การสกัดแป้งมันสำปะหลังโดยใช้สารพอลีออกซีเอทิลีนซอร์บิแทนโมโนโอลีเอตเป็นสารลดแรงตึงผิว

นางสาวกัลยาณี สายนาค

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EXTRACTION OF CASSAVA STARCH USING POLYOXYETHYLENE SORBITAN MONOOLEATE AS SURFACTANT

Miss Kallayanee Sainak

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Thesis Title	SELECTIVE HYDROGENATION OFACETYLENE ON PALLADIUM CATALYSTS SUPPORTED ON TITANIUM DIOXIDE CONSISTING OF VARIOUS RUTILE/ANATASE RATIOS
By	Miss Kanyaluck Kontapakdee
Field of Study	Chemical Engineering
Thesis Advisor	Assistant Professor Joongjai Panpranot, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

DL Lavansiri
.... Dean of the Faculty of Engineering
(Professor Direk Lavansiri, Ph.D.)

THESIS COMMITTEE

.... Chairman
(Professor Piyasan Praserthdam, Dr.Ing.)

.... Thesis Advisor
(Assistant Professor Joongjai Panpranot, Ph.D.)

Bunjerd Jongsomjit
.... Member
(Assistant Professor Bunjerd Jongsomjit, Ph.D.)

Amornchai Arpornwichanop
.... Member
(Amornchai Arpornwichanop, D.Eng.)

กัลยาณี สายนาค : การสกัดแป้งมันสำปะหลังโดยใช้สารพอลีออกซีเอทิลีนซอร์บิแทนโมโนโอลีเอตเป็นสารลดแรงตึงผิว (EXTRACTION OF CASSAVA STARCH USING POLYOXYETHYLENE SORBITAN MONOOLEATE AS SURFACTANT)
อ. ที่ปรึกษา : อ. ดร. เจิดศักดิ์ ไชยคุนา, 68 หน้า. ISBN 974-17-3847-1

งานวิจัยนี้ศึกษาการสกัดแป้งมันสำปะหลังโดยใช้สารพอลีออกซีเอทิลีนซอร์บิแทนโมโนโอลีเอต (ทวีน 80) เป็นสารลดแรงตึงผิว การทดลองทำในระบบกะ ในงานวิจัยนี้ได้แบ่งการทดลองออกเป็นสองส่วน ในส่วนแรกทำการทดลองเพื่อหาปริมาณน้ำในการสกัดแป้งจากหัวมันสำปะหลัง และ ได้ทำการเปลี่ยนแปลงเวลาการปั่นกวนเพื่อหาสภาวะที่เหมาะสม ซึ่งทำการเปลี่ยนแปลงอัตราส่วนโดยมวลของของเหลวและของแข็งแห้งเท่ากับ 10.5, 12.0, 13.5, 15.0, 16.5, 18.0, และ 19.5 ตามลำดับ เวลาการปั่นกวนเปลี่ยนแปลงระหว่าง 2 ถึง 14 นาที ในส่วนที่สอง ทำการศึกษาผลกระทบของสารลดแรงตึงผิวต่อการสกัดแป้งจากหัวมันสำปะหลัง ปัจจัยสำหรับการสกัดแป้งคือความเข้มข้นของสารละลายสารทวีน 80 (ร้อยละ 0.25, 1, และ 3 โดยน้ำหนัก) เวลาในการปั่นกวน (2 ถึง 14 นาที) และ อัตราส่วนโดยมวลของของเหลวและของแข็งแห้ง (10.5, 12.0, 13.5, และ 15.0)

ผลการศึกษาแสดงว่าประสิทธิภาพการสกัดแป้งเพิ่มขึ้น เมื่อปริมาณน้ำ และเวลาการปั่นกวนเพิ่มขึ้น สภาวะที่เหมาะสมสำหรับการสกัดแป้งคือเวลาการปั่นกวนเท่ากับ 10 นาที และอัตราส่วนโดยมวลของของเหลวและของแข็งแห้งเท่ากับ 15 ซึ่ง ภายใต้สภาวะเหล่านี้พบว่า ร้อยละประสิทธิภาพการสกัดเท่ากับ 73 การเติมสารพอลีออกซีเอทิลีนซอร์บิแทนโมโนโอลีเอต (ทวีน 80) ที่ความเข้มข้นสูงกว่าค่าความเข้มข้นวิกฤตในการเกิดไมเซลล์ช่วยปรับปรุงประสิทธิภาพการสกัดแป้ง ประสิทธิภาพในการสกัดเพิ่มขึ้นเมื่อเพิ่มอัตราส่วนโดยมวลของของเหลวและของแข็งแห้ง และ ความเข้มข้นของสารละลายสารทวีน 80

ภาควิชา...........วิศวกรรมเคมี...........ลายมือชื่อนิสิต กัลยาณี สายนาค
สาขาวิชา..........วิศวกรรมเคมี...........ลายมือชื่ออาจารย์ที่ปรึกษา..................................
ปีการศึกษา................2548...............

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KEY WORD: CASSAVA STARCH/ STARCH EXTRACTION/ SURFACTANT/ POLYOXYETHYLENE SORBITAN MONOOLEATE

KALLAYANEE SAINAK: EXTRACTION OF CASSAVA STARCH USING POLYOXYETHYLENE SORBITAN MONOOLEATE AS SURFACTANT. THESIS ADVISOR: JIRDSAK TSCHEIKUNA, Ph.D., 68 pp. ISBN 974-17-3847-1

The extraction of cassava starch using polyoxyethelene sorbitan monooleate (Tween 80) as surfactant was investigated. The experiment was conducted in a batch system. The study was divided into two sections. In the first section, the amount of water required for extraction of starch from cassava root and the stirring time were varied to find optimum conditions. Mass fraction of liquid and dry solid (L/S ratio) were varied at 10.5, 12.0, 13.5, 15.0, 16.5, 18.0, and 19.5, respectively. The stirring time were varied between 2 to 14 minutes. In the second section, effect of surfactant on extraction of starch from cassava root was studied. The parameters for extraction of starch were concentration of tween 80 solution (0.25%wt, 1%wt, and 3%wt), stirring time (2 to 14 minutes) and the mass fraction of liquid and dry solid (10.5, 12.0, 13.5, and 15.0).

Results showed that extraction efficiency of starch extraction increased with amount of water and stirring time. The optimum conditions for extraction of starch were stirring time of 10 minutes and the mass fraction of liquid and dry solid (L/S ratio) of 15. Under these conditions, the extraction efficiency was found to be 73%. Addition of polyoxyethelene sorbitan monooleate (Tween 80) at concentrations higher than the critical micelle concentration enhanced starch extraction efficiency. The extraction efficiency increased with the increase L/S ratio and concentration of tween 80 solution.

Department..............Chemical Engineering...Student's signature Kallayanee

Field of study...Chemical Engineering...Advisor's signature..................

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CHAPTER I

INTRODUCTION

The most important agricultural crops in Thailand are rice, sugarcane and cassava. The production of cassava roots was 18.16 million tones and the planting area was 1.5 million hectares in 2003. About two thirds of total root production is formerly converted into chips and pellets and rest is used as raw material in starch manufacturing. However, the demand for chips and pellets is being deceasing, while the production of cassava starch is increasing. The cassava roots generally contain a high starch content and low quantity of impurities such as protein and lipid. Thus, they were recognized as suitable source of pure starch for a wide range of applications. The cassava starch was used in many industrial products both food and non-food, such as sweetener textiles and paper industries.

At the present, 9 to 10 million tones of the cassava roots are converted to starch. There are now 52 starch factories registered at the Thai Tapioca Flour Industries Trade Association, with a total annual production of the cassava starch about 2 million tones. For the technology of starch production, water is used as a solvent for extraction and separation starch from other soluble impurities, such as protein and minerals. The consumption of water was varied from 25 to 30 m^3/ton starch, depending on the quality of water and processing efficiency.

There are many study about the extraction of starch. Siriwattanachaikul C. (1997) studied the effect of water used in the extraction to dry solid ratio (L/S ratio) on the efficiency of the cassava starch extraction. He reported that the optimum L/S ratio is 15:1 which was close to water consumption of extractor using in industry. Thanont K. (2001) studied effect of time on starch extraction from cassava. He reported that the extraction efficiency increases almost linearly with time. After 10 minutes, stirring time had not effect to extraction efficiency because all starch was extracted. Rittisang K. (2003) studied the extraction of starch influence of varieties and harvesting ages of cassava on the water usage in the extraction unit. She reported that the extraction efficiency from Rayong-5 root was slightly higher than other varieties. The optimum L/S ratio for starch extraction was 15:1 and this ratio is suitable for all varieties and harvesting ages of cassava root

In recent years, nonionic surfactant had a important role in many application, such as pharmaceutical technology, cosmetics, food products, and chemical technology. Moreover, aqueous surfactant solutions is use as alternative solvent system in the extraction of chemical constituents from plants or herbal materials.

There are many study for employing surfactant as solvent for extraction both organic and nonorganic substance. For example, Maggie P.K. and coworkers (2003) studied extraction of ginsenoside from medicinal plants using nonionic surfactant. They was found that an aqueous solution contain a nonionic surfactant at a concentration above its critical micelle concentration can increase the amount of extracted ginsenosides from ginseng roots. Qun F. (2000) studied an effect of solvent, such as water, methanol and nonionic surfactant (Triton X-100) to extract ginsenosides from Chinese herbal medicine. She reported that using nonionic surfactant as solvent yielded the fastest extraction kinetics and the highest recovery the gisenosides, followed by methanol and then water. Somwang P. (2001) used polyoxyethylene sorbitan monooleate (Tween 80) as solvent for extraction curcuminoids from tumeric. He found that tween 80 is effective solvent for curcuminoids extraction.

In this study, the extraction of starch from cassava roots use the factory process simulation. Water and surfactant are used as an extraction solvent for starch extraction from cassava root. The surfactant that is used in this experiment is polyoxyethylene sorbitan monooleate (Tween 80). The interested parameters are stirring time, liquid and dry solid ratio (L/S ratio), and concentration of the surfactant. The stirring time are varied between 2 to 14 minutes. The L/S ratios used in this study at

10.5, 12.0, 13.5, 15.0, 16.5, 18.0, and 19.5. The surfactant concentrations was used at 0%wt, 0.25%wt, 1%wt, and 3%wt.

The objective of this research is to study the effectiveness of starch extraction using nonionic surfactant (tween 80) as extraction solvent. It is compared with conventional extraction solvent (water extraction) in various experimental parameters, such as stirring time, L/S ratio, and concentration of the surfactant.

CHAPTER II

LITERATURE REVIEWS

2.1 Cassava

Cassava is common name for any of several related plants native to tropical regions in the Americas. Cassava is the West Indian name; manioc, or mandioc, is the Brazilian name; and juca, or yucca, is used in other parts of South America. The plant grows in a bushy form, up to 2.4 m (8 ft) tall. The roots are up to 8 cm (3”) thick and 91 cm (36”) long. The roots contain from 20 to 32% of starch.

Figure 2.1 Cassava plant (Sriroth, K. 2003)

Due to cassava is an excellent source of carbohydrates, low in vitamins and some minerals. Cassava can be very important for industrial use. The starch has unique properties such as a high viscosity and a resistance to freezing. The taste is neutral and does not change in the process. There is a wide variety of using tapioca in soups and sauces, in puddings instead of gelatin in bakery products as flour.

In Thailand, cassava is produced in large scale and most of it is exported widely in the world. Cassava has entered the modern market economy and there is a growing demand for its use in processed food and feed products. Dried cassava is used as animal feed and cassava starch is used for normal food products and for specialty markets, such as baby food, non-allergenic products and food for hospitalized persons. Cassava starch can be modified to provide characteristics that are required for more specialized food and industrial products. Moreover, modified cassava starch can be used for the production of alcohol, starch for sizing paper and textiles, glues, sweeteners such as dextin, glucose and fructose syrup.

2.2 Starch

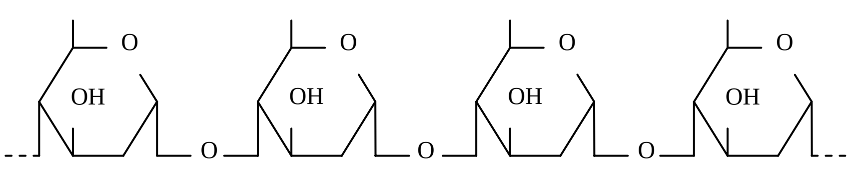
Starch is one of major components of cereal grains. It is a reserve carbohydrate found principally in the seeds, roots, tubers, fruits, and sometimes in the pith of plant. The major sources plant of commercial starch in Thailand is rice and cassava. The starch obtain from these plant sources as a fine powder (granular starch). It occurs as very small water-insoluble granules, usually associated with proteins, fats, and inorganic salts. The granules vary in shape and size ranging from about 1 to 100 µm in diameter depending on the sourses. For cassava starch, the size of the granule ranges from 5 to 35 µm.

Chemistry of starch

Starch is composed of carbon, hydrogen and oxygen in the ratio of 6:10:5 as an empirical formular of $C_6H_{10}O_5$. It is a condensation polymer of glucose. Starch is composed of 2 types of polysaccharide molecules, one amylose, an essantially linear polymer; and amylopectin, a highly branched polymer. In natural starch, these molecules are closely associated in structured microscopic granules. Cassava starch, amylose content typically lies within the range of 16-25% relative to amylopectin.

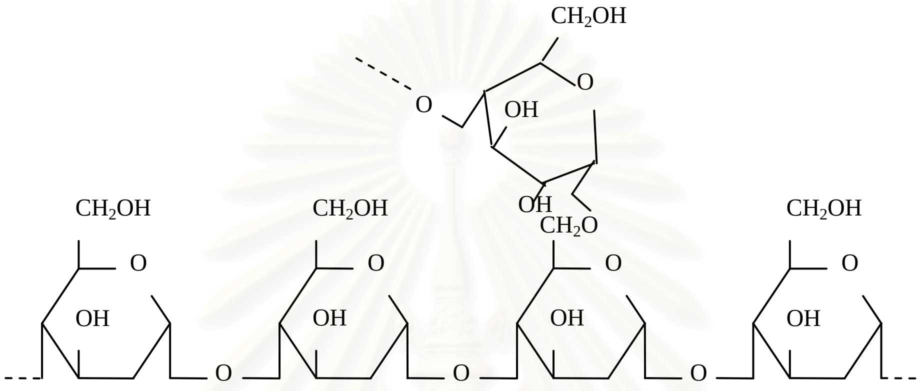
Amylose

Amylose is the linear polymer of glucose units with Alpha, 1-4 glucosidic linkage. The average chain length varied between 100-10,000 glucose molecules. It is minor component, typically ranging from 20%-30%, its molecular weight is about 0.2 to 2 millions. For cassava starch, the amylose content is about 16.5 to 22%.



Amylopectin

Amylopectin is the branched polymer molecule consisting of short linear amylose chains (Alpha, 1-4 glucosidic linkage) connected to each other by Alpha, 1-6 glucosidic linkage. Each amylopectin molecule contains up to 2 million glucoses. The molecular weight of amylopectin is about 100-400 millions, but the average chain length is only 20-30 glucosemolecules.



Starch molecules have a multitude of hydroxyl groups impart hydrophilic to starch. In addition to their affinity for water, these hydroxyl groups also tend to attract each other, forming hydrogen bonds. The linear amylose molecules can readily align themselvesn next to each other and form interchain hydrogen bonds through the hydroxyl groups. When sufficient interchain hydrogen bonds are formed, the individual amylose molecules are associated to from molecular aggregates with reduced hydration capacity and hence lower solubility.

Starch properties

Starch is a bright white color. Starch pH should fall within the range of pH 4-7 for edible starch and high quality cassava starch is typically within the range of 6.3-6.5. Flow properties are measured by the amount of powdered starch that will pass through a sieve within a determined time period. High flow rates indicate higher quality and low flow rates indicate a high moisture content or lumpiness. Starch granules vary insize; for cassava, the range is from 5 to 35 μm. Granule shape can be determined by viewing under a scanning electron microscope. Cassava starch granules are mainly round, with a flattened surface on one side containing a conical pit.

Molecular weight is determined by the amylopectin content, and the ratio between amylose and amylopectin is an important basic characteristic that affects starch performance. All of these parameters are used to classify starch into grades that relate to quality, price, and application.

2.3 Methods of starch extraction from cassava

Starch extraction from the cassava roots has 5 main stages: preparation rasping/pulping, purification, dewatering and drying, and finising. Critical factor in this case is age, planting area, and harvest time which the optimum harvest time is 12 months. For great extraction processes, fresh cassava roots need to be processed within 2-3 day.

Washing and peeling

The roots are conveyed to the sand removal unit for removing sand, soil and outer peel. The unit is a rotating drum that is partially immersed in a water bath. The roots inside the rotating drum are washed by a series of paddle arms or a spiral brush. About 1.6 cubic meters per ton of water are sprayed onto the roots to remove any dirt. The clean roots are conveyed to the root chopper which they are chopped into smaller pieces with large cutting blades.

Rasping and pulping

Rasping is the important stage in the process. The chopped roots are taken to a rasper to grind a fine mash or slurry. The tuber cells are broken down and the starch granules are released. During rasping, 0.4 m^3/ton of water is added to facilitate the process. The rasper consists of a rotating drum of about 40 to 50 centimeters diameter and 30 to 50 centimeters long drum with longitudinally arranged saw tooth blades in grooved Mills around the circumference. A linear velocity of 25 m/sec is maintained (about 1000 rpm) the blades have 8 to 10 blades per centimeter.

Starch extraction

The concentrated pulp is mixed with fresh water in a counter current direction before it is going to the extraction stage. The main purpose is to separate out the starch granule from the large fibrous cellulosic components. Starch is extracted from the fiber and pulp by centrifugal force with water as an extraction solvent. The simple extractor is round basket rotating at 600 to 800 rpm (continuous perforated-busket centrifuge).

The extractors are rotating centrifugal sieve cones with 60 to 80 mesh sieve for coarse extraction or cloth with 90 to 120 meshes in the subsequent fine extraction. The smaller starch granules pass through the screens while the larger fiber flow down the screen and are separated continuously. Water is sprayed on the pulp help good separation and reduces loss of starch in the fiber. The pulp leaving the extractor is dewatered by pressing and after drying used as animal feed. The amount of pulp will be around 6 to 10 kilograms for each 100 kilograms of fresh root. The crude starch milk leaving the fine screens have a concentration of 3^{o}Be which is about 54 kg dry starch per m^3.

Separation

The starch slurry from fine extractors is purified and concentrated by removing the fine fiber that passed through the sieves in a separator. Generally, the two phase nozzle type separation machine is used. This method utilizes centrifugal force created by rotating the machine at about 3,000 rpm. The slurry entering from the bottom of the machine is separated into two phases: the heavy phase (concentrated starch slurry) and light phase (clear water with impurities). Many factories have installed two sets of separators. The concentration of the starch slurry is increased to $19\text{-}20^{o}$Be (about 40% starch by weight).

The starch slurry from the separators is pumped to a dewatering centrifuge. With filter cloth placed inside it, rotates at about 1,000 rpm to remove water from the starch slurry. The starch cake scraped off the machine by workers which has a moisture content of 35-40 percent.

Drying

The starch cake is passed by a screw conveyor to a pneumatic flash dryer. In this unit, evaporation takes place using hot air at 170 to 200^{o}C. The drying is completed in a very shot time in order to get a fine starch powder and prevent swelling of starch granules. A burner is generally used to generate heat. Today, there are two types of burners: hot air burners and thermo-oil boilers. The dried starch is sifted to prevent the larger granules of starch in the product. The sifted starch is packaged in sacks.

In the modern starch producing plants in Thailand about 0.20-0.22 tons of starch are produced from 1 ton of tapioca roots (65 to 70 percent of efficiency).

