Separation and Purification Technology 127 (2014) 192–201

Contents lists available at ScienceDirect

Separation and Purification Technology

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

Recovery of tapioca starch from pulp in a conical basket centrifuge – Effects of rotational speed and liquid to solid (L/S) ratio on cake formation and starch–pulp separation efficiency

K. Saengchan [a], M. Nopharatana [a], W. Songkasiri [b,*]

[a] Department of Food Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi (KMUTT), Thung khru, Bangkok 10140, Thailand

[b] National Center for Genetic Engineering and Biotechnology (BIOTEC), Excellent Center of Waste Utilization and Management (EcoWaste), Bangkhuntien, Bangkok 10150, Thailand

ARTICLE INFO

Article history:
Received 18 February 2013
Received in revised form 6 January 2014
Accepted 17 February 2014
Available online 1 March 2014

Keywords:
Centrifugal force
Extraction
Filtration
Specific cake resistance
Starch separation efficiency
Tapioca starch

ABSTRACT

Thai tapioca starch factories have been facing a problem of starch loss in the extraction stage at approximately 30% of the total loss. In an extractor, tapioca starch granules are extracted from pulp through the mechanisms of centrifugation and filtration. Centrifugal force is the main driving force for filtration. To improve the starch recovery from pulps, this research investigated the starch–pulp separation mechanism and factors affecting the starch separation efficiency. Experiments were conducted with a pilot-scale conical-screen centrifuge at various rotational speeds (900–1500 rpm or 205.50–570.85 RCF) and liquid-to-solid (L/S) ratios (4.6–11.7). The deposited cake properties, specific cake resistance, and starch separation efficiency were determined along 6 sections of the filtering screen. Increasing rotational speed and basket radius resulted in an increase in starch separation efficiency due to an increase in centrifugal force generating a high pressure drop across the filtering screen. Centrifugal force affected the deposited cake properties that are specific cake resistance, cake solidosity, cake permeability and cake thickness.

1. Introduction

Tapioca or cassava is cultivated in most tropical countries including Thailand. Tapioca is an attractive source as edible product and as raw material for native tapioca starch, which is important for a wide range of industrial goods, including paper, textile, glue, cosmetic, pharmaceutical, and various bio-products. Thailand is one of the world's leaders on tapioca starch export. The exporting value of tapioca starch has been continually increased and reached a value of 1.54 billion USD in 2012 [1]. Native tapioca starch production, a process where starch granules are separated from grinded tapioca root, consists of 8 steps: tapioca root receiving, washing, rasping, extracting, separating, dewatering, drying, and packing the starch product.

Production of tapioca starch yields dry starch as an end product and pulps as solid-waste. The starch production process generates tapioca pulps of approximately 10–15% of initial fresh root weight, or in another word, equal to 1.4 tons of pulp residues per ton of starch. In general, tapioca pulp residues from an extraction unit are sent to a storage area waiting to be sun-dried before selling as a low value of animal feeds or fertilizer. However, starch can be lost with pulps up to 10% dry basis of starch input. The approximate starch loss value of pulp residues are 2.08 million USD annually in one factory with a capacity of 200 tons a day [2–3]. Further, fresh pulp residues spoil rapidly in the humid warm tropical environment as microorganisms quickly multiply on high nutrient substrate [3]. To reduce the starch loss and environmental impact, process optimization is applied. Other than minimizing wastes and emissions released to the environment, this research aimed to understand extraction mechanisms in order to increase production efficiency, resulting in the reduction of production cost.

2. Theory

A conical basket centrifuge is an equipment facilitating starch granule separation from tapioca pulps in the starch extraction step. Starch separation takes place on a rotating conical sieve, where centrifugal force drives starch granules to pass through the filtering screen. Fig. 1 presents a diagram of a conical-screen extractor. The starch separation efficiency depends on design, operation and feed variables. The design variables relate to the physical dimension of the machine, including basket radius and screen aperture. The operation variables are rotational speed and volumetric feed flow rate, while the feed variables are liquid to solid (L/S) ratio and grinded tapioca root size [4–7]. Starch loss in the process

* Corresponding author. Tel.: +66 86 909 5210; fax: +66 2 452 3455.
E-mail address: warinthorn@biotec.or.th (W. Songkasiri).

http://dx.doi.org/10.1016/j.seppur.2014.02.026
1383-5866/

Nomenclature

List of symbols

RCF	relative centrifugal force
F_G, F_g	centrifugal and gravitational force (N, kg m/s^2)
g	gravitational acceleration (m/s^2)
m	mass (kg)
r	radius (m)
Q	filtrate flow rate (m^3/s)
V	filtrate volume (m^3)
t	time (s)
A	filtration area (m^2)
Δp	operating pressure (Pa, N/m^2)
Δp_m, Δp_c	pressure drop across medium and cake (Pa, N/m^2)
R_m, R_c	medium and cake resistance (1/m)
w	mass of deposited cake per unit area (kg/m^2)
E	total starch separation efficiency (%)
C_o, C_i	starch content in filtrate and feed (kg/m^3)
Q_o, Q_i	volumetric flow rate of filtrate and feed (m^3/s)
m_{av}	ratio of mass wet/dry cake
K	cake permeability (m^2)
k_1	Kozeny constant
D_s	surface area average particle diameter (m^2)

Greek letters

ω	rotational speed (1/s)
α	specific cake resistance (m/kg)
ρ_l, ρ_s	liquid and particle density (kg/m^3)
ε, ε_s	cake porosity and cake solidosity
ϕ_s	particle sphericity
μ	filtrate viscosity (N s/m^2)

mainly occurs due to inappropriate design and operation of the extractor [8–9].

