Effects of Rotational Speed and Inlet Concentration on Fine Extraction Efficiency at Different Screen Apertures of an Extractor

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Abstract— Cassava starch is one of the most important agriculture-based products in Thailand. Thai cassava starch production factories have been facing one vital problem--starch loss in an extraction. Therefore, this research intended to overcome the problem by studying the effects of rotational speed and inlet concentration with different screen apertures on fine extraction efficiency. The experiments were divided into two parts. In the first part, centrifugation and filtration mechanisms in fine extraction process were studied. The experiment was conducted at 3 different centrifugal forces of 600G, 775G, and 950G. The results showed that the starch extraction efficiency increased with increasing centrifugal force. The centrifugal force of 950G yielded the highest starch extraction efficiency, which was higher than separation without centrifugal force of approximately 42.84%. At a lower centrifugal force, the starch extraction efficiency was less, because a low centrifugal force was insufficient to destroy cell wall and adhesive force between fibrous network and starch granules. To study filtration mechanism, pressure drop across the resistance was varied to be 25.3, 32.0, and 39.5 kPa. The pressure drop across the resistance of 39.5 kPa provided the highest extraction efficiency, because more pressure drop meant more driving force to make starch granules passed through the filter medium and cake. In the second part, experiments were conduct to study the effects of rotational speed and inlet concentration with different screen aperture using a conical screen extractor with Ø47 cm basket and half-angle of the cone of 45°. The experiments were conducted at five different screen apertures of 200, 250, 300, 350, and 400 mesh. The rotational speed was varied to be 600, 680, and 750 rpm. L/S ratio was varied to be 7:1 and 9:1. The results showed that the starch extraction efficiency increased with increasing rotational speed. The rotational speed of 750 rpm yielded the highest starch extraction efficiency. The starch extraction efficiency increased with increasing L/S ratio. The reason was that water influenced particle packing. The filtration rate was higher and starch granules easily moved through the screen aperture. A larger screen aperture meant a higher filtrate rate. In summary, a higher rotational speed and L/S ratio with a larger screen aperture increased filtration and starch extraction efficiency.

Keywords— Fine Extraction, Liquid-Solid Ratio, Rotational Speed, Screen Aperture, Starch Extraction

I. INTRODUCTION

CASSAVA is one of the most important commercial crops in Thailand. Thailand is the world’s largest producers and exporters of cassava starch. Thailand produces approximately 12% of total worldwide cassava root production inferior to Nigeria and Brazil, respectively. In 2010, Thailand exported cassava starch product of approximately 11% of the total Thai agricultural exported product or approximately 2.5 million tons, which is equal to 40,722 million baht [1]. Most starch exported products can be classified into three types, which are native starch, modified starch, and sago.

Cassava starch production process consists of 6 steps: root preparing, rasping, extracting, separating, dewatering, and drying. Many Thai cassava starch production factories have been facing one vital problem--starch loss during production. From the 28% of total starch loss during starch production process, the extraction unit has the highest starch loss of 17% with pulp and wastewater [2].

Starch extraction process can be divided into two steps: coarse and fine extraction. A conical screen centrifuge is used as an extractor. Water and sulfur dioxide are added during the extraction process to prevent filter clogging, protect starch loss from microbe, and bleach the starch. The loss of starch in this step is mainly due to unsuitable operating condition at specific design of an extractor.

The difference between the coarse and fine extraction, the fine extraction is the repeated process of extraction with a finer screen aperture. Starch slurry exiting the coarse extractor contains a large amount of fine fiber. Thus, the fine extractor is required for removing fine fiber from the slurry in order to have more starch content. This project intended to improve the starch extraction efficiency by studying the effects of rotational speed and inlet concentration on fine extraction efficiency with different screen apertures to increase the cassava starch production efficiency.
II. MATERIALS AND METHOD

A. Materials
The starch slurry at inlet of a fine extractor containing starch granules, fine pulps, and water were obtained from Cholcharoen factory (Banbung, Chonburi).

B. Method
The experiment was divided into two parts. First, the effects of centrifugation and filtration were studied using a refrigerated centrifuge and a vacuum pump in laboratory scale. Second, the effect of rotational speed and inlet concentration with different screen apertures were studied using a conical screen extractor in pilot scale.

Centrifugation Mechanism
Twenty-gram of starch slurry was taken into a 30-ml centrifuge tube centrifuged with centrifugal forces of 600G, 775G, and 950G for 3 min by a refrigerated centrifuge (Model himac CR21, Hitachi, Japan). Then, the sample was filtered through a nylon screen with a size of 300 mesh. Starch content in filtrate and pulp were determined. Samples were duplicated.

