DESIGN AND DEVELOPMENT OF PYROLYSIS SYSTEM TO PRODUCE WOOD VINEGAR

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ABSTRAK

Kajian ini diwujudkan bagi menukarkan sisa buangan pertanian kepada salah satu produk yang bermutu tinggi dan boleh diguna semuala. Memandangkan kajian ini dijalankan di utara semenanjung Malaysia, salah satu bahan buangan pertanian yang sentiasa dibakar adalah sekam dan jerami padi. Pembakaran terbuka sentiasa berlaku secara berleluasa terutamanya selepas musim menuai samaada oleh petani atau pengilang beras. Bagi mengatasi masalah ini, sistem Pyrolysis di bina khusus untuk menukar asap dari pembakaran sisa pertanian tersebut kepada salah satu produk yang dinamakan '*liquid oil'*. Analisa terhadap *'liquid oil'* yang dihasilkan mendapati, terdapat 13 komposisi kimia didalamnya seperti Acetic Acid, Ethanol, Furfural dan sebaginya. Peratusan kandungan jisim bagi Karbon, Nitrogen, Oksigen, Hidrogen dan Sulfur didalam *'liquid oil'* yang dihasilkan hampir sama dengan kajian yang lepas. Menerusi keputusan yang diperolehi, '*liquid oi'l* yang dihasilkan dari proses kondensasi asap sekam padi dapat dijadikan sebagai cuka kayu. Dimana cuka kayu adalah sejenis '*liquid oil'* yang digunakan didalam industi pertanian sebagai penggalak pertumbuhan, pendebungaan, ajen pengawal penyakit dan sebagainya. Selain dari dapat mengawal pencemaran udara akibat dari pembakaran terbuka, cuka kayu juga dapat digunakan oleh petani bagi menggantikan baja kimia. Seperti yang diketahui baja kimia akan menyebabkan tanah berasid dan mengakibatkan berlakunya pencemaran air. Oleh itu menerusi kajian ini, diharapkan masalah pencemaran alam akibat dari sisa buangan pertanian dapat diatasi.

ABSTRACT

Air pollution such as haze often occur due to the open burning of agricultural waste. In order to counter the problem this research existed with the target to turn agricultural waste to high quality product and reusable. Since this research located at the northern region of Malaysia, the most popular agricultural waste are paddy husk and paddy straw. Open burning normally happen after the harvesting season either by the farmers or paddy factory owners. Pyrolysis system is built to counter the problem by turning smoke from the agricultural waste to another product called 'liquid oil'. Liquid oil is analysed with 13 chemical compositions such as Acetic Acid, Ethanol, Furfural and etc. Content percentage for Carbon, Nitrogen, Oxygen, Hydrogen and Sulphur in the liquid oil produced is nearly the same with the previous research. Results shows that liquid oil produced from the paddy husk smoke condensation process can also form wood vinegar. Wood vinegar is a type of liquid oil used by the industry as growth catalyze, disease control agent for plant and etc. Other than controlling the air pollution from open burning, liquid oil also beneficial to the farmers as it can replace the use of chemical fertilizer. As publicly known chemical fertilizer can cause the soil to be acidic and leads to another problem which is water pollution

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Chapter 1

Introduction

1.1 Background

Liquid oil is a liquid substance that is obtained when organic materials such as wood, coconut shell, bamboo, grass and other plants are placed in a heating chamber. When these materials are heated their juices, oils and liquid contents evaporate as steam or vapor. When the vapor is cooled, it will turn into liquid (condensation process). Today, liquid oil production still uses the traditional production techniques. The burning process is done in the ground where smoke is streamed to the surface using a bamboo for condensation process [1]. Liquid oil production never been introduced/done in Malaysia, most of the production come from Thailand, Philiphines, Japan and few other Asian countries. In Asia county they used the liquid oil in agriculture industry to enhance fruit growth, kill pests, kill weeds, prevent pests and mold while accelerating plan growth and other usage [1]

Conversional pyrolysis system method is used to replace the traditional method in producing the liquid oil. Pyrolysis is the thermal degradation of waste in an oxygen free environment, or in an environment in which the oxygen content is too low for combustion or gasification to take place [2]. Pyrolytic products can be used as fuels, with or without prior upgrading, or they can be utilized as feedstock for chemical or material industries. The product comes from Pyrolytic process depend on raw material such as to produce fuel the raw material comes from plastic waste. Materials suitable for Pyrolysis processing include coal, animal and human waste, agriculture waste, food scraps, paper, cardboard, plastics, rubber and biomass.

Because of the nature of the process, yield of useful products is high compared to the other processes. In general, Pyrolytic products are more refined and therefore can be used with greater efficiency. In this study its agriculture waste as rice husk can be used to produce liquid oil by using Pyrolysis system.

In the international market the price of liquid oil is very expensive [3].Since Malaysia is one of the main paddy manufacturer, therefore liquid oil can be produced. The manufacturing can be made possible if the production is commercialized. It can generate the income of the farmer other than that the air pollution rate can be reduced.

1.2 Problem Statement

Paddy is mainly planted at the north of Malaysia especially Kedah and Perlis. Kedah for instance is synonym with the paddy production thus being called "The Rice Bowl of Malaysia". Apart from that, least have known the fact that this agricultural production have caused worrying nature pollution such as water pollution and air pollution. Water pollution occurred due to massive usage of fertilizers and poison which consists of high chemical composition for example; none dissolve nitrogen fertilizer. The fertilizer will cause the toxicity level in the water and soil to increase [4]. The open burning of paddy straws and husks will result bad air pollution after the harvesting season.

