Bio-char production from cassava peel with hydrothermal treatment method

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การผลิตถ่านชีวภาพจากเปลือกมันสำปะหลังโดยวิธีการไฮโดรเทอร์มอลทรีทเมนท์

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Field of Study	Petrochemical Engineering
Advisor	Asst. Prof. Dr. Thachanan Samanmulya

Accepted by the Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang in Partial Fulfillment of the Requirements for the Degree of Bachelor of Engineering (Petrochemical Engineering).

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ABSTRACT

The purpose of this project was to investigate the manufacture of bio-char from cassava peel utilizing a hydrothermal treatment using an auto cleave reactor.

The results showed that bio-char production from cassava peel by using hydrothermal treatment by auto cleave reactor. The first step was carbonization by using hydrothermal treatment which was carried out in the temperature and reaction times including 160, 180 and 200°C and 60, 120 and 180 min. It was found that the optimum condition for most yield was 180°C and 60 min, the percent yield was 34.7% When the carbonization temperature and time were increased, the percent yield decreased but has more porosity.

Keyword: Bio-char, Bio-mass, Hydrothermal treatment

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บทคัดย่อ

งานวิจัยนี้เป็นการศึกษากระบวนการผลิตถ่านไบโอจากเปลือกมันสำปะหลังด้วยกระบวนการไฮโดรเทอร์มอลทรีตเมนท์ด้วยเครื่องปฏิกรณ์ออโต้เคลฟ

ผลการศึกษาแสดงให้เห็นว่าการนำเปลือกของมันสำปะหลังมาผลิตถ่านไบโอโดยวิธีการไฮโดรเทอร์มอลทรีทเมนท์ด้วยเครื่องปฏิกรณ์ออโต้เคลฟ เริ่มต้นด้วยการหาอุณหภูมิและเวลาที่เหมาะสมสำหรับกระบวนการไฮโดรเทอร์มอลทรีตเมนท์ในช่วง 160-200 องศาเซลเซียส และ 60-180 นาที โดยสภาวะการดำเนินงานที่เหมาะสมสำหรับวิธีการไฮโดนเทอร์มอลทรีทเมนท์ที่ทำให้ได้ค่าร้อยละการผลิตที่มากที่สุดคือ ที่อุณหภูมิ 180 องศาเซลเซียส เวลา 60 นาที การวิเคราห์คุณสมบัติโดยมีร้อยละผลิตภัณฑ์ 34.7 จากการทดลองเมื่อเพิ่มอุณหภูมิและเวลาทำให้ได้ร้อยละผลผลิตที่ได้ลดลงแต่จะได้ถ่านไบโอที่มีรูพรุนที่มากขึ้นตามไปด้วย

คำสำคัญ ถ่านไบโอ, มวลชีวภาพ, ไฮโดรเทอร์มอลทรีทเมนท์

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CHAPTER I

INTRODUCTION

1.1 Background

Adsorption is a major unit in the chemicals and petrochemicals industries for separation and purification of gas or liquid mixtures. Adsorbents are also needed for various applications in either liquid or gas phase processes such as air purification, gas separation and purification, gas separation and purification, wastewater treatment, organic solvent recovery, heterogeneous catalysis, de-coloration of organic substances, etc. The extremely porous and strong adsorbed capacities of the activated carbons are commonly used as adsorbents in different technologies.

The demand for activated carbon is still growing as a result of environmental requirements in many countries and new application areas. In many countries other biomass matters have been tested for their suitability for activated carbon production due to the non-availability of key fundamental materials, such as hard coal, wood or cocoon shells.

Cassava is one of the most important commodities in Thailand, an agricultural country. The cassava production in Thailand is very huge, there are used as the raw material for cassava starch industries. Cassava starch making operation produces a huge quantity of solid wastes (cassava peel), and direct discharge of this solid wastes will cause the environmental problems.

The objective of this experimental work is the conversion of cassava peel into bio-char. Waste biomass is converted thermally in two steps. First the biomass undergoes a hydrothermal treatment process. The gaseous and liquid hydrothermal treatment products can be used alternative fuels. Second, the solid residue, activated carbon, is treated in an activation process in steam atmosphere in order to enhance the char surface area which was analyzed by standard test method for determination of iodine number of activated carbons. The increase of surface area depends on the type of biomass and on the activation parameters.