Filtration Mechanism
Forty-gram of starch slurry was taken into a 100-ml beaker. Then, the sample was filtered through a nylon screen with a size of 300 mesh with pressure drop across resistances of 25.3, 32.0 and 39.5 kPa. Starch content in filtrate and pulp were determined. Samples were duplicated.

Pilot Scale Experiments
In the experiment, the nylon was used as screen aperture which was varied to be 200, 250, 300, 350, and 400 mesh. Rotational speed of extractor was varied to be 600, 675, and 750 rpm. The liquid-solid ratio was varied to be 7:1 and 9:1. The feed flow rate was 15 l/min.

A conical screen centrifuge with half-angle at the apex of the cone of 45° was used as an equipment. The filter medium was nylon screen with different meshes. The filtrate outlet would be divided into 6 sections for studying the starch extraction mechanism on various radial distances. Figures 1 and 2 show the experimental setup and device of this research.

The starch content was determined using the optical method based on starch-iodine reaction (AOAC, 1995) and then the absorbance was determined.

For indicating the effect of rotational speed and inlet concentration with different screen apertures on fine extraction efficiency, flow rate of filtrate and fine pulp, specific cake resistance, %starch content in filtrate and fine pulp, and extraction efficiency were considered.

III. RESULTS AND DISCUSSION

A. Effect of Centrifugation on Starch Extraction Efficiency
Cassava extraction process consists of 2 mechanisms, centrifugation and filtration. Centrifugation is the process using a centrifugal force to separate solid from liquid phase generated by a spinning rotor. Driving force in this experiment is a centrifugal force which was changed with rotational speed.

\[ F = \frac{m \omega^2 r}{2} \]  

Centrifugation generated both the force for destroying adhesive force between fibrous network and granules and driving force for extraction.

Figure 3 showed the starch extraction efficiency with different centrifugal force. The results showed that the starch extraction efficiency increased with increasing centrifugal force. The centrifugal forces of 950G provided the highest starch extraction efficiency, which was higher than extraction without centrifugal force about 42.84%. At a lower centrifugal force, the starch extraction efficiency was less, because a low centrifugal force was insufficient to destroy cell wall and adhesive force between fibrous network and starch granules.
B. Effect of Filtration on Starch Extraction Efficiency

Another mechanism that occurs in cassava starch extraction is filtration. Filtration is the process of using filter medium to separate a mixture. The fluid and particles that are too small to pass through the holes can pass. The large particles retained on the medium are called “cake”. Water facilitates the starch granules to pass through the filter medium and cake. Fine pulps are retained on the filter medium. The reasons is followed the equation

\[ Q = \frac{A\Delta P}{\mu(R + R_c)} = \frac{A\Delta P}{\mu(R + \alpha w)} \]  

(2)

From figure 4, pressure drop across the resistance of 39.5 kPa provided the highest extraction efficiency because it had more driving force to make starch granules passed through the filter medium and cake.

C. Effects of Rotational Speed and Inlet Concentration with Different Screen Apertures on Filtrate Rate

A conical screen centrifuge was used to study the effects of rotational speed and inlet concentration with different screen apertures on starch extraction efficiency. Rotational speed is a parameter that affects on a centrifugal force. Inlet concentration is a parameter that affects on the moving of particles.

From figure 5, the rotational speed of 750 yielded the highest filtrate rate per open area, followed by 680 rpm and 600 rpm, respectively because the rotational speed affected the pressure drop across the resistance and the mass deposit on screen. So, the filtrate rate was reduced, which can be described by equation 2. When the pressure drop across the increased (\(\Delta P\)) with the rotational speed, the mass of cake deposited on the screen (w) would be decreased, the filtrate was increased.

At high rotation speed, the filtrate rate would be higher, because higher rotational speed meant more driving force to make the starch slurry pass through the screen surface.

Moreover, larger screen aperture had more filtrate rate because it had more open area for the starch slurry flowed through the screen.
D. Effects of Rotational Speed and Inlet Concentration with Different Screen Apertures on Specific Cake Resistance

In filtration process, starch slurry is filtered by screen and cake on the screen which are the resistances that obstruct water and starch granules flow through the screen. The resistances in filtration process are divided into 2 types: cake resistance and medium resistance.

