Effects of Feed Flow Rates with Different Liquid to Solid Ratio (L/S ratio) on Fine Extraction to Increase Cassava Starch Production Efficiency

Aruntip Roygulchareon, Jindarat Pimsamarn, Warinthorn Songkasiri, Wiwat Ruenglertpanyakul, and Annop Nopharatana

Abstract**—**Thailand is the world's largest producers and exporters of cassava starch. There are 6 steps of the production of Cassava starch: root preparing, rasping, extracting, separating, dewatering, and drying. Almost 17% of the loss of cassava starch during the production process was occurs in the extraction step. The focus of this work is to studies the effects of feed flow rates with different liquid to solid ratio (L/S ratio) on fine extraction to increase the production efficiency of cassava starch. The extractor was designed by fixing rotational speed of extractor at 750 rpm, screen aperture of woven nylon basket to be 250 mesh and using a conical screen extractor with a basket angle of 45°. The starch milk feed rates were varied from 9, 12, 15 liters per min and varied liquid-solid ratio 7:1, 8:1, 9:1, and 10:1. The experimental results showed that increasing starch milk feed flow rate the starch extraction efficiency increased. Further, as the L/S ratio increased, the starch extraction efficiency increased up to a constant value

Keywords**—** Fine Extraction, Liquid-Solid Ratio, Feed Flow Rate, Starch Extraction.

I. Introduction

CASSAVA is a plant in lowland tropics so it suitable to growth in Thailand. Cassava in Thailand generate income for the country are ranked fourth after rice, rubber and sugar cane.50 to 55 percent of harvested cassava are sent to manufacture cassava starch, for which the domestic demand is as high as 1.3-1.7 million tons per year [1]. Most starch exported products can be classified into three types, which are native starch, modified starch, and sago.

In the production of cassava starch has yield loss during production process, which most in extraction process.

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In general, the extraction process is divided into two sets. First is a set coarse extraction by using a stainless steel sieve and second is fine extraction by using fabric filters. The fine extraction is reprocessing 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 get more starch content and reduce fine pulp. A conical screen centrifuge is used as an extractor. The loss of starch in this step is mainly due to unsuitable operating condition at specific design of an extractor.

Mechanisms of starch extraction are 2 processes. One is filtration and two is centrifugation. Filtration is the main process to separation starch slurry. It passes starch slurry through filter medium. The fluid which has passed through the filter is called the filtrate. The large particles retained on the medium are called "cake". Pressure drop is used for flowing fluid through the filter medium is relates with equation (1),when Q is filtrate flow rate, ΔP is pressure drop, μ is viscosity, R is medium resistant, R_c is cake resistant and α is specific cake resistance, and w is mass of cake deposited per unit area

$$Q = \frac{A\Delta P}{\mu(R + R_C)} = \frac{A\Delta P}{\mu(R + \alpha w)} \tag{1}$$

Centrifugation is the driving force for filtration, which affects on the pressure drop for filtration. The centrifugal force drives the feed slurry through the cake and the filter medium. The solids are slide along the cone from the small to the large diameter. The ratio of liquid per solid is measured the relative centrifugal force with respect to the earth's gravitational force as shown by equation (2). Where m is particle mass, ω is rotational speed, and r is radius.

$$F = m\omega^2 r \tag{2}$$

This project intended to study the effects of feed flow rates with different liquid per solid ratio (L/S ratio) on fine extraction to increase cassava starch production efficiency.

II. Materials And Method

A. Raw Materials Preparation

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

A conical screen centrifuge with half-angle at the cone apex of 45° was used as an equipment[3]. The filter medium was nylon screen 250 mesh. The geometry of a conical screen centrifuge is shown in The liquid-solid ratio was varied to be 7:1, 8:1, 9:1, and 10:1.The filtrate outlet was divided into 6 sections for studying the starch extraction mechanism on various radial distances. Figure 1 and 2 show the experimental setup and device of this research.