1.2 Objectives

1.2.1 To investigate the effect of hydrothermal treatment on properties of bio-char.

1.2.2 To study optimal conditions for carbonization by hydrothermal treatment.

1.3 Scopes of Work

For the production of bio-char from cassava peel by hydrothermal treatment, the suitable condition such as temperature, and carbonization. The essential procedures are following:

1.3.1 Prepare the bio-char from the cassava peel by hydrothermal treatment and carbonization by varying hydrothermal treatment temperature and time.

1.3.2 Investigation of the properties and percent yield of bio-char.

1.3.3 Summarize the results and conclusion.

CHAPTER II

LITERATURE REVIEW

2.1 Activated carbon[1]

Activated carbon is a diverse and athletic adsorbent. It can be used to control the abundant majority of all the various molecules that environment pollution. These carbons are able to adsorb a large range of various molecules. Activated carbon can be made from various raw materials, different qualities and different shapes and sizes of porous. This is a very important character when the mix of chemicals is unknown, or variable, or perhaps too complex. Reforming these factors to optimize efficiency and lifetime for different applications. Depending on activated carbon operates with a physical adsorption, chemical adsorption or catalytic mechanism and the applications.

The principal properties of manufacture activated carbons depend on the type and properties of the raw material used. Any cheap substance with a high carbon and low ash content can be used as a raw material for the production of activated carbon. In Europe the most essential raw materials used for this purpose are wood, charcoal, peat, peat coke, certain types of hard and brown coal. To produce activated carbon, which should exhibit high adsorption capacity and a large volume of the smallest pores. Source materials that have been studied for the production of activated carbon.

Table 2.1 Raw materials for the production of activated carbon[2]

Bagasse	Beet-sugar sludges	Bones	Carbohydrate
Cereals	Coal	Coconut shells	Coffee beans
Corncobs and corn	Stalk	Distillery waste	Fish
Flue dust	Fruit pits	Graphite	Kelp and Seaweed
Leather waste	Lignite	Molasses	Nut shells
Oil shale	Peat	Polymer scrap	Petroleum ferricyanide
Potassium ferricyanide	Petroleum coke	Pulp-mill waste	Rice hulls
Rubber waste	Sawdust	Sewage treatment	Wood

2.2 Cassava peel

Cassava is one of Indonesia's most important agricultural commodities. Cassava is a frequent ingredient in traditional recipes, cakes, and other baked items in our country. Cassava output in Indonesia is huge, but only a small fraction is used by traditional food enterprises, with the majority used as raw material for cassava starch industries. Cassava starch production generates a significant amount of solid waste (cassava peel), and direct discharge of this solid waste will cause environmental problems.

Table 2.2 Proximate and ultimate analysis of cassava peel[3]

Analysis	wt%	Variation (%)
Proximate		
Moisture	11.4	1.2
Volatile matter	59.4	0.8
Fixed carbon	28.9	0.9
Ash	0.3	1.0
Ultimate		
Carbon	59.31	1.1
Nitrogen	2.06	1.1
Hydrogen	9.78	1.1
Oxygen	28.74	1.1
Sulphur	0.11	1.1

2.3 Adsorption[4]

Adsorption is a phenomenon in which the local concentration of a substance on the surface of a solid or liquid converts more than the mass concentration. The ability of all solids to attract gasses or solutions with which they are in contact to their surface molecules. Solids used to absorb gasses or dissolved substances are called adsorbents. Thus, we have a well-known phenomenon of gas molecules focusing on carbon or pigments passing from a solution in oil to a deposit in clay. Absorption, on the other hand relates to the uniform penetration and dispersion of one item into another. As a result, the solute molecules that reduce the surface tension will concentrate on the interface between the solid and the solution and tend to be adsorbed on the solid. If as happens in some cases, the solute increases the surface tension, the concentration at the interface decreases, which is known as negative adsorption. Water has a high surface tension most solutes reduce this, so they are easily taken up by an adsorbent.

2.3.1 Adsorption isotherm[5]

Physical adsorption is the result of a relatively weak solid-gas interaction. It is a physical attraction resulting from nonspecific, relatively weak Van der Waal's forces and adsorption energy not exceeding 5-50 kJ/mole. Physically adsorbed molecules may widespread along the surface of the adsorbent and normally are not bound to a specific location on the surface. Being only weakly bound, physical adsorption is simply reversed.