Other than causing air pollution, the open burning of paddy straws and husks can endanger the public. In Kedah and Perlis paddy plantation occupy most of the land. During the harvesting season open burning are everywhere, it will produce thick smoke. The visibility distance will become shorter and this will invite danger to the road user. In 2004, 21 vehicle were involved in an accident at KM 59.8 North-South Expressway and this is due to thick smoke where drivers were trapped inside it. [5]

The income of the locals can be generated if the agriculture waste is commercialized. All this while paddy straws and husks are left to rot and most Malaysians have no idea how to process the waste and making money out of it.

1.3 Research Aims / Objective

The purpose of this research to use west produce to generate something renewable product. This is because when the west produce can change to renewable product the green technology concept will be applied. Green Technology is the development and application of products, equipment and systems used to conserve the natural environment and resources, which minimize and reduces the negative impact of human activities. Green technology concept is very important to overcome environmental degradation and natural resources, improve health and lives, protect ecosystems, costs to the government in its efforts to mitigate the impact of development and serve as an alternative in order to boost the economy. Overall , the research objective involve two main stage which are :

i) To convert waste production into commercial renewable material.

ii) To design and develop the manufacturing process to produce liquid oil.

In this research, rice husk will be used to produce liquid oil. In this country especially in Kedah and Perlis husk and rice straw burning was still open, especially after the harvest. This has caused air pollution where dust in the air keeps increasing especially during the harvesting season between January to February and August to September [6]. This has contributed to the air pollution index in Malaysia [7].

1.4 Research Scope

In this research, the main focus is to develop the Pyrolysis system model using the mechanical principle. To develop Pyrolysis system the study about the combustion model and heat exchanger model will be a priority. Before developing the prototype of Pyrolysis system, the model of Pyrolysis will be developing using *Autodesk Inventor2012 Software* .

Mechanical components used in the construction of this system focuses on the appropriate selection of heat exchanger. Heat exchanger selection is based on the heat transfer capabilities. Calculation for the correlation for forced convective heat transfer in conduits can be used to predict heat transfer coefficient in the tube.

After the model of Pyrolysis system is done, the development of prototype of Pyrolysis system is fabricated. Size of the prototype of Pyrolysis system is developed in lab scale size. The raw material in this process is rice husk. Composition of chemical properties in the product (liquid oil) from rice husk is identified using suitable equipment. Normally the chemical composition in liquid oil is acid value, gases value, pH value and others.

1.5 Contribution

At the end of the study, there are few things expected to be achieved and known such as :

1.5.1 Pyrolysis System

The applicability of Pyrolysis system in replacing traditional method for liquid oil production can be determined. This new method can make us understand whether Pyrolysis system is suitable in producing liquid oil. If the system is not suitable, failure factor of the system can be identified.

1.5.2 Rice Husk

Husk is used as fuel material to produce the liquid oil. The applicability of rice husk in producing the liquid oil can be determined when the system is applied. If the applicability of the rice husk is not there factors that cause it can be identified.

1.5.3 Chemical Composition in Liquid Oil

There will be few tests to the liquid oil obtained. The chemical composition in the liquid oil such as the acid used can be determined after going through few tests.

Chapter 2

Literature Review

2.1 Introduction

Pyrolysis is the thermo-chemical conversion of organic materials in the presence of a limited amount of air, into combustible gases, char and oil products. The reaction is self sustaining requiring no external heat input. The technology was commercially applied on a large scale in the production of methanol from wood in the United States in the late 1800's and early 1900's. However, Pyrolysis system lost its popularity when methanol could be produced at a much lower cost from petroleum oil. In recent times, Pyrolysis system has received considerable attention in two areas. As first a conversion method for the disposal of biomass wastes in an environmentally acceptable manner with resource recovery and second as a method for converting biomass to more convenient fuels. Since 1960 much of the work in this field has been pioneered by the Georgia Institute of Technology with the objective of developing a non-polluting process for the disposal of peanut hulls with recovery of the charcoal for the briquettes market [8]. In recent years, because of the energy crisis, the focus of the program has been to develop the process as a means to convert forestry and agricultural residues to the more conventional energy forms of char and oil. Small scale Pyrolysis systems have been tested in a number of developing countries such as Papua New Guinea, Costa Rica, Indonesia, and the Philippine.

2.2 Types of Pyrolysis

There are three types of Pyrolysis, which are differentiated by temperature and the processing.

2.2.1 Slow Pyrolysis

Conventional Pyrolysis or slow Pyrolysis is characterized by the slow temperature around 500^0C above. Depending on the system heating rates for slow Pyrolysis are about 0.1 to 2^0C per second. Normally slow Pyrolysis used to burn wood, charcoal, and other material for produce hence, tar and char [2].

2.2.2 Flash Pyrolysis

Flash Pyrolysis is characterized by moderate temperatures exist (400-600^oC) and rapid heating rates than 2°C/s. Vapor residence times are usually less than two seconds. Compared to slow Pyrolysis, considerably less tar and gas are produced. However, the tar and oil products are maximized.