2.4. Water System

Water is used as a solvent to extract the starch and separate it from other soluble impurities, such as protien, minerals, as well as other suspended materials. The consumption of water varies from 15 to 30 m^3/ton starch that depend on the availability of water and the efficiency of the waste water treatment.

Table 2.1 The water supply for each step of cassava starch extraction industries(Sriroth K.).

Production stage	Water supply (m^3/ton fresh root)
Washing and peeling	1.6
Rasping and pulping	0.4
Starch extraction	5.8 – 6.0
Separation	3.2
Drying	-
Totle	11 – 11.2

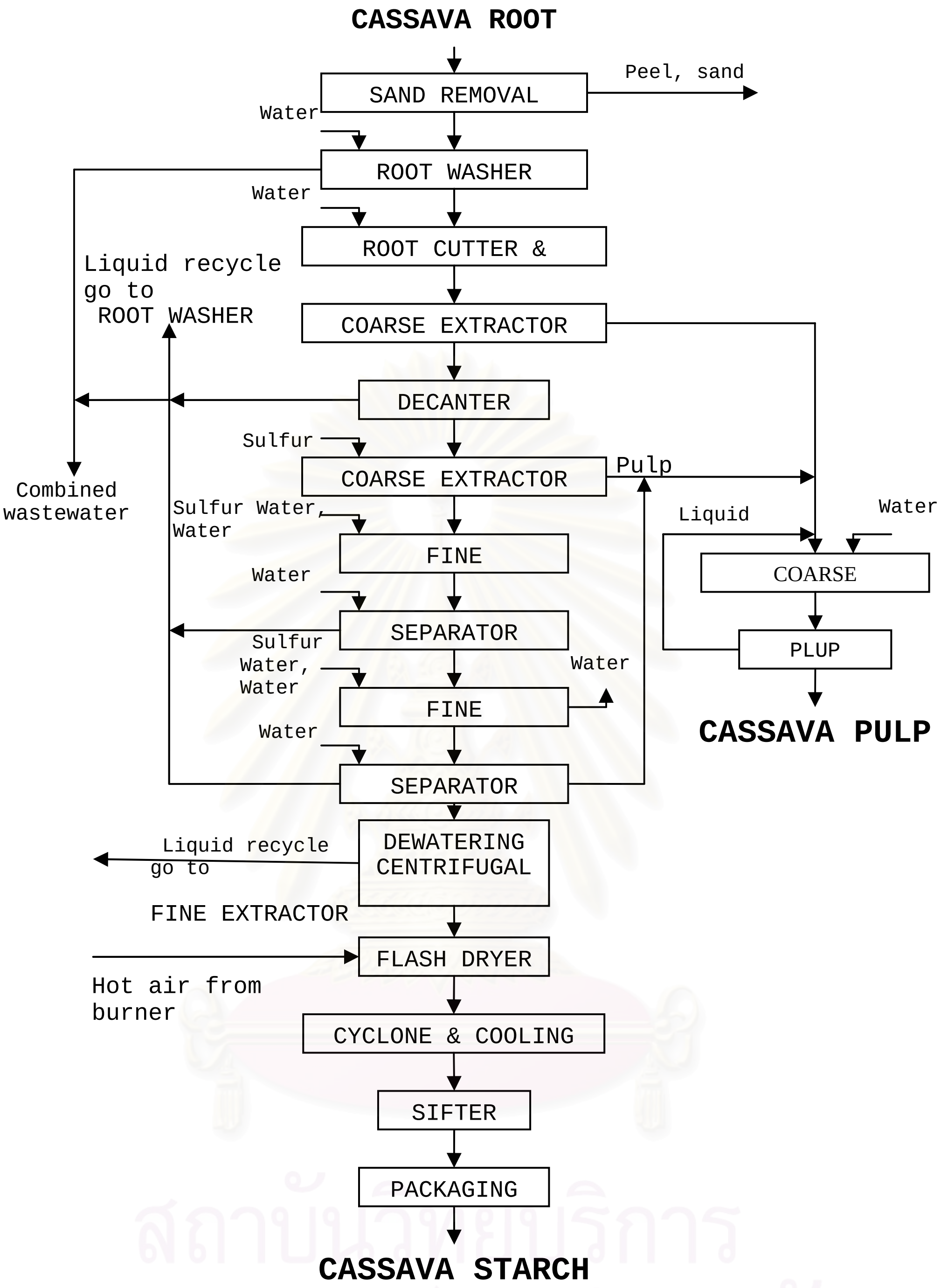


Figure 2.2 Flow diagram of cassava starch manufacturing process

Siriwattanachaikul C. (1997), studied the effect of water used in the extraction to dry solid (L/S ratio) on the efficiency of the cassava starch extraction. The experiments were divided into two sections. The first section was performed in laboratory by using stirred plates. The second section was performed in the cassava starch factory, Choncharoen Co.Ltd., by using the 3-stage industrial scale extractors. The first stage extractor used recycle water from separators for extraction, while the other two used pure water for extraction. From laboratory experiment, the optimum L/S ratio is 6:1 which nearly the same is as those obtained from the first and second stage industrial scale extractors. For the third stage extractor, the optimum L/S ratio is 3:1. Moreover, the recycle water with 3% starch can be reused for the first stage extractor to with 70% efficiency of extraction. The results from this study can be applied to the factory by setting the optimum L/S ratio for each stage of the extractor in order to get high extraction efficiency with minimum water usage.

Sriroth K. (2000), studied extraction of starch from cassava pulp. Cassava pulp is the solid waste produced as a consequence of starch production. This pulp contains a high starch content (50±60% dry basis). Pulp was treated either by sonication or incubation with a multi-enzyme mixture of cellulase and pectinase. Both methods were found to improve efficiency of starch extraction by disrupting the complex structure of polysaccharides associated with and entrapping starch granules. In the enzymatic treatment, the content of cellulase and pectinase for high efficiency of starch extraction determined as the yield of liberated starch was investigated using Response Surface Methodology. Cellulase concentration seemed to have a greater effect on efficiency of starch yield than pectinase concentration. Treatment of pulp with 15 Novo cellulose units (NCU) of cellulase and 122.5 polygalacturonase (PG) units of pectinase per g dry pulp for 60 minutes resulted in 40% starch recovery.

Rittisang K. (2003), studied the optimum water consumption for starch extraction from cassava root.

Rittisang, K. (2003) studied the optimum water consumption for starch extraction from cassava root. The varieties of cassava root were Kasetsart-50, Rayong-90 and Rayong-5 at different harvesting ages of 8, 10, 12 and 15 months. The amount of water usage to extract starch from root was varied to study the efficiency in starch extraction. The efficiency of starch extraction increased with the increase of water volume in extractor unit. The efficiency of starch extraction from Rayong-5 root was slightly higher than Kasetsart-50 and Rayong-90 root about 3%. The optimum volume of water per weight of cassava root on dry basis (L/S ratio) for starch extraction was at 15 and this ratio was suitable for all varieties and harvesting ages of cassava root. The efficiency of starch extraction of 50-55% was obtained. It was noticed that Rayong-5 root at harvesting age of 12 months was the appropriate raw materials in cassava starch extraction process.

Rahman, S.M.M. (2003) studied to determine the reason for the large variances in sweet potato starch yields during extraction. The study was conducted on 19 varieties of sweet potatoes harvested in both the wet and dry season. There was higher starch content in sweet potato harvested in the dry season. There seems to be no direct relationship between starch content and starch recovery. This was because the starch present in the tubers was held in different ways in the fiber. As a result different varieties of sweet potato require different amounts of rasping to release the starch. In the choice of the sweet potato variety for starch extraction the amount of tuber harvested per unit area of land, its starch content (which depends on the season of harvest) and most importantly the starch extractability needs to be taken into account. With increased rasping there was increase in the starch extracted from the sweet potato. However, increased in starch extraction levels above 85% require large increase in energy input which might not be economical. It was found that with increase in rasping there was no increase in fiber impurities and that the quality of the starch was acceptable.

2.5 Stucture and behavior of surfactant

A surfactant or surface active agent is a substance that, when present at low concentration in a system, has the property of adsorbing onto the surface or interfaces of the system and altering to a maked degree the surface or interfacial free energies of those surfaces or interfaces (Milton, J.R. (1993)). A surfactant has a characteristic molecular structure consisting of hydrophilic head group (water-loving) which is usually polar group and hydrophobic tail (water-hating) which is usually hydrocarbon long chain or non polar group (Qun, F. (2000)). In present, surfactants appear in the effluents of a number of industries such as textile, paper and pulp, food processing, and detergent manufacturing.

The water solubility of the surfactant can be used to obtain a rough approximation of its HLB number (hydrophile-lipophile balance). This number is useful for preliminary surfactant selection because maximum solubilization within a given surfactant's chemical family will occur at a specific HLB number (Milton, J.R. (1993); Borchardt, J.K. (1994)).

Table 2.2 Range of HLB value for water solubility of the surfactant

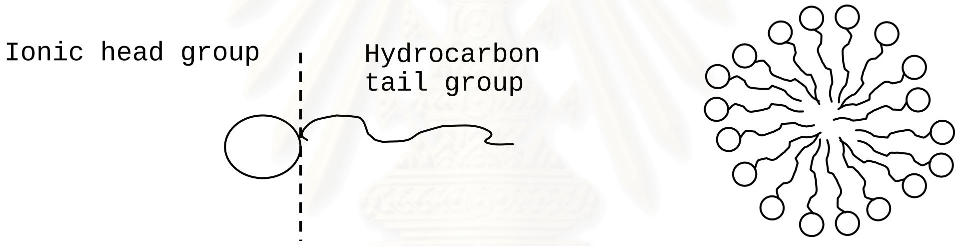
HBL range	
1-4	No dispersibility in water
3-6	Poor dispersion
6-8	Milky dispersion after vigorous agitation
8-10	Stable milky dispersion
10-13	Translucent to clear dispersion
13+	Clear solution

Table 2.3 Classification of surfactant in food industries and HLB values

Surfactant	HLB
1. Mono and diglycerides of fatty acid - Glycerol monostearate - Glycerol monolaurate	< 7 3.8 5.3
2. Organic acid esters of monoglycerides - Acetic acid esters of monoglyceride - Citric acid esters of monoglyceride - Diacetyl tartaric acid esters of monoglyceride	5.5 4.5 8.0
3. Polyglycerol esters of fatty acid	No dispersibility in water
4. Propylene glycol esters of fatty acid monostearate - Propylene glycol monolaurate - Propylene glycol monostearate	4.5 3.4
5. Sucrose ester esters of fatty acid - Sucrose monostearate - Sucrose monolaurate	14 15
6. Sorbitan esters of fatty acid - Sorbitan monostearate - Sorbitan tristearate	4.7 2.1
7. Polyoxyethelene sorbitane ester (Polysorbate) - PS-60 - PS-65 - PS-80	14.9 10.5 15.0

2.6 Micellization

At low concentration of surfactant solution, a single molecule of surfactant is called monomer. The monomer freely disperses in solution. When the concentration rise until reaching to a specific concentraion, the aggregation molecules will be observed as shown in figure 2.1. This aggregation molecule is called micelle and the concentration that first micelle is formed called “Critical Micelle Concentration” or CMC. CMC is the aqueous concentration of surfactant at which surface tension of the solution is smallest. As the concentration increases, the surface tension decreases until the CMC is reached. CMC is a significant parameter in solubilization can be expected to be highest at or above the CMC of the aqueous surfactant solution (Rosen, 1989).



Surfactant monomer

Surfactant Micelle
an oil-like droplet
structure

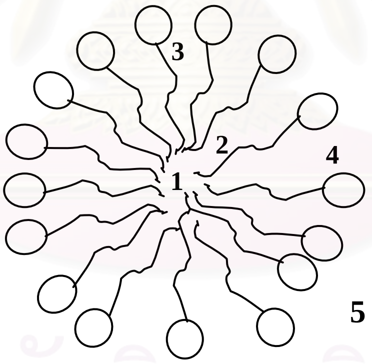
Figure 2.3. Surfactant monomer and Surfactant micelle

In ordinary, the aggregation number of micelle formation is about 20 to 200 monomer molecules (Rosen,1978). Micelle structures and shapes are in many different types depend upon the their nature, the environment, and also the aggregation number of surfactant. The major types appear to be spherical micelle, lamellar micelle, and vesicle micelle.

2.7 Solubilization of organic contaminants in micelle

Solubilization is important property of surfactant that concerns directly with the micellization. It is defined as the spontaneous dissolving of a substance be reversible interaction with micelle of the surfactant in a solvent (Rosen,1978). Therefore, when the surfactant is presented in aqueous solution with concentration above the CMC, the solubilization of substances will be enhanced. The solubility of organic can be much higher in a surfactant solution above CMC than in water due to solubilization (Rosen,1978; Tadros,1984; Hal and Tiddy,1981; Adamson,1967).

In spite of the characteristic of micelles that have both of hydrophilic and hydrophobic portion, there are five exact sites in the micelle at which solubilization occurs, inclusion into the inner core of micelle, deep penetration into the palisade layer, short penetrate into the palisade layer, between the hydrophilic head group, and on the micelle surface or at micelle-solvent interface. Figure 2.2 illustrates the sites of solubilization n surfactant solution.



1 - Inner core of micelle
2 - Deep penetrate in palisade layer
3 - Short penetrate in palisade layer
4 - Between the hydrophilic head groups
5 - In the micelle solvent interface

Figure 2.4 The sites in micelle provided for solubilization.

Maggie P.K. and Kelvin K.C. (2003), studied the feasibility of employing aqueous non-ionic surfactant solutions as an alternative solvent system in pressurized liquid extraction (PLE) for the first time using the roots of American ginseng as model solid samples. When compared to the use of pure water or methanol, the presence of a common non-ionic surfactant (Triton X-100) in water at a concentration above its critical micelle concentration was shown to enhance the amount of pharmacologically active ingredients (ginsenosides) extracted from ginseng roots. The advantages of using aqueous non-surfactant solutions were also demonstrated by comparing extraction performances between ultrasonic-assisted extraction and PLE methods. Furthermore, the combination of PLE and cloud point extraction was shown to be a new and effective approach for the rapid sample preconcentration of herbal materials prior to analysis by high-performance liquid chromatography.

Gecol H. (1998), studied removal ink from a commercial polyethylene film with water-based ink printing using different surfactants under a variety of conditions. At a pH of 12, water (containing no surfactant) can achieve about 90% deinking, but less basic solutions are less effective; at a pH 10 and below, insignificant-deinking occurs. Solutions of cationic surfactant are the most effective at deinking, showing high efficiency at surfactant concentrations both above and below the critical micelle concentration (CMC) over a pH range of 5–12. Amphoteric surfactant is effective above the CMC over a wide pH range. Both anionic and nonionic surfactants are only effective at deinking above the CMC at very basic conditions, with anionic surfactant being only slightly better than just water even at these high pH levels. The cationic surfactant is most effective and the anionic surfactant is least effective, possibly because the binder is an acidic acrylate with a negative charge.

Qun F. (2000), studied the feasibility of employing micelle-mediated extraction as an alternative and effective method for the solubilization, purification and preconcentration of active ingredients from herbal products for the first time using the root of American ginseng as a model. When compared to methanol and water, an aqueous surfactant solution containing 10% Triton X-100 yielded faster kinetics and higher recovery for the extraction of various ginsenosides. An experimental design approach (uniform design) was demonstrated as a novel and useful method for the optimization of experimental factors involved in the micelle-mediated extraction process. For the preconcentration of ginsenosides prior to chromatographic determination, a salting-out agent (sodium sulfate) was employed to make the efficient cloud point extraction of both hydrophobic and hydrophilic ginsenosides into the surfactant-rich phase possible, as well as to increase the preconcentration factor by reducing the volume of the surfactant-rich phase.

Somwang P. (2001), studied extraction of curcuminoids from tumeric for use as natural food colorant using polyoxyethylene sorbitan monooleate (Tween 80) as solvent. The study was divided into three section. In the first section, removal of volatile oil from turmeric was studied by comparing between water distillation and direct steam distillation methods. Optimum conditions of various factors for extraction of curcuminoids from tumeric were invesigated in the second section. The factors were temperature and time of extraction, speed of mixing, ratio of tumeric weight to solvent volume, particle size of tumaric, concentration of tween 80 in the solvent and pH value. In the last section, a basic economic analysis was performed for investment on curcuminoids production plant in Thailand. Results showed that the method of direct steam distillation for removal of volatile oil from tumaric was suitable and the time of extraction was 5 hours. Optimum conditions for curcuminoids exraction were as follow: exraction temperature of 60 C for 20 minutes; mixing speed of 340 revolutions per minute; ratio of tumeric weight to solvent volume was 1 gram per cubic centimeter; particle size of tumeric were those that passed through 60-mesh screen; concentration of tween 80 in solvent was 3 percent by weight and pH value ranging between 6.3 to 6.7 Under these conditions maximum amout of curcuminoids extracted was 99.6% . Estimation of investment cost in establishing a 6,000 cubic meters per year curcuminoids plant showed a total capital invesment of approximately 18 million baht, with rate of return on investment before tax of 15.71% and after tax of 13.35% giving a pay back period of 3.97 year. Therfore it is considered to be an attractive project for investment on an industrial scale.

CHAPTER III

EXPERIMENTS AND ANALYSIS TECHNIQUE

The preparation of experiment and analytical method were described in this chapter. It was divided into three sections. The first section concerned with the roots and surfactant solution preparation. The second part described the extraction procedures and analysis technique. The final section referred to errors of the experiments.

3.1 Materials

3.1.1 Fresh cassava roots

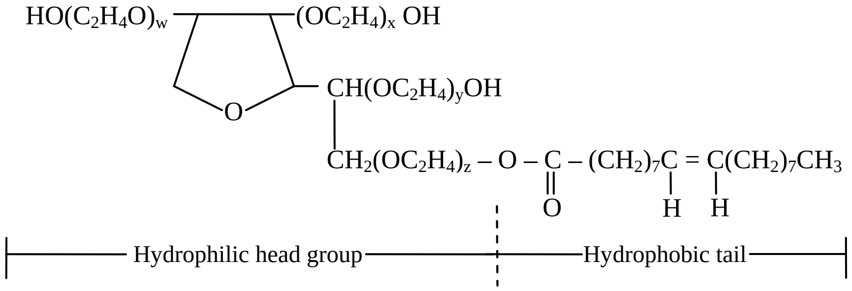
The condition of cassava fresh roots in this experiment were decided, the condition of roots were the same type in both planting area and harvested time, because of its result in the starch content in the root. The type of cassava roots was Rayong 5. They were planted under identical field condition at Tumbon Juntuk, Umpure Pakchong, Nakhorn Ratchasima, Thailand. The roots were manually harvested at 12 months. The composition of fresh cassava roots used in this experiment were determined before the experiments.

3.1.2 Surfactant

In this study, the surfactant was the nonionic surfactant, polyoxyethylene sorbitan monooleate (Tween 80), which obtained Honghod Chemical Co.

The chemical structure and properties of Tween 80 are defined as

Chemical structure: $C_{18}S_6(CH_2CH_2O)_{20}$
Molecular weight: 1308
Boiling point: $100^{o}C$
Critical micelle concentration(CMC): 0.012nM or 13-15 mg/L



Polysorbate 80
(Sum of w, x, y and z is 20)

Figure 3.1 Chemical structure of Tween 80

3.2 Experimental procedures

3.2.1 Fresh cassava roots preparation

The fresh cassava roots were normally washed and peeled then dried in the laboratory at ambient condition of about 30 ^{o}C. Then, it was sliced to 2-3 cm. cubic pieces and mixed them thoroughly. The samples were stored at 0 ^{o}C. Before starting experiments, the cassava fresh roots were analyzed to average starch content.