Chemical adsorption can result in a surface complex, a union much stronger than a physical bond with heats of adsorption up to about 200-400 kJ/mole for C-N bonds and 800 kJ/mole for chemical bonds. A chemical bond involves sharing of electrons between the adsorbate and the adsorbent and may be regarded as the formation of a surface compound. Due to the bond strength, chemical adsorption is difficult to reverse.

Table 2.3 Comparison between physisorption and chemisorption

Physical adsorption	Chemical adsorption
Low enthalpy (5–50 kJ/mol)	High enthalpy (200–400 kJ/mol)
Reversible process	Irreversible process
Intermolecular forces of attraction are van der Waals forces, hydrogen bonding, etc.	Valence forces of attraction are chemical bond forces
Multi-molecular layers may be formed	Generally, monomolecular layer is formed
Process is taking place at low temperature	This process takes place at high temperature
It is not specific	It is highly specific

2.3.2 Factor Affecting Adsorption [6]

- Surface area of adsorbent. Larger sizes imply a greater adsorption capacity.

- Adsorbent particle size. Smaller particle sizes reduce the internal diffusion and transfer of mass by limiting the penetration of the adsorbate inside the adsorbent. However, the wastewater drops over a column packed with powdered material is too high to be used in packed beds. The addition of powdered adsorbents must be followed by their removal.

- Contact time or residence time. The complete adsorption might need longer residence time.

- Solubility of solute (adsorbed) in liquid (wastewater). Low solubility substance will be more easily removed from water than high solubility substances.

- Non-polar substances will be more easily removed than polar substances since the latter have a greater affinity for water.

- Affinity of the solute for the adsorbent (carbon). The surface of activated carbon is only slightly polar. Hence non-polar substances will be more easily picked up by the carbon than polar ones.

- Number of carbon atoms. For substances in the same homologous series a larger number of carbon atoms is generally associated with a lower polarity and hence a greater potential for being adsorbed.

2.3.3 Adsorption isotherm[4]

Adsorption in a solid-liquid system results in the removal of the solute from the solution and its concentration at the surface of the solid, at a time when the concentration of the solute remaining in the solution is in dynamic balance with that at the surface. At this equilibrium position, there is a set distribution of the solute between the liquid and the solid phases. The distribution expresses the quantity qe as a function of C at fixed temperature, the quantity qe being the amount of solute adsorbed per unit weight of solid adsorbent, and the concentration of solute remaining in solution at equilibrium. An expression of this type is called an isotherm of adsorption.

Type of adsorption isotherm

1. Type I isotherm is concave to the p/p0 axis and approaches a limiting value as p/p°. Type I isotherms are given by microporous solids having relatively small external surfaces the limiting uptake being governed by the accessible micropore volume rather than by the internal surface area.
2. Type II isotherm is the normal form of isotherm is given by a non-porous or macroporous adsorbent. Type II isotherm represents unlimited monolayer-multilayer adsorption. Point B, the beginning of the almost linear middle section of the isotherm, is often taken to indicate the stage at which monolayer coverage is complete and multilayer adsorption about to begin.

3. Type III isotherm is convex to the p/p0 axis over its entire range and therefore does not exhibit a Point B. Isotherms of this type are not common; the best-known examples are found with water vapor adsorption on pure non-porous carbons. However, there are a number of systems which give isotherms with gradual curvature and an indistinct Point B. In such cases, the adsorbent-adsorbate interaction is weak as compared with the adsorbate-adsorbate interactions.
4. Type IV isotherm are its hysteresis loop, which is associated with capillary condensation taking place in mesopores, and the limiting uptake over a range of high p/p°. The initial part of the Type IV isotherm is attributed to monolayer multilayer adsorption since it follows the same path as the corresponding part of a Type II isotherm obtained with the given adsorptive on the same surface area of the adsorbent in a non-porous form. Type IV isotherms are given by many mesoporous industrial adsorbents.
5. Type V isotherm is uncommon; it is related to the Type III isotherm in that the adsorbent-adsorbate interaction is weak, but is obtained with certain porous adsorbents.
6. Type VI isotherm represents stepwise multilayer adsorption on a uniform non-porous surface. The step height now represents the monolayer capacity for each adsorbed layer and, in the simplest case, remains nearly constant for two or three adsorbed layers. Amongst the best examples of Type VI isotherms are those obtained with argon or krypton on graphitized carbon blacks at liquid nitrogen temperature.

