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CONTENT

Introduction

Biomass is one of alternative sources for energy to substitute fossil fuel consumption. ASEAN countries (viz. Brunei Darussalam, Cambodia, Indonesia, Laos PDR, Malaysia, Myanmar, Philippines, Singapore, Vietnam and Thailand) have the same goal in increasing production and utilization of biomass for energy to decrease fossil fuel dependency. It therefore benefits not only energy security enhancement but also raising life quality of their people particularly in rural areas.

Main sources of biomass for energy in the region are agricultural wastes, thus ASEAN countries recognize a problem of their seasonal availability. They notably increase their attention to energy crop plantation and relevant research and development to sustain biomass for energy production and utilization in the region. Biomass for energy production and utilization are concerned in national energy policy of each ASEAN country. However, the utilization of biomass for energy in some ASEAN countries are limited and mostly in traditional way which are low efficiency. Technology and knowledge transfer as well as investment are necessary to reach a concrete achievement of biomass for energy production and utilization in the region.

ASEAN Bioenergy and Bioeconomy Conference 2017: *Sustainable management and partnership* will provide opportunities for researchers, private sectors, business developers and policy maker to update biomass and bioenergy database, status and situation in ASEAN countries. Moreover, new knowledge, technologies and innovations about biomass and bioenergy will be shared in this conference, and they would be implemented and commercialized in ASEAN countries. Biomass for energy production and utilization are expected to support the growth of biomass and bioenergy research, innovation and utilization in community and industrial level. As a final point, biomass and bioenergy network from this workshop will be established to encourage, and to be the mechanism for sustainable biomass and bioenergy development.

Objectives

1) To exchange and transfer useful information on biomass and bioenergy database, status and situation, new knowledge and technologies and innovation among ASEAN countries
2) To enhance sustainable biomass for energy production and utilization in ASEAN region to relieve environmental crisis and increase competitiveness of biomass for energy from ASEAN countries to the world market
3) To strengthen the biomass and bioenergy network within ASEAN countries

Date and venue

9 June 2017

The Bangkok International Trade and Exhibition Centre (BITEC), Bangkok, Thailand

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Kasetsart Agricultural and Agro-industrial Product Improvement Institute (KAPI),

Kasetsart University, Bangkok, Thailand

UBM Asia (Thailand) Co Ltd, Bangkok, Thailand

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Development of Mahogany (*Swietenia macrophylla*) Leaves as a Source of Green Battery to Help Rehabilitation of Bukit Suligi Educational Forest in Sumatra, Indonesia

Mahtuf Ikhsan *

ABSTRACT

The problems now faced by Bukit Suligi Educational Forest in Sumatra, Indonesia are that 70 % of the forest has been burned and oil palm is illegally planted by the surrounding community. Rehabilitation of the burned area is necessary in order to preserve Bukit Suligi Educational Forest. There is a need to prove that trees in the forest can produce an alternative energy for the community. This may change the perception of people who think the value of forest is lower than oil palm plantation. Mahogany (*Swietenia macrophylla)* leaves are a possible alternative source that can generate electricity based on their chemical properties which produce a bitter taste. This research was carried out by using mahogany leaves from Bukit Suligi Educational Forest to develop green battery model from the leaf extract. Results showed that 720 ml green battery model could generate 3.87 volts of electricity. Therefore, mahogany leaf extract has potential for a new alternative electrical energy. From this research, it is hoped that the community around the forest will take an initiative to restore degraded forests with mahogany plant.

Key words: mahogany leaf, green battery, rehabilitation

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INTRODUCTION

Indonesia's forest wealth is one of the greatest biodiversity ecosystems in the world. Its diversity spreads across the country especially in Kalimantan and Sumatra. Various plant species have vast benefits as foods, traditional medicine and renewable energy alternative that have not been fully optimized.

Bukit Suligi Educational Forest is an important forest resource in Riau province in Sumatra, Indonesia. Due to illegal logging and expansion of oil palm plantation, 70% of the forest has been degraded from burning and in need of rehabilitation. Mahogany (*Swietenia macrophylla*) trees are often found in the forest. All parts of this plant ranging from roots, stem, fruit and leaves can be utilized. One of the lesser known benefit and usefulness is the leaves, which are often wasted. Apart from being an air pollutant absorber mahogany leaves can serve as a source of electrical energy. Extract from mahogany leaves can be used as renewable energy to overcome the increasing demand for electricity in Indonesia.

The supply of community electricity based on the Microhydro Power Plant (PLTMH) resources can be set at 200 W per household connection (220 V, 1A). The capacity of electrical energy currently generated by the State Electricity Company (PLN) accounts for 73 % of the energy generated from fossil fuels. New potential local energy sources, among others such as solar, wind, and microhydro energy, can be realized into power plants. Therefore, new and renewable energy especially that from local potential sources, should be studied and utilized as a primary energy source for electricity generation (Widodo, 2012).

Based on chemical properties, mahogany leaves, which are alkaline with a bitter taste along with other solutions such as metal lead (Pb), can be utilized as an electrolyte solution in battery cells. Accumulator with strong electrolyte solution is not environmentally friendly and also dangerous. Therefore, it is of interest in reviewing and applying the utilization of wasted mahogany leaves as an environmentally friendly electrolyte solution. It is also a learning experience for inland communities, which are not yet reached by electricity, to utilize mahogany leaf extract as engineered from green accumulators.

The purposes of this study were: (1) to examine the contents in mahogany leaves as a source of alternative electrical energy, (2) to investigate the process of utilization of electrical energy from mahogany leaves as green accumulator, and (3) to understand the role of green accumulators in supporting the supply of electricity in Indonesia.

METHODS

In carrying out this study, several steps were implemented. Scientific journals and publications related to forest rehabilitation, mahogany plant, and green battery were reviewed. Primary data was obtained by conducting an experiment to develop green battery model from the extract of mahogany leaves which were obtained from Bukit Suligi Educational Forest. The work was carried out at the Forestry Vocational School of Pekanbaru on December 20 – 26, 2016. Primary data from the experiment was then used to compare with that from existing publications.

The experimental procedure is illustrated in Figure 1. An amount of 500 grams of mahogany leaves was taken from Bukit Suligi Educational Forest and ground in a blender for 7 min. This was intended to extract the mahogany leaf by adding the water. This process produced 720 ml of mahogany leaf extract. Using a multimeter tester, electrical conductivity was determined by putting all 720 ml of mahogany leaf extract into a jar. The next step was to insert red wire (positive pole) of the multimeter and black wire (negative pole) of the multimeter into the extract. The reading on the multimeter showed a voltage of 1.3 which was almost equivalent to one large dry battery size of 1.5 volt. This process was to determine the ability of mahogany leaf extract to deliver electric current without putting it into the accumulator. After that the mahogany leaf extract solution was put into the accumulator of a 6-V battery to the maximum level. The extract of mahogany leaves was filtered four times to ensure no leaf particles entered into the accumulator. After reading the voltage on the multimeter, the battery was placed in a cool place to avoid direct sunlight.

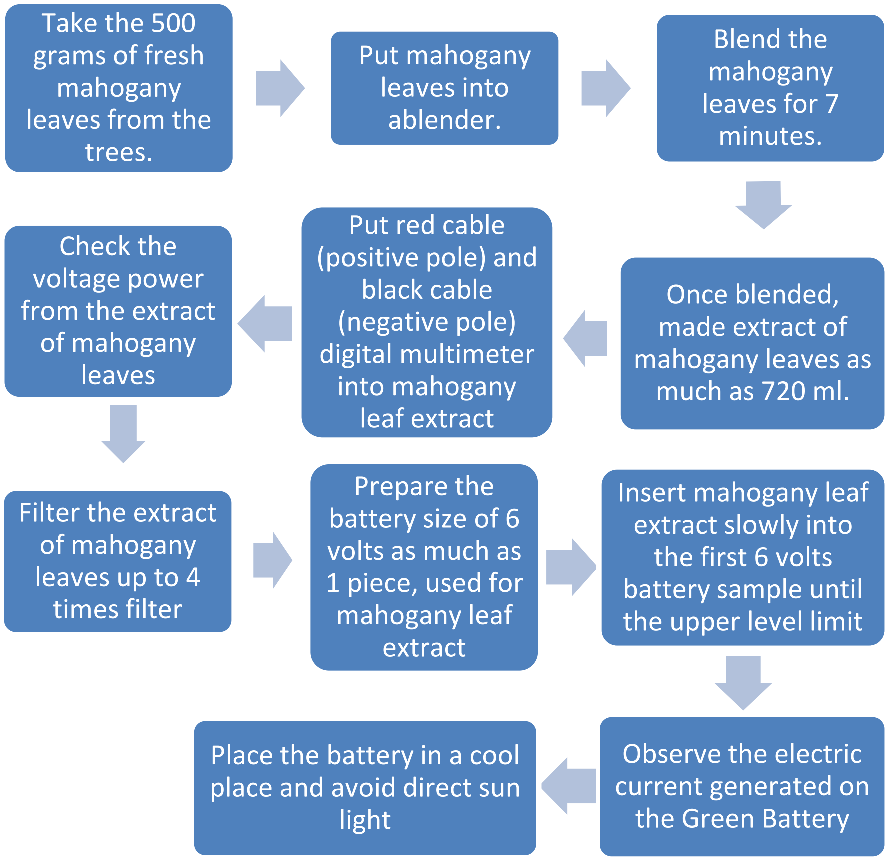

Figure 1 Diagram showing experimental procedure

RESULTS AND DISCUSSION

Results are summarized in Table 1. Mahogany leaf extract contained electrical conductivity of 1.3 volts before it was put into the accumulator. After putting into a 6-V accumulator for 20 min the electrical conductivity increased to 3.87 volts as shown on the multimeter. This is because when the leaf extract solution was still in the jar, not in the accumulator, the electric power generated was 1.3 volts as it used 3 cells only. When the leaf extract was put into a 6-V accumulator, the electric power reached 3.87 volts which was equivalent to two 1.5-V dry batteries. Since the accumulator had 6 pieces of cells the electricity generated was two times of that when it was not put into the accumulator.