3.2.2 Procedure of experiments using water as an extraction solvent

Two hundred grams of the roots was used in each experiment. It was rasped in a rasper and slurry of root pulp was mixed with water. The quantity of water in this experiments are shown in Table 3.1 and defined mass fraction of liquid and dry solid(L/S ratio)L/S ratio is defined as

$$\text{L/S ratio} = \frac{\text{Total Mass of solvent for extraction(g)}}{\text{Mass of root pulp (g dry basis)}}$$

The slurry was stirred at a given time between 2 to 14 minutes with stirring speed of 600 rpm. The liquid sample were separated every two minutes to analyze starch content. Slurry was filtered through centrifugal screen to separate starch milk from fiber. While separation starch milk, water was added to centrifugal screen. The filtered starch milk was mixed water for dilute impurities. Later, starch milk was allowed to sediment for 10 hours. Subsequently the upper layer of water decanted and concentrate starch was filtered through filter paper Whatman

No.1. Thereafter, the wet starch sample was dried at $55^{o}C$ for 48 hours. Finally the sample was weighed and kept to analyze for their characteristics. After completion of each experiment, the pulp residue from final extraction wre kept to analyze for their characteristics.

The extraction efficiency is the quantification of the amount of starch released from the fiber that is divided two parts.

1. Equation below shows the extraction efficiency of cassava roots using water as an extraction solvent. The extraction efficiency is defined as

$$\text{extraction efficiency(\%)} = \frac{W1}{W2+W3} \text{ x } 100 \quad (3.1)$$

where :

$W1$ = Starch content in solution, g
$W2$ = Weight of extracted starch, g
$W3$ = Starch content in pulp residual, g

2. The extraction efficiency is defined the fraction of the starch which remains bound to the fiber. The fraction can be calculated from the difference between the starch content in the cassava roots and the pulp. While quantities fiber of cassava root and pulp are constant. If the starch content of the roots and the pulp are S_r and S_w and corresponding to the fiber content are F_r and F_w.

$$\text{extraction efficiency(\%)} = 1 - \frac{Sw \times Fr}{Sr \times Fw} \times 100 \qquad (3.2)$$

Table 3.1 The water quantity for each step of extraction

L/S ratio	Water for extraction(g)		
	Water for mixed slurry	Water for screening	Total water
10.5	240	600	840
12.0	360	600	960
13.5	480	600	1080
15.0	600	600	1200
16.5	720	600	1320
18.0	840	600	1440
19.5	960	600	1560

3.2.3 Procedure of experiments using water as an extraction solvent

In this section, Tween 80 was used as extraction solvent. Concentrations of Tween 80 were varied of 0.25%wt, 1%wt, and 3%wt. The solvent quantities of experiments are shown in Table 3.2. L/S ratio is defined mass fraction of liquid and dry solid (L/S ratio). L/S ratio is defined as

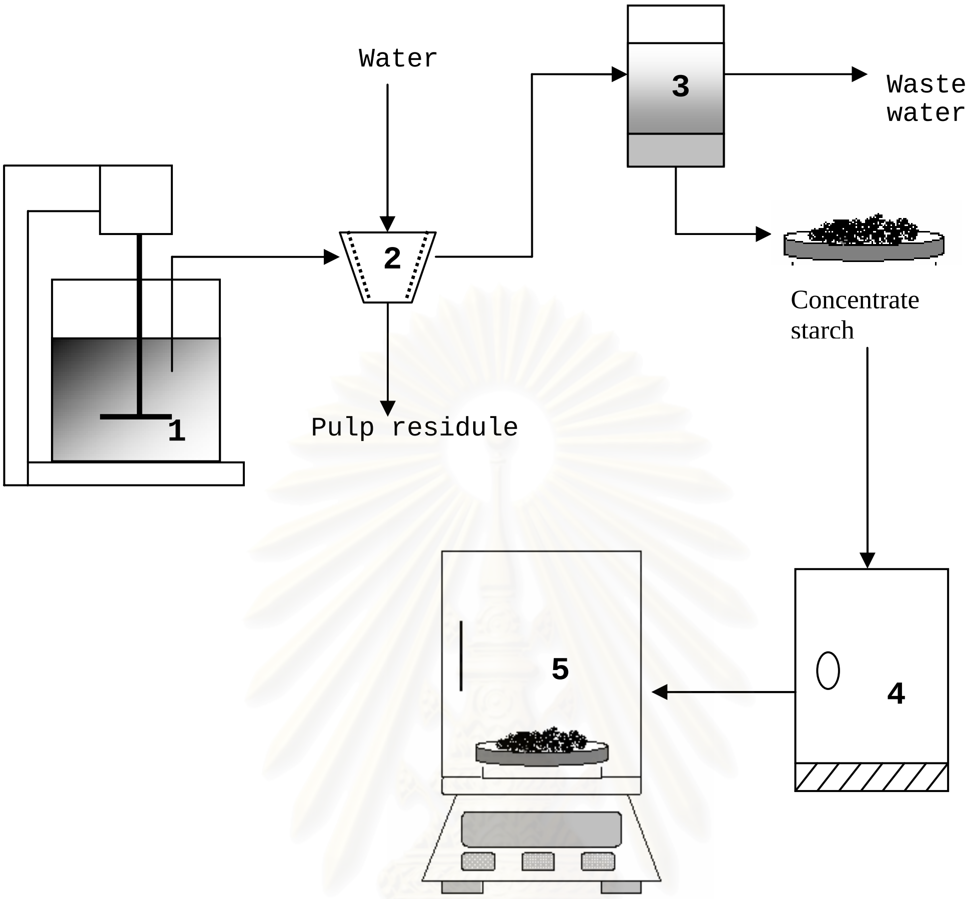
$$\text{L/S ratio} = \frac{L1 + L2}{S} \qquad (3.3)$$

where:

$L1$ = Mass of Tween 80 solution(g)
$L2$ = Mass of water for filter process(g)
S = Mass of root pulp (g dry basis)

Table 3.2 Tween 80 and water quantity for each step of extraction

L/S ratio	Surfactant for extraction(g)		
	Tween 80 for mixed slurry	Water for screening	Total solvent
10.5	240	600	840
12.0	360	600	960
13.5	480	600	1080
15.0	600	600	1200



1. Stirring tank
2. Centrifugal screener
3. Sedimentation tank
4. Oven
5. Balance

Figure 3.2 Schematic diagrams of the experimental apparatus

3.2.4 Analysis method

Determination of starch content in roots and pulp residue

A modified version of the polarimetric method of Thai Industrial Standard for Tapioca Products (TIS 52-1973) is used to determination of starch content in roots and pulp residue.

- **Preparation of sample**

The tested sample was ground fine enough to pass through a No.20 mesh or 0.835 mm sieve and then subjected to tests. It shall be thoroughly. Unless otherwise specified, distilled water and reagents used shall be of analytical grade.

- **Analytical Procedure**

  Determination of Total Rotatory power, P

1. 2.5 g of the sample in a 100-ml volumetric flask by using the funnel.
2. Add 25 ml of 1.128% by weight hydrochloric.
3. Shake the flask until the sample is saturated and then add a further 25 ml of 1.128% by weight hydrochloric acid.
4. Immerse the flask with the funnel on top in a boiling water bath and swirl vigorously for 3 minutes to prevent flocculation. The flask shall not be taken out of the water bath during swirling. The volume of water in the bath must be sufficient for the water to remain boiling when the flask is plunged into it.
5. After 15 minutes, remove the flask from the boiling water bath, add 30 ml of cold water and cool immediately to 20°C.
6. Add 10 ml of sodium phosphotungstate solution or dodecaphosphotungstic acid and shake vigorously for the forming of precipitate.
7. Make up volume with water at 20°C , mix thoroughly and filter through a dry filter paper(Whatman No.1). Discard the first 25 ml of the solution obtained.
8. Transfer the solution to a 200 mm tube of the polarimeter.
9. Read the total rotary power (P) in terms of angular degrees(Before reading the “P” of the filtrate, add one drop of deficient to

approximately 2 ml of filtrate. Wait for 3 minutes and check whether a precipitate forms. If so, the operation has to be repeated using more deficient.).

Determination of rotary power of active water-soluble substances after treatment with hydrochloric acid (P’)

1. 12.500 g of the sample in a 250-ml volumetric flask add approximately 200 ml of water.
2. Shake until the sample is wet and let stand for 1 hour at room temperature, shaking occasionally 6 times.
3. Make up volume to 250 ml with water, mix thoroughly, set aside until the starch precipitates, and filter through a filter paper (Whatman No. 42)(The filtrate shall be free from starch, which can be tested by adding one drop of dilute iodine solution into 2 ml of the filtrate. The solution shall not become blue.).
4. Pipette 50 ml of the solution (=2.500 g of the sample) into a 100-ml volumetric.
5. Add 2.1 ml of hydrocholric acid 25% by weight or sp.gr. 1.126 and shake.
6. Place the funnel on the flask and immerse the flask from the boiling water bath.
7. After 15 minutes, remove the flask from the boiling water bath, add 30 ml of cold water and cool immediately to 20°C.
8. Defecate with the solution Sodium phosphotungstate or dodecaphosphotungstic acid solution, 4% by weight in the same manner as determining “P” in clause 2.1. Make up volume to 100 ml with water at 20°C homogenize by shaking and filter through a dry filter paper(Whatman No.1)(discarding the first 25 ml of filtrate).
9. Transfer the solution to a 200 mm tube of the polarimeter. Read “ P′ ” of the filtrate in the same manner as P.

Calculate starch content from following formula:

$$A = 2000 \times \frac{(P-P')}{D} \qquad (3.4)$$

where :

A = starch content, % by weight
P = total rotary power, angular degrees
P'= rotatory power of the soluble substance, angular degrees
D = specific value for starch, angular degrees, (D=184.0 for tapioca starch).

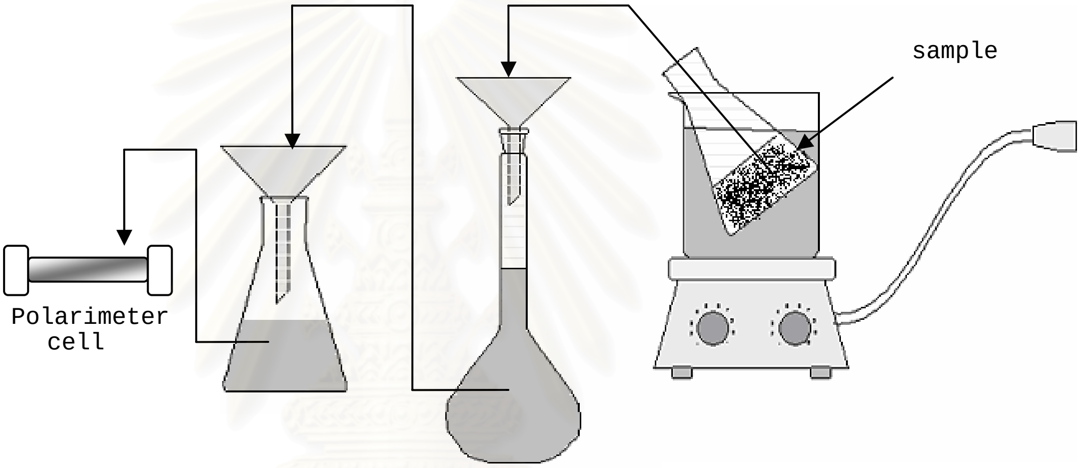


Figure 3.3 Schematic diagrams of analytic apparatus

Determination of moisture

1. Dry the aluminium dish and cover in the electric air at 105-107°C for 15 minutes.
2. Cool to room temperature in desiccator and weigh.
3. Weigh accurately 5 g of the sample in the aluminium dish.
4. Dry in the electric air oven at 105-107°C for about 5 hours.
5. Cool to room temperature in the desiccator and weigh.
6. Repeat the process of 30 minutes drying, cooling and weighing until the difference between two successive weighing is less than 2 mg.

Note the lowest weight which shall be considered as the weight of the aluminium dish and sample after drying.

Calculate moisture content from following formula:

$$\text{Moisture content}(\%\text{wt}) = \frac{(M1-M2)}{M1-M} \times 100 \qquad (3.5)$$

Where :

M = weight of dish with cover, g

$M1$ = weight of dish with cover and sample before drying, g

$M2$ = weight of dish with cover and sample after drying, g

3.3 Experimental and Analytical Error

3.3.1 Experimental Error

In this section, experiments were conducted to verify repeatability, an average and a standard deviation value of the experiment. Equation 3.6 and Equation 3.7 define an average value and percent deviation, respectively.

$$\text{Average value, } \overline{X} = \frac{\sum x}{n} \qquad (3.6)$$

$$\text{Percent deviation from average value} = \frac{\sqrt{(X-\overline{X})^2}}{\overline{X}} \times 100 \qquad (3.7)$$

The experiments were repeated for 3 times at the same condition. The experiments were conducted at various L/S ratios of 10.5, 15, and 19.5 and conducted using water and 0.25%wt of Tween 80 solution as solvent. In addition to, experiments were operated at stirring time 10 minutes, stirring velocity of 600 rpm. The pulp residue from final extraction was kept to analyze for their characteristics.

The experimental results average extraction efficiency of starch and percent deviation are calculated and summarized in Tables 3.3.

Table 3.3 Average percents extraction efficiency and maximum percent deviation on experiment of starch extraction by using water as solvent, stirring time 10 min and various L/S ratios.

Experiment	L/S ratio	Extraction efficiency (%)	Average extraction efficiency (%)	Maximum deviation (%)
1	10.5	50.34	50.62	2.08
2		51.68		
3		49.86		
4	15	73.97	73.47	1.15
5		73.04		
6		73.39		
7	19.5	77.58	76.63	1.59
8		76.37		
9		75.93		

The result shows that the maximum experimental error is approximately 2.08%.

Table 3.4 Average percents extraction efficiency and maximum percent deviation on experiment of starch extraction by using Tween 80 of 0.25 wt% as solvent, stirring time 10 min and various L/S ratios.

Experiment	L/S ratio	Extraction efficiency (%)	Average extraction efficiency (%)	Maximum deviation (%)
1	10.5	68.62	67.09	1.50
2		68.33		
3		64.31		
4	15	82.40	82.46	1.54
5		82.11		
6		82.88		
7	19.5	84.34	85.07	1.14
8		84.72		
9		86.16		

The result shows that the maximum experimental error is approximately 1.54%.

CHAPTER IV

RESULTS AND DISCUSSIONS

Extraction of the starch granules from the cassava root experiments were conducted in a batch system. The system was set up using laboratory equipments representing each step in extraction process. The extraction procedures were conceptually identical to industrial process. The processes of cassava starch extraction in industry can be divided into the following stages:

1. Preparation and rasping: Cassava roots are washed and peeled. The clean roots are cut into small pieces and rasped into fine particles by rasper. The water is added during rasping.
2. Extraction: Starch is extracted from fiber through agitation and addition of water. The starch passes through the screen or cloth into a centrifuge that separates the fiber from the starch milk.
3. Purification: Pure starch is separated from soluble contaminants. Substitution of pure water for aqueous solution surrounding the starch granule.
4. Removal of water by centrifuging and drying.

In this study, fresh cassava roots were washed and peeled. The peeled roots were cut to 2-3 cm cubic pieces and mixed thoroughly. The prepared root was stored at 0^{o}C. Samples of fresh cassava roots were taken and analyzed for starch content. Two hundred grams of the roots was used in each experiment. It was rasped in a rasper and slurry of root pulp was mixed with water. The slurry was then stirred at a given time between 2 to 14 minutes at stirring speed of 600 rpm. The slurry was filtered using centrifugal screen to separate starch from fiber. Starch slurry was allowed to stand for a period of time so that starch granules was separated from water. Wet starch was separated and dried at 55^{o}C. After completion of each experiment, the starch was weighted and pulp residue was kept for analyze. The analysis procedure of starch content in liquid sample and pulp residue are described in Chapter III. The extraction efficiency is defined by the fraction of the starch which remains bounded to the fiber. The fraction can be calculate from the difference between starch content in the cassava roots and the pulp. If the starch content of the roots and the pulp are S_r and S_w and corresponding fiber content are F_r and F_w.

$$\text{\% extraction efficiency} = 1 - \frac{Sw \times Fr}{Sr \times Fw} \times 100 \qquad (4.1)$$

Surfactant, polyoxyethylene sorbitan monooleate was added to water for comparison. Details of experimental method were are described in Chapter III. Experimental results are summarized in Appendix A. Discussion of the results is devided into two parts:

4.1 Composition of cassava fresh roots

The composition of cassava fresh roots is determined before starting the experiments. The cassava root, Rayong 5, having harvest time of 12 months was used. The determination method of cassava root composition is performed by Thai Industrial Standard for Tapioca Products (TIS 52-2516(1973)). The majority of composition is water (65% of wet basis) and starch (30% wet basis). Mass ratio of each component in the root is defined as fpllow:

$$\text{Mass ratio(wet basis)} = \frac{\text{Mass of component}}{\text{Total mass of wet solid}} * 100 \qquad (4.2)$$

Table 4.1 Mass ratio of each component in fresh cassava root.

Composition	Mass ratio (wet basis)
Water	63.80
Starch	29.73
Fiber	3.55
Other	2.92

4.2 Results of experiments using water as an extraction solvent.

In this section, the experiments are subdivided into 2 parts. The first part is conducted to evaluate the effect of stirring time focusing on extraction efficiency. The second part is performanced to study the effect of liquid to solid ratio (L/S ratio) on extraction efficiency. L/S ratio is defined as

$$\text{L/S ratio} = \frac{\text{Total Mass of solvent for extraction(g)}}{\text{Mass of root pulp(g dry basis)}} \qquad (4.3)$$

Each experiment in this section was conducted by adding the suitable amounts of water to 200 grams of root rasped and then the mixture is stirred. Table 4.2 summarizes the quantity of water used in each step of the extraction process. The experiment was conducted with the stirring speed of 600 rpm and the stirring time between 2 to 14 minutes. While stirring, the liquid sample was taken every 2 minutes to analyze for starch content in the liquid. Later, the slurry was filtered through centrifugal screening for separating between the starch milk and fiber. While filtering, water was added. The pulp residue from final extraction were kept for analysis. Table A3 in Appendix A shows the results of these experiments.

Table 4.2 The water quantity for each step of extraction process

L/S ratio	Water for extraction(g)		
	Water for mixed slurry	Water for screening	Total water
10.5	240	600	840
12.0	360	600	960
13.5	480	600	1080
15.0	600	600	1200
16.5	720	600	1320
18.0	840	600	1440
19.5	960	600	1560

4.2.1 Effect of stirring time on the efficiency of cassava starch extraction

Table 4.3 shows extraction efficiency of cassava roots using water extraction solvent. The extraction efficiency is defined as

$$\text{Extraction Efficiency(\%)} = \frac{W1}{(W1+W2)} \times 100 \qquad (4.4)$$

W1 = Starch content in solution
W2 = Weight of extracted starch
W3 = Starch content in pulp residue

Table 4.3 Extraction efficiency of starch from cassava roots.