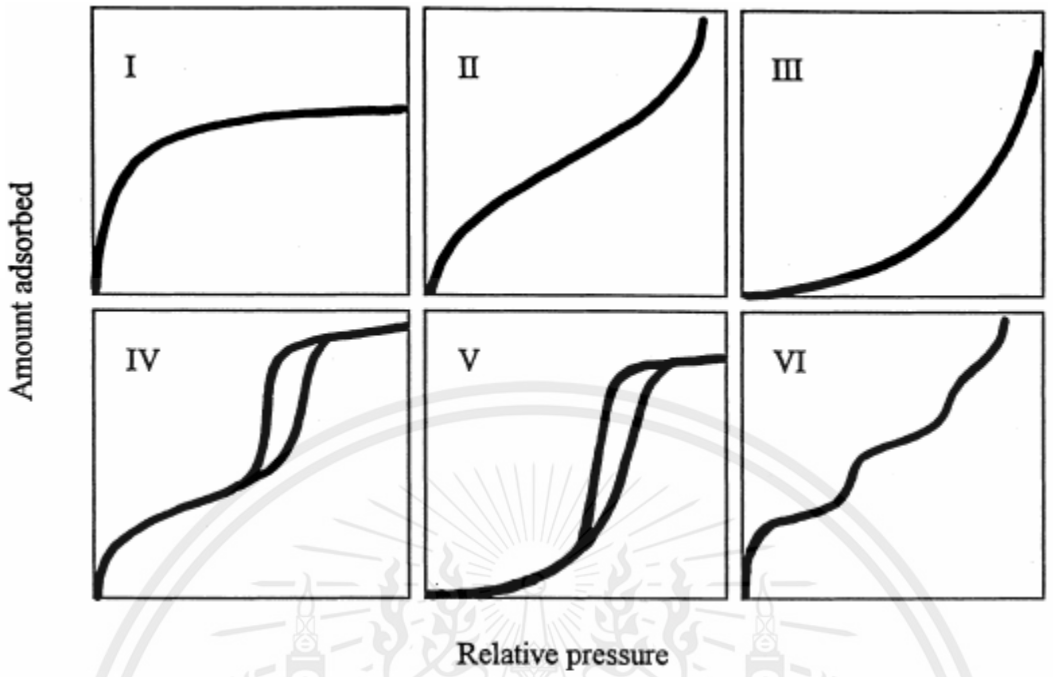

Figure 2.1 The IUPAC classification of adsorption isotherms showing both the adsorption and desorption pathways. Note the hysteresis in types IV and V.

Langmuir adsorption model[7]

The Langmuir adsorption isotherm is based on the following assumptions.

1. The adsorbent surface consists of a certain number of active sites, at each of which only one molecule may be adsorbed.
2. No lateral interaction between the adsorbed molecules, thus the heat of adsorption is constant and independent of coverage.
3. The adsorbed molecule remains at the site of adsorption until it is desorbed.
4. At maximum adsorption, only a monolayer is formed: molecules of adsorbate do not deposit on the other, already adsorbed, molecules of adsorbate, only on the free surface of adsorbent.

$$k_a C_e(1-\theta)=k_d\theta \quad (3.1)$$

where

k_a is the respective rate constant for adsorption

k_d is the respective rate constant for desorption.

Usual form of the equation.

$$\theta=\frac{q}{q_m}=\frac{bC_e}{(1+bC_e)} \quad (3.2)$$

where

$$b = k_a/k_d$$

C_e is the equilibrium aqueous-phase concentration of adsorbate ($mg\cdot L^{-1}$)

q_m is the quantity of adsorbate adsorbed in a single monolayer ($mg\cdot g^{-1}$)

The form of linearization and nonlinearization of the Langmuir equation.

$$q_e=\frac{Q^0bC_e}{1+bC_e} \text{ (nonlinear from)} \quad (3.3)$$

$$\frac{C_e}{q_e}=\frac{1}{Q^0b}+\frac{1}{Q^0}C_e \text{ (linear from)} \quad (3.4)$$

where

q_e is equilibrium adsorbent-phase concentration of adsorbate ($mg\cdot L^{-1}$)

C_e is equilibrium aqueous-phase concentration of adsorbate ($mg\cdot L^{-1}$)

Q^0 is the monolayer adsorption capacity ($mg\cdot g^{-1}$)

b is the constant related to the free adsorption energy and the reciprocal of the concentration at which half saturation of the adsorbent is reached.

