Journal of Food Engineering 195 (2017) 85–96

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Protein recovery from potato processing water: Pre-treatment and membrane fouling minimization

Shirin Dabestani [a, b], Jayashree Arcot [b, c, *], Vicki Chen [a, b]

[a] UNESCO Centre for Membrane Science and Technology, School of Chemical Engineering, The University of New South Wales, Sydney 2052, Australia
[b] ARC Training Centre for Advanced Technologies in Food Manufacture, School of Chemical Engineering, The University of New South Wales, Sydney 2052, Australia
[c] Food Science and Technology Group, School of Chemical Engineering, UNSW Australia, Sydney 2052, Australia

ARTICLE INFO

Article history:
Received 6 February 2016
Received in revised form
9 September 2016
Accepted 17 September 2016
Available online 28 September 2016

Keywords:
Potato protein
Ultrafiltration
Fouling
Cleaning efficiency

ABSTRACT

Extracting desirable potato proteins from potato processing industry water that contained other major components such as starch and fibre was investigated using membrane processes. The method was assessed based on the recovery yield, concentrating the protein and minimising the fouling by different operating conditions and combination of pre-treatments.

In this laboratory scale study, the recovery of protein from potato processing water (PPW) was evaluated by using seven combinations of sedimentation, centrifugation, paper filtration, microfiltration (MF) and ultrafiltration (UF) processes to achieve high yields of highly concentrated protein. The removal of 95% of starch and 78% of fibre were achieved by centrifugation at selected conditions and using 2.5 μm filter paper. The filtrate was treated with a 0.22 μm Polyvinylidene difluoride (PVDF) MF membrane prior to the UF process. The inclusion of the MF process led to the reduction of UF fouling by 30% assessed from the transmembrane pressure. UF membrane of 10 kDa Polyethersulfone (PES) was effective in concentration of protein, rich in protein from the patatin family. Little loss of the higher molecular weight proteins was observed with the combination of pre-treatments and ultrafiltration. Fouling minimization was approached through different pre-treatments, without chemical addition and pH change to prevent denaturation of protein. Fouling was improved by 72% using the proposed process compared to that of centrifugation as pre-treatment only prior to ultrafiltration. Three types of cleaning detergents including acid, base and surfactant were studied to investigate cleaning efficiency and the mechanism of fouling. Higher cleaning efficiency (97%) and sustainable cleaning were achieved with base cleaning (100 ppm Sodium hydroxide) compared to acid cleaning (100 ppm Hydrochloric acid) and surfactant cleaning (5 wt % Sodium dodecyl sulfate).

1. Introduction

Waste treatment has been a challenge for the potato processing industry for many years. The wastewater effluent with high concentrations of potassium and Chemical Oxygen demand (COD) caused by the presence of starch, proteins, amino acids and sugars, imposes expensive treatment processes to the companies (Meindersma, 1980; Strætkvern and Schwarz, 2012). However, this waste effluent contains high amounts of valuable by-products. Starch content of this waste stream is being recovered using simple separation systems such as hydro-cyclones in some manufacturing sites but the commercially valuable protein is still being discharged in the waste stream. In Fig. 1, a schematic representing the process of the potato chips production is shown.

Potato proteins have high functionality and nutritional value and are considered as one of the best plant proteins (Friedman, 1996; Kapoor et al., 1975; Liedl et al., 1987; Løkra et al., 2009; Meister and Thompson, 1976) and can be utilized in food applications if recovered in native form with high quality and be isolated by the methods that do not result in denaturation (Ghosh, 2003). Good foaming and emulsion properties of these proteins have been reported by several authors (Edens et al., 1997; Holm and Eriksen, 1980; Jackman and Yada, 1988; Wojnowska et al., 1982) and many

* Corresponding author. ARC Training Centre for Advanced Technologies in Food Manufacture, School of Chemical Engineering, The University of New South Wales, Sydney 2052, Australia.
E-mail address: j.arcot@unsw.edu.au (J. Arcot).

http://dx.doi.org/10.1016/j.jfoodeng.2016.09.013
0260-8774/

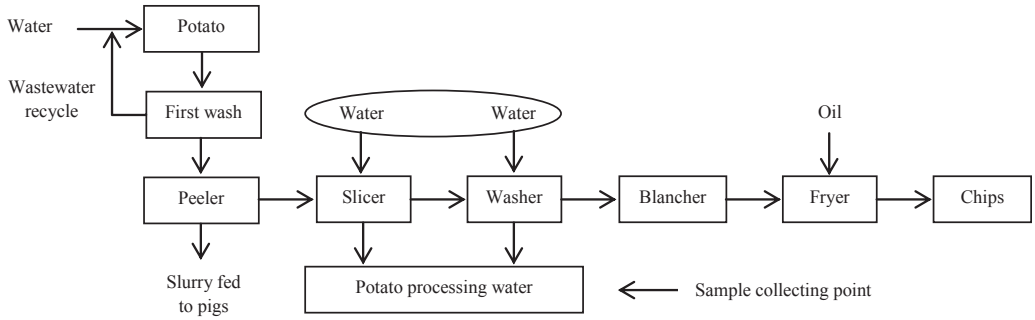

Fig. 1. Block diagram of the potato chips production and processing water.

studies have been done to recover high quality un-denatured protein (Ghosh, 2003; Løkra and Strætkvern, 2009).