The mechanism of tapioca starch granule–pulp separation relates to centrifugation and filtration effects. The driving force for filtration is the centrifugal force acting on starch slurry – a mixture of starch granules, water, tapioca pulp, and impurities. After starch slurry is fed through a feed inlet pipe at the bottom of the filtering screen, the slurry is accelerated up along the inclined screen due to the centrifugal force. Water facilitates starch granules to pass through the screen, while tapioca pulp is retained and discharged at an upper screen outlet.

In a conical-screen extractor, centrifugal force is typically specified as relative centrifugal force (RCF) rather than rotational speed. RCF is the ratio of centrifugal and gravitational forces as shown in Eq. (1), where F_G is centrifugal force, F_g is gravitational force, m is particle mass, ω is rotational speed, r is basket radius, and g is gravitational acceleration. Since RCF includes rotational speed and basket radius in the calculation, it is applied to scale up or down of centrifugal separation process.

$$RCF = \frac{F_G}{F_g} = \frac{mG}{mg} = \frac{\omega^2 r}{g} \quad (1)$$

The centrifugal force generates high pressure drop across the filtration system, driving the water and small particle through the media of deposited cake and screen as shown in Fig. 2. The pressure drop (Δp) from centrifugal action is calculated using Eq. (2), where ρ_s is density of cake, ω is rotational speed, r_2 is an outer radius (basket radius), r_1 is an inner radius, or in another word, the difference between basket radius and cake thickness. r_1, relating cake thickness and feed condition, is constant when the system reached steady state. As the cake thickness and solid fraction in feed increase, the r_1 decreases, leading to the rise in the pressure difference across the cake.

$$\Delta p = \frac{\rho_s \omega^2 (r_2^2 - r_1^2)}{2} \quad (2)$$

The centrifugal-filtration performance depends on the mass flow rate of starch at the filtrate outlet and deposited cake properties, including specific cake resistance, cake solidosity, and cake permeability.

2.1. Starch separation efficiency

In the tapioca starch–pulp separation process, total starch separation efficiency (E) is calculated using Eq. (3), where C_o and C_i are starch content in filtrate and feed, Q_o and Q_i are volumetric flow rate of filtrate and feed, respectively.

$$E = \frac{C_o \cdot Q_o}{C_i \cdot Q_i} \times 100 \quad (3)$$

2.2. Specific cake and medium resistance

The total resistance of centrifugal-filtration process is the combination of medium and cake resistances. Eq. (4) is a typical filtration equation to obtain Q, the filtrate flow rate, where t is

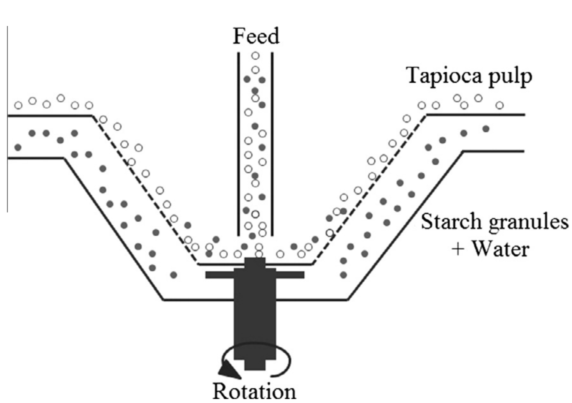

Fig. 1. Conical-screen extractor.

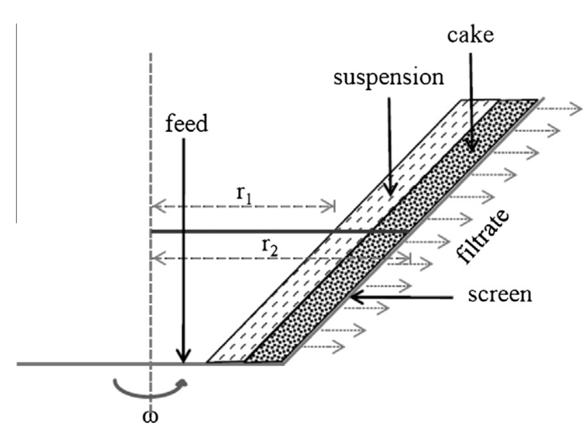

Fig. 2. Filtration system in conical-screen extractor.