2.4 BET method for determine specific surface area[8]

The specific surface area of the powder is determined by the physical adsorption of the gas on the surface of the solid and by the calculation of the amount of the adsorbate gas corresponding to the monomolecular layer on the surface. Physical adsorption results from relatively weak forces (van der Waals forces) between the adsorbent gas molecules and the adsorbent surface area of the test powder. The determination is usually made at the temperature of the liquid nitrogen. The amount of gas adsorbed may be measured by a volumetric or continuous flow procedure.

The specific surface area is an important parameter that affects the course of chemical reactions occurring in coal during pyrolysis, combustion, hydrogenation and other processes. The adsorption characteristics of the fine-grained (<0,071 mm) samples of activated carbons were measured by low-temperature argon adsorption, the BET method. The BET equation does not predict the surface area of microporous carbons. However, it is important for practice to estimate the surface areas of different porous materials. Nitrogen, argon and carbon dioxide are most commonly used to evaluate specific surface areas of different carbonaceous materials. In this work, argon at 77 K is used as an adsorbate to monitor the surface evolution properties of the carbon materials tested as the treatment progresses.

Spherical shape case

$$\frac{P}{V(P_0-P)}=\frac{1}{V_m c}+\frac{(c-1)P}{V_m c P_0} \quad (3.5)$$

where

V is volume of gas adsorbed (cm^3)

P/P_0 is relative pressure

V_m is the quantity of gas adsorbed for monolayer coverage of surface (cm^3)

C is BET constant

$$S=\frac{V_m N_{AV}}{22400}a \quad (3.6)$$

where

S is porous surface area (m^2)

N_{AV} is Avogadro constant (6.02×10^{23} molecules mol^{-1})

a is area by unit of molecular gases (cm^2 $molecule^{-1}$)

2.5 Adsorption capacity of activated carbon[9]

The number of iodine is a relative porosity indicator for activated carbon. It does not necessarily provide a measure of the ability of the carbon to absorb other species. Iodine number may be used as an approximation of the surface area for certain types of activated carbons. It must be realized, however, that any relationship between surface area and iodine number cannot be generalized. It varies with changes in carbon raw materials, processing conditions and distribution of pore volumes. The presence of adsorbed volatiles, sulfur, and water extractables may affect the measured iodine number of activated carbon.

Calculation of iodine absorbed per gram of carbon (X/M)[9]

$$X/M=[A-(DF)(B)(S)]/M \quad (3.7)$$

where

X/M is iodine absorbed per gram of carbon (mg/g)

S is sodium thiosulfate (mL)

M is carbon used (g)

$$DF=(1+H)/F \quad (3.8)$$

DF is dilution factor

I is iodine (mL)

H is 5 % hydrochloric acid used (mL)

F is filtrate (mL)

$$N_1=(P\cdot R)/S \quad (3.9)$$

where

$$N_2=(S\cdot N_1)/I \quad (3.10)$$

N_2 is iodine (N)

N_1 is sodium thiosulfate (N)

P is potassium iodate (mL)

R is potassium iodate (N)

Carbon dosage may be estimated as follows

$$M=[A-(DF)(C)(126.93)(50)]/E \quad (3.11)$$

M is carbon (g)

A is (N_2) (12693.0)

DF is dilution factor

C is residual iodine

E is estimated iodine number of the carbon

2.6 Hydrothermal treatment conversion of biomass [10] [11]

Technologies for conversion waste biomass into bio-based chemicals and biofuels are hydrothermal (HT) processes that use sub-critical and super-critical water for processing. Fig. 2.2 presents the water phase diagram. Subcritical water is pressurized at a temperature below the critical point and above the boiling point. System properties become more sensitive to changes in pressure and temperature. By increasing the temperature, the density of the liquid phase decreases, the vapor density increases and becomes more like at the critical point. Water above the critical point is known as supercritical water and has properties between the liquid phase and the gas phase.

Generally, HT processes are divided into four main processes: carbonization (HTC), aqueous phase reform (APR), liquefaction (HTL) and gasification (HTG). In these processes, water takes on the role of a reactant, a solvent, and also a catalyst. The main advantage over other processing methods is the ability to use wet biomass without prior dewatering and to produce versatile chemicals and fuels in a gaseous, liquid or solid state.