Patatin, the major protein of potato of high functionality, forms around 40% of the whole protein for different cultivars of potato. Molecular weight of patatin is around 40–45 kDa and its EAAI (essential amino acid index) is 89% which is relatively high comparing to EAAI of many animal and plant proteins (Pouvreau et al., 2001; Strætkvern and Schwarz, 2012). The other potato proteins are in the range of 19–22 kDa (Strætkvern and Schwarz, 2012; van Koningsveld et al., 2001). Nutritional value of potato protein is comparable to the protein of whole egg and some of its amino acid contents are relatively high compared to many plant proteins based on the amino acid composition (Friedman, 1996; Kapoor et al., 1975; Liedl et al., 1987; Meister and Thompson, 1976).

Different techniques such as traditional concentration, heat coagulation and precipitation, Ion-exchange on carboxymethyl cellulose, Ion-exchange using Expanded Bed Adsorption (EBA) and UF have been used to recover the potato fruit juice (PFJ) protein (potato fruit juice is the juice generated from potato starch production that mainly contains water, salts and protein while potato processing water that was used in this study is the water sprayed on potato during processing to wash the excess starch and fibre out). The first four methods (concentration, coagulation, precipitation and ion exchange on carboxymethyl cellulose), have resulted in relatively high yield of recovered protein but have failed to recover completely un-denatured high quality protein due to the usage of heat and acids (Gonzalez et al., 1991; Løkra and Strætkvern, 2009; Pots et al., 1998; Strætkvern et al., 1999). Heat precipitation is being commercially used to recover protein but the product can only be used for animal feed due to low re-solubility of the product at neutral pH (Knorr, 1980; Knorr et al., 1977; Løkra et al., 2008; Løkra and Strætkvern, 2009; Meister and Thompson, 1976; Seibles, 1979).

The use of EBA has been reported to be appropriate to recover Patatin i.e. the major potato protein (Strætkvern and Schwarz, 2012; Strætkvern et al., 1999). This technique is not only complex and expensive but the removal of glycoalkaloids has not been very successful. Hence, the process must be used in combination with another process to remove glycoalkaloids (Strætkvern and Schwarz, 2012). However, EBA in combination with simulating moving bed technology is currently used to fractionate potato protein industrially by Solanic Company in The Netherlands (Alting et al., 2011).

Membrane technology has been successfully employed and commercialised for protein recovery from wastewater effluent from dairy processing for many years. MF, UF and Reverse Osmosis (RO) have been used widely in the dairy industry to separate different components such as casein and whey protein. UF has been used in plant protein extraction from jojoba (Nabetani et al., 1995) and alfalfa (D'Alvise et al., 2000) and showed acceptable results in the removal of impurities (sugar, toxicants, polyphenols and other low molecular weight components). RO also has been used for wastewater treatment in potato starch production plants (Rausch, 2002; Rüffer et al., 1997; Zwijnenberg et al., 2002). It has been used after starch separation to concentrate protein before the coagulation process and the permeate being recirculated back in to the process line for initial washing of potatoes. RO, however, is not appropriate to concentrate and recover protein due to retention of low molecular weight components and mineral in the final protein product (Strætkvern and Schwarz, 2012; Zwijnenberg et al., 2002). UF has been reported as an appropriate technology to recover relatively high yield of high quality potato protein (Strætkvern and Schwarz, 2012; Wojnowska et al., 1982; Zwijnenberg et al., 2002). However, the optimization of membrane process to mitigate fouling problems, enhance removal of toxicants and impurities such as micron size fibres and glycoalkaloids to achieve high quality protein products has not been systematically examined. In this study, fouling and protein recovery from potato process water was investigated utilizing a number of potential pre-treatments and filtration conditions to target high quality protein production. Sedimentation, centrifugation, prefiltration with filter paper and microfiltration were assessed as pre-treatments to remove particulate and fibrous matter prior to a final concentration with 10 kDa molecular weight cut-off ultrafiltration with the aim of simultaneously removing glycoalkaloids and other low molecular weight components. Flux stepping and constant flux experiments were used to evaluate operating conditions where fouling was relatively slow and was conducted using a dead end filtration configuration. Protein recovery was assessed by colorimetric assays and SDS-PAGE. Additional characterisation of the feed was undertaken using total organic carbon and Liquid Chromatography – Organic Carbon Detection (LC-OCD).

Membrane fouling by protein has always been a challenge for membrane use in the food industry due to environmental and economic factors. A reduction in separation efficiency and consecutive replacement of the fouled membrane can be minimised by regular chemical cleaning (Chen et al., 2006). The important factors of ideal cleaning include ease, speed, efficiency, meeting all sanitary requirements of installation, and cause no damage to the membrane (Makardij et al., 1999). The type of cleaning agent, its concentration, the cleaning cycle and its frequency, the hydrodynamic conditions and operating temperature and pressure determine the success of a chemical cleaning process (Field et al., 2008). Acid, base, surfactant and enzymatic cleaning agents are among the common cleaning solutions for membrane cleaning in industry based on severity of fouling (Mulder, 1996). Alkalline and surfactant cleaners such as NaOH and SDS are more effective for protein fouling removal rather than acid cleaners such as HCl for PES membrane (Chen et al., 2006). In this study, cleaning of PES UF membrane fouled with potato protein was investigated