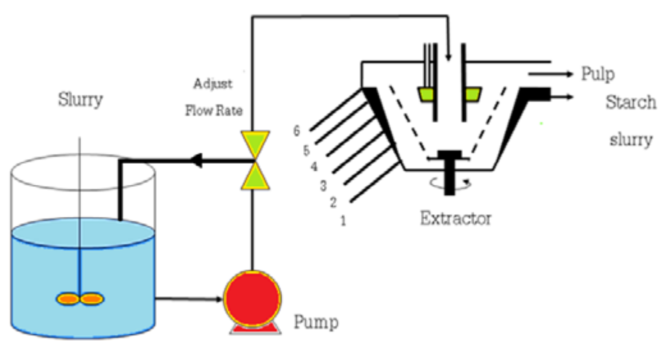
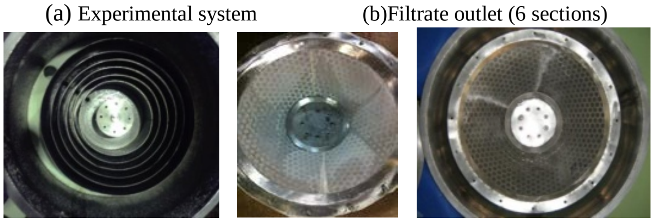


Fig.1 Experimental Setup

(a) Experimental system

(b)Filtrate outlet (6 sections)



(c) Top view of device

Fig.2 A Pilot--Scale Conical Screen Extractor

C. Analysis

The starch content was determined using the optical method based on starch-iodine reaction (AOAC, 1995) and then the absorbance was determined [4].

TABLE I
GEOMETRY OF PILOT—SCALE CONICAL SCREEN CENTRIFUGE

Parameters	R (m)	Filtration Area (m^2)	Open Area (m^2)
			250 Mesh (59 μm)
Top Radius	0.2350	-	-
Top Edge	0.2181	0.0372	0.01052
6th Section	0.1986	0.0461	0.01303
5th Section	0.1790	0.0418	0.01181
4th Section	0.1595	0.0374	0.01058
3rd Section	0.1400	0.0331	0.00936
2nd Section	0.1204	0.0288	0.00814
1st Section	0.1053	0.0234	0.00661
Bottom Radius	0.8846	0.0159	0.00450
Total		0.2639	0.07455

For indicating the effects of feed flow rates with different liquid to solid ratio (L/S ratio) on fine extraction efficiency, flow rate of filtrate and fine pulp, %starch content in filtrate, starch extraction efficiency, and fine pulp removal efficiency were considered.

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 separate starch from feed. Thus, this research will call the starch extraction efficiency in term of starch separation efficiency. The higher filtrate rate and starch content in filtrate mean higher separation efficiency, which are described by following equation 3.

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

The fine pulp removal efficiency was determined in term of total fine fiber in filtrate by AOAC (1990) [5].

III. Results And Discussion

The results were obtained from the experiment by varying liquid-solid ratio at 7:1, 8:1, 9:1, and 10:1 and varying feed flow rates in extractor at 9, 12, 15 liters per min .

The starch separation efficiency increased with increasing L/S ratio shown in figure 3, the starch separation efficiency of L/S ratio at 10:1 was higher than 7:1due to the amount of water, which had an influence on the particle dispersion when filtration occurred. When high amount of water made the solid particles easily moved along with water and made the new arrangement, especially the small starch granules can move out a small space between the fibers. Water in the solid particles can move easily because the water is out of pulp of starch.An increasing in L/S ratio meant decreasing inlet concentration (c), resulting in higher filtrate rate in equation 1.