Table 1. Results of electric power test

Condition of mahogany leaf extract	Electrical power (volt)
Before entering into the accumulator	1.30
Observation after 5 min	3.77
Observation after 10 min	3.80
Observation after 15 min	3.80
Observation after 20 min	3.87

The electric current in mahogany leaf extract was caused bythe fact that mahogany leaves contained lead (Pb) heavy metal which was absorbed by the leaves from vehicle fumes and air pollution resulting from residual combustion. Lead (Pb) has toxic and carcinogenic properties. The lead content (Pb) inside the mahogany leaves is 40.28 ppm and lead (Pb) is commonly used as the poles on the battery (Sedi, 2014).

In a positive polar, accumulator uses lead peroxide and a negative polar uses lead plate. When accumulator is used, chemical reactions caused sediment in negative (reduction) and positive (oxidation) electrodes. This could be the reason why mahogany leaf extract can deliver electric current induced by lead (Pb) in the content. This suggests that the extract of mahogany leaves can be used as an accumulator filler and a substitute of H_2SO_4 solution. Accumulator containing mahogany leaf extract can conduct electricity well to accumulator with 6 volt capacity.

Therefore, the extract of mahogany leaves can be utilized as a new alternative energy source as accumulator filler solution. From this research, it is hoped that local community of Bukit Suligi Educational Forest is aware of the benefits of mahogany leaves so that they will not carry out illegal logging which can cause further damage to the forest. There is a potential benefit to forest communities both in the economic aspect and forest conservation aspect in order to support better environmental management and sustainable energy development.

CONCLUSION

Mahogany plant in Bukit Suligi Educational Forest in Sumatra is a potential source of green energy but this species has been in a decline due to illegal logging and expansion of oil palm plantation.

Therefore, it is hoped that utilization of mahogany leaves as an alternative source of electrical energy will make people aware of the benefits of this tree. Further research is however needed to determine the ability of electric conductivity of mahogany leaf extract and the factors that influence the conductivity of mahogany leaf extract so that it can produce an optimal energy.

ACKNOWLEDGEMENTS

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Biogas Production Using Water Hyacinth from the Chao Phraya River

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ABSTRACT

Water hyacinth is a highly problematic invasive weed clogging up inland waterways. This study aimed to assess the potential of utilizing this weed as a renewable energy source for biogas production by anaerobic digestion. Samples were collected from the Chao Phraya River in Pathumthani Province, Thailand. An experiment was conducted in a single-stage semi-continuous anaerobic reactors. Two reactors were operated at 30°C by a 5-day feeding. One reactor was fed with a slurry of water hyacinth and water (20:80 by fresh weight). The other reactor was fed with a mixture of water hyacinth, cow dung and water (10:10:80). Mixed ruminal microorganisms of 3.75 g mixed liquor volatile suspended solid per liter were used as inoculum in both reactors. The reactor working volume was 5 L and the feeding rate was 625 mL/5 days giving rise to the hydraulic retention time of 40 days. The pH was initially adjusted to neutral in both reactors at the commencement and the reactors functioned without pH control. The results showed that the average methane content for the digestion of water hyacinth alone was 48.56 % and that of water hyacinth mixed with cow dung was 51.14%. The methane yield obtained from the digestion of water hyacinth was 145 L at STP/kg total solids added to the reactor. The pH of both reactors was slightly over 7. Biogas production from water hyacinth is feasible.

Key words: anaerobic digestion, bioenergy, biogas, co-digestion, cow dung, methane, water hyacinth

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes* family: Pontedericeae) is a perennial aquatic plant which can live and reproduce floating freely on the surface of fresh water or anchor in mud. It grows to 1 m in height above the surface of water. The stems and leaves contain air-filled tissue which give the plant a considerable buoyancy. The reproduction takes place at a rapid rate under favourable conditions (Herfjord *et al*., 1994). It can spread to cause infestations over large areas of water causing a wide range of problems. It grows in mats up to 2 m thick which can reduce light and oxygen, and change water chemistry. It is now considered a serious threat to biodiversity. The plant originated in the Amazon Basin and has been introduced to many parts of the world except in Europe. It thrives well in the tropical and sub-tropical climates, and has become a problematic plant in areas of southern USA, South America, East, West and Southern Africa, South and South East Asia and Australia. In the last ten years the rapid spread of the plant in many parts of the world has led to serious concern. Governments in many countries have tried to find ways to control it. To turn this invasive plant to good use one option is to produce biogas from this weed by anaerobic digestion. Anaerobic digestion can be applied to convert biodegradable wastes such as plant biomass, energy crops and grasses to produce biogas (Seppala *et al*., 2009, Sinbuathong *et al*., 2016). Biogas production can be improved by co-digestion of plant with manure (Romano and Zhang, 2008). Nitrogen can be supplied by co-digestion with cattle dung (Shyam and Sharma, 1994).

The aim of this study was to convert water hyacinth to biogas and provide a source of fuel by anaerobic co-digesting water hyacinth with cow dung. Anaerobic digestion and co-digestion of water hyacinth with cow dung were investigated in semi-continuously fed laboratory reactors.

MATERIALS AND METHODS

Two reactors were constructed from 6-L capacity plastic containers in which the working reactor volume was 5 L. Each reactor was equipped with two outlet ports, one for digested slurry overflow and the other for gas venting. The reactor was connected to a gas collection system, which was based on water displacement by the exiting gases. A 0.05 M sulfuric acid solution was used for the displacement by gas in the gas collection system.

Approximately 50 kg of fresh water hyacinth (30 cm in height) were collected from the Chao Phraya River in Pathumthani Province, Thailand, and brought to a laboratory in Kasetsart University, Bangkok. The water hyacinth samples were chopped and ground to a particle size of approximately 2 mm in diameter. The moisture content (MC) of the water hyacinth was determined by oven-drying to a constant weight at 105ºC. Total solids (TS) content was calculated as 100% - % MC. Total volatile solids (TVS) was obtained by igniting the TS in a muffle furnace at 550ºC for 20 min. Cow dung was obtained from a farm of Kasetsart University at Kamphaeng Saen Campus, Nakhon Pathom Province. Water hyacinth and cow dung were stored at 4ºC before use. Ruminal microorganisms from cow were used as inoculum because of their ability to degrade a particular substrate such as grass, plant and weed. The substrate mixture was prepared at a proportion of 20 % by fresh weight. The substrate mixture for digestion (water hyacinth: water = 20:80) and that for co-digestion (water hyacinth: cow dung: water = 10:10: 80) were prepared to be 20 % by fresh weight.

The reactor was filled with one liter of the mixed ruminal microorganisms from cow containing originally 18.77 g/L mixed liquor volatile suspended solids (MLVSS), giving rise to the biomass in the reactor of 3.75 g/L MLVSS. Initially, the prepared substrate mixture for digestion and that for co-digestion were analyzed for chemical oxygen demand (COD), total volatile solids (TVS), total solids (TS), pH, nitrogen (N) and phosphorous (P). Nitrogen (N) was determined using the Kjeldahl method by digesting samples to convert organic nitrogen to NH_4^+-N and determining the amount of NH_4^+-N in the digest (Walkley, 1947). Total phosphorous was determined by digesting samples with sulfuric acid and analyzed using the Vanadomolybdophosphoric acid colorimetric method (APHA and AWWA, 2005). The substrate was added to the reactor to 5-L capacity. The reactor was operated for 5 days in a batch mode before feeding with the substrate semi-continuously in an upflow mode by a 5-day feeding at a rate of 625 mL/5 days to the reactor giving rise to hydraulic retention time (HRT) of 40 days. Prior to feeding, an equivalent volume of digester content was removed from the reactor. The ambient temperature of the reactor was 30 ± 1ºC. The initial pH of the substrate mixture was recorded. The system was operated for 100 days. The produced biogas was measured daily by water displacement. The biogas samples were collected to determine the CH_4 content by a Shimadzu GC-14B gas chromatography equipped with a Thermal Conductivity Detector (TCD). At the steady state conditions (from day 62 onwards), the digested slurry from the reactors was analyzed for COD, TVS, and pH according to the procedure of the Standard Methods (APHA and AWWA, 2005). Organic waste degradation (in terms of COD and TVS degradation) and CH_4 production from the system were used as indicators of the reactor performance. The experimental conditions were: MLVSS 3.75 g/L, initial pH 6.31 and 6.75, temperature 30°C and working volume 5 L.

RESULTS AND DISCUSSION

Fresh water hyacinth contained 92.88% moisture content and 7.12% total solids (TS), of which 76.75% was total volatile solids (TVS). Initial COD, TVS and TS as well as the calculated organic loading rates (OLR) of the prepared substrate mixtures for digestion (water hyacinth: water = 20:80) and those for co-digestion (water hyacinth: cow dung: water = 10:10:80) are presented in Table 1. The substrate mixture for digestion contained 277 mg N/L and 0.329 mg P/L, while that for co-digestion contained 367 mg N/L and 4.70 mg P/L. The results of the digester performance in terms of biogas production and organic waste reduction are shown in Table 1.