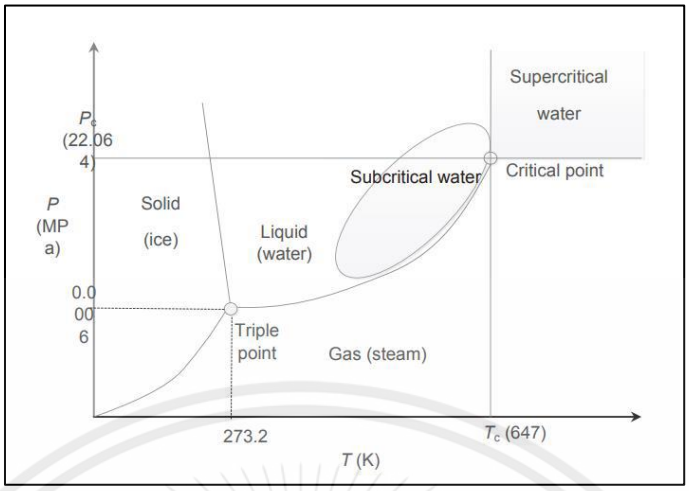

Figure 2.2 Phase diagram of water with area of application for hydrothermal treatment; (Tc - critical temperature, Pc - critical pressure)

Hydrothermal (HT) reactions appear in water media at higher temperature and pressures (sub- and supercritical water) where hot compressed water can act as a solvent, as a reactant, or as a catalyst. The advantage of hydrothermal reaction processes over conventional ones is that wet biomass usually contains around 70 wt% or more water which can be more economically converted to chemicals and bio-based fuels. The four main HT reactions of biomass conversion into desired energy products and different operating parameters are presented in Fig 2.3

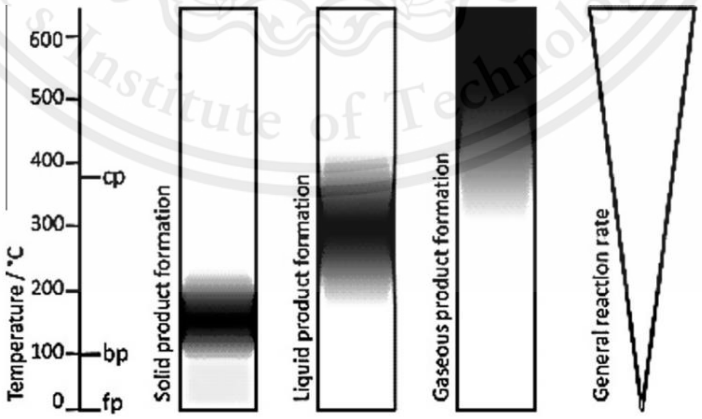

Figure 2.3 Hydrothermal reactions for biomass conversion products are controlled by changing process parameters.

Fig. 2.3 presents reaction rate as a strong function of temperature. Depending on the reaction temperature and pressure it may vary considerably; from some seconds to several hours. Different products are obtained by fine-tuning process parameters. As demonstrated in Fig. 2.3, hydrothermal carbonization is performed at mild temperature, usually up to 200 °C. Solid products with a high content of carbon are obtained. Such products have high energy contents and are suitable chemicals for different applications. Hydrothermal liquefaction is demonstrated as a process that is typically carried out at temperature between 200 °C and 400 °C. The product is highly viscous liquid - pyrolysis oil which can be applied as a pure chemical or can be added to diesel fuel. It is also demonstrated that at highest temperature, above 400 °C, supercritical water gasification is performed. Gaseous products with a high content of hydrogen and carbon monoxide are obtained. CO_2 and other hydrocarbons are present in lower concentrations. This gas could be used as a source of energy or as "syngas" for synthesis of higher value chemicals. The operating conditions of biomass treatment by hot compressed water effect both, product distribution and characterization. The physicochemical properties of the target products are influenced by hydrothermal temperature and residence time.

2.7 Chemical activation[12]

Activated carbon materials are produced by either thermal or chemical activation as granular, powdered or molded products. In addition to the form of activated carbon, the final product may vary in particle size and pore structure. The properties of the activated carbon will determine the type of application for which the carbon is to be used.

