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Enhancement of starch-pulp separation in centrifugal-filtration process: Effects of particle size and variety of cassava root on free starch granule separation

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ABSTRACT

Cassava root and starch are used for human food consumption, animal feed and raw material for various industries, including the renewable energy industry. The composition and structure of cassava root depend on variety, age, environmental conditions and planting season. Starch granules following rasping step are divided into free and bound starch; the latter remains in the pulp and is difficult to separate, while the former is not bound inside the pulp complex structure. In a starch extractor, cassava starch granules are separated from pulp through the mechanisms of centrifugation and filtration. This research aimed to study the effects of particle size and variety of cassava root, centrifugation and filtration mechanisms on free starch granule separation efficiency. Three cassava root varieties, Rayong 9, Rayong 11 and Kasetsart 50, were classified by particle size after grinding and sieving. Experiments were conducted at various relative centrifugal forces (RCF: 0–487 × G) and pressure drops (2.5–12.0 kPa). The free starch separation efficiency increased with decreasing particle size of all cassava root varieties. The grinding of cassava root into small pieces caused cell wall breakage, facilitating free starch separation from the pulp. As the RCF increased, some bound starch granules were released due to the force acting on the cassava pulp. The pressure drop in filtration process drove the free starch granules to pass through the screen although this force was insufficient to separate the bound starch granules from the fiber.

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Nomenclature

List of symbols

A	filtration area (m^2)
D_s	surface area average particle diameter (m^2)
F_G	centrifugal force (N, $kg\,m/s^2$)
F_g	gravitational force (N, $kg\,m/s^2$)
G	centrifugal acceleration (m/s^2)
g	gravitational acceleration (m/s^2)
k_1	Kozeny constant
m	mass (kg)
Δp	operating pressure (Pa, N/m^2)
Q	volumetric flow rate (m^3/s)
RCF	relative centrifugal force
R_c	cake resistance (m^{-1})
R_m	medium resistance (m^{-1})
r	radius (m)
t	time (s)
V	volume (m^3)
w	mass of deposited cake per unit area (kg/m^2)

Greek letters

α	specific cake resistance (m/kg)
ε	cake porosity (volume fraction of void in the cake)
ϕ_s	particle sphericity
μ	filtrate viscosity ($N\,s/m^2$)
ρ_s	particle density (kg/m^3)
ω	rotational speed (1/s)

1. Introduction

Cassava (*Manihot esculenta* Crantz) or tapioca is ranked as the third most essential carbohydrate source, which is cultivated in the tropical and subtropical countries including Thailand (Reinhardt et al., 2013). Cassava is a drought-tolerant crop and often grows under uncertain rainfall conditions, infertile soils and limited input resources (Fregene and Puonti-Kaerlas, 2002; Saengchan et al., 2009). The tuber of cassava is an attractive source as an edible product and as raw material for native cassava starch. Cassava root and starch are used directly as human food and have many other uses, including pharmaceutical, textile, cosmetic, petroleum, biodegradable products paper and pulp industries, while cassava chips and pellets are used as animal feed and in alcohol production (Reinhardt et al., 2013).

The main cassava product is dried starch which can be classified into three types: native starch, modified starch and sago pearls (Sriroth and Piyachomkwan, 2002). Native cassava starch production, a process where starch granules are separated from ground cassava root, consists of 8 steps: cassava root receiving, washing, rasping, extracting, separating, dewatering, drying, and packing the starch product. Starch granules are locked with cassava pulp and other constituents: proteins, soluble carbohydrates and fats. The major components of cassava pulp are cellulose, hemi-cellulose, lignin and protein matrix, which form lignocellulosic material. Separation of starch granules from the cassava pulp is essential in the manufacture of the cassava starch (Sriroth et al., 2000b).

The mechanism of cassava starch granule-pulp separation in a starch extractor 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, cassava pulp and impurities. Starch slurry is fed through a feed inlet pipe at the bottom of the filtering screen and then the slurry is accelerated up along the inclined screen due to the centrifugal force. Water facilitates starch granules to pass through the screen, while cassava pulp is retained and discharged at an upper screen outlet (Grimwood, 2005; Svalovsky, 2000; Wallace and Leung, 1998).

The starch-pulp separation efficiency depends on design, operation and feed variables. The design variables relate to the physical dimension of the machine, including basket radius, filtering screen 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 cassava root characteristics (Saengchan et al., 2014). The characteristics and chemical compositions of cassava root depend on variety, age and environmental growing conditions (Galliard and Bowler, 1987). Starch loss in the process mainly occurs due to inappropriate design and operation of the extractor (Schwille et al., 2002). The starch loss with pulp residues are approximately US$2 million annually in one factory with a capacity of 200 t a day (Saengchan et al., 2014).

The affecting variables on total starch production efficiency have been studied. However, the research did not fully describe the starch granule characteristics and the effects of centrifugation and filtration on starch granule and pulp separation process (Saengchan et al., 2014). To improve the starch recovery from pulp, the starch-pulp separation mechanism and factors affecting the starch separation efficiency need to be investigated. Thus, this research explored the effects of particle size and variety of cassava root on starch-pulp separation efficiency. The effects of centrifugation and filtration, the main mechanisms in an extractor, on starch granule-pulp separation were studied.

1.1. *Characteristics and composition of cassava root*

Cassava root is a long tuber with a thin brown skin and a white inner flesh. Cassava root portion is divided into three main parts which are periderm, cortex and starch flesh. The starch flesh is the central portion of the root, where starch granules are deposited (Reinhardt et al., 2013). The peel of cassava root consists of the outer periderm and the cortex. The periderm consists of a few layers of dead cork cells, sealing the outer layer of the root, while the cortex is a 1–2 cm thick white layer located beneath the periderm (International Institute of Tropical Agriculture, 1990)

Several cassava varieties exist in Thailand. Most varieties in the country are the bitter type, used for the production of animal feed, starch and its derivatives. The chemical composition and structure of cassava root depend on the cassava variety, harvesting age, climate condition and other environmental factors during cultivation (Galliard and Bowler, 1987). Rayong 1, the first cassava variety developed in Thailand, was released in 1975. Its production yield and starch content (wet basis) are approximately 14.0 t/ha and 18.1–23.0%, respectively. Since 1978, new cassava varieties with high starch content, good adaptability and suitable for starch industrial purposes have been bred locally. The characteristics, i.e., productivity, starch content, and advantage, of cassava varieties in Thailand are summarized in Table 1.