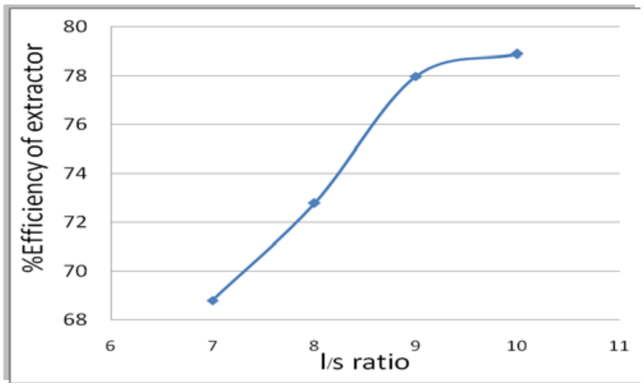
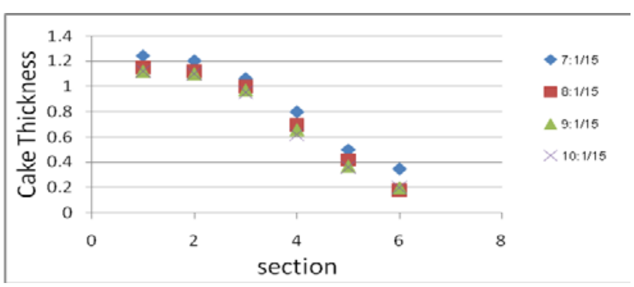
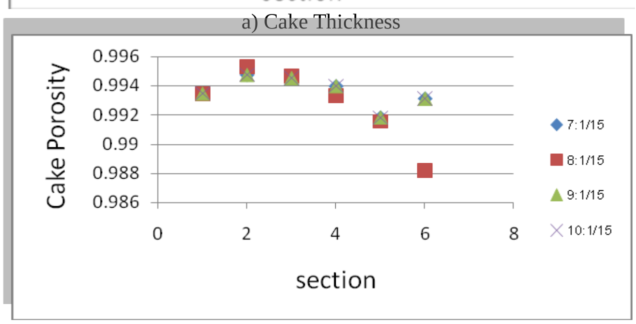


Fig.3 Starch Separation Efficiency at Inlet difference L/S ratio

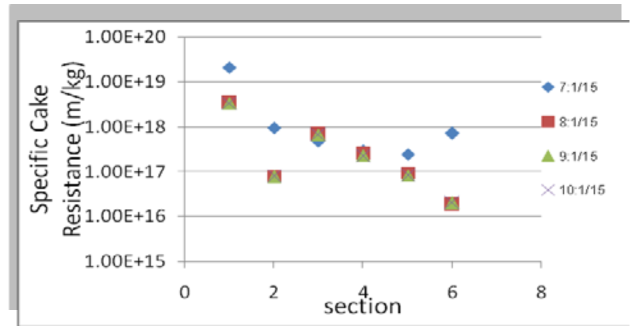
The results in figure 4 shows the measurement results for cake thickness, cake porosity, and specific cake resistance on each section on feed flow rate constant, which varied with the inlet concentration. The cake thickness decreased with the decreasing in solid content in starch slurry. When solid contents increase in starch slurry, the solid particle would clog easily due to the lower solid dispersion in starch slurry. The lower cake thickness provided a lower cake porosity, resulting in higher specific cake resistance. The slurry is to clog up the screen, making the cake. The slurry can be the cake into a loosely packed powder. Large particles that cannot pass filter will accumulate and clog in the screen and the spaces between the fibers. The cake thickness reduce with increasing L/S ratio, therefore, the sixth section has the highest L/S ratio and lowest cake thickness. However some of the sixth sections do not have the lowest thickness because pulp accumulated at top ring.



a) Cake Thickness



b) Cake Porosity



c) Specific Cake Resistance

Fig.4 Effect of Inlet difference L/S ratio on Cake Properties on Screen

The results in figure 5 show that show the starch content in pulp outlet in each experiment. A higher L/S ratio inlet gave the lower starch content in the fine pulp because higher starch content in the filtrate. So, the starch content in fine pulp should be inversely with the starch content in filtrate. The lower starch content in the fine pulp meant higher starch content in the filtrate, resulting in the higher starch extraction efficiency.

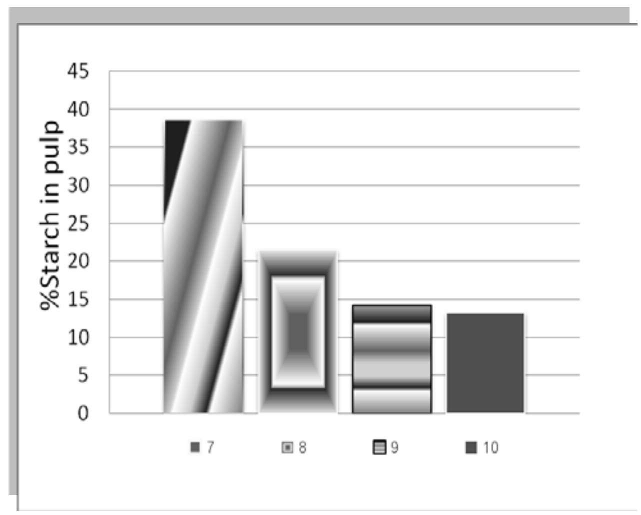


Fig.5 %Starch content in pulp at Inlet difference L/S ratio

Changing in feed flow rates to study their effect on efficiency of extractor. The second is the impact feed flow rate at feed velocity and solid content of feed. For reasons are as the following equation4, where ρ is density, v is velocity, and A is cross sectional area.