The initial pH of the substrate mixture for the digestion and co-digestion was 6.31 and 6.75, respectively. The pH of the slurry in both reactors was adjusted to neutral at the commencement of the experiment. During operation the reactors functioned without pH control. The calculated OLR of the reactor for digestion and co-digestion was 0.21 kg COD/m^3.day (or 0.20 kgTVS/m^3.day) and 0.51 kg COD/m^3.day (or 0.51 kgTVS/m^3.day), respectively. At the steady state conditions (from day 62 onwards), the biogas produced from the reactor was stable. The average amount of CH_4 content from digestion and co-digestion was 48.56% and 51.14 %, respectively (Table 1). The results revealed that water hyacinth mixed with cow dung could be a good carbon source for CH_4 production. The CH_4 content was fairly high when co-digesting with manure. Macias *et al*. (2008) reported that methane producing bacteria in cow rumen played an important role in the digestion process.

The reactor performance in terms of COD and TVS degradation efficiency was over 60% (Table 1). Lehtomaki *et al*. (2007) studied the effect of crop to manure ratio and found that the co-digestion of grass with cow dung at the ratio of 2:5 could remove 53% of TVS in the system.

CH_4 yields obtained from the digestion of water hyacinth and co-digestion of the water hyacinth with cow dung, calculated from CH_4 production and organic waste added to the reactor are shown in Table 1. The co-digestion of water hyacinth with cow dung at the tested proportion (the OLR of 0.51 kg COD/m^3·day) gave CH_4 yield of 145 L/kg COD added or 115 L /kg TVS added or 144 L at STP/kg TS added. Sawanon *et al*. (2017) studied the co-digestion of 20% by fresh weight of the mixture of napier grass and cow dung (napier grass: cow dung: water = 10:10:80), and found that the CH_4 yields were 143 L/kg COD added, 169 L/kg TVS added and 142 L/kg TS added.

Table 1 Operational conditions, CH_4 production, organic waste degradation efficiency and CH_4 yields obtained from the reactor fed with water hyacinth alone and water hyacinth mixed with cow dung.

Reactor	A (Digestion)	B (Co-digestion)
Proportion of Substrate Slurry (Water hyacinth : Cow dung : Water)	20:0:80	10:10:80
Reactor volume (L)	5	5
Feeding rate (mL/day)	125 (625 mL/5 days)	125 (625 mL/5 days)
Hydraulic retention time (day)	40	40
Organic loading rate (kg COD/m^3.day)	0.21	0.51
Organic loading rate (kg TVS/m^3.day)	0.20	0.51
Biomass (g MLVSS/L)	3.75	3.75
N (mg N/L)	277	367
P (mg P/L)	0.329	4.70
Initial pH of slurry	6.31	6.75
pH of digested at steady state	7.19	7.23
CH_4 (mL/5days)	1,103	1,823
CH_4 in biogas (%)	48.56	51.14
Initial COD (g/L)	8.28	20.53
COD at steady state (g/L)	2.29	7.06
COD degradation (%)	71.55	65.34
Initial TVS (g/L)	7.91	20.29
TVS at steady state (g/L)	2.75	6.84
TVS degradation (%)	64.38	66.03
Initial TS (g/L)	12.15	25.35
CH_4 Yield (L at STP/kg COD added)	213	145
CH_4 Yield (L at STP/kg TVS added)	145	115
CH_4 Yield (L at STP/kg TS added)	223	144

The pH of the substrate mixture in the reactor for digestion and co-digestion was 6.31 and 6.75, respectively at the commencement of the experiment. At the steady-state conditions, the average pH of the digested slurry in the reactor for digestion and co-digestion was 7.19 and 7.23, respectively (Table 1). This was in concurrence with previous studies which revealed that in co-digestion of plant material and manures, the manures provided buffering capacity (Hills and Roberts, 1981; Hashimoto, 1983). The positive synergy effects were often observed in co-digestion due to the balancing of several parameters in the substrate mixture (Mata-Alvarez *et al*., 2000).

CONCLUSION

Biogas production from water hyacinth in the Chao Phraya River by digestion (water hyacinth: water = 20:80) and co-digestion with cow dung (water hyacinth: cow dung: water = 10:10:80) in a single-stage semi-continuous is feasible. At the tested proportion, the average methane content obtained from co-digestion was 51.14%, higher than that obtained from digestion of water hyacinth alone (48.56%). Water hyacinth could be a good carbon source for CH_4 production. Using water hyacinth as a carbon source to produce biogas is useful not only to obtain renewable energy but also to reduce the weed that causes problem in the Chao Phraya River.

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Development of Prototype Batch Reactor for Torrefied Wood Chip Production

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ABSTRACT

This research aimed to improve the solid fuel properties of para rubber wood chips by thermal upgrading, the torrefaction process. A conventional rotating drum was modified as a reactor. The maximum temperature in the reactor was fixed at 250°C under tighten oxygen condition by using liquid petroleum gas (LPG) as fuel. The reaction time, torrefied biomass properties, and production yield were studied in order to optimize the process. The wood chips were fed into the drum reactor at 25, 50 and 75% volume of the reactor capacity. Moreover, the angular speed was set at 5, 10 and 20 rpm. The results showed that the reaction time increased with the feed load of wood chips. Additionally, the angular speed did not affect the reaction time directly but it had an effect on the heating value of wood chip products: the lower angular speed applied, the higher heating value of wood chip products received. Torrefied wood chips from the optimum angular speed of 5 rpm showed the heating values (C.V.) of 4,849 cal/g. The heating value of torrefied wood chips was increased by 17% from the original rubber wood chips. Proximate properties were in accordance with the heating value. However, in contrast with heating value and % fixed carbon from approximate analysis, higher angular speed produced higher mass yield. In summary, the wood chip products from this torrefication process had higher fixed carbon, energy density, but lower yield when compared to those from original wood materials.

Key word: Renewable energy, Biomass, Torrefication, Rotating reactor, Rubber wood, Wood Chip

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INTRODUCTION

The global warming discussion and continuous rise in world population have impacted directly on the energy demand. This effect has spearheaded increasing demand for clean and sustainable sources of energy. These global challenges have triggered an increase in the adoption of alternative sources of energy, including renewable sources (Bimal *et al.,* 2012). Bio-energy has been discovered to be one of the key renewable energy initiatives to sustainable energy regeneration electricity in industrial application. Biomass energy product is referred to as bio-energy, which can be in the form of solid (bio-solids), liquid (bio-oil), or gas (bio-gas).

Biomass is a biological or organic material, which can serve as a source of renewable energy through thermal or biochemical conversion processes. It can also be classified as carbon-based material, which is composed of mixture of organic including hydrogen, oxygen, nitrogen and small quantities of atoms, alkali, alkaline, and heavy metals. However, as a high potential source for renewable energy route, biomass still has some challenges that, for example, it has limitations for energy generations, high moisture content/hygroscopicity/alkali contents, but low energy density and combustion efficiency.

A mild pyrolysis, torrefaction is a thermochemical pretreatment for upgrading fuel properties of biomass by applying maximum temperature of 200-300°C in absent oxygen condition. During torrefaction process, the biomass properties are gradually changed to reach better fuel characteristics for combustion and gasification applications. The property of torrefied wood products can be ranged between original wood raw materials and charcoals. The fuel properties are better than those of wood chips and the reaction time of the process is faster than that of the charcoal-making. Moreover, the fuel qualification of final torrefied products is hydrophobic behavior, inhibiting biological decomposition, improved grindability, and higher heating value. The improved grindability of torrefied biomass makes it advantageous for pelletization, which facilitates storage, transportation and co-combustion of biomass with coal.

As an agriculture-based country, Thailand has a lot of agricultural wastes including, for example, rice husks, corn stalks, corn kernels, palm oil palm, shell oil palm, and rubber wood, which can be utilized as renewable energy sources. Especially for para rubber wood, currently, the planting area has reached 3.25 million ha, and about 18 million tons of plantation residues are generated annually (Kasetsart Agricultural and Agro-Industrial Product Improvement Institute, 2015). However, these potential of this agricultural waste has a great challenges in collecting and pre-processing to comply with logistics and financial constraints. To overcome such obstacles, this research attempted to modify a cheaper machine and simple method for agricultural waste owners, especially farmers, to pretreat the residues by themselves. This experiment was based on a pilot scale machine suitable for small community enterprise nearby biomass source. Besides, an outcome of this research was value-added of underutilized biomass residues and to extend the energy security policy of the government.

MATERIALS AND METHODS

1. Materials

The wood residues of para rubber RRIM 600, a hybrid species, were gathered from a 25-year-old plantation in Surat Thani province, southern Thailand. After chipping process, the para rubber wood chips were screened with an acceptable size of 2 cm × 2 cm × 0.5 cm, and then air-dried to reduce the moisture content to below 10%. The prepared wood chips were stored in containers for the next steps of the study.

2. Developing torrefied reactor

The horizontal rotating drum reactor from oil palm industry was chosen to modify as a torrefied reactor in this study. This drum reactor was made from high grade steel with a large combustion room located at the bottom of the reactor (Figure 1). The dimension of cylindrical drum was 1 m in diameter and 2 m in length with a steel jacket. The fixed blade baffles were also mounted inside the shell of cylindrical rotating drum in order to better mix and heat transfer during production period (Alok *et al.,* 2012). The drum could be loaded with the wood chips up to 200 kg depending on their size and moisture content. Thermocouples (K-type) were inserted to one position of the reactor to monitor the reaction temperature, record and analyze the reaction behavior inside the drum. The size of combustion room was 1.16 m × 2.20 m × 0.85 m (Figure 1) and a 1.4 kW step motor with maximum speed of 37 rpm was installed.