L/S Ratio Time (min)	% Extraction Efficiency						
	10.5	12.0	13.5	15.0	16.5	18	19.5
2	32.39	39.45	43.55	49.32	53.44	57.79	60.7
4	38.21	43.84	50.43	54.93	57.86	62.25	66.78
6	42.43	47.23	56.31	61.52	65.29	67.74	70.23
8	48.62	55.17	61.65	67.92	71.13	72.93	73.64
10	50.62	57.65	66.86	73.47	76.77	77.31	77.81
12	54.11	64.01	70.52	75.66	77.36	78.29	78.66
14	58.46	67.32	73.81	77.27	77.87	78.35	78.76

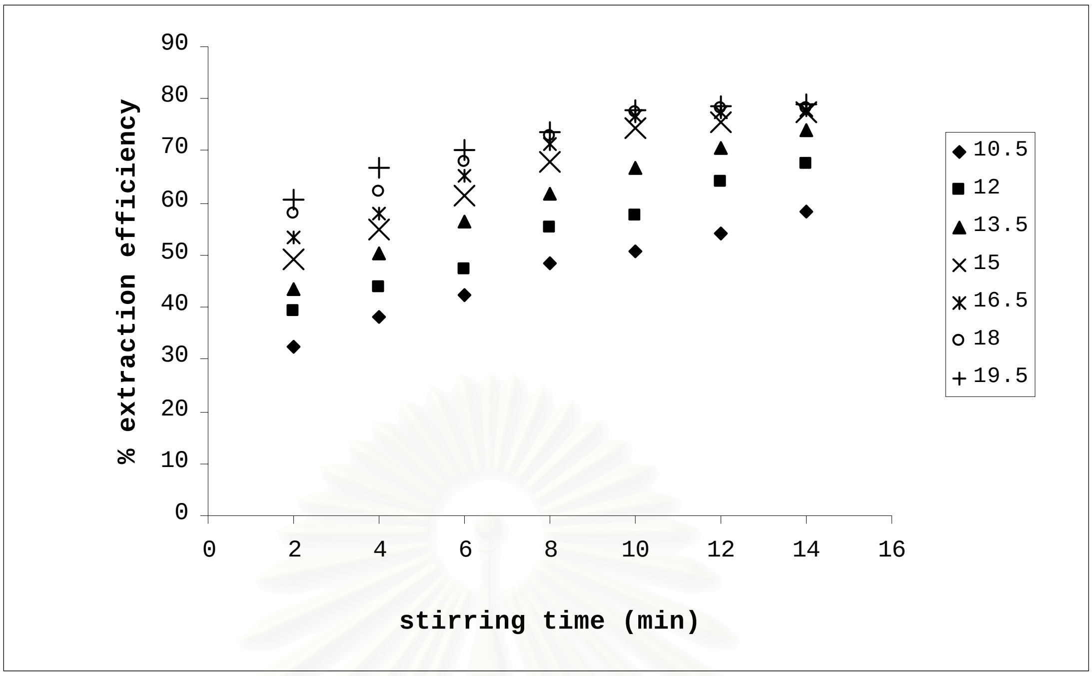


Figure 4.1 Effect of stirring time and L/S ratio on extraction efficiency.

Figure 4.1. illustrates the extraction efficiency percentage of starch from cassava roots versus stirring time at various L/S ratio. The results indicate that extraction efficiency increases with stirring time. At L/S ratio of less than 15, the extraction efficiency increases almost linearly with time while at L/S ratio of greater than 15, the efficiency levels off after 10 minutes of stirring time.

Thanont K. (2001), studied the effect of time on starch extraction. He reported that the extraction efficiency increases almost linearly with time. After 10 minutes, stirring time does not have any effect to extraction efficiency of starch because all starches are extracted.

During the initial period, the surface of cassava fiber contains a lot of starches can be easily which extracted. At the low L/S ratio, the quantity of water is not enough to separate all free starch granules from the fiber so the extraction efficiency of starch depends strongly on time. At the high L/S ratio, water quantity is more than enough to separate free starch from fiber, so most of the starch is extracted in shot time. In addition, the stirring promotes contact between the two phases, allowing transfer of the starch granule from the fiber matrix to the water (Susanne R., 2005).

4.2.2 Effect of water and cassava pulp weight ratio (L/S ratio) on extraction efficiency

Figure 4.2 shows plot of extraction efficiency at various L/S ratio for a stirring time of 10 minutes. It is observed that extraction efficiency increases continuously to L/S ratio of 15. At L/S ratio of higher than 15, the extraction efficiency remains constant.

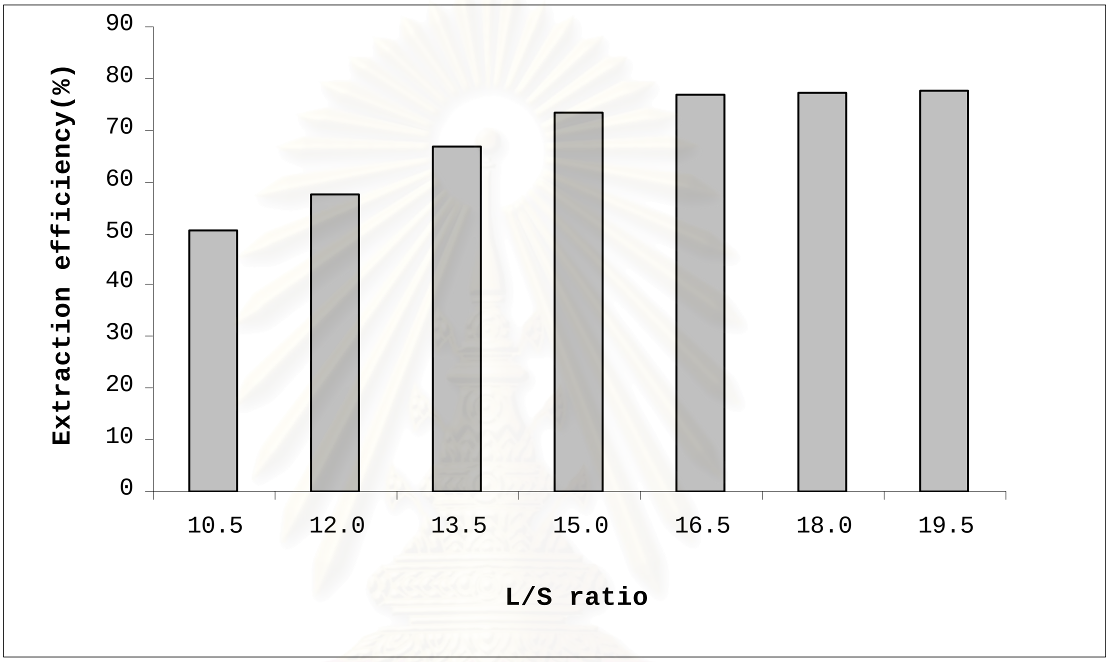


Figure 4.2 Effect of L/S ratio on extraction efficiency at stirring time of 10 minutes.

The extraction efficiency increases as the L/S ratio increases because water acts as a carrier to convey free starch from fiber. At L/S ratio higher than 15 and stirring time higher than 10 minutes, the extraction efficiency are constant at about 77%.

Siriwattanachaikul C. (1997), studied the effect of water consumption to dry solid ratio (L/S ratio) on the efficiency of the cassava starch extraction. He described the mechanism of starch extraction that water acts to liberate starch granules on the surface of cassava fiber by breaking weak hydrogen bonds hold starch to fiber. Which free starch granules that be convected into the water. So increasing water quantity can increase the extraction efficiency of starch. He presented the optimal L/S ratio is 15:1 which is approximately the same ratio as found in this study.

Base on the experimental results obtained from this study, the L/S ratio of 15 and the stirring time of 10 minutes are selected as suitable conditions for extraction of starch from cassava root. The stirring time of 10 minutes is the time when the maximum amount of starch is extracted from cassava root. Comparison of effect of surfactant will discuss later on this Chapter conducted using the stirring time of 10 minutes. Table 4.4 shows the comparison between water quantity used in each starch extraction of this study and the amount of water normally used in industry. It can be observed that the amount of water used at our suitable conditions is comparable to the amount of water used in the industry.

Table 4.4 Comparison between amount of water used in this study and industry

Step of extraction	Amount of water(m^3/ton fresh root)	
	Industrial	Experiment
Stirring	5.8	6.0
1st Extraction	3.5	6.0
2nd Extraction	2.5	

4.3 Result of experiments using surfactants an extraction solvent

In this section, surfactant, polyoxyethylene sorbitan monooleate (Tween 80), was added to water and the solution was used as extraction solvent. The Experiment was conducted at surfactant concentration of 0.25%wt, 1%wt, and 3%wt. Other operating conditions were similar to the conditions used in section 4.2. Table 4.5 shows quantity of surfactant solution used in this study. Experimental results are summarized in Table A3, Appendix A

Table 4.5 Solvent quantity for each step of extraction

L/S ratio	solvent for extraction(g)		
	Tween 80 for mixed slurry	Water for screening	Total solvent
10.5	240	600	840
12	360	600	960
13.5	480	600	1080
15	600	600	1200

4.3.1 Effect of surfactant on extraction of starch.

In this section, effect of addition of surfactant into water on extraction of starch is discussed. Table 4.6 shows extraction efficiency of starch calculated using Equation 4.4. The results are plotted and shown in figure 4.3.

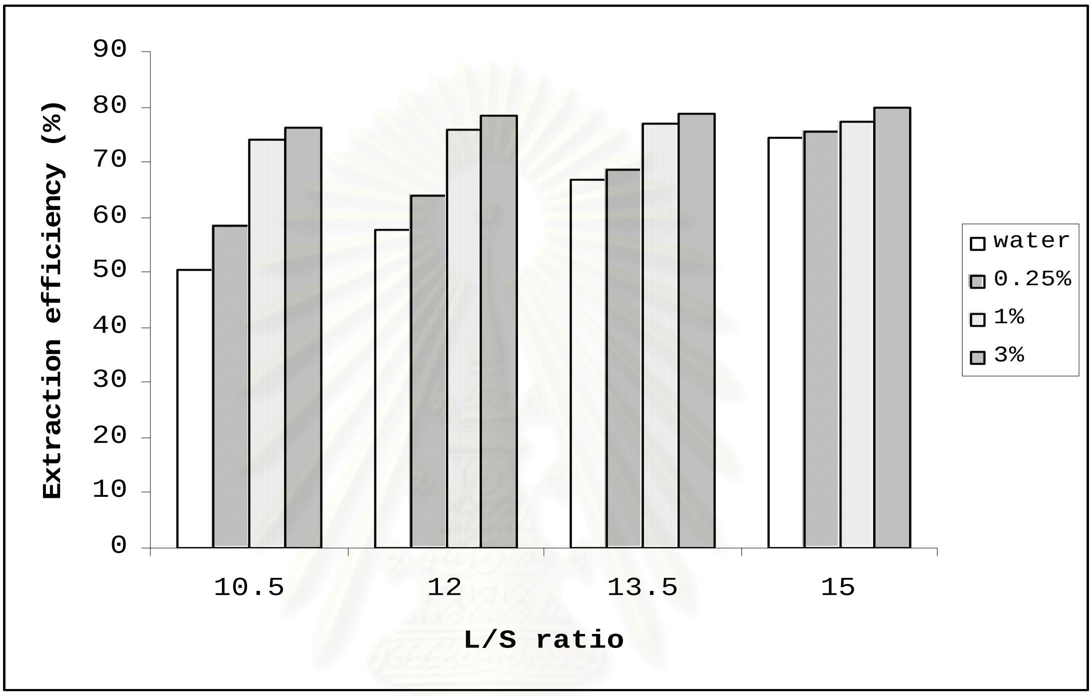


Figure 4.3 Comparison of extraction efficiency between water and the different surfactant concentration again L/S ratio at stirring time of 10 minutes.

Table 4.6 Starch extraction efficiency in different surfactant concentrations

L/S ratio	Time	Efficiency (%)			
		Surfactant concentration (%wt.)			
		0	0.25	1	3
10.5	2	32.39	38.49	54.22	61.46
	4	38.21	45.29	60.89	71.85
	6	42.43	50.28	67.19	73.21
	8	48.62	54.49	70.44	75.22
	10	50.62	58.44	74.19	76.21
	12	54.11	63.78	76.22	77.34
	14	58.46	66.71	79.38	79.09
12.0	2	39.45	45.70	56.88	67.46
	4	43.84	50.21	65.36	75.64
	6	47.23	57.34	70.73	76.81
	8	55.17	60.22	74.19	77.07
	10	57.65	63.94	75.73	78.22
	12	64.01	68.32	77.98	79.75
	14	67.32	71.25	79.98	80.05
13.5	2	43.55	51.52	62.49	71.83
	4	50.43	57.32	67.47	76.07
	6	56.31	63.71	74.05	77.57
	8	61.65	66.02	76.19	77.69
	10	66.86	68.53	77.05	78.69
	12	70.52	75.30	78.22	80.05
	14	73.81	77.09	81.76	81.58
15.0	2	49.32	58.68	66.03	74.94
	4	54.93	62.21	70.65	78.47
	6	61.52	67.77	75.41	79.00
	8	67.92	71.56	76.98	79.75
	10	73.47	75.35	77.41	79.75
	12	75.66	78.30	79.98	81.05
	14	77.27	79.40	82.38	82.05

The results show that the addition of surfactant into water can enhance the extraction efficiency. The enhancement depends on L/S ratio. At low L/S ratio the enhancement is more pronounced than at high L/S ratio. It is also observed that extraction efficiency does not depend on L/S ratio at high surfactant concentration.

Borchardt (1994) studied the removal of particles (starch granule) from substrate (pulp fiber) and the mechanism of removal of particles from substrate using surfactant. He suggested that the surfactant can reduce the interfacial tensions of particles and substrate which enhance the removal of the particles from substrate. Moreover, particles are adsorbed on the surface of the micelle which can prevent the readsorbing of the removed particles by disperse them in solution. The illustrations of this mechanism are shown in Figure 4.9.

The micelle of polyoxyethylene sorbitan esters (Tween 80 group) contain an inner core of hydrocarbon tails whereas polyoxyethelene group on the outer shell. The polyoxtethylene group will have strong affinity with the starch particles (Shick M. J., 1966). Starch granule are attracted on the outer shell of micelle and removed from fiber.

Where;

● represents Polyoxyethelene chain (polar portion)

∼ represents Hydrocarbon chain (non polar portion)

○ represents strach granule

Figure 4.4 The micelle formation of Polyoxyethylene sorbitan esters and position solubilization of hydrophilic solute in micelle (Shick M. J., 1966).

Sahoo D. (1997), studied relatively effect of Triton X-100 concentrations on trichloroethene (TCE) desorption from field-contaminated soil to water. He reported that the addition of Triton X-100 (at low concentrations but close to critical micelle concentration) to the soil-water system increased the rate of TCE desorption from the soil at early times, although only by a small amount. The similar results were obtained by increasing the solution pH from 7 to 10.

Maggie P.K.and cowokers (2003), studied extraction of ginsenoside from medicinal plants using different solvent, water and nonionic surfactant (Triton X-100). They was found that an aqueous solution containing a nonionic surfactant (Triton x-100) as the solvent at a concentration above its critical micelle concentration can increase the amount of extracted ginsenosides from ginseng roots.

David A.E. (1991), studied effect of surfactant concentration at above the critical micelle concentration (CMC). He described the primary function of incremental surfactant is to adsoption of particle molecules on micelles. It can be explain that the aqueous surfactant concentration above CMC, all of added surfactants are formed new micelles. So number of micelle in solution increase when concentration of surfactant in solution increase. It indicates that increasing concentration of Tween 80 results to raise number of micelle in solution.

In this research, Tween 80 is used as extraction solvent and all concentrations of Tween 80 above CMC. The CMC of Tween 80 is 0.012 mM or 0.0152 g/l (Yeom I.T., 1995). So the extraction efficiency increases concurrent with Tween 80 concentration because the solubilization of starch into other portion of micelle is increase.

4.3.2 Effect of stirring time on cassava starch extraction efficiency with surfactant

Figures 4.5 to 4.8 show the starch extraction efficiency versus time at various surfactant concentration and at various L/S ratio. The results indicate that the extraction efficiency increases when the stirring time increases.