2.2.3 Fast Pyrolysis

Fast Pyrolysis is identifying when the heating rates are between 200 to 1000000^0C per second and prevailing temperature are usually higher than 550^0C. The different between flash and fast Pyrolysis is heating rates and hence residences time. Product from the fast Pyrolysis normally is higher quality and the fast

Pyrolyssis normally used to produce ethylene rich gases that could subsequently be used to produce alcohols or gasoline.

2.3 Principle of Pyrolysis System

Pyrolysis System can be design in various types reactors including vertical fluidized bed, horizontal and inclined reactor with either direct heat transfer. However for the renewable material process in Pyrolysis, the reactor commonly used is vertical and fluidized bed reactor only.

2.3.1 Vertical Bed Reactor

Normally for the vertical bed reactor is consider to be most appropriate for use with wood, coconut shell and plan base material. The advantage of vertical bed Pyrolysis system lies in its flexibility in varying yields of the pyrolytic product through the heating rate of the system. The initial work on the vertical bed Pyrolysis system was started at the Georgia Institute of Technology in Atlanta, Georgia, approximately ten years ago. At that time the disposal of agricultural wastes due to new and impending air pollution regulations was a serious problem and a study was initiated to design a small, cheap incinerator which would meet emissions regulations and be suitable for use by small and intermediate sized, agricultural businesses. An evaluation of the inherent combustion characteristics of these lingo cellulosic wastes indicated that such an incinerator would be large and very expensive [9].

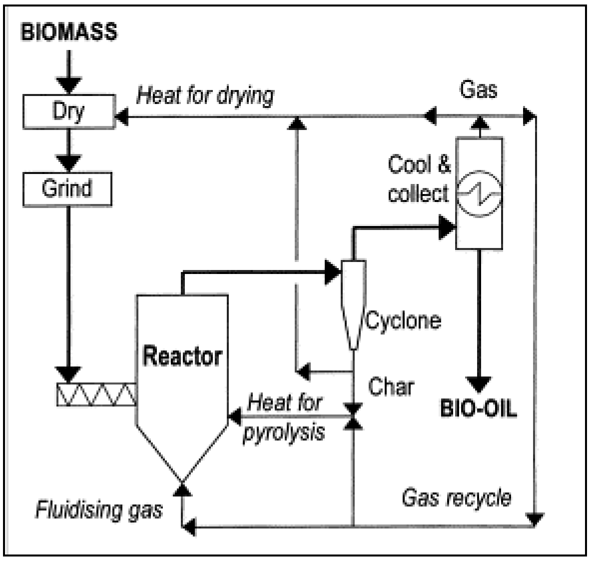


Figure 2.1 : The example of vertical bed Pyrolysis system [10]

2.3.2 Fluidized Bed Reactor

In Pyrolysis system fluidized bed Pyrolysis normally used to produce the bio oil product. In fluidized bed reactor, a gas or fluid a passed through a granulator solid material such as catalyst at high enough velocities to suspend the solid and cause it to behave as though it were a fluid. The solid material in fluidized normally supported by a distributor plate. The fluid is than forced through the distributor up through the solid material. At lower fluid velocities, the solid remain in place as the fluid passed through the voids in the material. As the fluid velocity increase, the reactor will reach the stage where the force of the fluid on the solids is enough to balance the weight of the solid material. This situation knows as incipient fluidization and occurs at this minimum fluidization velocity. Once this minimum velocity is surpassed, the contents of the reactor bed begin to expand and swirl around much like an agitated tank or boiling pot of water. The reactor is now a fluidized bed. Depending on the operating conditions and properties of solid phase various flow regimes can be observed in this reactor [11].

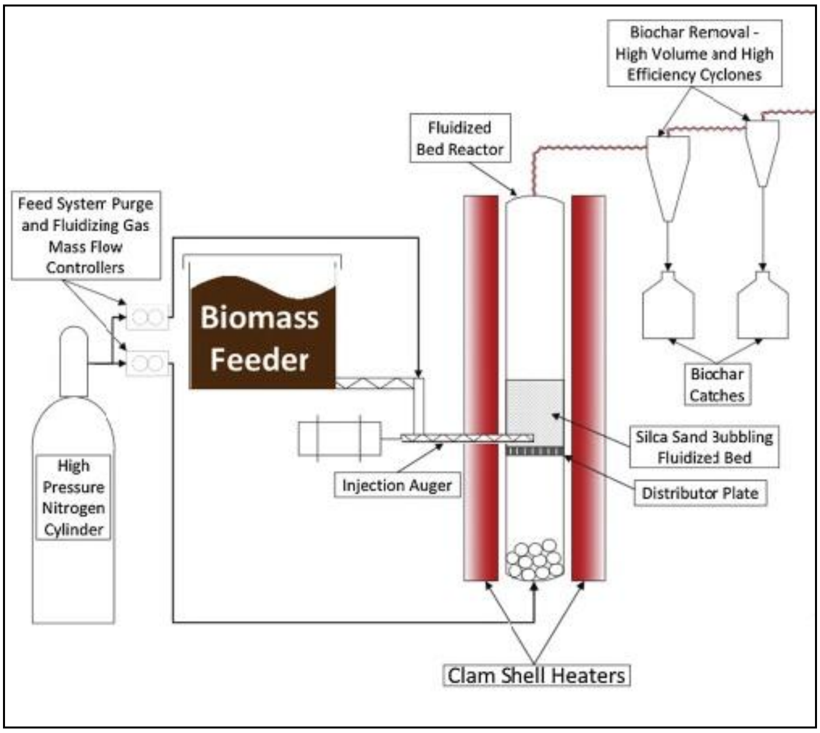


Figure 2.2 : The example of Fluidized bed Pyrolysis system [12]

2.4 Mechanism of Pyrolysis

The mechanism of Pyrolysis system has a three main stage such as dehydration, fragmentation and formation of product. The biomass is directly and visibly affected as the Pyrolysis process proceeds. For example the change of color biomass from white to brown and finally the color change to the black. Size and weight are reduce while flexibility and mechanical strength are lost [2] .