An indirect heat system was applied as energy source for torrefied reaction in this study. For better temperature control inside the drum and lower system disturbance from rough combustion in this first prototype model, the liquid petroleum gas (LPG) was burned to generate heat and hot flue gas. Heat and hot flue gas were forced to transfer from combustion chamber to the drum and wood chips inside. Heat is transferred from the hotter drum wall to the biomass. That was controlling factor in such reactors (Daya *et al.,* 2016). Unfortunately, at the early stage of the experiment, the temperature inside the drum did not reach the defined temperature of 250°C, therefore the combustion room was modified by adding more burners and reducing the chamber sized. With this additional effort, the temperature inside the drum reached the required temperature in 50 minutes. Finally, an inverter was installed for fine adjusting speed requirement of the cylindrical drum.

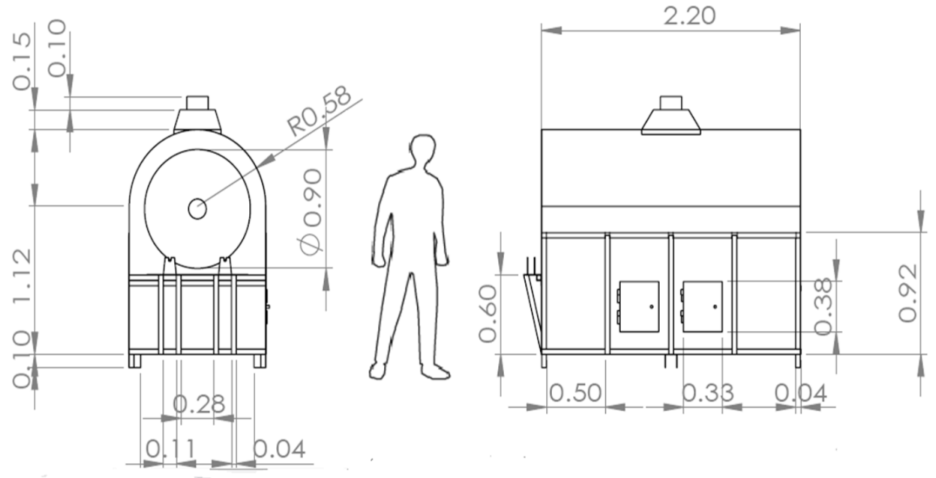


Figure 1 Rotating drum torrefied wood chip reactor.

3. Torrefaction

Wood chips were dried by ambient condition before torrefaction in order to remove excess moisture in the biomass. After that, the wood chips were fed into the rotating drum reactor and were torrefied at 250°C. For better controlling, the temperature inside the drum must be raised to the defined temperature before every batch of wood chips was fed. Torrefaction reaction was performed under absent oxygen condition. Experimental design was factorial with two factor; feed load and angular speed. The design facilitates determination of interaction terms and single factor term. The dried wood chips were loaded at 25, 50 and 75 % by volume of the reactor drum capacity with various angular speed of 5, 10 and 20 rpm.

Temperature inside the rotating drum was recorded every 5 minutes and correcting samples every 15 minutes. When the wood chips were fed into the drum, the reaction temperature dropped simultaneously. The difference in the temperature before and after feed load of the wood chips depended mainly on moisture content, feed load, angular speed, and ambient condition. When the temperature reached 250°C again, the burner was turned off and the reactor was left to cool to room temperature.

For laboratory analysis, the moisture content of torrefied wood chip products was tested by the oven-dry method (ASTM E872). The gross calorific value (CV) or high heating value (HHV) of the torrefied products was determined following ASTM E711 by bomb calorimeter (Automatic Isoperibol calorimeter, IKA C 5001 Instrument Inc.). For ash content, product sample was checked by burning 2 g of sample inside a ceramic crucible in a muffle furnace model at 580 ± 20°C (ASTM E874). Energy yield per dry raw material indicated the total energy preserved in the torrefied biomass. It was calculated by considering weight loss during torrefaction. The mass and energy yields were determined according to Bridgeman *et al.* (2008) as

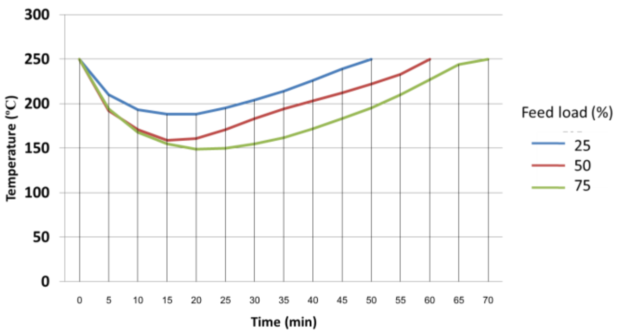
Mass yield = 100 × (mass of dried torrefied product/mass of dried biomass) (1)

Energy yield = Mass yield × (CV after pretreatment - CV before pretreatment)/ CV before pretreatment (2)

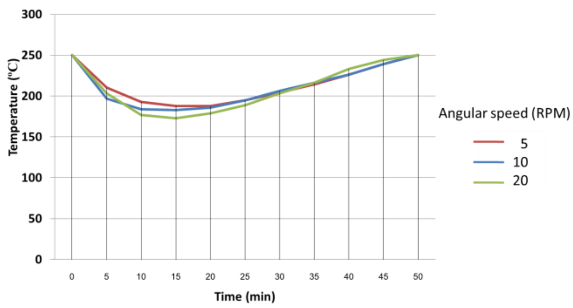
RESULTS AND DISCUSSION

1. Temperature profile in the rotating drum reactor

The behavior of reaction temperature in the rotating drum reactor could be divided into three phases. At the first phase, the temperature in the reactor decreased rapidly after loading wood chips into the rotary drum. The more feed load applied, the faster the decline of temperature. The second phase, temperature in the reactor was constant or temperature rate changed be low 2°C/min. The heat of wood chip were equaled heat in the drum, this phase has a lot of smoke because moisture in wood chip were removed. And the last phase, temperature in the reactor was increased rapidly to 250°C. On this phase the chemical in wood chip were degradation and that had heat form the transition too. The temperature decline had a direct influence on the recovery time. The result showed that the maximum feed load led to the longest reaction time. Figure 2 (a) shows that the reaction time depended unswervingly on the feed load., Feed load 25, 50 and 75% of the reactor drum volume required reaction time of 50, 60 and 70 minutes, respectively. On the other hand, angular speed was not affected by the temperature change in the reactor as illustrated in Figure 2 (b).



a



b

Figure 2 Temperature profile in the torrefied reactor. a) effect of feed load on reaction time; b) effect of angular speed on reaction time

2. Torrefied wood chip products

The appearance of final wood chip products from this study was observed visually. Changes in color of wood chips are an easy indicator to show the degree of torrefaction. A number of factors such as losses in mass, types of wood, polymeric compositions content of biomass, changes in the surface properties of biomass that affect absorption, reflection, and scattering properties and the movement of sugar molecules with low molecular weight to the surface of biomass may affect the color of the solid product after the thermal treatment (Nhuchhen *et al*., 2016). Different parameters, feed loads and angular speeds are considered to be the main operating parameter that affects the degree of torrefaction (Bach and Skreberg, 2016). Figure 3 shows the effect of the torrefaction factor on the product color. The darkness of the torrefied product deepened on angular speed factor. Torrefation wood chip at lowest speed (5 rpm) that made the darkest final product. But torrefaction at difference feed, the color of product was similar. However, one could notice that the color of the solid products was uniform, indicating a similar level of thermal degradation to all particles in the torrefied reactor.

Figure 3 Final product torrefied wood chips, on column is difference feed load, on row is difference angular speed

Torrefied product properties were statistically analyzed, to determine the effect of feed load and angular speed of the reactor. The results from this study were in line with those reported in other previous studies. Torrefaction of wood chips resulted in higher heating value, higher percent carbon content and higher percent ash content (Kim *et al.,* 2012, Strandberg *et al*., 2015) while the moisture content of torrefied biomass was decreased. The heating value of torrefied wood chips ranged from 4,565 kcal/kg to 4,895 kcal/kg which represented 10-18% higher than that of the untreated wood chips. The increase in the heating value of biomass during torrefaction in this study was also comparable with those in other previous studies utilizing various agricultural residues and wood chips (Prins *et al.,* 2006; Granados *et al.,* 2014).

Raw data from proximate and process results from the present work are compiled in table. Because no combined effect of angular speed and feed load. Table 1 show mean values of testing properties effect with feed load and Table 2 show mean values of testing properties effect with angular speed. Fix carbon between 13-20% were obtain, which is a large interval that covers most torrefaction degrees. Feed loads were no effects with heating value (Table 1). As the temperature in the reactor needs to be 250˚C in every batch, the more wood chips added to reactor resulted in the longer reaction time. The wood chips in the reactor were subjected to equal heat. On the other hand, angular speed had a significant effect on heating value of the torrefied product as shown in Table 2. Product from torrefaction at angular speed of 5, 10 and 20 rpm had heating value of 4,849, 4,727 and 4,596 kcal/kg respectively. An explanation for higher heating value at lower angular speed is that there was more duration of contract between drum surface and wood chips at low speed so that torrefied product had higher heat transfer via conduction.

Mass yield of the products decreased with an increase in heating value. The reaction occurring in reactor during torrefication leads to hemicellulose degradation resulting in decreased mass yield and increased heating value of wood chips. Angular speeds significantly affected with mass yield and heating value. The suitable of torrefication process is considered form the mass yield, energy and reaction times (Chen *et al.,* 2016), especially the reaction times, that have an effect on capacity and cost for production.