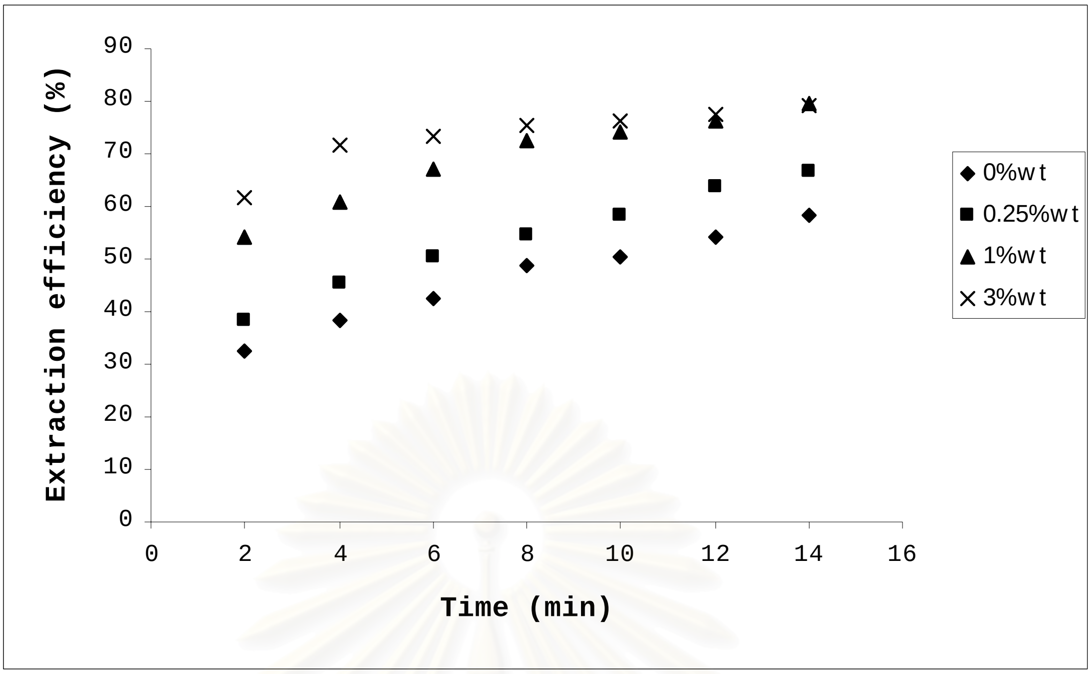


Figure 4.5 Effect of stirring time on extraction efficiency at L/S ratio of 10.5

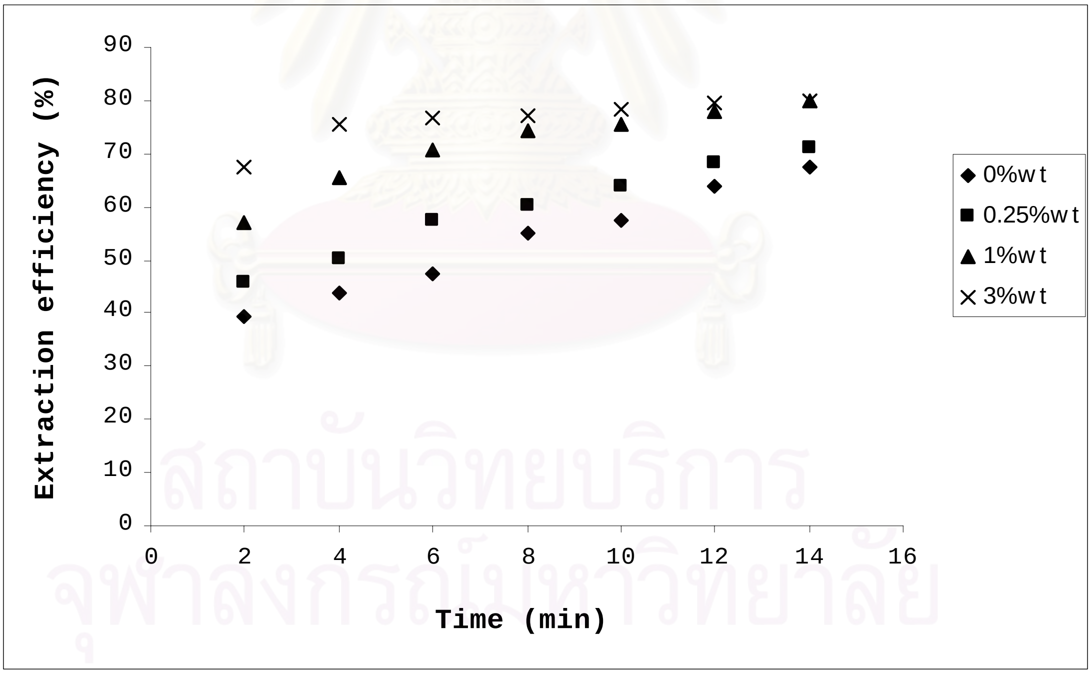


Figure 4.6 Effect of stirring time on extraction efficiency at L/S ratio of 12.0

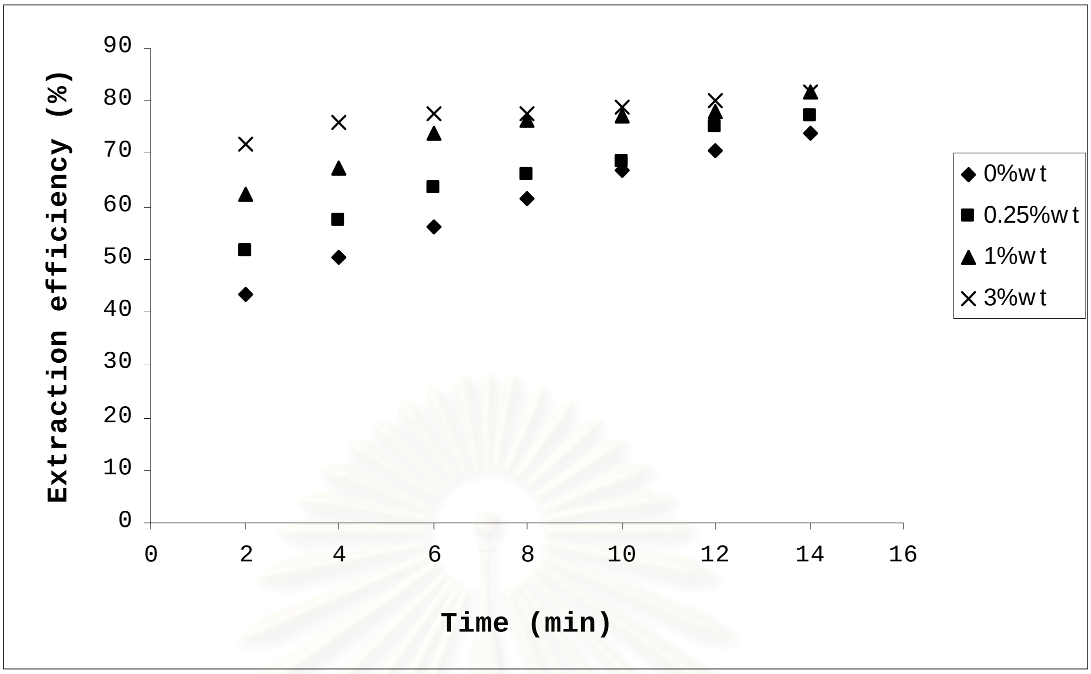


Figure 4.7 Effect of stirring time on extraction efficiency at L/S ratio of 13.5.

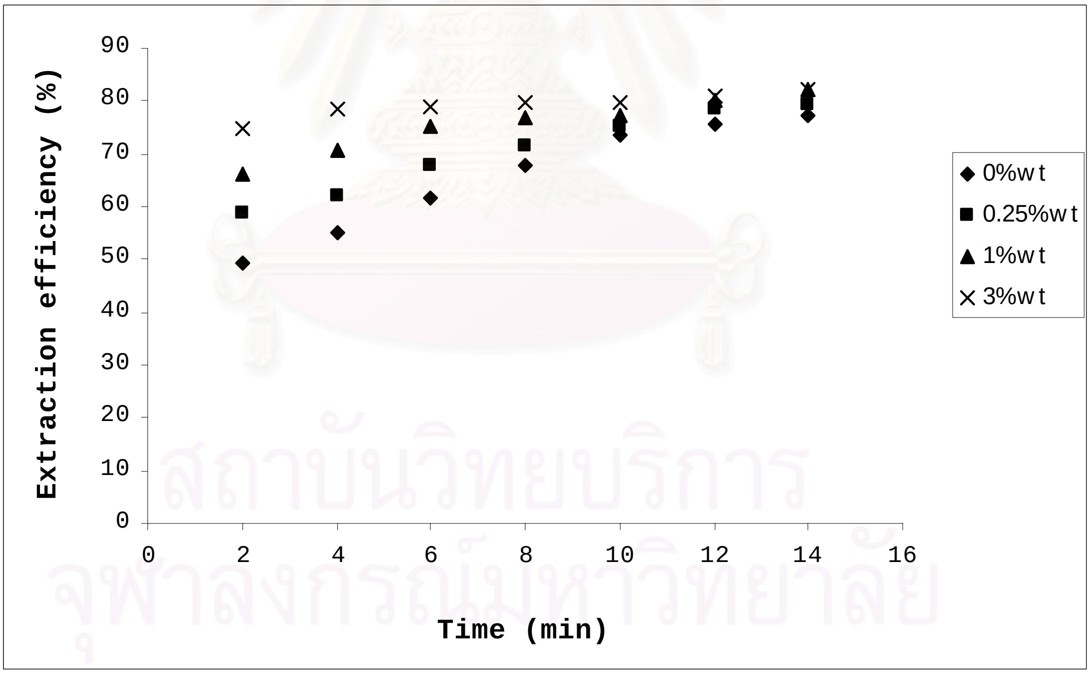


Figure 4.8 Effect of stirring time on extraction efficiency at L/S ratio of 15.0

The stirring time required for maximum amount of starch extracted from cassava root depends on L/S ratio and surfactant concentration. The high values of L/S ratio and surfactant concentration results are less stirring time for starch to be extracted.

Zhihong S. (2004), studied the influence of extraction time on the extraction recovery of tanshinones. It was from Salvia miltiorrhiza using nonionic surfactant as extraction solvent. He found that recovery of tanshinones increased concurrent with the extraction time. It reached the highest value when extracted for 45 minutes because the extraction recovery depended on the contact time.

Qun F. (2000), studied the difference solvent, such as water, methanol and nonionic surfactant (Triton X-100), for extracting ginsenosides from the Chinese herbal medicine. She reported that using nonionic surfactant as solvent yielded the fastest extraction kinetics and the highest recovery for the extraction of gisenosides, followed by methanol and then water. She described that micelle of surfactant in water provided a solubility enhancment effect which increased the rate of desorption of organic compounds from solid substrate.

Somwang P. (2001), studied optimum conditions of various factors for curcuminoids extraction from tumeric using polyoxyethylene sorbitan monooleate (Tween 80) as solvent and. He found that the curcuminoids recovery percentage increased with increasing stirring time and constant after 20 minutes because the most of curcuminoids is extracted in this time.

In this research, surfactant (Tween 80) is solvent for starch extraction which surfactant can increase solubility of starch in solution by adsorption of starch on micelle surface. The solubility of starch increase with increasing surfactant concentration because micelles in solution is increase. So increasing number of micelle at high concentration can reduce time for extraction.

Sriroth K. (2000), studied the improved starch recovery from cassava roots. They reported that the pulp residual after the starch extraction contains a high starch content and high fiber content. The high fiber content probably plays significant role in retarding starch extraction as the fibrous network holds starch granules. There are 2 remained starch granules that are small granule (hold on outer of fiber matrix) and embedded in fibrous network are difficult to liberate. Figure 4.9 illustrates SEM of microstructure of cassava pulp

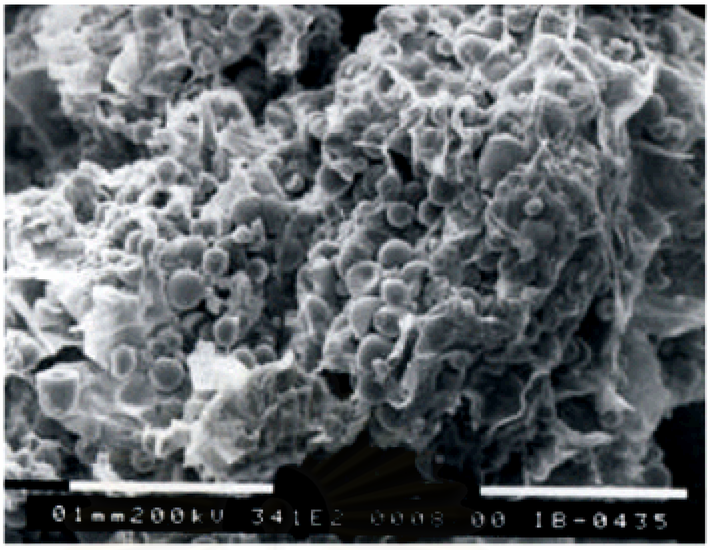


Figure 4.9 Scanning electron microscope of cassava pulp (Sriroth K.,2003)

Andersson A. and coworker (1994), studied microstructure of potato. She reported that cell walls consist of microstructure composed of cellulose embedded in a polysaccharide and protein matrix surrounded by an outer layer composed mainly of pectic material. The starch granules in pulp residual contained in this complex polymer matrix are difficult to liberate. Therefore to remove starch extraction from pulp, this complex matrix must be destroyed.

From both studies, It can be observed that surfactant can help desorbtion of small starch granules on fiber but it can not destroy fiber matrix and liberate starch granules. The extraction efficiency is constant when all starches holded on fiber are extracted from fiber. The remained starch that are embedded in the fiber matrix can not be extracted from fiber matrix. The starch granules can be liberated when fiber matrix is destroyed by using enzyme.

4.3.3 Effect of mass ratio of surfactant and cassava pulp (L/S ratio) on extraction efficiency

Figures 4.10 to 4.16 show the starch extraction efficiency versus L/S ratio at various surfactant concentrations and times. The results indicate that extraction efficiency increases when L/S ratio increases in the short period.

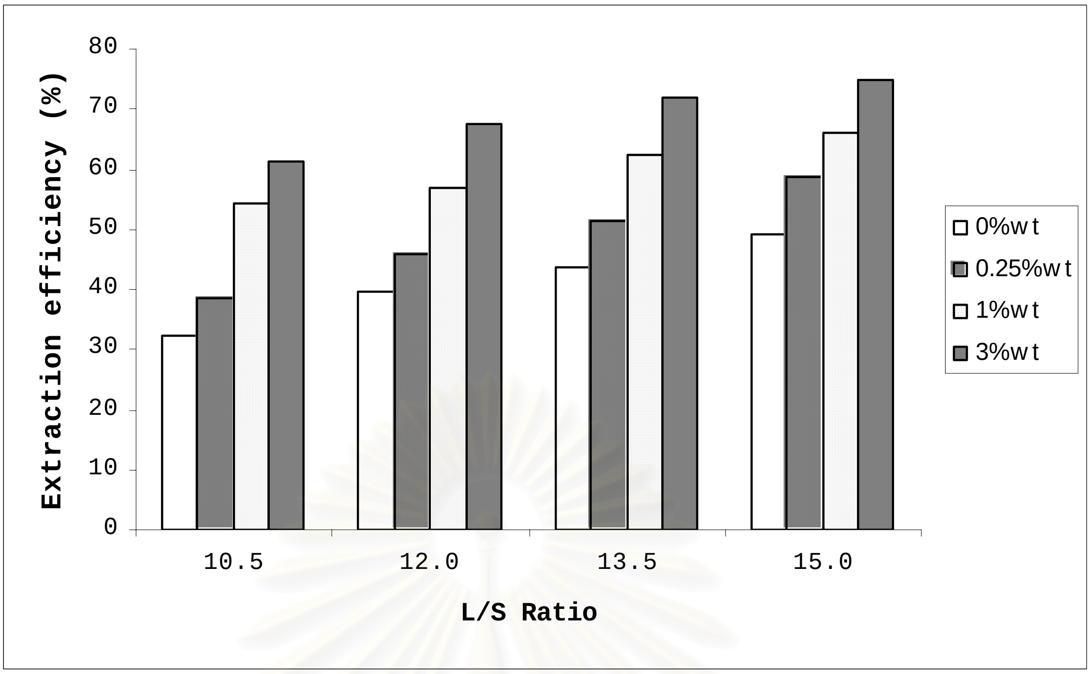


Figure 4.10 Effect of L/S ratio on extraction efficiency at stirring time of 2 minutes.

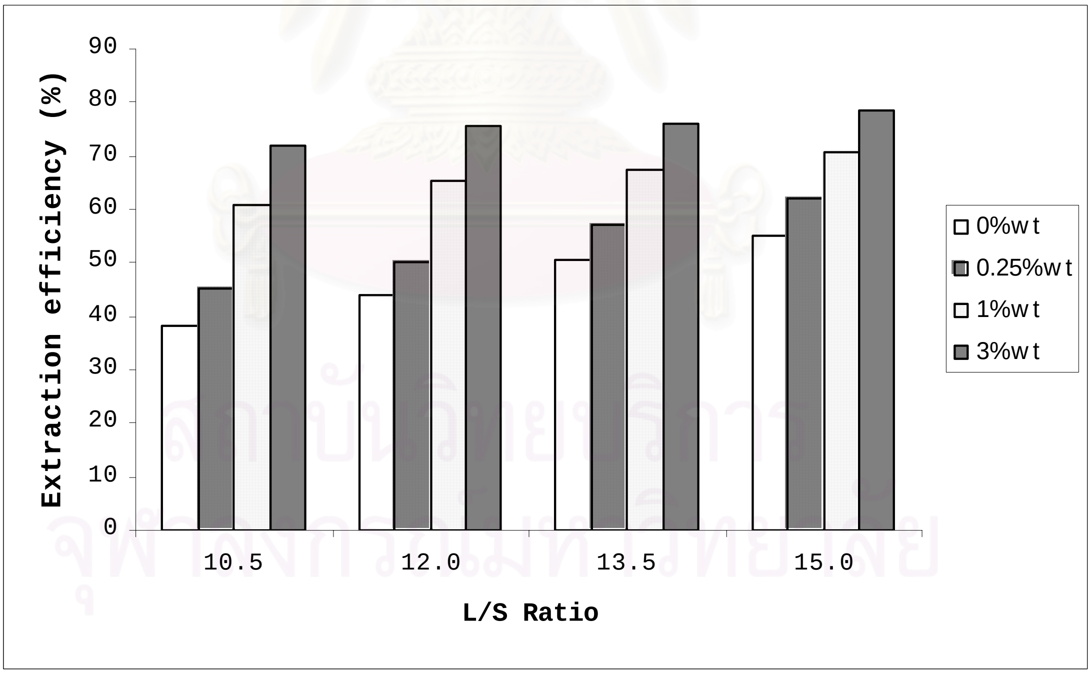


Figure 4.11 Effect of L/S ratio on extraction efficiency at stirring time of 4 minutes.

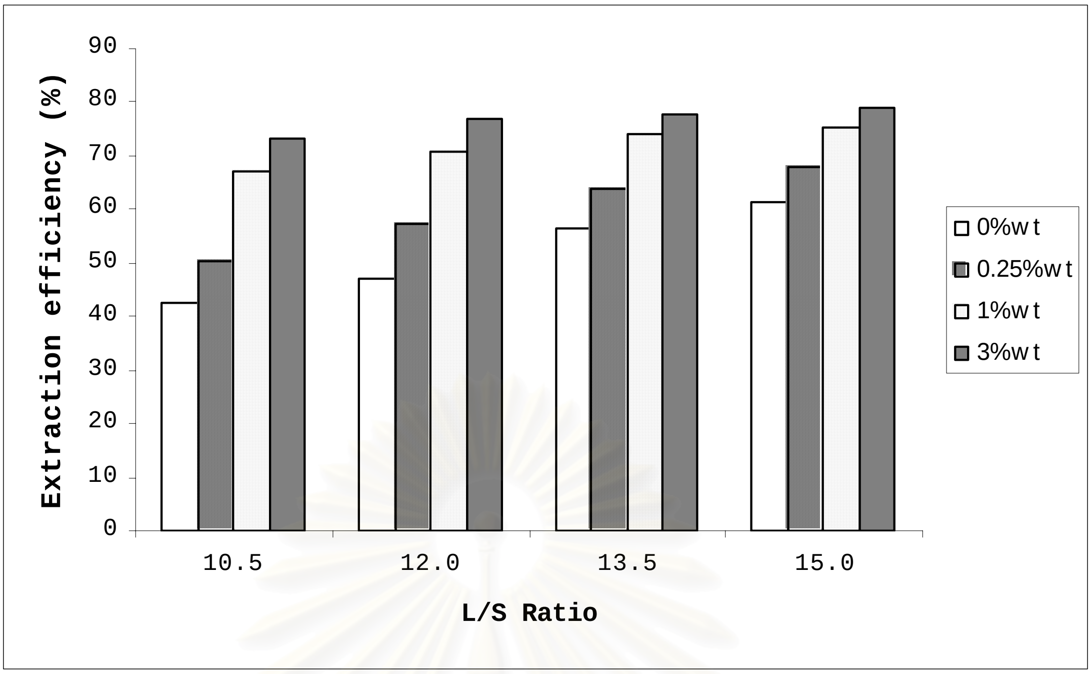


Figure 4.12 Effect of L/S ratio on extraction efficiency at stirring time of 6 minutes.

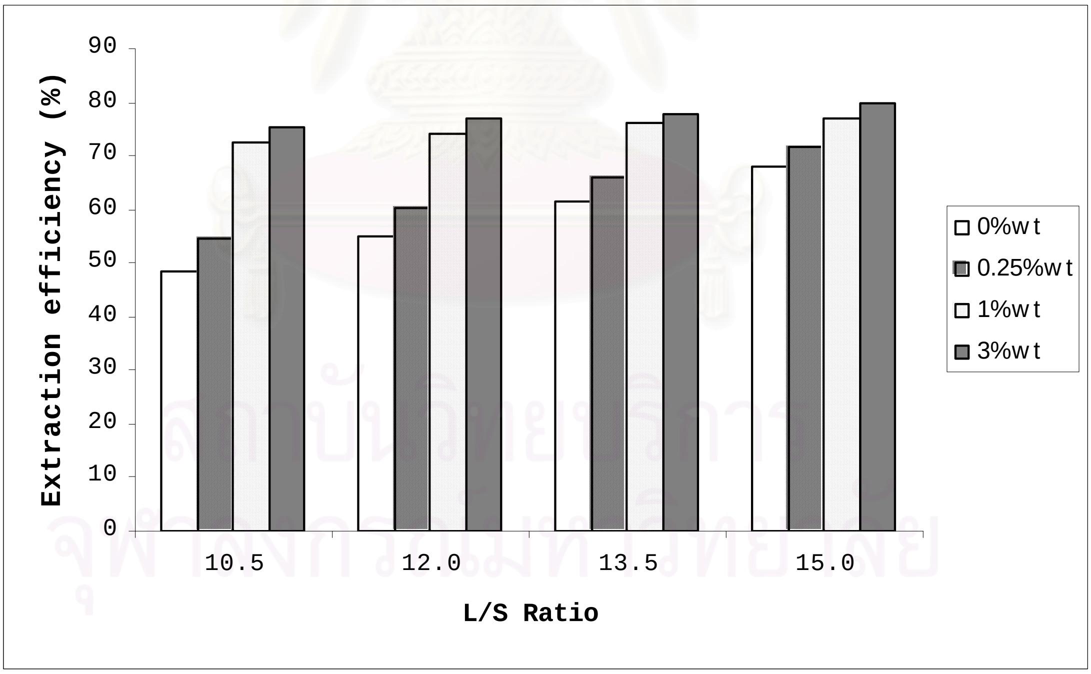


Figure 4.13 Effect of L/S ratio on extraction efficiency at stirring time of 8 minutes.