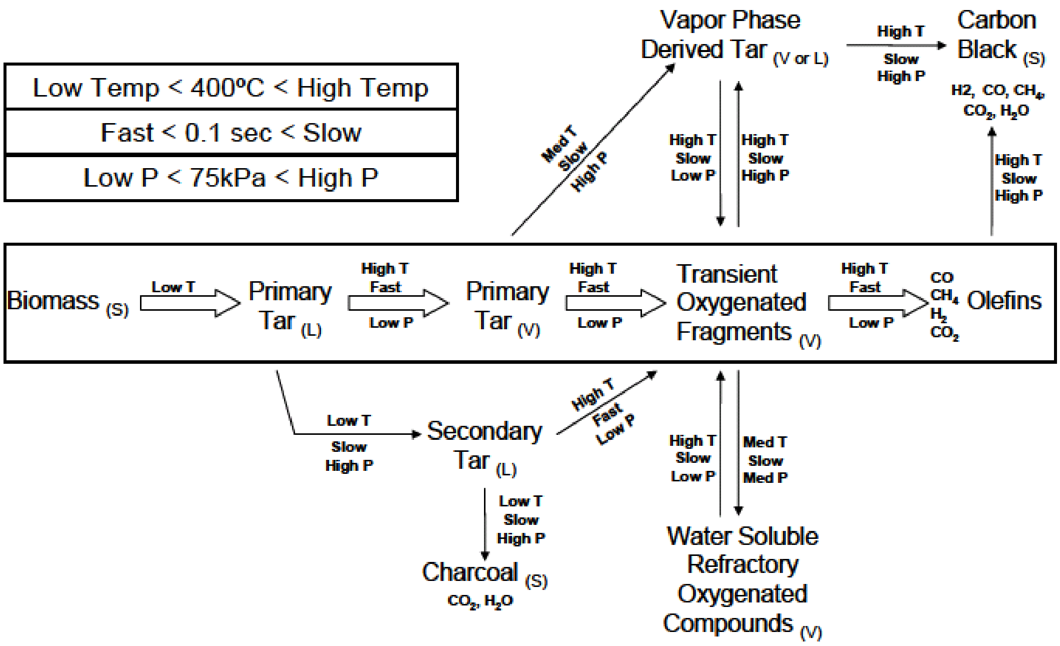


Figure 2.3 : Reaction taking place in fast Pyrolysis [2]

2.4.1 Dehydration

Dehydration , which is dominant at low temperature, is the primary of the two reactions during slow Pyrolysis. Normally the reaction take place below 300^0C and result in the reduction of the biomass molecular weight , the evaluation of water, Carbon Monoxides (CO), Carbon Dioxides (CO_2) and char.

2.4.2 Fragmentation

Fragmentation dominates at temperature above 300^0C. It involves the deploymerization of the biomass to an hydro glucose compound and other light combustible volatiles. Because of the temperature range involve, fragmentation is of greater interest in flash and fast Pyrolysis.

2.4.3 Formation of Product

Biomass is complex and information know about it is often limited it is specimen used, the stable end product and how some of these product depend on the pyrolitic treatment. Normally the final product can be divided into three categories. The first categories is volatile product of molecular weight (M) below than 105 such as Carbon Monoxides (CO), Carbon Dioxides (CO_2), Acetol and unsaturated Aldehydes. The second product is tars with higher molecular weight and the last product is chars.

2.5 Pyrolysis Technology in Developing Countries

Small scale Pyrolysis of rice husk experimentation was conducted in Indonesia, Philippines, Papua New Guinea, Costa Rica and Thailand. In all cases, the reactors used a vertical bed system with some slight modification.

2.5.1 Review of Pyrolysis System in Indonesia

There were two phases of the Pyrolysis System development project in Indonesia. The preliminary study and the development phase. The preliminary study involved forest wastes for the preparation of Pyrolysis System raw material and the construction of three types of converters for comparative system design study. The work was carried out by the Bandung Institute of Technology jointly with the Georgia Institute of Technology, USA. The findings identified the appropriate feed stocks and Pyrolysis Technology models for further study in the development phase.

The development phase involved the construction of two prototype Pyrolysis one for research and development converters and for personnel training, and the other for demonstration at a rice mill. Both converters have a similar nominal capacity of one ton per day of rice husk as dry feed material. For the cost benefit analysis of the system, it was revealed that the return on investment was as high as 73.8% which was sufficiently attractive to warrant widespread adopting of Pyrolysis System application among rice mills [13].

2.5.2 Review of Pyrolysis System in Philippines

In Philippines, a study on Pyrolysis of rice husk was carried out by the University of the Philippines. A manually operated ton per day of coconut fiber Pyrolysis system with a capacity of one as dry feed material was constructed to investigate Pyrolysis system techno economic feasibility for rice mill application. The calculation on the savings earned by installing a Pyrolysis system for rice that the Pyrolysis unit could be paid off within mill application showed one year.