Table 1 Mean values of testing properties without mutual influence on feed load amount

Feed load (%)	Moisture Content (%)	Ash (%)	Fixed Carbon (%)	HHV (cal/g)	Yield (%)	Reaction Time (min)
25	1.62^{AB}	3.75	15.06	4,712	86.67^{B}	49^{C}
50	2.19^{A}	4.42	16.97	4,756	88.37^{A}	60^{B}
75	0.92^{B}	3.83	17.28	4,703	86.29^{B}	73^{A}

Mean values within column with different superscript letter are significantly different ($P < 0.05$).

Table 2 Mean values of testing properties without mutual influence on angular speed.

Angular speed (rpm)	Moisture content (%)	Ash (%)	Fixed carbon (%)	HHV (cal/g)	Yield (%)	Reaction time (min)
5	2.24^{A}	3.89	20.94^{A}	$4,849^{A}$	84.36^{B}	59
10	1.56^{AB}	5.39	15.19^{B}	$4,727^{AB}$	88.08^{A}	61
20	0.93^{B}	2.72	13.17^{B}	$4,596^{B}$	88.89^{A}	63

Mean values within column with different superscript letter are significantly different ($P < 0.05$).

CONCLUSION

This study demonstrated that the reaction time depended largely on the feed load of wood chips. The more feed load was used, the longer the reaction time. Additionally, the angular speed did not affect the reaction time directly but it had effect on the heating value of wood chip products. Torrefaction at angular speed of 5 rpm generated the highest heating value. Considering the reaction time and energy yield in comparison with the production yield for optimum performance, the optimum condition was 75 % feed load volume and 5 rpm angular speed.

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Characteristics and Papermaking Potential of Jute Fibers Produced by Soda and Refiner Mechanical Pulping Methods

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ABSTRACT

Jute (*Corchorus olitorius*) can be used as an alternative to wood-based fiber for pulp and paper products. This study examined the characteristics of jute pulp fibers and their papermaking potential. Fibers were produced from the bast part of jute by two most commonly used methods for non-wood pulping, i.e. soda and refiner mechanical pulping (RMP) methods. Morphological characteristics of the fibers obtained from the two pulping methods were studied using light microscopy and Fiber Quality Analyzer. Physical and mechanical properties of paper sheets made from soda and RMP jute pulps were examined after the pulps were refined to a target freeness of 350 mL CSF using a PFI mill. The results showed that jute fibers produced by RMP method had more fibrillation on the fiber surface and the pulp contained a relatively high amount of kinked fibers, curled fibers and fines fraction. In contrast, the pulp produced by soda pulping method consisted mostly of undamaged jute fibers and contained lower fines content. Moreover, jute fibers produced by RMP method had shorter fiber length than those produced by soda pulping method. Based on physical and mechanical properties, the sheets made from the refined RMP jute pulp had lower mechanical strength but higher bulk and opacity than those made from the refined soda pulp.

Key words: Jute, Soda, RMP

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INTRODUCTION

The pulp and paper industry is one of the largest industrial sectors in the world that plays an important role in economic development in many countries. It is generally categorized as the forest-based industry or the industry in which wood is used as the primary raw materials in the production of the forest-based products such as wood pulp, paper, paperboard and other wood products. Due to environmental concern, restrictions on harvest in natural forests and significant increases in wood cost, the use of non-wood fiber resources has currently gained more attention in the pulp and paper industry (Saijonkari-Pahkala, 2001; Kamoga *et al.,* 2013).

Generally, non-wood fibers can be obtained from three sources, viz. agricultural by-product, industrial crops and naturally growing plants. Jute (*Corchorus olitorius*) is one of the most important industrial crops that shows great potential for use as an alternative fiber resource for the pulp and paper industry (Rahman, 2010; Roy and Lutfar, 2012). It has been reported that jute fibers, extracted from the bast or skin of the stem, are similar to softwood fibers and suitable for pulping and papermaking (Jahan *et al.,* 2007; Ramamoorthy *et al*., 2015; Sorrenti, 2017). However, there is limited information available on the use of jute as pulping and papermaking raw materials. Therefore, the objective of this study was to examine the characteristics of jute pulp fibers and their papermaking potential. In this work, two most commonly used pulping methods for non-wood material, soda pulping and refiner mechanical pulping (RMP) methods, were chosen for jute pulping.

MATERIALS AND METHODS

1. Raw materials

The raw material in this study was the bast part of jute, which was obtained from Mahaphant Fibre Cement Public Company Limited, Thailand. The jute bast had a cut length of 4 cm and moisture content of 8%. Chemical compositions of the jute bast and its fiber morphology are given in Table 1 and Table 2, respectively.

Table 1 Chemical compositions of jute bast

Chemical compositions	Value (% on dry weight)	Analysis method
Holocellulose	84.62±0.43	Browning method
Alpha-Cellulose	72.06±0.62	TAPPI T203
Hemicellulose	12.56±0.02	TAPPI T223
Lignin	12.34±0.11	TAPPI T222
Extractives	4.59±0.07	TAPPI T204
Ash	2.88±0.01	TAPPI T211

Table 2 Morphological properties of jute bast fibers prepared by Franklin's method

Fiber morphology	Value	Analysis method
Length (mm)	1.864±0.01	ISO 16065-1
Width (µm)	25.30±0.06	ISO 16065-1
Coarseness (mg/m)	0.064±0.00	ISO 16065-1

2. Soda pulping

Soda pulping was carried out in a rotary batch cylindrical digester heated by means of electric resistance. In the pulping, the effective alkali charge of 18% on oven-dry raw material was used. The pulping was continued for 2 h at 165°C, with the jute bast to liquor ratio of 1:5. Thereafter, the pulp was washed until free from residual chemicals and screened to remove any remaining fiber bundles.

3. Refiner mechanical pulping

Refiner mechanical pulping of jute bast was carried out using a high-consistency disc refiner at the Department of Forest Products, Faculty of Forestry, Kasetsart University (Figure 1a). In this process, jute bast with about 45% moisture content was fed continually in the refiner which was equipped with the refiner plate made of high-chrome stainless steel (Figure 1b). The plate clearance was set at 0.18 mm for this study.

a)

b)

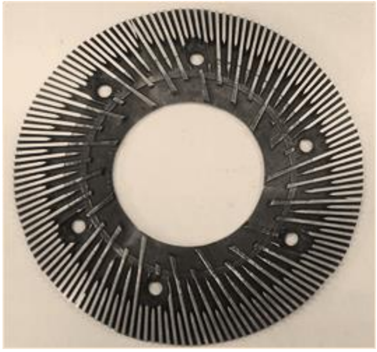

Figure 1 a) High- consistency disc refiner and b) coarse bar refiner plates

4. Determination of fiber and paper properties

Fiber characteristics were determined using a light microscope with 10X magnification. The morphology and quality of fibers such as length, width, coarseness, fines content, curl and kink were measured using a fiber quality analyzer (opTest FQA) according to the ISO 16065-1 standard method. Determination of paper properties was conducted after the pulp was refined to the target freeness of 350 ml CSF with a PFI mill according to the ISO 5264-2 standard method. The refined pulp was then made into a laboratory sheet with a basis weight of 60 g/m^2 according to the ISO 5269-1 standard method. Physical and mechanical properties of the sheet were determined according to the ISO 5270 standard method.

RESULTS AND DISCUSSION

1. Fiber characteristics of soda and RMP pulp from jute bast

The light microscopy image showed that jute fibers obtained from soda pulping method were relatively long and slender, and were mostly undamaged (Figure 2 left). Jute fibers obtained from RMP method (Figure 2 right) had a relatively high degree of fibrillation on the fiber surface, and most of the fibers were curling.

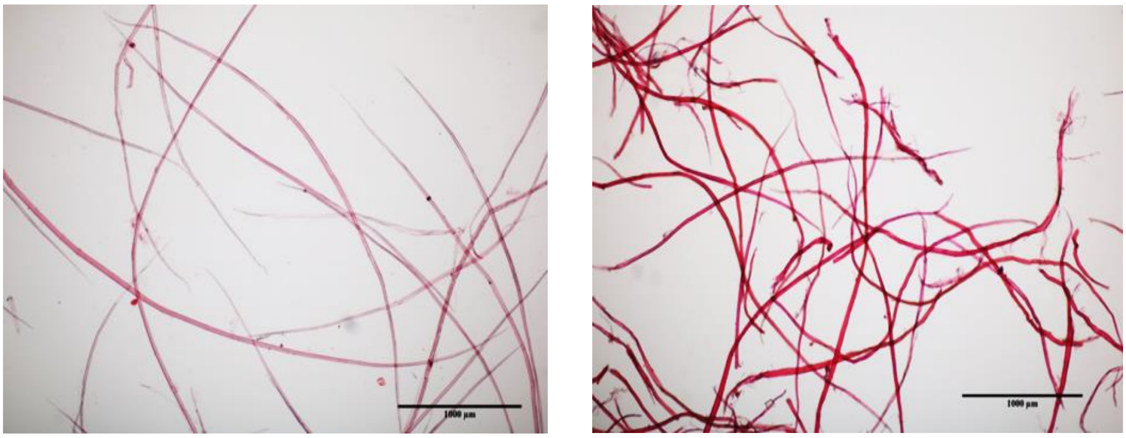

Figure 2 Light microscopy image of jute fibers produced from soda process (left) and refiner mechanical process (right)

Based on the fiber quality analyzer, jute fibers produced by soda pulping method had longer fiber length than those produced by RMP method (Table 3). The length-weighted average fiber length of soda jute pulp was 1.87 mm, while that of the RMP pulp was 1.19 mm. On the other hand, jute fibers produced by RMP method had higher coarseness value. These results indicated that the RMP fibers had high stiffness and low conformability compared with the soda jute fibers. In addition, the RMP pulp contained a relatively high amount of fiber kink and fines fraction.