$$Q = \rho v A \tag{4}$$

The increasing of feed velocity affects motion of particles that residence time in extractor decrease. So increasing feed flow rate means increases the force to slide on the screen.

The starch separation efficiency increased with increasing feed flow rate shown in figure 6. The increasing feed flow rate increased feed velocity and solid content per area. v will not increase at centrifugal force.

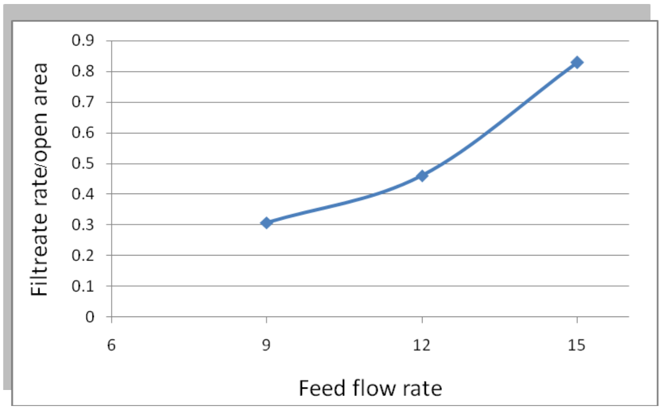


Fig .6 Effect of Feed Flow Rate on Filtrate Rate per Open Area

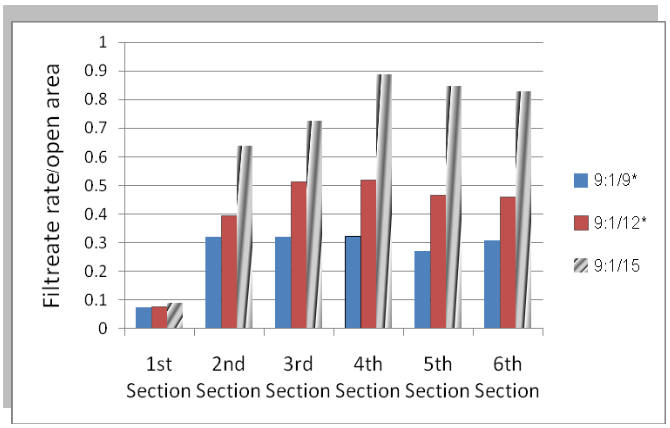


Fig.7 Effect of Feed Flow Rate on Filtrate Rate per Open Area at Different Section

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Figure 6 to 7 show filtrate rate per area in each section of the screen. Every trends show that filtrate rate increased from section 1 to 2 and 3 to 4 and decreased at section 5 and 6. This trend also used to indicate draining and drying section. The regions where has high level of filtrate is draining section. As the drainage continue to reach the point where non of gaps between the cake is filled with liquid. This point is called drying section. Therefore sections 1 to 4 are draining section while section 5 and 6 are drying section. It also found that section 1 had the highest flux because it has the lowest area but received the highest feed flow rate, therefore, the open area was covered by pulp in feed and low open area for liquid to pass through.

Figure 7 also represent that at the increasing feed flow rate did not affected draining and drying section especially at higher feed flow rate. Even though the higher feed flow rate changed filtrate rate but it did not change draining and drying section because of the constant centrifugal force as can be seen from the peaks of the figures. However the filtrate rate at 9 liters per minute was quite constant because of low remained feed at higher section. Therefore it can be conclude that the feed flow rate did not affect draining and drying section on the screen but it depends on the centrifugal force at each section.

