evaluated at collection and during assays to verify the homogeneity of the parameters of water used in the experiments.

2.2. Obtaining the coagulant

Prior to the preparation of Moringa coagulants, the seeds underwent an oil-removal process with ethanol as solvent, as described by Sánchez-Martín et al. [13].

Further, 1 g of defatted seed was used for 0.1 L of distilled water to obtain the Moringa aqueous coagulant (WC). Extraction was performed in a blender by turbolysis, during 3 min, with distilled water, followed by stirring in a magnetic shaker, during 30 min [3]. After stirring, the solution underwent two consecutive filtrations, or rather, in quality filter paper and in a 0.9 μm pore glass fiber membrane.

Saline coagulant (SC) was prepared from 1 g of de-fatted Moringa seed for a 0.1 L saline solution of NaCl 1 M. The process followed the same methodology described for the aqueous coagulant.

2.2.1. Ultrafiltration stage

Coagulants underwent the ultrafiltration (UF) stage in a tangential flux module at 1 bar pressure. A hollow fiber polyethersulfone membrane, cut-off 50 kDa and 0.056 m^2 of filtrating area, was employed in the process. Concentrated aqueous coagulant (CWC), permeated aqueous coagulant (PWC), concentrated saline coagulant (CSC) and permeated saline coagulant (PSC) were thus obtained.

Filtration assays with distilled water were initially performed to characterize membrane flow. Volumes of the permeated coagulants were retrieved during the process at pre-determined periods, at known time intervals and flows calculated by Eq. (1):

$$J = \frac{Q}{A} \tag{1}$$

where J is the flow of the permeated coagulant; Q is the collected charge; A is the membrane's filtrating area. Samples of the permeated coagulant were retrieved at short periods at the start of filtration; the intervals were later increased to determine the permeate flow curve as a function of time. After the filtration of the coagulant, the membrane was quickly rinsed and the flow of distilled water was once more measured to compare it with the water flow of the clean membrane and the further calculation of percentage fouling. Fouling was calculated by Eq. (2) [18]:

$$\%Fouling = \frac{(J_{initial} - J_{final})}{J_{initial}} \times 100 \tag{2}$$

where $J_{initial}$ is the flow of distilled water of the clean membrane and J_{final} is the flow of distilled water measured after the ultrafiltration process.

2.3. Characterization of the coagulants

2.3.1. Protein rates

The Kjeldhal method was initially employed to determine the protein in the Moringa seed, following methodology described by Standard Methods [17]. The method gives total nitrogen by employing the conversion factor 6.25 to transform total nitrogen in protein. Lowry's method [19] quantified the soluble protein in the saline and aqueous coagulant and its permeated and concentrated fractions by ultrafiltration.

2.3.2. Dissolved organic carbon (DOC)

Dissolved organic carbon (DOC) was analyzed in water and saline coagulants and in the water treated by them. Prior to DOC determination, the samples were filtered in a Millipore cellulose ester membrane, average pore diameter 0.45 μm, by a vacuum pump. DOC concentration was determined by TOC Analyzer (Shimadzu 5000[a]), in mg/L, following Standard Methods [17].

2.3.3. SUVA

Specific ultraviolet light absorbance (SUVA) is the ratio between UV absorbance at 254 nm and dissolved organic carbon (DOC).