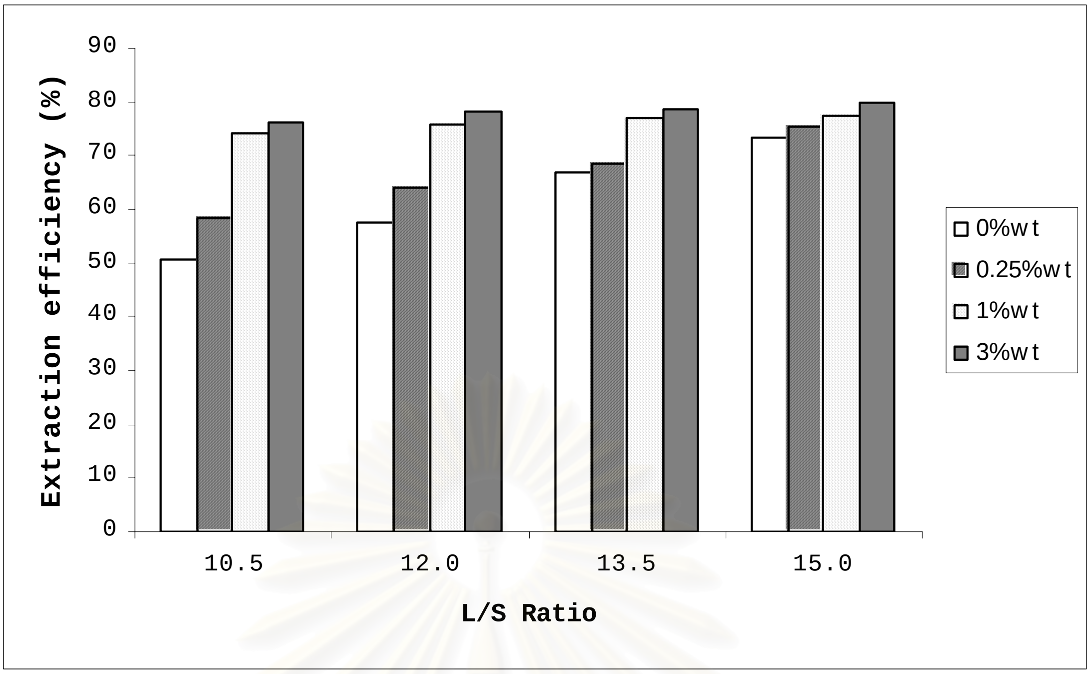


Figure 4.14 Effect of L/S ratio on extraction efficiency at stirring time of 10 minutes.

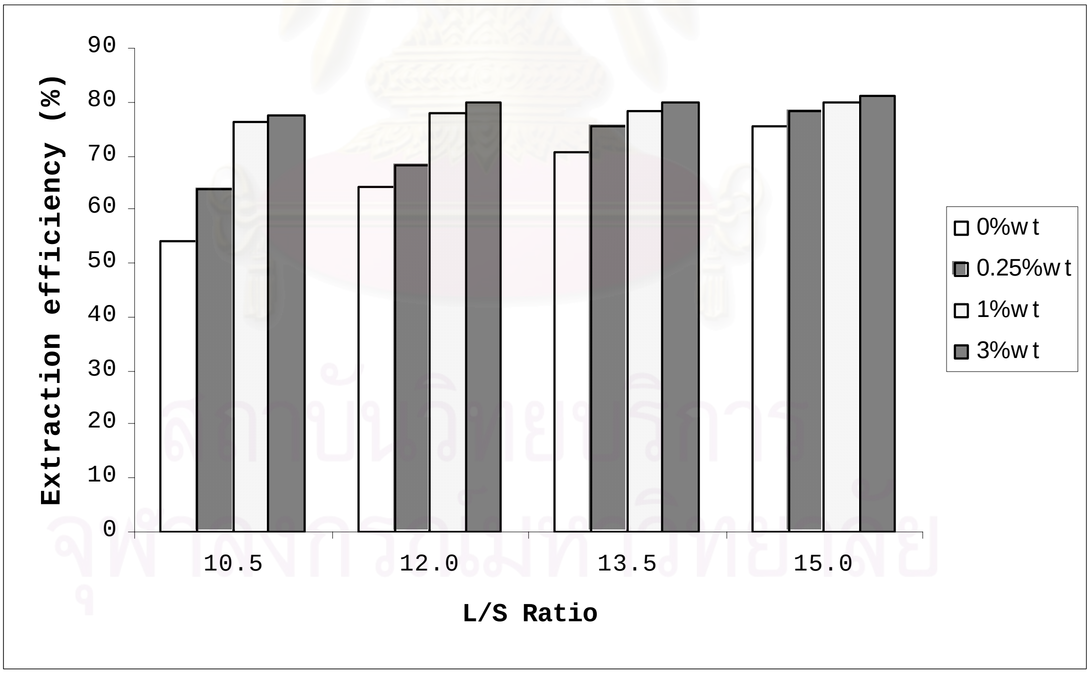


Figure 4.15 Effect of L/S ratio on extraction efficiency at stirring time of 12 minutes.

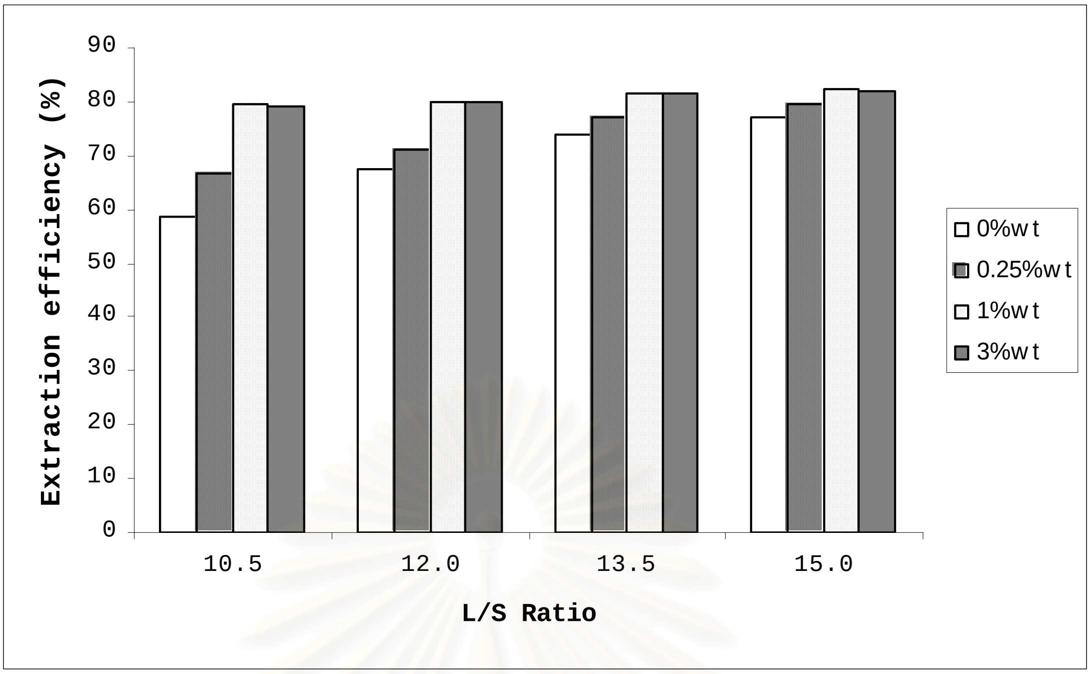


Figure 4.16 Effect of L/S ratio on extraction efficiency at stirring time of 14 minutes.

The results can easily by observed at the initial period of extraction. During the initial period, from start up to approximately 6 minutes, , L/S ratio and surfactant concentration increasing can rise the extraction efficiency. At time progress, only slightly effects can be observed especially at high L/S ratio.

Christi A. 1995, described the phenomenon of convection mass transfer that fluid flows passed through the solid surface in forced convection motion and the rate of convection mass transfer of starch from the fiber surface is followed by

$$N_A = k_L A(C_{AS}-C_A) \qquad (4.5)$$

k_L : mass transfer coefficient(g/min)
C_A : concentration of A in the solution (bulk solution)at time t(g)
C_{AS} : concentration of A at interface(g)
A : interfacial area(m^2)

When increasing L/S ratio or increasing solvent volume, the concentration in solution (C_A) are decrease whereas the difference of concentration between bulk of liquid and the surface of solid is high. So mass transfer of starch is increase.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The following conclusions are drawn from the study:

1. Increasing stirring time and mass ratio of liquid and dry solid(L/S ratio) increase the percent starch extraction efficiency.
2. The optimal condition for starch extraction that use water as solvent is L/S ratio of 15 and stirring time for extraction of 10 minutes. The extraction efficiency of these condition is 73.47%.
3. When compared to the use of water and the nonionic surfactant(Tween 80) in water at concentrations above the CMC was found to enhance starch extraction efficiency from cassava roots.
4. Increasing in L/S ratio and surfactant concentration increases the extraction efficiency and high values of L/S ratio and surfactant concentration result is less stirring time for starch to be extracted.

Recommendations

Recommendations for future studies and research are as follows:

1. The compared to the use of different surfactant(Tween 80) enhance starch extraction efficiency from cassava roots.

Reference

Andersson, A. et al. (1994). Effect of preheating on potato texture. Critical Reviews in Food Science and Nutrition. 34 : 229-251.

Balagopalan, C. (1996). Improveing the nutritional value of cassava by solid state fermentation : CTCRI Experiences. Journal of Scienctific and Industrial Research. 5 : 479-482.

Borchardt, J.K. (1994). Mechanistic insights into de-inking. Colloids and Surfaces A: Physicochemical and Engineering Aspects. 88 : 13-25

Christi, A. and Jennifer, A.F. (2003). Predictors of 6-month tobacco abstinence among 1224 cigarette smokers treated for nicotine dependence. Addictive Behaviors. 28 : 1203–1218.

David, A.E. and Zafar, A. and Rlchard, G.L.(1994). Distribution of Nonionic Surfactant and Phenanthrene in a Sediment/Aqueous System. Environ. Sci. Techno. 28 : 1550-1560.

Deshpande, S. and Shiau, B.J. (1999). Surfactant selection for enhancing EX SITU soil washing. Wat. Res. 33 : 351-360.

Dixit, S.G. and Vanjara, A.K. and Nagarkar, J. (2002). Co-adsorption of quaternary ammonium compounds-nonionic surfactants on solid-liquid interface. Physicochemical and Engineering Aspects. 205 : 39-46.

Gecol, H. (2001). Use of surfactants to remove water based inks from plastic films. Physicochemical and Engineering Aspects. 189 : 55-64.

Gongyuan, W. and Yin, L. (2003). Effect of surfactant on extracellular accumulation of glutathione by Saccharomyces cerevisiae. Process Biochemistry. 38 : 1133-1138.

Jansawang, S. (2001). The adsorption of surfactant on inks and on paper fibers related to paper recycling. Master’s Thesis, Petroleum and Petrochemical College. Chulalongkorn University.

Lineback, D.R. (1984). The starch granule: Organization and properties. Bakers Digest. 58 : 16-21.

Maggie, P.K. and Kelvin, K.C.(2003). Pressurized liquid extraction of active ingredients (ginsenosides) from medicinal plants using non-ionic surfactant solutions. Journal of Chromatography A. 983 : 153–162.

Milton, J.R. (1993). Surfactant and interfacial phenomena. New York: John Wiley & Sons.

Patrolecco, L. (2004). Determination of endocrine disruption chemicals in environmental solid matrices by extraction with a non-ionic surfactant (Tween 80). Journal of Chromatography A. 1022 : 1-7.

Paul, P.C. and Palmer ,H.H. (1972). Food Theory and Application. New York: John Wiley & Sons.

Qun, F. (2000). Micelle-mediated extraction and preconcentration of ginsenosides from Chinese herbal medicine. Journal of Chromatography A. 904 : 47-55.

Radley, J.A. (1976). Starch Production Technology. Essex: Applied Science Publisher.

Rahman, S.M.M. (2003). Selection of sweet potato variety for high starch extraction. International Journal of Food Properties. 6 : 419-430.

Rittisang, K. (2003). Influence of cassava root varieties and harvesting ages on water usage in starch extractor unit. Master’s Thesis, Natural Resources Management. School of Bioresources and Technology. King Mongkut’s University of Technology Thonburi.

Sahoo, D. and Smith, J.A. (1997). Enhanced Trichloroethene Desorption from Long-Term Contaminated Soil Using Triton X-100 and pH Increases. Environ. Sci. Technol. 31 : 1910-1915.

Scame, J.F. and Harwell, J.H. (1989). Surfactant-based separation processes. New York: Marcel Dekker.

Schick, M.J. (1966). Nonionic surfactant. New York: Marcel Dekker.

Siriwattanachaikul, C. (1997). A study of starch extraction from cassava root. Master’s Thesis, Department of Chemical Engineering. Faculty of Engineering. King Mongkut’s University of Technology Thonburi.

Somwang, P. (2001). Extraction of curcuminoids from turmeric using polyoxyethylene sorbitan monooleate. Master’s Thesis, Department of Chemical Engineering. Faculty of Engineering. Chulalongkorn University.

Songsiri, D. (2002). Use of cationic surfactant to remove solvent-based ink from rigid high density polyethylene surfaces. Physicochemical and Engineering Aspects. 204 : 261-269.

Sriroth, K. (2000). Processing of cassava waste for improved biomass utilization. Bioresource Technology. 70 : 63-69.

Sriroth, K. and Piyajomkhun, K. (2003). Starch Technology. Bangkok: KU Press.

Supiruk, S. (1996). Surfactant-enhanced carbon regeneration in liquid phase applications. Master’s Thesis, Petroleum and Petrochemical College. Chulalongkorn University.

Susanne, R. and Sonja, W. (2005). Impact and interaction of lipophilic antioxidants in mutants and transgenic plants. Journal of Plant Physiology. 162 : 1197-1209.

Swe, S.M. (1999). Removal of ink from rigid high-density polyethylene surfaces to permit plastic recycling. Master’s Thesis, Petroleum and Petrochemical College. Chulalongkorn University. Thailand

Teerawat, P. (2001). Cassava starch filtration. Master’s Thesis, Department of Chemical Engineering. Faculty of Engineering. King Mongkut’s University of Technology Thonburi. Thailand.

Thai Industrial Standards Institute. (1973). Thai Industrial Standard for Tapioca Products. TIS 52-2516.

Thanont, K. (2001). Tapioca Starch Extraction by Stirring During Filtration. Master’s Thesis, Department of Chemical Engineering. Faculty of Engineering. King Mongkut’s University of Technology Thonburi. Thailand.

Thitipong, K. (2000). The Adsorption of surfactant on inks related to paper recycling. Master’s Thesis, Petroleum and Petrochemical College. Chulalongkorn University. Thailand.

Yeom, I.T. (1995). Micellar solubilization of polynuclear aromatic hydrocarbons in coal tar-contaminated soil. Environ. Sci. Technol. 29. 3 : 15-21.

Zhihong, S. and Jiantao, H. and Wenbao, C. (2004). Micelle-mediated extraction of tanshinones from Salvia miltiorrhiza bunge with analysis by high-performance liquid chromatography. Talanta. 64 : 401–407.

APPENDICES

APPENDIX A

Table A1. Analysis result of standard soluble starch by Polarimetric method

sample (g/l)	P-P’			% starch (dry basis)			Starch concentration(g/L)				
	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3	Avg.	STDEV
0.1	8.742	8.833	8.907	95.023	96.01	96.820	0.095	0.096	0.097	0.096	0.001
0.2	8.786	8.926	8.925	95.501	97.023	97.011	0.191	0.194	0.194	0.193	0.002
0.3	8.833	8.863	8.709	96.007	96.333	94.667	0.288	0.289	0.284	0.287	0.003
0.4	8.809	8.625	8.717	95.750	93.750	94.751	0.383	0.375	0.38	0.379	0.004
0.5	8.538	8.630	8.703	92.800	93.802	94.603	0.464	0.469	0.473	0.469	0.005

% starch = 2000 * $\frac{(P-P')}{100}$,

Starch concentration (g/L)= % starch (dry basis) * starch sample

Table A2. Analysis result starch content of cassava root by Polarimetric method

sample (g/l)	P-P’			% starch (dry basis)			Starch concentration(g/L)				
	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3	Exp. 1	Exp. 2	Exp. 3	Avg.	STDEV
0.1	6.810	6.625	6.607	74.023	72.010	71.820	0.074	0.072	0.072	0.073	0.001
0.2	6.670	6.580	6.763	72.501	71.523	73.511	0.145	0.143	0.147	0.145	0.002
0.3	6.685	6.593	6.593	72.667	71.667	73.333	0.218	0.215	0.220	0.218	0.003
0.4	6.670	6.601	6.601	72.500	71.750	73.750	0.290	0.287	0.295	0.291	0.004
0.5	6.771	6.716	6.716	73.601	73.000	74.600	0.368	0.365	0.373	0.369	0.004

% starch = 2000 * $\frac{(P-P')}{100}$,

Starch concentration (g/L)= % starch (dry basis) * starch sample

Calculation of starch extraction efficiency

The percent extraction efficiency in solution can be calculate from the following formular:

$$\text{extraction efficiency}(\%) = \frac{W1}{(W2 + W3)} \times 100$$

Where ;
W1 = Starch content in solution (g)
W2 = Weight of extracted starch (g)
W3 = Starch content in pulp residue (g)

The percent starch extraction efficiency from cassava roots by use water at any L/S ratio

Table A3. Analysis result of starch content.