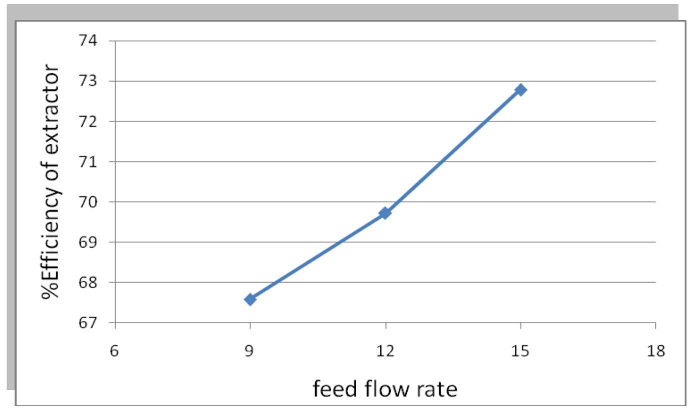

Fig.8 Starch Separation Efficiency at Different Feed Flow Rate in fine extraction

Figure 8 shows that starch separation efficiency at different feed flow rate in fine extraction starch. The starch separation efficiency increased separation efficiency increase with increasing feed flow rate when L / S ratio constant. So increasing feed flow rate means increases the force to slide on the screen. So increasing feed flow rate means increases the force to slide on the screen

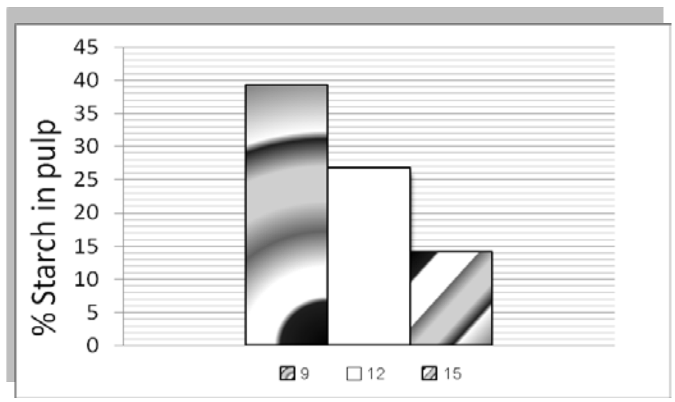

Fig.9 % Starch content in pulp at Different Feed Flow Rate in fine extraction

Figure 9 shows that % starch content in pulp at different feed flow rate in fine extraction. Starch content in pulp reduce with increasing feed flow rate in fine extraction when concentretion constant.

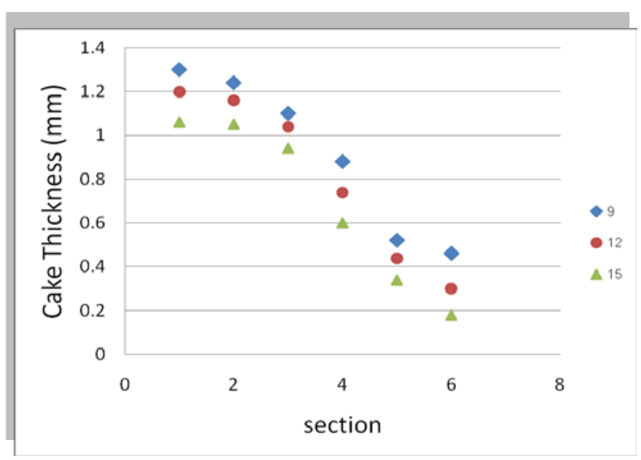

Fig.10 Effect of Feed Flow Rate in fine extraction On Cake Thickness at Different Section

The results in figure 10 show that cake thickness reduce with increasing feed flow rate, therefore, the sixth section has the highest centrifugal force and lowest cake thickness. However some of the sixth sections do not have the lowest thickness because of pulp accumulated at top ring. The sizes of particles in starch slurry are in the same range therefore, the cake thickness of the same screen aperture was not affected by the particle size. The mass flux also results the highest thickness at section 1 because of highest mass flux and the lowest centrifugal force.

IV. CONCLUSION

The starch separation efficiency increased with increasing feed flow rate with the lower solid in starch slurry. Feed flow rate increased filtration rate, but it had more fine pulp in filtrate. A Liquid-Solid ratio of 10:1 had highest extraction efficiency

These results can be used for designing and operating in the real process to improve the starch production efficiency in the factory.

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