Journal of Applied Research and Technology

www.jart.icat.unam.mx

Journal of Applied Research and Technology 21 (2023) 384-396

Original

Recovery of membrane permeability after filtration of sago starch suspension by tangential flow filtration

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Received 10 17 2021; accepted 05 26 2022
Available 06 30 2023

Abstract: Sago starch is extracted from the stems of the sago palm, Metroxylon sagu, in Southeast Asia. A typical Sago starch processing mill in Malaysia generates approximately 20 tons of starch daily containing effluents that can be recovered and marketed to sustain a small-scale industry. Tangential flow filtration (TFF) using microfiltration membranes (MFM) has been demonstrated as an effective method for separating suspended solids in biological effluents. When TFF was applied to concentrate the starch from the sago starch suspensions (SSS), the membrane permeability and lifecycle were impacted due to frequent fouling. This study evaluated cleaning methods to recover the permeability and extend the life cycle of MFM following TFF application. Polysulfone membrane filter cassettes of pore size 0.45 µm and surface area 0.1 m2 were each used to separate starch in 100 L of SSS. Following separation, six chemical and physical cleaning methods were tested at laboratory-scale and the degree of cleaning was measured by normalized permeate flux (NPF) and normalized water permeability (NWP). The results showed that soaking the membranes in a 0.2 M NaOH solution (up to 91%, ($p<0.05$) within a minimum of 72 h, ($p<0.05$) was the best cleaning method. The procedure has been utilized to maintain and extend the life cycle of the MFM for streams containing starch suspensions.

Keywords: membrane cleaning, membrane fouling, membrane permeability, microfiltration, sago starch, tangential flow filtration

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Peer Review under the responsibility of Universidad Nacional Autónoma de México.

1. Introduction

Membrane filtration technology is used extensively in industrial applications. Nonetheless, fouling of the membrane is the biggest issue in membrane applications because it involves relatively high capital, operational and membrane costs (Ghernaout, 2018). Membrane cleaning has been widely studied and practiced to solve the fouling problem and ultimately reduce costs in membrane technology application. Fundamentally, fouling of the membrane can be classified as either reversible or irreversible fouling (Chang et al., 2002; Zularisam et al., 2006). Physical or chemical cleaning are options to remove foulants and contaminants attached to the membrane surface or within the pores of the membrane using various cleaning agents and techniques (Fujioka et al., 2018; Goosen et al., 2005; Gul et al., 2021; Le-Clech et al., 2006; Loganathan et al., 2015; Wang et al., 2014). As a result, membranes can be reusable after their cleaning and disinfection without disposing of or replacing them with new membranes. Chemical usage for membrane cleaning should be optimized to reduce recovery costs and safety concerns.

Different membrane materials have different degrees of water permeability to transmembrane pressure (TMP) and respond differently to types of chemicals used for cleaning procedures (Cheryan, 1998; Lee et al., 2016). Starchy suspensions as effluents usually are treated by conventional methods, and few reports are found in the literature related to membrane technology (Moghaddam & Sargolzaei, 2012).

Microfiltration has been applied for the extraction of amaranth starch from starch milk containing 2.16% total solids, 1.10% starch, 0.54% non-starch polysaccharides, 0.33% protein, 0.09% fat, 0.10% ash, and a pH of 6.7. A water flush to remove loosely bound material and a hot 0.2 M NaOH solution wash to remove adsorbed organic material were ineffective methods to recover membrane permeability. The membrane used for all trial work was a Pellicon 2 Ultracel PLCXK membrane (Millipore). This had a flat plate (cassette) configuration, a filtration area of 0.1 m2, a nominal molecular weight limit (NMWL) of 1000 kDa and was constructed of regenerated cellulose (Middlewood & Carson, 2012). Following the two-step cleaning cycle, the membrane was stored overnight in 0.1 M NaOH, recovering permeability up to only 66%. Further cleaning using Triton X-100 and phosphoric acid washes recovered permeability up to 76%. The use of Triton X-100 was basically because amaranth starch contains proteins, and this detergent is used to extract proteins from cells and used in membranes clogged with proteins.

It is reported that after processing high starch concentration suspensions, the combination of low crossflow velocities and/or high transmembrane cleaning procedure functioned better to recover membrane permeability. For the experiment, a module of four tubes with an internal diameter of 18 mm and a length of 1.83 m, offered an effective membrane area of 0.35 m2. (Shukla et al., 2000). In addition, Shukla and coworkers found that the effectiveness of a sequence of chemical and enzyme cleanings somehow depended on the order in which the chemicals were applied. The most used chemical for cleaning fouled membranes is NaOH; however, its usage is limited by the properties of the material used for the manufacturing of the membranes (Antón et al., 2015). The most efficient membrane cleaning procedure recovered almost 90-96% permeability, depending on the application and membrane type (Filloux et al., 2015; Jepsen et al., 2018).

This study sought to find the most efficient process for cleaning the MF membranes used for the concentration of sago starch suspensions. At the end of the MF process by tangential flow filtration, the membranes were rinsed with tap water. The methods were evaluated with respect to their normalized permeate flux (NPF) and normalized water permeability (NWP).

2. Materials and methods

2.1. Microfiltration membrane cassettes

A microfiltration polysulfone flat sheet membrane filter cassette (Centramate cassette, Pall Corporation, USA) with a surface area of 0.1 m2 and pore size 0.45 μm (PSM45C110.45 μm) was used. Initial water permeability analysis, reported as NPF and NWP of a clean MF membrane cassette (Pall Corporation, USA), was necessary prior to any experiment for purposes of comparison. Dirty MF membrane cassettes (cassettes used in the tangential filtration process for the concentration of 1% and 3% model sago starch suspensions) were the focus of this study.

During processing of the starch suspension by TFF, the membranes were clogged by starch granules, and these were designated “dirty membranes”. Firstly, the dirty membrane was washed with tap water to remove the starch on the membrane surface, which was an easy process, then the membranes were rinsed with distilled water. The permeability was measured to ascertain the efficiency of the first cleaning. After the first cleaning, we proceeded to wash the membrane by a backflushing or suction method and the permeability was measured. Finally, after completing the second cleaning permeability, the chemical method and the same process to measure the permeability were applied. The permeating flux was measured as a function of the membrane area and the transmembrane pressure applied, and then the third permeability was reported.

All the procedures for TFF, starch suspension preparation, and membrane cassette characteristics are reported elsewhere (Siong et al., 2019). The chemical used for cleaning MF membranes was NaOH, and in order to neutralize it, 1 MH_2SO_4 solution was used (Fisher Scientific, Pittsburgh, PA)and rinsed with distilled water to eliminate all residual chemicals.