Tween 80 conc (%wt)	L/S ratio	Time (min)	Starch content in solution (g)	Total Extracted starch (g)	Starch in pulp (g)	Total starch in roots (g)	Extraction efficiency (%)
0	10.5	2	16.415	33.736	17.501	51.237	32.39
		4	19.364	33.736	17.501	51.237	38.21
		6	21.503	33.736	17.501	51.237	42.43
		8	24.640	33.736	17.501	51.237	48.62
		10	25.654	33.736	17.501	51.237	50.62
		12	27.422	33.736	17.501	51.237	54.11
		14	29.627	33.736	17.501	51.237	58.46
	12.0	2	20.407	35.760	15.349	51.109	39.45
		4	22.677	35.760	15.349	51.109	43.84
		6	24.431	35.760	15.349	51.109	47.23
		8	28.538	35.760	15.349	51.109	55.17
		10	29.821	35.760	15.349	51.109	57.65
		12	33.111	35.760	15.349	51.109	64.01
		14	34.823	35.760	15.349	51.109	67.32
	13.5	2	22.138	37.859	12.976	50.835	43.55
		4	25.636	37.859	12.976	50.835	50.43
		6	28.625	37.859	12.976	50.835	56.31
		8	31.339	37.859	12.976	50.835	61.65
		10	33.988	37.859	12.976	50.835	66.86
		12	35.848	37.859	12.976	50.835	70.52
		14	37.521	37.859	12.976	50.835	73.81
	15.0	2	24.775	39.061	11.173	50.234	49.32
		4	27.593	39.061	11.173	50.234	54.93
		6	30.903	39.061	11.173	50.234	61.52
		8	34.118	39.061	11.173	50.234	67.92
		10	36.906	39.061	11.173	50.234	73.47
		12	38.007	39.061	11.173	50.234	75.66
		14	38.815	39.061	11.173	50.234	77.27

Tween 80 conc (%wt)	L/S ratio	Time (min)	Starch content in solution (g)	Total Extracted starch (g)	Starch in pulp (g)	Total starch (g)	Extraction efficiency (%)
0	16.5	2	26.957	39.638	10.807	50.445	53.44
		4	29.187	39.638	10.807	50.445	57.86
		6	32.935	39.638	10.807	50.445	65.29
		8	35.881	39.638	10.807	50.445	71.13
		10	38.726	39.638	10.807	50.445	76.77
		12	39.024	39.638	10.807	50.445	77.36
		14	39.281	39.638	10.807	50.445	77.87
	18.0	2	29.078	39.884	10.434	50.318	57.79
		4	31.322	39.884	10.434	50.318	62.25
		6	34.085	39.884	10.434	50.318	67.74
		8	36.696	39.884	10.434	50.318	72.93
		10	38.901	39.884	10.434	50.318	77.31
		12	39.393	39.884	10.434	50.318	78.29
		14	39.424	39.884	10.434	50.318	78.35
	19.5	2	30.411	39.957	10.143	50.100	60.70
		4	33.457	39.957	10.143	50.100	66.78
		6	35.185	39.957	10.143	50.100	70.23
		8	36.894	39.957	10.143	50.100	73.64
		10	38.983	39.957	10.143	50.100	77.81
		12	39.409	39.957	10.143	50.100	78.66
		14	39.459	39.957	10.143	50.100	78.76
0.25	10.5	2	19.369	36.309	14.014	50.323	38.49
		4	22.791	36.309	14.014	50.323	45.29
		6	25.302	36.309	14.014	50.323	50.28
		8	27.315	36.309	14.014	50.323	54.49
		10	29.408	36.309	14.014	50.323	58.44
		12	32.096	36.309	14.014	50.323	63.78
		14	33.570	36.309	14.014	50.323	66.71
	12.0	2	23.392	38.6142	12.574	51.188	45.70
		4	25.701	38.6142	12.574	51.188	50.21
		6	29.351	38.6142	12.574	51.188	57.34
		8	30.825	38.6142	12.574	51.188	60.22
		10	32.729	38.6142	12.574	51.188	63.94
		12	34.971	38.6142	12.574	51.188	68.32
		14	36.471	38.6142	12.574	51.188	71.25
	13.5	2	25.567	39.4321	11.176	50.608	51.52
		4	29.008	39.4321	11.176	50.608	57.32
		6	32.242	39.4321	11.176	50.608	63.71
		8	33.411	39.4321	11.176	50.608	66.02
		10	34.681	39.4321	11.176	50.608	68.53
		12	38.107	39.4321	11.176	50.608	75.30
		14	39.013	39.4321	11.176	50.608	77.09
	15.0	2	29.641	40.6091	9.904	50.513	58.68
		4	31.424	40.6091	9.904	50.513	62.21
		6	34.232	40.6091	9.904	50.513	67.77
		8	36.147	40.6091	9.904	50.513	71.56
		10	38.061	40.6091	9.904	50.513	75.35
		12	39.551	40.6091	9.904	50.513	78.30
		14	40.107	40.6091	9.904	50.513	79.40

Tween 80 conc (%wt)	L/S ratio	Time (min)	Starch content in solution (g)	Total Extracted starch (g)	Starch in pulp (g)	Total starch (g)	Extraction efficiency (%)
1	10.5	2	27.584	41.107	9.769	50.876	54.22
		4	30.978	41.107	9.769	50.876	60.89
		6	34.183	41.107	9.769	50.876	67.19
		8	35.837	41.107	9.769	50.876	70.44
		10	37.744	41.107	9.769	50.876	74.19
		12	38.777	41.107	9.769	50.876	76.22
		14	40.385	41.107	9.769	50.876	79.38
	12.0	2	29.086	41.698	9.438	51.136	56.88
		4	33.422	41.698	9.438	51.136	65.36
		6	36.168	41.698	9.438	51.136	70.73
		8	37.937	41.698	9.438	51.136	74.19
		10	38.725	41.698	9.438	51.136	75.73
		12	39.875	41.698	9.438	51.136	77.98
		14	40.898	41.698	9.438	51.136	79.98
	13.5	2	31.569	41.799	8.721	50.520	62.49
		4	34.085	41.799	8.721	50.520	67.47
		6	37.410	41.799	8.721	50.520	74.05
		8	38.491	41.799	8.721	50.520	76.19
		10	38.925	41.799	8.721	50.520	77.05
		12	40.092	41.799	8.721	50.520	79.22
		14	41.305	41.799	8.721	50.520	81.76
	15.0	2	33.627	42.176	8.651	50.827	74.94
		4	35.979	42.176	8.651	50.827	78.47
		6	38.404	42.176	8.651	50.827	79.00
		8	39.203	42.176	8.651	50.827	79.75
		10	39.422	42.176	8.651	50.827	79.75
		12	37.675	42.176	8.651	50.827	81.05
		14	41.953	42.176	8.651	50.827	82.05
3	10.5	2	31.399	41.174	9.309	50.483	61.46
		4	36.708	41.174	9.309	50.483	71.85
		6	37.402	41.174	9.309	50.483	73.21
		8	38.429	41.174	9.309	50.483	75.22
		10	38.935	41.174	9.309	50.483	76.21
		12	39.513	41.174	9.309	50.483	77.34
		14	40.407	41.174	9.309	50.483	79.09
	12.0	2	34.080	41.840	8.679	50.519	67.46
		4	38.212	41.840	8.679	50.519	75.64
		6	38.803	41.840	8.679	50.519	76.81
		8	38.934	41.840	8.679	50.519	77.07
		10	39.515	41.840	8.679	50.519	78.22
		12	40.288	41.840	8.679	50.519	79.75
		14	40.440	41.840	8.679	50.519	80.05
	13.5	2	36.440	42.0776	8.653	50.731	71.83
		4	38.591	42.0776	8.653	50.731	76.07
		6	39.352	42.0776	8.653	50.731	77.57
		8	39.412	42.0776	8.653	50.731	77.69
		10	39.920	42.0776	8.653	50.731	78.69
		12	40.61	42.0776	8.653	50.731	80.05
		14	41.386	42.0776	8.653	50.731	81.58

Tween 80 conc (%wt)	L/S ratio	Time (min)	Starch content in solution (g)	Total Extracted starch (g)	Starch in pulp (g)	Total starch (g)	Extraction efficiency (%)
3	15.0	2	38.196	42.380	8.590	50.970	74.94
		4	39.996	42.380	8.590	50.970	78.47
		6	40.266	42.380	8.590	50.970	79.00
		8	40.648	42.380	8.590	50.970	79.75
		10	41.183	42.380	8.590	50.970	80.80
		12	41.541	42.380	8.590	50.970	81.50
		14	41.821	42.380	8.590	50.970	82.05

Table A4 Extraction efficiency

Tween 80 conc (%wt)	L/S ratio	Total Extracted starch (g)	Starch in pulp (g)	Total starch (g)	Extraction efficiency (%)
0	10.5	33.736	17.501	51.237	65.84
	12.0	35.760	15.349	51.109	69.97
	13.5	37.859	12.976	50.835	74.47
	15.0	39.061	11.173	50.234	77.76
	16.5	39.638	10.807	50.445	78.58
	18.0	39.884	10.434	50.318	79.26
	19.5	39.957	10.143	50.100	79.75
0.25	10.5	36.309	14.014	50.323	72.15
	12.0	38.614	12.574	51.188	75.44
	13.5	39.432	11.176	50.608	77.92
	15.0	40.609	9.904	50.513	80.39
1	10.5	41.107	9.769	50.876	80.80
	12.0	41.698	9.438	51.136	81.54
	13.5	41.799	8.721	50.520	82.74
	15.0	42.176	8.651	50.827	82.98
3	10.5	41.174	9.309	50.483	81.56
	12.0	41.840	8.679	50.519	82.82
	13.5	42.078	8.563	50.731	82.94
	15.0	42.380	8.590	50.970	83.15

Table A5. Analysis result starch content in starch

Tween 80 conc (%wt)	L/S ratio	Sample (g)	Moisture (%)	P-P′	starch (%)	Starch (g)
0	10.5	33.736	13.56	8.903	96.77	32.646
	12.0	35.760	13.48	8.869	96.34	34.451
	13.5	37.859	13.54	8.969	97.49	36.908
	15.0	39.061	13.51	8.954	97.33	38.018
	16.5	39.638	13.50	8.870	96.41	38.214
	18.0	39.884	13.52	8.886	96.59	38.523
	19.5	39.957	13.56	8.842	96.11	38.402
0.25	10.5	36.309	12.82	8.862	96.33	34.976
	12.0	38.614	12.50	8.935	97.12	37.501
	13.5	39.432	12.95	8.875	96.47	38.040
	15.0	40.609	12.61	8.885	96.58	39.220
1	10.5	41.107	12.99	8.910	96.85	39.812
	12.0	41.698	13.34	8.865	96.36	40.180
	13.5	41.799	12.25	8.923	96.99	40.541
	15.0	42.176	13.45	8.919	96.95	40.889
3	10.5	41.174	13.21	8.999	97.82	40.276
	12.0	41.840	14.03	8.916	96.91	40.547
	13.5	42.078	13.71	8.900	96.74	40.706
	15.0	42.380	13.35	8.942	97.20	41.193

Table A6. Analysis starch content in pulp residual at

Tween 80 conc (%wt)	L/S ratio	Weight of pulp (g)	Moisture (%)	P-P’	starch (%)	Starch in pulp (g)
0	10.5	38.664	10.22	4.164	45.264	17.501
	12	36.64	10.02	3.854	41.891	15.349
	13.5	34.541	11.15	3.456	37.566	12.976
	15	33.339	11.64	3.083	33.513	11.173
	16.5	32.762	10.03	3.035	32.986	10.807
	18	32.516	10.64	2.952	32.088	10.434
	19.5	32.443	11.18	2.876	31.264	10.143
0.25	10.5	36.091	10.78	3.572	38.829	14.014
	12	33.786	11.55	3.424	37.216	12.574
	13.5	32.968	10.97	3.119	33.899	11.176
	15	31.791	11.74	2.866	31.153	9.904
1	10.5	31.293	10.04	2.866	31.217	9.769
	12	30.702	11.14	2.872	30.740	9.438
	13.5	30.601	10.32	2.828	28.499	8.721
	15	30.224	11.21	2.622	28.622	8.651
3	10.5	31.226	10.66	2.746	29.811	9.309
	12	30.560	11.86	2.613	28.399	8.679
	13.5	30.322	11.20	2.598	28.240	8.563
	15	30.020	10.64	2.633	28.614	8.590

Table A7. Analysis fiber content in rasped cassava roots

Tween 80 conc (%wt)	L/S ratio	Sample (g)	Moisture (%)	Sample (g dry basis)	Fiber in cassava roots	
					Percent	g dry basis
0	10.5	200.00	63.8	72.40	3.55	2.570
	12.0	200.03	63.8	72.41	3.55	2.570
	13.5	200.15	63.8	72.45	3.55	2.572
	15.0	200.12	63.8	72.44	3.55	2.572
	16.5	200.08	63.8	72.43	3.55	2.571
	18.0	200.15	63.8	72.45	3.55	2.572
	19.5	200.07	63.8	72.43	3.55	2.571
0.25	10.5	200.12	63.8	72.44	3.55	2.572
	12.0	200.07	63.8	72.43	3.55	2.571
	13.5	200.08	63.8	72.43	3.55	2.571
	15.0	200.11	63.8	72.44	3.55	2.572
1	10.5	200.05	63.8	72.42	3.55	2.571
	12.0	200.14	63.8	72.45	3.55	2.572
	13.5	200.03	63.8	72.41	3.55	2.571
	15.0	200.10	63.8	72.44	3.55	2.571
3	10.5	200.09	63.8	72.43	3.55	2.571
	12.0	200.03	63.8	72.41	3.55	2.571
	13.5	200.12	63.8	72.44	3.55	2.572
	15.0	200.06	63.8	72.42	3.55	2.571

Table A8. Analysis fiber content in pulp residual and extracted starch

Tween 80 conc(%wt)	L/S ratio	Cassava pulp(g)	Fiber in pulp (g)	Extracted starch (g)	Fiber in starch(g)
0	10.5	38.664	1.373	51.237	1.197
	12.0	36.640	1.301	51.109	1.269
	13.5	34.541	1.226	50.835	1.346
	15.0	33.339	1.184	50.234	1.388
	16.5	32.762	1.163	50.445	1.408
	18.0	32.516	1.154	50.318	1.418
	19.5	32.443	1.152	50.100	1.419
0.25	10.5	36.091	1.218	50.323	1.291
	12.0	33.786	1.199	51.188	1.372
	13.5	32.968	1.170	50.608	1.401
	15.0	31.791	1.285	50.513	1.443
1	10.5	31.293	1.111	50.876	1.460
	12.0	30.702	1.090	51.136	1.482
	13.5	30.601	1.086	50.520	1.485
	15.0	30.224	1.073	50.827	1.498
3	10.5	31.226	1.109	50.483	1.462
	12.0	30.560	1.085	50.519	1.486
	13.5	30.322	1.076	50.731	1.496
	15.0	30.020	1.066	50.970	1.505

APPENDIX B

LIST OF PUBLICATION

1. Kallayanee Sainak and Jirdsak Tscheikuna, “Extraction of Starch from Cassava Root Using Polyoxyethylene Sorbitan Monooleate as Surfactant”, Fifteenth Thai Institute of Chemical Engineering and Applied Chemistry Conference, Chonburi, Thailand, October 27-28, 2005, 75

การสกัดแป้งจากหัวมันสำปะหลังโดยใช้ สารพอลีออกซีเอทิลีน ซอร์บิแทน โมโนโอลีเอต เป็นสารลดแรงตึงผิว

กัลยาณี สายนาค และ เจิดศักดิ์ ไชยคุนา*
ภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ถนนพญาไท เขตปทุมวัน กรุงเทพมหานคร 10330

บทคัดย่อ

งานวิจัยนี้ศึกษาการสกัดแป้งออกจากหัวมันสำปะหลัง โดยทำการศึกษาเปรียบเทียบผลของการสกัดโดยใช้สารลดแรงตึงผิวกับการใช้น้ำ ซึ่งสารลดแรงตึงผิวที่ใช้คือสารพอลีออกซี เอทิลีนซอร์บิแทน โมโนโอลีเอต (ทวีน 80) หัวมันสำปะหลังที่นำมาทำการทดลองคือมันสำปะหลังพันธุ์ระยอง 5 ที่มีอายุการเก็บเกี่ยวอยู่ระหว่าง 12 ถึง 14 เดือน ซึ่งจากการวิเคราะห์ทางเคมีพบว่าภายในหัวมันสำปะหลังประกอบด้วย ความชื้นร้อยละ 65 และแป้งร้อยละ 30 โดยน้ำหนัก ในงานวิจัยนี้จะทำการศึกษาที่ความเร็วรอบในการปั่นกวนเท่ากับ 10 นาที และได้แบ่งการทดลองออกเป็น 2 ส่วน คือทำการศึกษาหาปริมาตรน้ำในการสกัดที่เหมาะสม โดยทำการศึกษาที่อัตราส่วนระหว่างปริมาตรน้ำในการสกัดต่อน้ำหนักมันบด 10.5 12 13.5 15 16.5 18 และ 19.5 ตามลำดับ ในส่วนที่สองทำการศึกษาผลของการใช้สารทวีน 80 ในการสกัดโดยความเข้มข้นของสารทวีน 80 ที่ใช้คือร้อยละ 0 0.25 1 และ3 โดยน้ำหนัก และทำการทดลองที่อัตราส่วนระหว่างปริมาตรสารละลายในการสกัดต่อน้ำหนักมันบดเท่ากับ 10.5 15 และ19.5 ตามลำดับ

จากการศึกษาพบว่า การเพิ่มปริมาตรน้ำมีผลต่อประสิทธิภาพการสกัด คือประสิทธิภาพการสกัดจะสูงขึ้นเมื่อปริมาตรน้ำเพิ่มขึ้น โดยอัตราส่วนระหว่างปริมาตรน้ำในการสกัดต่อน้ำหนักมันบดที่เหมาะสมคือ 15:1 สามารถให้ร้อยละประสิทธิภาพการสกัดเท่ากับ 66 และเมื่อทำการเปรียบเทียบการใช้สารทวีน 80 กับการใช้น้ำในการสกัดพบว่าการใช้สารทวีน 80 สามารถสกัดแป้งได้ดีกว่าการใช้น้ำในการสกัด อีกทั้งการใช้สารทวีน 80 ยังสามารถช่วยลดปริมาณน้ำในการสกัดแป้งได้อีกด้วย โดยพบว่าที่อัตราส่วนระหว่างปริมาตรสารละลายต่อน้ำหนักมันบดมีค่าคงที่นั้นเมื่อเพิ่มความเข้มข้นของสารทวีน 80 จะทำให้ค่าร้อยละประสิทธิภาพในการสกัดเพิ่มขึ้น และเมื่อเปรียบเทียบผลของอัตราส่วนระหว่างปริมาตรสารละลายในการสกัดกับน้ำหนักมันสำปะหลังบด พบว่าที่ความเข้มข้นของสารทวีน 80 เท่ากับร้อยละ 3 โดยน้ำหนัก ค่าประสิทธิภาพการสกัดเกือบคงที่ในช่วงที่อัตราส่วนระหว่างปริมาตรสารละลายต่อน้ำหนักมันบดมีค่าสูงกว่า 10.5 โดยค่าร้อยละประสิทธิภาพการสกัดที่ได้คือ 78

คำสำคัญ : มันสำปะหลัง, กระบวนการสกัดแป้ง, สารลดแรงตึงผิว

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* Authors to correspondence should be addressed via e-mail:
jiedsak.t@eng.chula.ac.th

1. บทนำ

ในประเทศไทยอุตสาหกรรมการผลิตแป้งมันสำปะหลังเป็นอุตสาหกรรมการเกษตรที่สำคัญ และเจริญเติบโตอย่างรวดเร็ว กระบวนการผลิตแป้งมันสำปะหลังนั้นจะใช้แรงทางกลช่วยทำลายผนังเซลล์เพื่อให้อนุภาคแป้งหลุดออกจากเส้นใย และใช้น้ำเป็นตัวกลางในการพาอนุภาคแป้งออกจากเส้นใย และกาก ดังนั้นการผลิตแป้งมันสำปะหลังจึงเป็นกระบวนการที่ใช้น้ำในปริมาณมาก คือประมาณ 30 ลูกบาศก์เมตรต่อตันแป้ง (กรมโรงงานอุตสาหกรรม กระทรวงอุตสาหกรรม) ซึ่งก่อให้เกิดปัญหาน้ำเสีย นอกจากนั้นกากมันสำปะหลังยังก่อให้เกิดปัญหามลพิษเนื่องจากกลิ่น การผลิตแป้งมันสำปะหลังจากหัวมัน 10 ตัน จะก่อให้เกิดกากมันอย่างน้อย 1 ตัน ซึ่งกากมันเหล่านี้มีแป้งเหลืออยู่ในปริมาณมาก คือประมาณร้อยละ 50 – 60 โดยน้ำหนักแห้ง (Balagopalan, 1996) ดังนั้นจึงมีการศึกษาหาวิธีการปรับปรุงกระบวนการสกัดเพื่อให้แป้งสามารถหลุดออกจาเส้นได้มากขึ้น ไม่ว่าจะเป็นวิธีการที่ใช้แรงสั่นสะเทือน หรือการใช้เอนไซม์ย่อยเส้นใยเพื่อให้เส้นใยขาดทำให้อนุภาคแป้งสามารถหลุดออกมาได้ (Klanarong, 2000)

ปัจจุบันมีการใช้สารลดแรงตึงผิวเป็นตัวทำละลายในการสกัดสารซึ่งมีลักษณะเป็นอนุภาคออกจากตัวยึดเกาะ เช่นการสกัดสารเคอร์คูมินอยด์จากขมิ้นชัน เนื่องจากสารลดแรงตึงผิวมีคุณสมบัติชนิดหนึ่งที่จะเกิดขึ้นเมื่อความเข้มข้นของสารลดแรงตึงผิวสูงกว่าค่าความเข้มข้นวิกฤติในการเกิดไมเซลล์ นั่นคือโมเลกุลของสารลดแรงตึงผิวจะรวมตัวกันเกิดเป็นไมเซลล์ทำให้สารอินทรีย์สามารถละลายเข้าไปยังส่วนต่าง ๆ ของไมเซลล์ ทำให้การสกัดด้วยสารลดแรงตึงผิวสามารถสกัดสารที่ต้องการได้มากกว่าการใช้ตัวทำละลาย (พรเกียรติ, 2544)