Table 3 Morphology and quality of soda and RMP pulp fibers from jute bast

Properties	Soda jute pulp	RMP jute pulp
Fiber length (mm)	1.869±0.01	1.191±0.01
Fiber width (μm)	25.77±0.06	28.57±0.25
Coarseness (mg/m)	0.064±0.00	0.119±0.00
Curl index	0.103±0.00	0.168±0.00
Kink (mm-1)	0.545±0.01	1.083±0.02
Fines content (%)	6.37±0.38	20.07±0.42

2. Properties of paper made from the refined soda and RMP pulp from jute bast

A summary of basic physical and mechanical properties of paper made from soda and RMP jute pulps after they were refined to a pulp freeness of 350 mL CSF is presented in Table 4. At a given freeness, the density of sheets made from the RMP jute pulp was 323.91 kg/m^3, which was clearly lower than that of the sheets made from the soda jute pulp. This showed that the RMP jute pulp generated the sheets with higher bulk, which was mainly due to its coarser and stiffer fibers (Höglund, 2009). According to Kappel (1999), bulk is one of the most important quality parameters of paper, especially paperboard grades. It affects not only the performance properties such as stiffness but also the appearance of the paper (Brännvall and Annergren, 2009). Hubbe *et al*. (2008) reported that high bulk contributes to improved light scattering coefficient of paper. Therefore, the sheets made from the RMP pulp were found to have higher opacity degree compared to those made from the soda pulp. However, the brightness of the sheets made from the RMP jute pulp was slightly lower than that of the sheets made from the soda jute pulp. This was likely due to high lignin content of the RMP pulp. Höglund (2009) explained that the production of mechanical pulp results in small removal in lignin content. As noted by Suess (2009), lignin component is one of the main sources of the chromosphere in mechanical pulp, which negatively affects the pulp brightness.

As shown in Table 4, the sheets made from the RMP pulp had poorer mechanical strength, including tensile, burst, tear and ring crush strength, compared to the soda jute pulp. This result was probably attributed to the low degree of interfiber bonding in the RMP jute fibers as indicated by low density of the sheets. According to strength theories, the strength properties of paper are primarily dependent on the interfiber bonding (Retulainen *et al*., 1998; Uesaka *et al*., 2002). Therefore, when the bonding potential of the fibers decreases, the strength properties also decrease. Additionally, the poorer mechanical strength of the RMP jute pulp was probably due to its shorter fiber length (Table 3).

Table 4 Physical and mechanical properties of paper made from the refined soda and RMP jute

Properties	Soda jute pulp	RMP jute pulp
Sheet density (kg/m^3)	487.04±5.78	323.91±4.40
Opacity (%)	90.58± 0.18	98.83± 0.23
Brightness (%ISO)	38.84± 0.25	32.15± 0.32
Tensile index (Nm/g)	55.08± 3.30	17.10± 0.43
Bursting index ($kPa \cdot m^2/g$)	3.94± 0.28	0.45± 0.18
Tearing index ($mN \cdot m^2/g$)	16.29± 1.64	3.10± 0.11
Ring crush index (Nm/g)	7.18± 0.52	4.33± 0.34

CONCLUSION

This study demonstrated that:

- Soda pulping method produced jute fibers with less damage while RMP method provided jute fibers with more external fibrillation. Moreover, the length of jute fibers produced by soda pulping method was longer than that by RMP method.
- Both soda and RMP jute fibers had a good potential to be used as alternative raw material for papermaking. After pulp refining, RMP jute fibers provided the sheets with high bulk and opacity while the soda pulp produced the sheet with good mechanical strength.

ACKNOWLEDGEMENTS

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Performance and potential of fast growing trees for biomass energy in degraded soil, Thailand

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ABSTRACT

Fourteen treatments of fast growing trees (*acacias, eucalyptus and leucaena*) were planted in randomized complete block designs using 2m x3m spacing on two planting sites, Khon Kaen (KK) province in northeastern and Chachoengsao (CC) province in eastern Thailand in 2013. The objective was to screen suitable species for energy plantation in degraded soil. Results up to 2.5 years of age in terms of survival rate, growth and biomass yield showed considerable differences among treatments and between sites. Survival rate of most acacias and eucalyptus were higher than 80% while those of leucaena were below 80 %. Diameter at breast height (DBH) and total tree height in CC was greater than those in KK, likely due to higher precipitation in CC. Total biomass of all treatments in CC was also greater than that in KK. *A. mangium* produced the highest biomass yield (37.1 ton ha^{-1}) in CC while the biomass yield of *Eucalyptus* hybrid (*E. camaldulensis x E. urophylla*) (31.5 ton ha^{-1}) was significantly the highest in KK. *L. leucocephala* obviously showed the lowest biomass yield at both sites (11.3 ton ha^{-1} in CC and 2.2 ton ha^{-1} in KK). The results have implications for selection of the most suitable fast growing trees for planting on degraded soil on two sites of different annual rainfalls to provide biomass yield as alternative energy source. Long term monitoring on coppicing ability of the species and financial analysis should be included to aid decision for future extension work in this degraded area.

Keywords: biomass, fast growing tree, degraded soil, Thailand

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INTRODUCTION

Biomass is the alternative and renewable energy resource which becomes more popular due to the rising cost of fossil fuel. Wood biomass is one of the main sources of energy and is currently the most important supply of renewable energy (Lauri *et al*., 2014). Wood biomass is a sustainable source of energy if proper management of vegetation is ensured.

The fast growing tree is a high potential source for wood biomass energy resources because it is sustainable production compared to other biomass such as agricultural residuals and its. Production of heat from fast growing trees, target was set by considering the potential of deteriorated soil area such as high deteriorated area and area of deterioration in crisis of the land for agricultural reform which was outside the main irrigation area. This make no impact or affect to the area of food crops (Ministry of energy, 2015).

The aim of this research was to screen the suitability of fast growing tree species which might have potential to grow as an energy plantation on degraded lands in Khon Kaen province and Chachoengsao province, Thailand.

MATERIALS AND METHODS

1. Study site

Experimental plots were established in two degraded areas in Khon Kaen (KK) province in northeastern and Chachoengsao (CC) province in eastern Thailand. The total area of each site was 0.63 ha^{-1}. The soil of CC was a sandy clay loam of the coarse-loamy, kaolinitic, isohyperthermic, typic and kandiustults, altitude above mean sea level 180 m and annual rainfall of 1220 mm. The soil of KK was a sandy clay loam of the coarse–loamy, siliceous, isohyperthermic, typic and kandiustults, altitude above mean sea level 175 m and annual rainfall of 920 mm.

2. Plot establishment

In order to determine the potential of fast growing tree species and their performance for energy utilization, the study employed randomized complete block design of 14 treatments (acacia, eucalyptus and leucaena) for 3 replications. Each experimental plot consisted of 25 trees with 2mx3m spacing.

Plantation management such as fertilization, weed control, pruning, harvesting was also studied to find out the proper silvicultural practice for energy plantation.

3. Data collection

Growth data were collected every 6 months for assessment of total height and diameter (at breast height) growth. At the age of 2.5 year, biomass yields were estimated and wood was sampled for its energy property analysis.

RESULTS AND DISCUSSION

The results up to 2.5 years of age in terms of survival rate and growth showed significant differences among treatments and sites ($p<0.05$). Survival rates of most acacias and eucalyptus were higher than 80 % while those of *Leucaena* l*eucocephala* and *Eucalyptus urophylla* (in CC) and were below 80 %. (Figure 1)

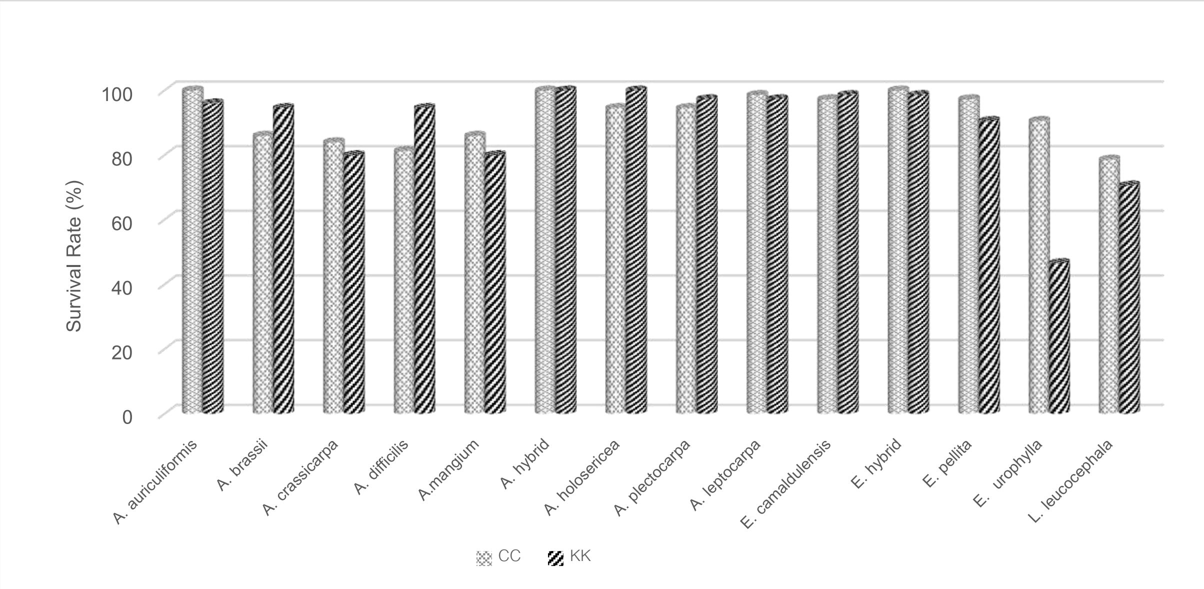

Figure 1 Survival rate of fast growing trees at 2.5 years old in Khon Kaen (KK) and Chachoensao (CC) provinces, Thailand

Total height and diameter at breast height (DBH) of the trees in CC were higher than those in KK due to its higher precipitation. In CC, the result revealed that *A. mangium* presented the highest growth (10.2 cm, 9.6 m) followed by *A. auriculiformis* and *A. crassicarpa*, respectively. In KK, *E. hybrid* showed the highest growth (7.4 cm, 10.4 m) followed by Acacias and *L. leucocephala,* respectively. In addition, KK experiments showed higher pest damage than CC in drying season.