A survey on marketability of pyrolytic products and a survey on biomass waste production in the Philippines were also conducted by the Philippines National Oil Company (PNOC) to assess the potential demand for Pyrolysis system application and to establish the required plant capacity for each of the three main wastes such as rice husk, coconut shell and saw dust. In brief, the findings indicated that the units of about 100 kg/hr, 400 kg/hr and 1000 kg/hr were appropriate to the needs of the Philippines for the three types of wastes, respectively.

2.5.3 Review of Pyrolysis System in Thailand

In Thailand, Pyrolysis system has been considered by energy technology as a comprehensive means to convert wastes from biomass into conventional forms of fuel. There are many research institutes as well as universities involved in the research activities of this technology. However, in all cases, only laboratory scale studies have been carried out. The Thailand Institute of Scientific and Technological Research (TISTR) has also gained experience from conducting a series of batch type Pyrolysis experiments with capacities up to 100 kg per batch of biomass [14].

2.5.4 The Composition in Rice Husk

Table 1 represents the composition material in the rice husk from the Occidental Research Corporation USA, Bandung Institute of Technology Indonesia, University of Philippines and Thailand Institute of Scientific and Technological Research in Thailand. From the collection data the major composition in rice husks ischar, oil, gas and H_2O. Occidental Research Corporation USA has a higher production per day is 4 ton/day. The lower production per day comes from TISTR as 100kg/day only. This is because TISTR conducting a series of batch type Pyrolysis experiments with capacities up to 100 kg per batch of biomass. The content value of the char differs between two researches. For example in Indonesia, the value of mass in char is 0.25 in the production 1 ton/day, but in Philippines the value of mass in char 0.05 higher than the value of mass in Indonesia. Different results are believed to be caused by the dry material used.

Table 2.1 : Mass and Energy Yields For Rice Husk Pyrolysis

Production	Indonesia		Philippines		TISTR***		U.S.A	
	1 ton/day		1 ton/day		100 kg/day		4 ton/day	
	Mass*	Energy**	Mass*	Energy**	Mass*	Energy**	Mass*	Energy**
Char	0.25	0.27	0.30	0.43	0.50	0.63	0.36	0.38
Oil	0.18	0.29	0.09	0.18	0.08	0.12	0.23	0.42
Gas	0.32	0.12	0.30	0.07	0.19	0.07	0.12	0.06
H_20	0.32	-	0.30	-	0.23	-	0.29	-
Total	1.07	0.68	0.99	0.68	1.00	0.82	1.00	0.86
Symbol	Guidance							
*	Mass of product per unit mass of dry input feed							
**	Ratio of energy content of product to energy content per "nit mass of dry input feed							
***	Batch type Pyrolysis experiment							

2.6 Traditional Preparation to Produce Liquid Oil

Even though Pyrolysis method was introduced to countries such as Thailand and Indonesia, the traditional methods are still in used. This is due to the high cost required to build the Pyrolysis system especially for mass production.

2.6.1 Traditional Preparation to Produce Liquid Oil (Wood Vinegar) in Philippines.

In Philippines, preparation to produce liquid oil is conducted by JAEC Project. Philippines society call the wood vinegar is *Mokusaku*. This project intended to help Benguet farmers cultivate soil by using organic materials such as compose, charcoal and wood vinegar to produce safe and healthy vegetables. Here in Philippines, the development to produce liquid oil have two season, the dry seasons and the rainy season and temperature is not low enough to obtain a high value of yield. Water need to pour into the chimney to hasten the cooling. Bamboo could be used as a substitute for the stainless cooling chamber. It is much cheaper although not as durable. If the place is cool, wood vinegar can be collected in a long chimney.

In this research, after wood vinegar is collected, the liquid must undergo sedimentation for at least six months. The process need because there are some toxic substances such as tar mix with wood vinegar. To separate these substances sedimentation process is needed. Sedimentation process takes 6 month to separate the substance into three layers. The first portion is water, the middle portion will contain the wood vinegar and the bottom contains a higher percentage of tar.

Figure 2.4 : Process to produce of wood vinegar in Benguet, Philipines [15]

Figure 2.5 : Farmers in Benguet collect wood vinegar using a long bamboo chimney [15]