Chemical activation is usually performed using chemical agents to impregnate raw materials at temperature between 450 and 900 °C. Activated carbons obtained by chemical activation have a high surface area and a well-developed micro-porosity, which can be controlled and kept narrow. In chemical activation processes, all the chemical agents used are dehydrating agents that influence pyrolytic decomposition and inhibit the formation of tar and therefore increase carbon yield.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Raw material

This research was experimental in the laboratory to determine the condition in the production of bio-char from cassava peel by hydrothermal treatment.

3.1.1 Preparation of the cassava peel

1. Rinse the cassava rind with distilled water and dry in the oven for 24 hours at 120 °C.
2. Then take the cassava peel to grind it with a biomass blender to have a smaller particle size.
3. Take each powder of cassava peel through a sieve of smaller than 150μm, and collect in an air seal bag.

3.1.2 Analysis of moisture content

1. Weigh the fresh cassava peel before drying. Record the weight. Then put in the oven at 70 °C to expel the moisture from each part.
2. Weigh the samples every 6 hours in order to record the weight change from drying.
3. Drying the sample until the weight of cassava peel is constant or there is a difference of the weight measured 3 times, the difference must not be more than 0.003-0.005 grams and then calculate the percentage of moisture.

3.2 Apparatus

1. High pressure auto clave reactor.
2. Oven: 0-200 °C, WT binder, Germany.
3. Desiccator.
4. Laboratory test sieve.
5. Shaker.
6. Crucible.
7. Analytical Balance, accuracy 60.0001 g.
8. Beakers, assorted sizes.
9. Funnels, 100-mm top inside diameter.
10. Filter Paper.
11. Graduated Cylinders, 100 ml.

3.3 Hydrothermal treatment

The variation of temperature and time for carbonization of cassava peel were studied at 160,180 and 200 °C. 10 g of cassava peel char with particle size of 1.18-2.36 mm was loaded into the auto clave. Then the auto clave was passed 100 mL/min with N_2 flow through from the top to the bottom. Then the reactor was heated to the desired temperature to vary at 160, 180 and 200 °C. The superheated steam was charged continuously on, vary for 60,120 and 180 min of reaction time.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Carbonization

The cassava peel powder was carbonized at temperature of 160, 180, and 200°C, with carbonization times of 60, 120, and 180 minutes for each temperature condition. The final products of the carbonization step are known as bio-char. At 160°C percent yield is 10.4, 6.8 and 10.1% at carbonization time 60, 120 and 180 minutes respectively. At 180°C percent yield is 34.7, 30.4 and 27.2% at carbonization time 60, 120 and 180 minutes respectively. At 200°C percent yield is 36.4% and 32.7% at carbonization time 60, 120 and 180 minutes respectively.

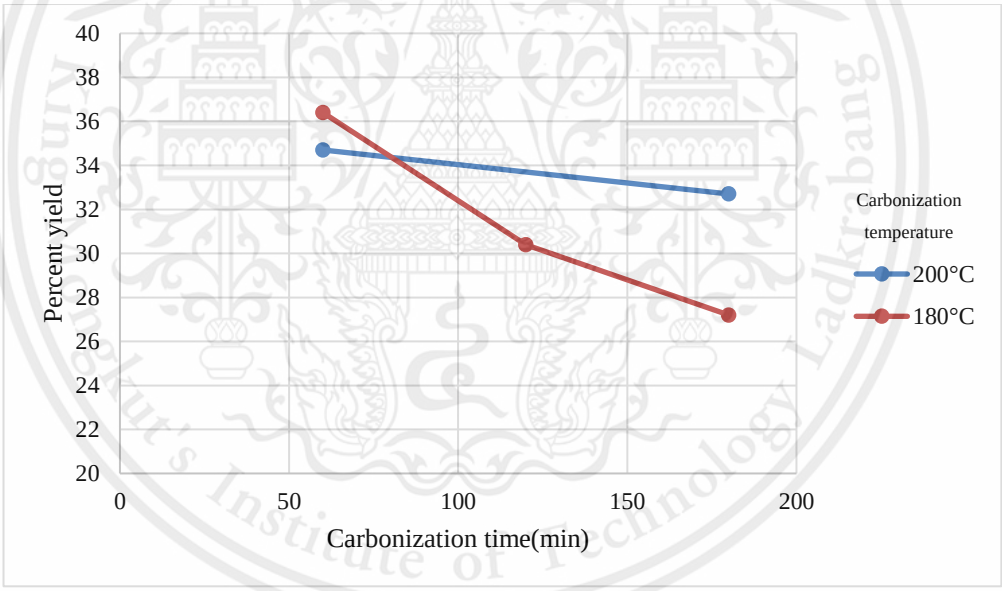

Figure 4.1 The effect of temperature and time on percent yield (180,200)

From figure 2.3 hydrothermal treatment from biomass to bio-char temperature that suitable for solid formula is range between 160-220°C. The carbonization temperature of 160°C was found to have the lowest percent yield, followed by 180°C and 200°C, respectively.