Specific cake resistance indicates the performance of the filtration, which is related to the cake thickness. The cake thickness increases due to the deposition of solid on the filter medium, which can be changed by changing a feed flow rate and a pressure drop across the resistance, but the feed flow rate was fixed in this research. So, the pressure drop across the resistance is the main factor that affected on the cake thickness.

Figure 7 showed the specific cake resistance with different rotational speeds and screen apertures. The results showed that the rotational speed and the screen aperture inversely affected the specific cake resistance. At 600 rpm, a screen aperture of 400 mesh had the highest specific cake resistance ($1.69 \times 10^{15}$ m/kg) followed by a screen aperture of 350 mesh ($1.33 \times 10^{15}$ m/kg), 300 mesh ($1.31 \times 10^{15}$ m/kg), 250 mesh ($7.41 \times 10^{14}$ m/kg), and 200 mesh ($3.64 \times 10^{14}$ m/kg) because of the effect of the screen aperture. The screen aperture also affects on specific cake resistance. The smaller screen aperture gave the higher specific cake resistance because small screen aperture had low opportunity for the fine pulp to pass through the filter medium. So, there is more fine pulp particles deposited on the screen. At higher rotational speed (680 and 750 rpm), the specific cake resistance had lower because it had more pressure drop across the resistance to compress the cake structures.

Figure 8 showed the specific cake resistance with different inlet concentrations and screen apertures. The results showed that the L/S ratio increased with increasing rotational speed. The rotational speed of 750 rpm yielded the highest specific cake resistance at any screen aperture, because high rotational speed meant high centrifugal force to separate the starch granules and fine pulp. Moreover, the screen aperture of 200 mesh gave the highest specific cake resistance because the larger screen aperture releases more starch and liquid pass through the screen, the filtration rate was higher and the starch granules easily moved through the screen aperture resulting in higher the starch extraction efficiency. Therefore, higher rotational speed with larger screen aperture had higher starch extraction efficiency.

E. Effect of Rotational Speed and Inlet Concentration with Different Screen Apertures on Starch Extraction Efficiency

The starch content and filtrate rate were used to calculate the starch extraction efficiency. The starch extraction efficiency is the parameter that used to indicate the efficiency of extractor in term of extract starch from feed. The higher filtrate rate and starch content in filtrate mean higher extraction efficiency, which are described by following the equation:

$$\eta = \frac{C_{\text{inlet}} \cdot q_{\text{inlet}}}{C_{\text{outlet}} \cdot q_{\text{outlet}}} \times 100$$  (3)

The results of starch extraction efficiency in figure 8 were obtained from the experiment by varying screen aperture to be 200, 250, 300, 350, and 400 mesh and varying rotational speed of extractor to be 600, 675, and 750 rpm. The results showed that the starch extraction efficiency increased with increasing rotational speed. The rotational speed of 750 rpm yielded the highest starch extraction efficiency at any screen aperture, because high rotational speed meant high centrifugal force to separate the starch granules and fine pulp. Moreover, the screen aperture of 200 mesh gave the highest extraction efficiency because the larger screen aperture releases more starch and liquid pass through the screen, the filtration rate was higher and the starch granules easily moved through the screen aperture resulting in higher the starch extraction efficiency. Therefore, higher rotational speed with larger screen aperture had higher starch extraction efficiency.
resistance affected on starch extraction process. Higher centrifugal force and pressure drop across the resistance determined. The centrifugal force and pressure drop across the resistance decreased of porosity in the cake layers. So, the starch into a small space between the fibers, resulting in the arrangement, especially the small starch granules can move the filtration occurs.

The amount of water made the particles had more dispersion while particle dispersion and the cake compressibility. The high formation. The amount of water had an influence on the particle packing and cake extractability. Therefore, higher inlet concentration with larger screen aperture had higher the starch extraction efficiency.

Another experiment, screen aperture was varied to be 200, 250, 300, 350, and 400 mesh. The liquid-solid ratio was varied to be 7:1 and 9:1. The results showed that the starch extraction efficiency increased with increasing L/S ratio. The reason was that water influenced particle packing and cake formation. The amount of water had an influence on the particle dispersion and the cake compressibility. The high amount of water made the particles had more dispersion while the filtration occurs.

Solid that moved along with water can make the new arrangement, especially the small starch granules can move into a small space between the fibers, resulting in the decreasing of porosity in the cake layers. So, the starch granules can easily move through the screen aperture. Therefore, higher inlet concentration with larger screen aperture had higher the starch extraction efficiency.

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