Total biomass yields of all treatment in CC were also higher than those in KK. *A. mangium* provided the highest biomass yield of 37.1 ton ha^{-1} in CC. In KK, *E.* hybrid (*E. camaldulensis x E. urophylla*) showed the significant highest biomass yield (31.5 ton ha^{-1}). *L. leucocephala* produced the lowest biomass yield in both sites (11.3 ton ha^{-1} in CC and 2.2 ton ha^{-1} in KK) (Table 1).

The higher heating values (HHV) of all fast growing tree wood were in the same range between 17.3 and 19.1 MJ kg^{-1} (moisture content < 10 %) with low ash content (0.5 – 1.2 %) and chlorine (0.01 – 0.02 %).

The result indicated that the total height, DBH and biomass of tree in CC were also higher than those in KK. Weather conditions and pest damage had a substantial impact on growth rate and yield. Therefore, technical knowledge on wood biomass materials and plantation management would benefit fast growing tree planting on both sites.

Table 1 Growth and yield of fast growing trees at 2.5 years old in Khon Kaen (KK) province and Chachoengsao (CC) province, Thailand

Treatment (Species)	DBH (cm)		Height (m)		Biomass (ton ha^{-1})		HHV (MJ kg^{-1})	
	CC	KK	CC	KK	CC	KK	CC	KK
Acacia auriculiformis	7.4 ± 0.3	4.46 ± 0.6	9.7 ± 0.5	4.6 ± 0.5	27.8	8.5	18.0	17.3
Acacia brassii	7.6 ± 0.4	5.5 ± 0.4	7.2 ± 0.4	5.2 ± 0.2	17.1	18.9	17.7	19.1
Acacia crassicarpa	8.2 ± 0.7	6.3 ± 0.5	8.7 ± 0.7	6.9 ± 0.5	23.7	14.5	18.4	17.7
Acacia difficilis	6.2 ± 0.3	5.8 ± 0.5	7.5 ± 0.4	6.1 ± 0.2	16.1	15.9	17.6	18.4
Acacia holosericea	6.6 ± 0.5	N/A	7.5 ± 0.3	N/A	18.3	18.5	17.6	18.2
Acacia hybrid	7.8 ± 0.4	6.0 ± 0.2	8.5 ± 0.1	5.9 ± 0.1	27.4	21.7	18.5	18.2
Acacia mangium	10.2 ± 0.4	6.6 ± 0.6	9.6 ± 0.2	6.3 ± 0.2	37.1	15.4	18.3	18.3
Acacia leptocarpa	7.5 ± 0.5	5.0 ± 0.3	9.1 ± 0.3	5.6 ± 0.3	24.3	13.9	18.1	18.9
Acacia plectocarpa	6.3 ± 0.4	5.7 ± 0.4	7.4 ± 0.3	6.9 ± 0.1	12.9	19	17.9	18.5
Eucalyptus camaldulensis	6.1 ± 0.4	6.2 ± 0.6	8.6 ± 0.4	7.9 ± 0.4	12.9	20.9	18.2	17.8
Eucalyptus hybrid	6.5 ± 0.1	7.4 ± 0.3	10.2 ± 0.4	10.4 ± 0.7	20.7	31.5	18.3	18.1
Eucalyptus pellita	7.4 ± 0.5	6.0 ± 0.1	10.7 ± 1.0	8.3 ± 0.5	26.3	18.2	17.7	17.6
Eucalyptus urophylla	6.7 ± 0.5	6.6 ± 0.5	9.8 ± 0.9	8.9 ± 0.1	17.13	10.5	18.4	17.8
Leucaena leucocephala	5.0 ± 1.3	2.3 ± 0.7	7.6 ± 1.1	3.7 ± 0.6	11.3	2.2	18.0	17.7

CONCLUSION

Growth and yield of all fast growing trees at 2.5 years old in CC was also greater than that in KK. For the first rotation, A. *mangium* and E. hybrid (E. *camaldulensis* x E. *urophylla*) were the most suitable fast growing tree species for energy plantation on degraded land in CC and KK respectively. Long term monitoring in case of coppicing species and financial analysis should be included to provide significant decision for future extension work in these degraded area.

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Bioeconomy Policies in the G7, the EU, Asia-Pacific and Thailand

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ABSTRACT

Nowadays, bioeconomy policy is important to the improvement of health, quality of life, food, and sustainable economic growth. Bioeconomy policy should be considered in accordance with strength of domestic economy, bioresources, value chain of agricultural products, logistics, employed technology, regional and global stakeholders, and political approaches. The policy strategies, always fostering high-technology, emerging industries and industrial innovation, have also driven biotechnology and industrial strategies. The green biotechnology, blue technology and biomass, renewable resources, bioenergy, green growth, green and biobased industry are regarded as bioeconomy.

This study focuses on bioeconomy policies of the countries with high market share value of world bioeconomy such as the G7 and the EU which provide a basis for bioeconomy policy development in Thailand. Moreover, the bioeconomy policies of the Asia-Pacific countries are also studied. The natural bioresources, technologies, and development strategies could support each other in the Asia-Pacific region. Finally, this study assesses and compares the bioeconomy-related policies among the leading nations and Asia-Pacific region. The impacts of political goals, approaches and priorities for bioeconomy development are also demonstrated.

Key words: Bio-economy policy, Green technology, Renewable resources, Biobased materials, Bioenergy

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INTRODUCTION

Bioeconomy has become an important strategy of most countries in industrialized, developing and underdeveloped countries in order to increase the competitiveness of the economy and sustainability of bioresources. Although the definition and terminology may vary among countries, bioeconomy policies generally encompass innovation, sustainability plan, economic growth and employment. For the purpose of this study, bioeconomy is defined as the knowledge-based production and utilization of available biological resources to provide products, processes and services in all sectors of trade and industry. The bioeconomy uses scientific knowledge, technology and innovation to develop biobased process and transform natural resources into sustainable products and services.

The study reported here is directed towards policy makers, industry, research communities, and representatives of civil society. The primary aim is to contribute to the establishment of an international discussion and coordination platform for future development of Thailand's bioeconomy. This study provided an overview of the political strategies for promoting the bioeconomy within the G7 member countries, the EU, and the Asia-Pacific region including Thailand, and demonstrated the impacts of political goals, approaches and priorities for bioeconomy development.

APPROACH AND METHODOLOGY

The study was largely based on internet information and publicly accessible documents published by government agencies, research institutions and international organizations. If there was no specific bioeconomy strategy published, a search was conducted for policy strategies with strong linkage to bioeconomy development such as biotechnology, bioenergy, biobased economy or biobased industry. In keeping within the scope of the study, political strategies in the traditional bioeconomic areas such as the primary production sector and the manufacture of food, timber products, and the wider policy areas such as research and innovation, green/blue growth and food security, were only considered if they were specifically oriented towards the bioeconomy or innovation. Moreover, the emphasis was placed on the latest bioeconomy development or related policies since 2005 until present.

RESULTS AND DISCUSSION

1. Bioeconomy Policies in the G7 and the European Union

The G7 members have made considerable efforts to position themselves in biobased economy. The European Union has become a driving force behind G7 group bioeconomy policy as well as being anchored within the EU policy strategies. The EU, Japan, Germany and USA act on a “top-down” approach driven by the political sector in order to develop the bioeconomy. The development of visions, strategies and action plans are to promote and shape the biobased economy. In Italy, France and Canada, it is rather the industry driving the bioeconomy on a “bottom-up” approach. Initiatives are primarily started and funded by the private sector. The political sector restricts itself to funding research and accompanying development.

Both USA and Canada have huge areas of forest, coast line and arable land. Traditionally, their bioeconomies are in practice on a large scale in the areas of agricultural and forestry production. New technologies are not only increasing the value of the agricultural and forestry sectors but also promoting rural development. Consequently, they have developed utilization strategies focusing on their natural assets. Major areas are the production of platform chemicals or bioenergy, such as wood pellets, bioethanol, and recently the next generation biofuels.

Although Germany, Japan, France and Italy have few natural resources, they develop a strong industrial structure. They also have the “alternative biomass” such as CO_2, waste or other residues, which are needed to be accessed and utilized. Their bioeconomies are driven by innovative potential focusing on replacing fossil fuels, and the associated reduction in greenhouse gases. Moreover, they are also achieving a technological advantage by means of new methods for processing biomass to make new products, as well as trying to establish an international technology and resource partnership with emerging countries, which have a plentiful supply of biomass.