As shown in Figure 4.1, carbonization time has little effect on activated carbon yield, although carbonization temperature has a substantial effect. The initial significant number of volatiles that can be easily released with increasing temperature, as well as the loss of moisture to a lesser extent, contribute to the rapid rate of weight loss at higher carbonization temperatures.

Normally, raising the carbonization temperature decreases the percent yield of bio-char, however 160°C was not a suitable carbonization temperature for bio-char from cassava peel. The carbonization temperature that produced the highest percent yield of hydrochory from cassava peel was 180°C.

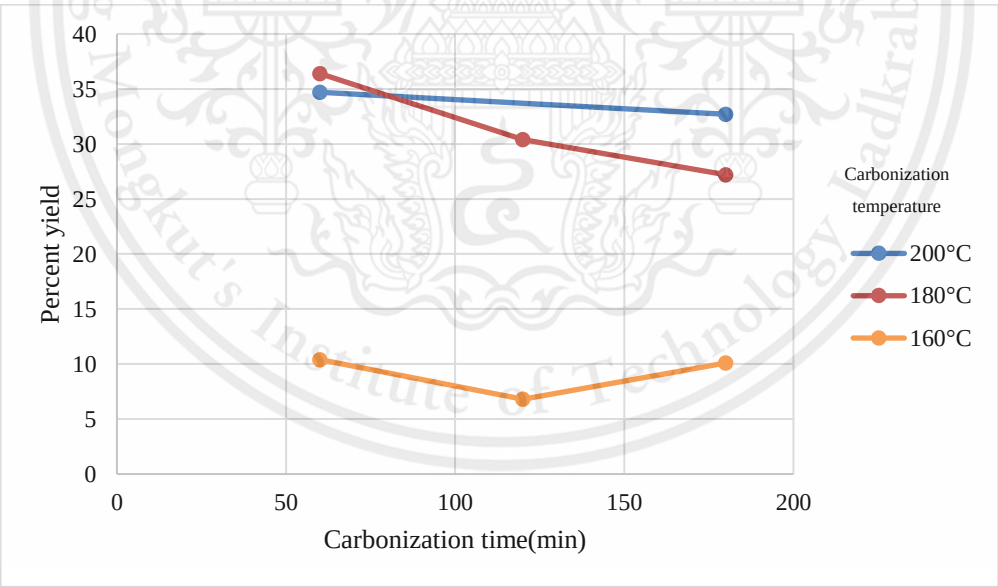

Figure 4.2 The effect of temperature and time on percent yield (160,180,200)

The color of bio-char obtained from 160°C carbonization temperature is mostly brown and sticky, similar to dry clay, whereas bio-char obtained from 180°C and 200°C carbonization temperature is crumbly and black, similar to char, suggesting that 160°C carbonization temperature cannot generate bio-char perfectly,

Fig 4.3 Bio-char from 160°C carbonization temperature

Fig 4.4 Bio-char from 200°C carbonization temperature

CHAPTER V

CONCLUSION

5.1 Conclusion

The experimental result showed the possibility to produce the activated carbon from cassava peel. In this research, carbonization by hydrothermal treatment produce bio-char from cassava peel. In the carbonization, the studied variables were temperature and time at the range of 160-200°C and 60-180 min respectively. The optimum condition of this step for most percent yield was 180°C and reaction time of 60 minutes with 34.7% yield.

It can be concluded that 180-200°C is most suitable carbonization temperature for generated bio-char from cassava peel.

5.2 Suggestion

1. CHN was measured because the proximate and ultimate analysis of cassava peel from the reference used may not be the same as that used in the experiment because the experimental use included both cassava peel and cassava rhizome.

2. Activation with various acids for the suitable acid for bio-char from the cassava peel because the temperature and time are suitable. After obtaining the appropriate acid, the activation time trial should be carried out to obtain the highest quality activated carbon from the cassava peel.

3. Compare iodine number of activated carbon from activation with suitable acid and time with standard.

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