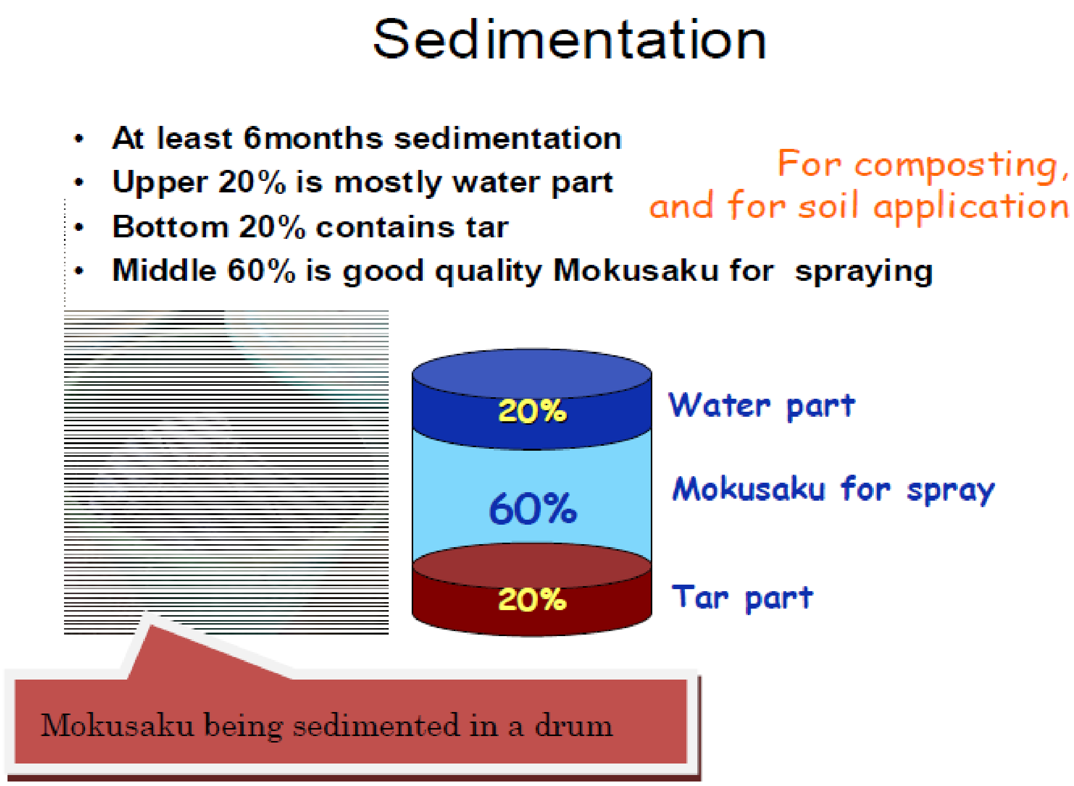


Figure 2.6 : Sedimentation process diagram [15]

In Philippines, they used the wood vinegar together with charcoal for soil supplement. Wood vinegar is poured on charcoal and should be mixed well. The mixture of charcoal and wood vinegar should be incorporate in the soil immediately. Other than that, wood vinegar used for fertigation in agriculture sector. In fertigation process they used liquid collected from upper and lower portion of the liquid container after sedimentation is complete. In this situation the composition of wood vinegar has high water contents and tar, so it is not good to direct use for fertigation, but it good for soil. However, to use the wood vinegar for fertigation, they diluted the one liter of wood vinegar with 10 to 20 times of water. When the farmer used the wood vinegar for fertigation agent the agriculture income increase [15].

2.6.2 Traditional Preparation to Produce Liquid Oil (Wood Vinegar) in Thailand

In Thailand, traditional method to produce wood vinegar was introduced by The Office of Royal Highness Princess Maha Chakri Sirindhorn’s Projects. This project objective is to teach student about practical science topic in an exciting way especially to save the environment. The knowledge can help them proper in their future careers. They chose to produce wood vinegar because the production of wood vinegar is cost effective where it takes only one day and offer a versatile range of beneficial application that are gentle to the environment. In this project, producing wood vinegar using traditional method they used just three days to collect the wood vinegar liquid [16].

Table 2.2 : Traditional technique step to produce wood vinegar [16]

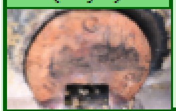
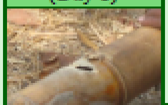
Step 1 (Day 1) 	**To build the kiln:** • Cut the lid off of one end of a 200 L metal tank. • Cut a 20 cm x 20 cm square hole at the bottom of the lid as shown in the picture to the left.
Step 2 (Day 1)	Cut a 10 cm diameter circular hole on the other side of the tank at point A in Diagram 1.
Step 3 (Day 1)	Attach an asbestos joint to the 10 cm hole as shown in A of diagram. Then, attach an asbestos pipe to the joint as shown in B.
Step 4 (Day 1) 	Make a bamboo pipe by hollowing out a 4 m bamboo stalk with a metal pole. Cut one end of the pipe at an angle.
Step 5 (Day 1) 	Cut a notch 30-50cm away from the angled end of the pipe. This notch will allow wood vinegar to drip out later on in the process.
Step 6 (Day 2) 	**To produce charcoal and wood vinegar:** • Load three short logs in the kiln horizontally to promote air flow. • Stack logs from smallest to largest and perpendicular to the 3 short logs as shown in the picture to the left. This allows all logs to fully burn.
Step 7 (Day 2)	Seal the kiln lid in place with a layer of clay about 5 cm thick. Proceed while the clay is wet.
Step 8 (Day 2)	To build a fireplace, put 4 bricks around the 20 cm square hole in the lid. Seal with clay.

Table 2.3 (continue) : Traditional technique step to produce wood vinegar [16]

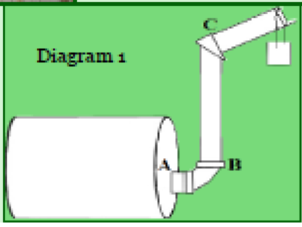
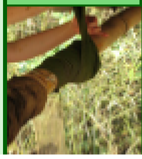
Step 9 (Day 2) 	**Start and maintain a fire** slightly inside the brick fireplace. **Wait** approximately **2 hours** until **a strong white smoke** emerges from the asbestos pipe.
Diagram 1 	
Step 10 (Day 2)	**Attach** the angled end of the bamboo pipe to the asbestos pipe at point C. **Seal with clay**, making sure the notch is facing downward.
Step 11 (Day 2) 	**Wrap** the length of the bamboo pipe with cool, damp cloths to aid in the condensation of raw wood vinegar. **Hang** a collection bottle at the notch to capture the product .