ในการศึกษานี้จะทำการสกัดแป้งจากหัวมันสำปะหลังโดยจำลองวิธีการสกัดแป้งในโรงงานอุตสาหกรรม เพื่อหาปริมาณน้ำในการสกัดที่เหมาะสม และศึกษาการสกัดแป้งโดยใช้สารลดแรงตึงผิวเพื่อหาสภาวะที่เหมาะสมในการสกัด และเปรียบเทียบประสิทธิภาพการสกัดระหว่างการใช้น้ำและสารลดแรงตึงผิวในการสกัดรวมถึงปริมาณน้ำที่ใช้ในการสกัด

2. การทดลอง

2.1. วัตถุดิบและสารเคมี

2.1.1. หัวมันสำปะหลังพันธุ์ระยอง 5 จากพื้นที่เพาะปลูกที่ตำบลจันทึก อำเภอปากช่อง จังหวัดนครราชสีมา และมีอายุการเก็บเกี่ยวอยู่ระหว่าง 12 – 14 เดือน

2.2.2. สารพอลีออกซีเอทิลีน ซอร์บิแทน โมโนโอลีเอต (ทวีน 80)

2.2. อุปกรณ์

2.2.1. เครื่องบด และอุปกรณ์สำหรับสกัดแป้ง

2.2.2. เครื่องวัดปริมาณแป้งในผลิตภัณฑ์ (Polarimeter)

2.2.3. เครื่องปั่นกวน

2.2.4. เครื่องชั่งน้ำหนักทศนิยม 4 ตำแหน่ง

2.2.5. กระดาษกรอง Whatman เบอร์ 1

2.2.6. ตู้อบไฟฟ้าแบบควบคุมอุณหภูมิ

2.3. การสกัดแป้ง

2.3.1. ชั่งหัวมันสำปะหลังบด 200 กรัม ผสมกับน้ำในอัตราส่วนระหว่างปริมาณน้ำต่อน้ำหนักมันบดเท่ากับ 15:1 (โดยแบ่งชุดการสกัดออกเป็น 3 ชุด และปริมาณน้ำที่ใช้ในแต่ละชุดคือ 6:1, 6:1 และ 3:1)

2.3.2. นำหัวมันบดผสมกับน้ำไปปั่นกวนเป็นเวลา 10 นาที จากนั้นนำน้ำมันบดที่ได้ในแต่ละชุดการทดลองเข้าเครื่องเหวี่ยงแยกผ่านผ้ากรองเพื่อแยกน้ำแป้งและกากมันออกจากกัน

2.3.3. นำน้ำแป้งที่ผ่านผ้ากรองรวมกัน ทิ้งไว้ให้ตกตะกอนอย่างน้อย 6 ชั่วโมงจากนั้นกรองน้ำแป้งผ่านกระดาษกรอง Whatman เบอร์ 1 แล้วนำแป้งไปอบที่อุณหภูมิ 60 องศาเซลเซียส เป็นเวลา 12 ชั่วโมง แล้วนำแป้งแห้งไปชั่งน้ำหนัก

2.3.4. นำกากมันที่ได้จากการกรองไปวิเคราะห์หาปริมาณแป้งในกากมัน

2.4. การศึกษาผลของปริมาณน้ำ

2.4.1. การศึกษาผลของปริมาณน้ำ ให้ทำตามขั้นตอนในกระบวนการการสกัดแป้ง แต่ให้เปลี่ยนอัตราส่วนระหว่างปริมาณน้ำต่อน้ำหนักมันบดเท่ากับ 10.5 12 13.5 15 16.5 18 และ19.5

2.5. การศึกษาผลของความเข้มข้นของสารทวีน 80

2.5.1. ทำการทดลองตามขั้นตอนในกระบวนการสกัดแป้ง แต่เปลี่ยนจากการใช้น้ำในการสกัดเป็นสารทวีน 80 ที่ความเข้มข้นร้อยละ 0.25 1 และ 3 โดยน้ำหนัก

2.6. วิธีการวิเคราะห์

2.6.1. วิเคราะห์ปริมาณแป้งในหัวมัน กากมัน และ แป้งมัน โดยใช้วิธี Polarimetric method ตาม มอก. 52-2516

2.6.2. หาความชื้นในหัวมัน กากมัน และแป้งมัน ตามวิธีของ AOAC (1990)

3. ผลการทดลอง

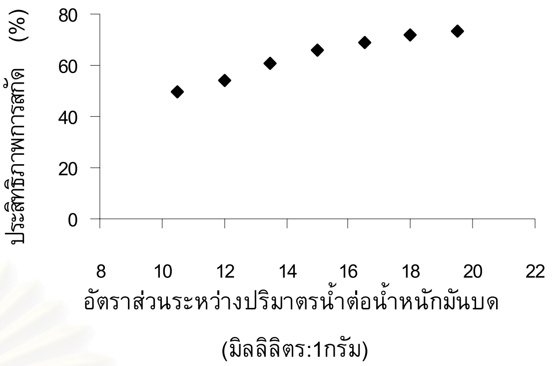
หัวมันสำปะหลังที่ใช้ในการทดลองจะใช้หัวมันสำปะหลังพันธุ์ระยอง 5 และอายุการเก็บเกี่ยวระหว่าง 12 – 14 เดือน เนื่องจากหัวมันสำปะหลังต่างชนิดกัน และอายุการเก็บเกี่ยวต่างกัน ปริมาณแป้งในหัวมันจะไม่เท่ากัน เมื่อนำหัวมันสำปะหลังไปทำการวิเคราะห์หาองค์ประกอบในหัวมันด้วยวิธีตามมาตรฐานกระทรวงอุตสาหกรรม (มอก. 52-2516) พบว่าองค์ประกอบส่วนใหญ่คือ น้ำ (65%) และแป้ง (30%)

ตารางที่ 1 องค์ประกอบภายในหัวมันสำปะหลัง

ส่วนประกอบ	% โดยน้ำหนักเปียก	% โดยน้ำหนักแห้ง
น้ำ	63.80	-
แป้ง	29.73	82.13
เส้นใย	3.55	9.81
อื่น ๆ	2.92	8.07
รวม	100	100

3.1. ผลของอัตราส่วนระหว่างปริมาตรน้ำในการสกัดต่อน้ำหนักมันสำปะหลังบด (L/S ratio)

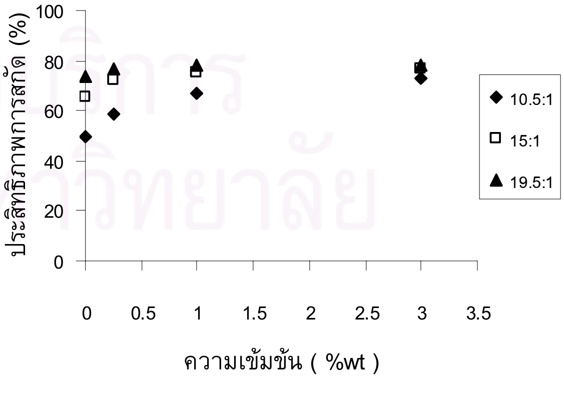
การศึกษาผลของอัตราส่วนระหว่างปริมาตรน้ำในการสกัดต่อน้ำหนักมันบด ทำการศึกษาโดยใช้เวลาในการปั่นกวนคงที่คือ 10 นาที พบว่าที่อัตราส่วนระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมันสำปะหลังบด อยู่ในช่วง 10.5 – 15 เมื่อปริมาตรน้ำในการสกัดเพิ่มขึ้นประสิทธิภาพในการสกัดแป้งจะเพิ่มขึ้น เนื่องจาก เมื่อปริมาตรน้ำเพิ่มขึ้นจะทำให้สามารถแยกเม็ดแป้งออกจากเส้นใยได้สูงขึ้น แต่เมื่ออัตราส่วนระหว่างปริมาตรน้ำมีค่าสูงกว่า 15 ประสิทธิภาพในการสกัดจะเริ่มคงที่ (รูปที่ 1) เนื่องจากเม็ดแป้งที่ยังคงหลงเหลืออยู่ในกากมันนั้นติดอยู่ในโครงข่ายของเส้นใยซึ่งน้ำไม่สามารถนำพาออกมาได้ (ชาย, 2540)



รูปที่ 1 ความสัมพันธ์ระหว่างอัตราส่วนระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมันสำปะหลังบด และประสิทธิภาพการสกัด

3.2. ผลของความเข้มข้นของสารละลายสารลดแรงตึงผิวที่ใช้ในการสกัดแป้ง

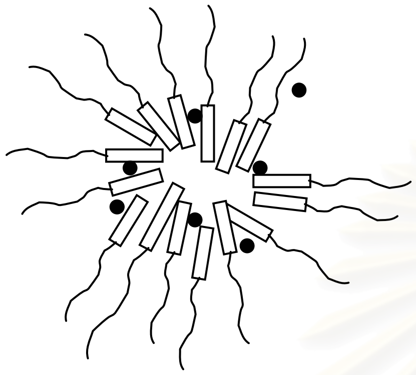
ทำการสกัดแป้ง ในช่วงความเข้มข้นของสารละลายสารทวีน 80 ตั้งแต่ร้อยละ 0 ถึง 3 โดยน้ำหนัก ทำการทดลองโดยใช้เวลาในการปั่นกวน 10 นาที จากผลการทดลองพบว่า ที่ทุกๆ ค่าของอัตราส่วนระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมันสำปะหลังบด เมื่อความเข้มข้นของสารทวีน 80 เพิ่มขึ้นจะทำให้ค่าประสิทธิภาพการสกัดเพิ่มขึ้น แสดงดังรูปที่ 2



รูปที่ 2 ความสัมพันธ์ระหว่างประสิทธิภาพการสกัดแป้งกับความเข้มข้นของสารทวีน 80

ประสิทธิภาพในการสกัดเพิ่มขึ้นเนื่องมาจากเมื่อความเข้มข้นของสารลดแรงตึงผิวมีค่าต่ำมาก สารลดแรงตึงผิวจะ

ละลายอยู่ในน้ำในรูปของโมเลกุลอิสระ แต่เมื่อความเข้มข้นของสารลดแรงตึงผิวมีค่าสูงกว่าค่าความเข้มข้นวิกฤติในการเกิดไมเซลล์ (critical micelle concentration : CMC) จะเกิดการรวมตัวกันของโมเลกุลของสารลดแรงตึงผิวเกิดเป็นไมเซลล์ โดยหันด้านที่มีขั้ว (hydrophillic) เข้าหาน้ำและด้านไม่มีขั้ว (hydropobic) รวมตัวกันภายในไมเซลล์ (พรเกียรติ,2544) ดังรูป 3 (Rosen,1989)



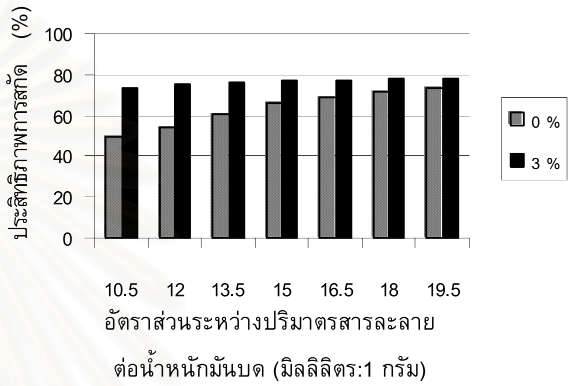
รูปที่ 3 แสดงลักษณะไมเซลล์ของสารลดแรงตึงผิวจำพวกพอลีออกซีเอทิลีน ซอร์บิแทน เอสเทอร์ และตำแหน่งของอนุภาคสารภายในไมเซลล์ (Rosen,1989)

ในการทดลองชุดนี้ค่าความเข้มข้นของสารทวีน 80 ที่ละลายในน้ำล้วนมีค่าสูงกว่าค่าความเข้มข้นวิกฤต (CMC) ซึ่งมีค่าเท่ากับ $1.2*10^{-5}$ โมลาร์ หรือ 0.0152 กรัมต่อลิตร (Ick,1995) ดังนั้นสารทวีน 80 ที่ใช้ในการทดลองชุดนี้จะรวมตัวกันอยู่ในรูปของไมเซลล์ และที่ความเข้มข้นสูงกว่าค่าความเข้มข้นวิกฤต สารทวีน 80 ที่เติมลงไปในสารละลายจะรวมตัวกันเกิดเป็นไมเซลล์อันใหม่ (Songsiri, 2002) แสดงว่าที่ความเข้มข้นของสารทวีน 80 เพิ่มขึ้น จำนวนไมเซลล์ในสารละลายเพิ่มขึ้นด้วย ทำให้อนุภาคสารสามารถเข้าไปอยู่ในตำแหน่งต่าง ๆ ของไมเซลล์ (พรเกียรติ,2544) ดังนั้นการเพิ่มขึ้นของจำนวนไมเซลล์เมื่อความเข้มข้นเพิ่มขึ้น ส่งผลให้อนุภาคของแป้งสามารถเข้าไปอยู่ในไมเซลล์เพิ่มขึ้น

จากรูปที่ 2 เมื่อพิจารณาอัตราส่วนระหว่างปริมาตรสารละลายในการสกัดกับน้ำหนักมันบดมีค่าอยู่ในช่วง 10.5 – 15 พบว่าเมื่อความเข้มข้นของสารละลายสารทวีน 80 มีค่าสูงขึ้นประสิทธิภาพในการสกัดจะเพิ่มขึ้นอย่างชัดเจน แต่ที่อัตราส่วนระหว่างปริมาตรสารละลายในการสกัดต่อน้ำหนักมันบดมีค่าอยู่ในช่วง 15 - 19.5 นั้นแม้จะเพิ่มค่าความเข้มข้นของสารทวีน 80 ค่าประสิทธิภาพการสกัดเพิ่มขึ้นเพียงเล็กน้อยเท่านั้น

3.3. ผลของอัตราส่วนระหว่างปริมาตรสารละลายต่อน้ำหนักมันบดน้ำหนักมันสำปะหลังบด

ที่ความเข้มข้นของสารละลายสารทวีน 80 เท่ากับร้อยละ 3 โดยน้ำหนัก พบว่าการเพิ่มปริมาตรสารละลายมีผลต่อประสิทธิภาพการสกัดน้อยมาก (ดังรูปที่ 4) เนื่องจากสารลดแรงตึงผิวสามารถช่วยดึงเม็ดแป้งออกจากเส้นใยได้ แต่ไม่สามารถทำลายโครงร่างตาข่ายของเส้นใยได้ทำให้ยังมีเม็ดแป้งบางส่วนหลงเหลืออยู่ในโครงตาข่ายของเส้นใย



รูปที่ 4 เปรียบเทียบการใช้น้ำ และสารลดแรงตึงผิวในการสกัดแป้งจากหัวมันสำปะหลัง

จากรูปที่ 4 แสดงให้เห็นร้อยละประสิทธิภาพการสกัดเมื่อใช้น้ำ และสารทวีน 80 (ความเข้มข้นร้อยละ 3 โดยน้ำหนัก) จากรูปจะเห็นว่าการใช้สารลดแรงตึงผิวช่วยเพิ่มประสิทธิภาพการสกัดโดยเฉพาะที่อัตราส่วนระหว่างปริมาตรสารละลายต่อน้ำหนักมันบดมีค่าน้อย

ดังนั้นการใช้สารลดแรงตึงผิวในการสกัดจึงช่วยลดปริมาณน้ำในการสกัดได้

4. สรุปผลการทดลอง

1. อัตราส่วนระหว่างปริมาตรน้ำในการสกัดต่อน้ำหนักมันสำปะหลังบดเท่ากับ 15:1 (โดยแบ่งตามชุดการสกัดคือ 6:1, 6:1และ 3:1) เป็นปริมาตรน้ำที่เหมาะสมที่ใช้ในการสกัดแป้งออกจากหัวมันสำปะหลัง
2. การสกัดแป้งโดยใช้สารทวีน 80 สามารถสกัดแป้งออกจากหัวมันได้ดีกว่าการใช้น้ำในการสกัด อีกทั้งยังช่วยลดปริมาณน้ำที่ใช้ในการสกัด
3. การเพิ่มค่าความเข้มข้นของสารทวีน 80 ทำให้ค่าประสิทธิภาพในการสกัดแป้งเพิ่มขึ้น โดยเฉพาะที่อัตราส่วนระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมัน

สำปะหลังบดมีค่าต่ำ แต่เมื่ออัตราส่วนระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมันสำปะหลังบดมีค่าสูง ประสิทธิภาพการสกัดเมื่อใช้สารทวีน 80 เพิ่มขึ้นเพียงเล็กน้อยเท่านั้น

4. ที่ความเข้มข้นของสารทวีน 80 เท่ากับร้อยละ 3 โดยน้ำหนักจะเห็นว่าประสิทธิภาพการสกัดเกือบ คงที่ตั้งแต่อัตราระหว่างปริมาตรน้ำในการสกัดกับน้ำหนักมันสำปะหลังบดมีค่าเท่ากับ 10.5 แสดงว่าการใช้สารละลายสารทวีน 80 สามารถลดปริมาณน้ำในการสกัดแป้งจากหัวมันสำปะหลังได้

เอกสารอ้างอิง

[1] กล้าณรงค์ ศรีรอต. 2543. เทคโนโลยีของแป้ง. พิมพ์ครั้งที่ 2. สำนักพิมพ์มหาวิทยาลัย เกษตรศาสตร์. กรุงเทพ.

[2] คู่มือการจัดการสิ่งแวดล้อม. 2540. อุตสาหกรรมแป้งมันสำปะหลัง แป้งดัดแปร. สำนักเทคโนโลยีสิ่งแวดล้อมโรงงาน กรมโรงงานอุตสาหกรรม กระทรวงอุตสาหกรรม.

[3] ชาย สิริวัฒนชัยกุล. 2540. การศึกษาการสกัดแป้งจากหัวมันสำปะหลัง. วิทยานิพนธ์ปริญญาวิศวกรรมศาสตร์บัณฑิต ภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์ มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี.

[4] พรเกียรติ สมหวัง. 2544. การสกัดสารเคอร์คูมินอยด์จากขมิ้นชันโดยใช้สารพอลีออกซีเอทิลีน ซอร์บิแทนโมโนโอลีเอต. วิทยานิพนธ์ปริญญามหาบัณฑิต ภาควิชาวิศวกรรมเคมี คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย.

[5] Balagopalan, C., 1996. Improveing the nutritional value of cassava by solid state fermentation:CTCRI Experiences. Journal of Scienctific and Industrial Research 5. 479-482.

[6] Ick, T.Y.1995. Micellar solubilization of polynuclear aromatic hydrocarbon in coal tar-contaminated soil. Environ. Sci. Technol ;29 :3,015-3, 021

[7] Rosen, M.J., 1989. Surfactants and Interfacial Phenomena. second ed. Wiley. New York. Chapter 10.

[8] Sriroth, K., 2000. Processing of cassava waste for improved biomass utilization. Bioresource Technology. 71:63-69

[9] Songsiri, D. , Min, S. S. , Scamehorn, J. F. , Osuwan S. , Ellis J. W., 2002. Use of Cationic surfactant to remove solvent-based ink from rigid high density polyethylene surfaces. Colloids and Surfaces: A. 204:261-269.

VITA

Miss Kallayanee Sainak was born on June 21, 1979 in Saraburi, Thailand. She received the Bachelor degree of chemical engineering from Institute of Engineering, Suranaree University of Technology in April 2001. The last education is studying in Master Degree in Chemical Engineering, Chulalongkorn University that began in 2001.