Table 2.4 (continue) : Traditional technique step to produce wood vinegar [16]

Step 12 (Day 2)	**Maintain** the fire and dampness of the cloths. The raw wood vinegar is finished producing when the droplets **turn black**, indicating that tar has formed.
Step 13 (Day 2)	**To make charcoal:** • **Remove** the collection bottle and the bamboo pipe. • **Place** a small clay pot on the opening of the asbestos pipe and seal any remaining openings with clay. • **Stack** two bricks in front of the entrance and seal with clay. • **Wait 8 hours** for charcoal to form.
Step 14 (Day 2-92) 	**To purify raw wood vinegar:** • **Let** the wood vinegar sit for 90 days and settle into 3 layers. • **Extract** the middle layer of wood vinegar with a syringe. • **Dilute** the wood vinegar depending on its purpose.

Table 2.2, 2.3 and 2.4 represent that the technique to produce wood vinegar in traditional method. First step to start the technique is they build the kiln and the final step they produce the pure wood vinegar used the extract technique. They need 90 days to collect pure wood vinegar in 3 layers. Each layers has the quality depending on its purpose.

2.7 Summary Chapter 2

In Chapter 2, the information from the previous research about the Pyrolysis system and method to produce liquid oil will be showed. Based on the information obtained, Pyrolysis system selected in this study is the slow Pyrolysis. By using slow Pyroysis system, traditional method to produce liquid oil can be converting to the modern method.

Chapter 3

Methodology

3.1 Design of Research

The research is done to identify the solution of air pollution course by the open burning of paddy straws and husks. After the identification, information related to the problem was taken to be analyzed.

The first step taken to start the research is review the technique to convert agriculture waste production into highly commercial renewable material. From the review, the agricultural waste can produce liquid oil if it goes through the right process. Most of the liquid oil productions were done using traditional method, but in this study simple Pyrolysis system will be developed in order to process the agricultural waste.

3.2 Methodology Chart

The methodology of the project phases can be summarized in the flow chart as shown in figure.

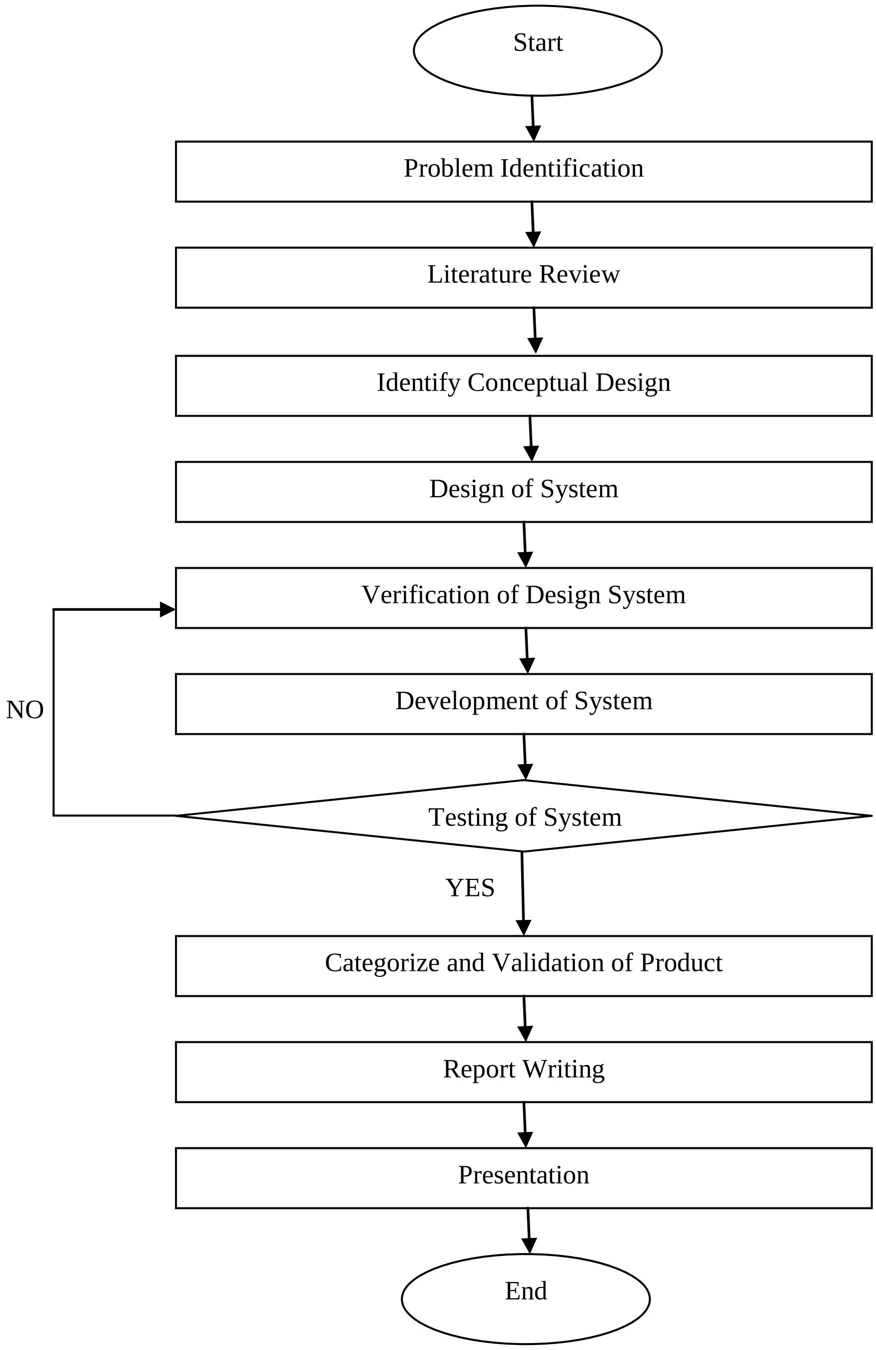


Figure 3.1 : The frame work of research

3.3 Conceptual Design

The Pyrolysis concept is used in producing the product from the agricultural waste. Rice husk will be the material used for this Pyrolysis concept. From the study the main product for production is liquid [16].

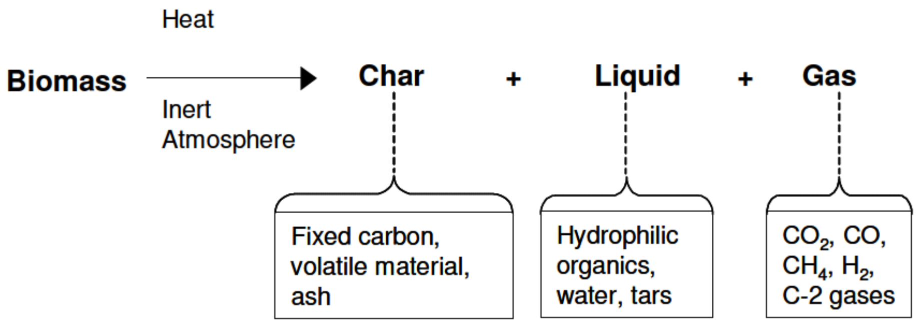


Figure 3.2 : Simple representation of Pyrolysis Process [17]

Pyrolysis concept consists of three main components which are heater, combustion or reactor and condenser. Heater is used to heat the organic material used to produce liquid oil and normally used for the fast and flash Pyrolysis system. Manual combustion or reactor system for slow Pyrolysis is used to maintain the natural combustion of the organic material. Normally, in the combustion or reactor the biomass production are char and gas in smoke form like CO_2,CO, CH_4, and H_2.Condensation process will take place where smokes from the combustion will go through the condenser thus producing the liquid. The liquid from the condensation process is called liquid oil or wood vinegar [17]. The reaction pathway of pyrolysis show in figure 8.

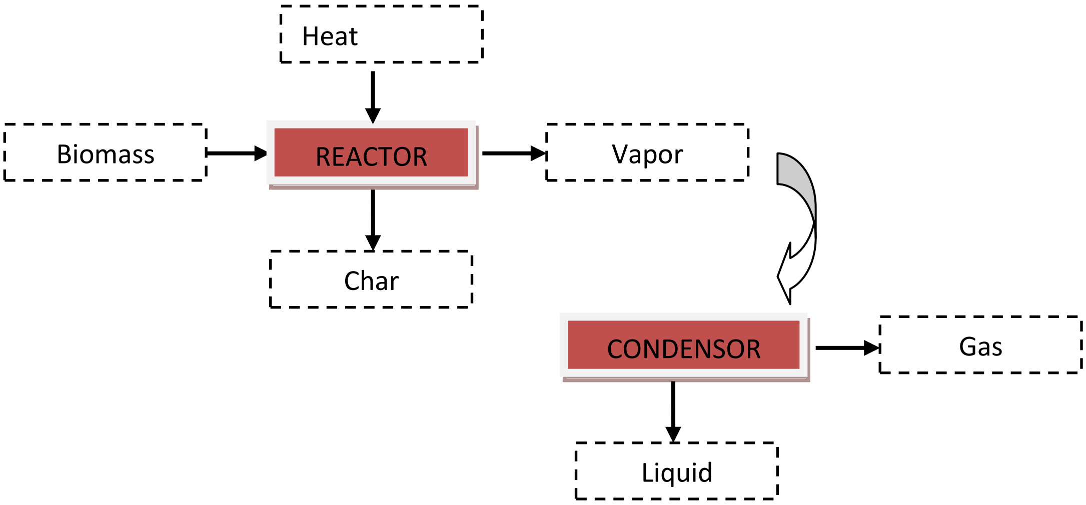


Figure 3.3 : Reaction pathway of Pyrolysis process

3.4 Design of System

Pyrolysis liquid usually corrosive in natural and the process operating temperature depend on the type of Pyrolysis. In this research, the slow Pyrolysis process will be used. The temperature for slow Pyrolysis around 500^{0}C above. The major component of the system fabricated by stainless steel of grade AISI 304 due to its rationale properties.

3.4.1 Combustion Design

In this combustion the heating rate usually less than 2 second for slow Pyrolysis. A cylindrical combustion was design and fabricates using mild steel plate of outer diameter is 45cm. The combustion volume and length were 56548cm^3 and 40cm respectively. The dimensional view of vertical bed reactor or combustion show by Figure 3.4.

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