Table 1 Overview on bioeconomy policies in the G7 and the EU (Dieckhoff *et al.,* 2015)

Member/Country	Strategy	Key Funding Area
Canada	Growing Forward	R&D on renewable resources and Bio-based materials, Bioenergy
France	Bundle of Bioeconomy–Relevant Policies	Bioenergy, Green chemicals, Clusters, Circular economy
Germany	Research Strategy Bioeconomy, Policy Strategy Bioeconomy	R&D on food security, Sustainable Agriculture, Healthy nutrition, Industrial processes, Bioenergy
Great Britain	Bundle of Bioeconomy–Relevant Policies	Bioenergy, Agri-science and technology
Italy	No Specific Bioeconomy Policy	Participation in EU programs
Japan	Biomass Utilization and Industry Strategies	Research & innovation, Circular economy, Regional development
United States	Bioeconomy Blueprint, Farm Bill	Life Sciences (Biomedicine), Agriculture (multiple areas)
EU	Innovating for Sustainable Growth	Research & Innovation (Horizon 2020), Public-Private-Partnerships

2. Bioeconomy Policies in the Asia Pacific

In Asia Pacific countries, the promoting bioeconomy development varies according to a country's resource endowment, specialization and economic development.

Malaysia is the only country in the Asia Pacific region which has a holistic bioeconomy strategy. The government adopts a dedicated perspective and focus on leveraging the full potential of renewable biomass and bioinspired process across all economic sectors. With regard to the other countries, this study also identified further strategies which clearly refer to bioeconomy development. Australia, Indonesia, New Zealand, Malaysia and Thailand, having huge potential of biomass resources but still importing oil, often strive for higher independence, and seek to increase the value of bioresources.

China and India which are the industrializing countries with an important share of rural population and primary industry jobs also develop bioeconomy as a means of fostering rural development and social participation. Russia and South Korea which are industrialized countries with fewer bio-resources and smaller share of primary industry jobs also highly focus on opportunities for arising of an industrialized biology and on creating added value from the bioscience (Fund *et al.,* 2015).

3. Bioeconomy Policy in the Context of Thailand

Nowadays, bioeconomy development in Thailand is driven by the "Biotechnology Development Policy Framework" set by the National Science Technology and Innovation Policy Office (STI) and the National Center for Genetic Engineering and Biotechnology (BIOTEC). The framework which was adopted by the Thai government in 2012 provided a holistic view of biotechnology as a knowledge-based industry with diverse applications across the agricultural, medical, aquatic, and industrial fields (Kingdom of Thailand, 2012). In 2008, bioplastic was raised as a new biobased industry via the "National Bioplastics Roadmap". Moreover, renewable energy strategy was prescribed in the Alternative Energy and Development Plan (AEDP) 2015-2036 by the government. The plan supports bioenergy and biofuel based on the country's vast agricultural feedstock, especially by-products and residues. Biomass is accounting for approximately 80% of Thailand's renewable energy.

The factors affecting bioeconomy policy should be concerned with the following 5 issues. (Dubois *et al.,* 2016):

1. Environmental sustainability, such as land, natural resources management and environment, biodiversity, soil, water, greenhouse gas, air and waste

2. Socio-economic sustainability, such as access to resources, rural and social development, employment/ income, health and safety, energy security and access, gender, social acceptance, productivity, economic development, competitiveness and investments, R&D and infrastructure

3. Competition and synergy among biomass end-use sectors, such as biomass, uses of land, infrastructure and skilled labor

4. Food security with its four dimensions: availability, accessibility, utilization and stability

5. Enabling factors, such as policies, regulations and markets, rule of law, institutional setups, monitoring and accountability, participation and transparency, human capacity development and cooperation.

CONCLUSION

Strategy for developing bioeconomy policy can be mainly considered on bioresource and technology or innovation of each particular country. The driven emerging bioeconomy can be taken by two directions, i.e. Top-Down and Bottom-Up approaches. The development of bioeconomy by Top-Down approach is usually driven by the political sector. For Bottom-Up approach, the initiation is primarily started and funded by the private sector.

Thailand has a huge potential of biomass resources and the bioeconomy policy is also driven by the government or the Top-Down approach. Nowadays, under the Thailand 4.0 strategy, the government is stimulating innovation in applications of biotechnology including providing some advantages to industrial sectors which use or support biobased-technology. To improve and foster bioeconomy in Thailand, Malaysia's bioeconomy policy should be intensively studied because Malaysia is a close neighbor and has a holistic bioeconomy both in policy and practice. With further improving roadmap, Thailand should develop a dedicated sustainable bioeconomy from bioresourecs including by-products and residues to both renewable energy and bio-based products.

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Improving Strength Properties of OCC Recycled Fibers using Medium Consistency Refining under Alkaline Conditions

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ABSTRACT

Due to concern about environmental issue, human population growth and the shortage of wood supplies, the use of recycled fibers as alternative raw material for paper production has steadily increased. However, the use of recycled fibers has some disadvantages compared to virgin pulp. A significant disadvantage of recycled fibers is their poor strength properties. Hence, the objective of this research was to improve the strength properties of recycled fibers. In this work, the strength properties of recycled fibers made from old corrugated container (OCC) waste paper were improved by refining at medium consistency (10%) under alkaline conditions. The OCC recycled fibers were refined in a PFI mill at 1000, 3000 and 5000 revolutions under different alkali charges of 0, 1, 2 and 3% on oven dry (O.D.) weight of pulp. The effect of refining revolutions and alkaline charges on the strength properties of OCC recycled fibers were examined. The results showed that the strength properties of OCC recycled pulp including tensile, burst and tear strength was increased as refining revolutions increased. Moreover, it shows that refining under alkaline conditions provided higher efficiency in improving of the strength properties of OCC recycled pulp compared to the process without the addition of alkaline solution. Refining at medium pulp consistency under alkaline charge of 1% (O.D. weight of pulp) was found to be the most suitable treatment for developing the strength properties of OCC recycled pulp.

Key words: recycled fiber, medium consistency refining, alkaline condition

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INTRODUCTION

Waste paper is an indispensable source of raw material for the global paper industry. Its utilization is primarily because the cost of recycled fibers from waste paper materials is cheaper than virgin chemical and mechanical pulp. Apart from the economic benefits, recycling of waste paper has also a number of environmental benefits. The recycling helps conserve natural resources because it reduces the demand for virgin wood fiber. By using waste paper to produce new produce, disposal problem are reduced. Moreover, manufacturing paper from waste paper uses less water and energy compared with producing paper from natural wood products (; Kinsella, 2012; Bajpai, 2014). For these reasons, the recovery and recycling rate for waste paper has increased steadily over the past several years all over the world.

Old corrugated container (OCC) is the most significant category of waste papers, based on the percentage of recovery rate. OCC is primarily used in production of paperboard products, such as linerboard and corrugating medium, for packaging where the strength of boxes is very important. Unfortunately, recycling of old corrugated container tends to decrease the strength properties of recycled paperboard, mainly due to the loss in the interfiber bonding strength through hornification phenomenon (Ackermann *et al*., 2000; Hubbe *et al*., 2007). Therefore, to obtain the paperboard with quality required for its end-use applications, some methods to improve the bonding strength of recycled fibers have been proposed. These methods include mechanical or chemical treatment, fiber fractionation and blending of the recycled fibers with virgin pulp (Howard, 1995; Hubbe *et al*., 2007).

Refining is the simplest and most common method used to improve papermaking properties of all virgin fibers. It generally refers to a mechanical process that involves modification of the fibers so that they can be formed into paper or paperboard of the desired properties (Lumiainen, 2000). According to Gharehkhani *et al.* (2015), refining causes a variety of simultaneous changes in the fiber structure, such as internal delamination and external fibrillation. These changes lead to development of the fiber bonding capacity and result in paper with higher strength properties (Wang, 2006). However, in the case of recycled fibers, mechanical refining often causes a reduction in fiber length and an increase in fines content in the pulp (Howard, 1995). Bajpai (2014) has reported that the fines produced during refining of recycled pulp do not improve the interfiber bonding strength in the sheet but increases the drainage resistance of the pulp, which adversely influences the runnability of paper machine. Although mechanical refining has some limitations for use in developing the recycled pulp quality, it has been showed by some authors that the strength properties of recycled fibers can be enhanced by refining performed under an optimum condition (Lumiainen, 1992; Ny and Messmer, 2007). Lumiainen (2000) has suggested that refining at medium consistency (8-12%) is sometime more suitable for improving the strength properties of recycled fibers.

Besides mechanical refining, alkaline treatment is the second most reliable way to improve the papermaking potential of recycled fibers. Freeland and Hrutfiord (1993) showed that soaking the recycled pulp with sodium hydroxide solution could greatly increase the physical strength of 100% recycled paperboard. They have explained that alkaline treatment increases the swelling capacity of fibers, which is essential for the interfiber bonding. Moreover, some investigators have found that the surface free energy of fiber can also be improved when recycled pulp is treated with alkaline solution (Tze and Gardner, 2007).

In this study, a combined method of refining at medium consistency and alkaline treatment is presented, with the aim to improve the strength properties of recycled fibers. Effect of the number of refining revolutions and alkaline charges on the strength properties of OCC recycled fibers including tensile, burst and tear strength were examined.

MATERIALS AND METHODS

1. Raw material preparation

The recycled pulp sample was obtained by repulping old corrugated container (OCC). OCC was torn into pieces of about 30x30 mm and soaked in water for 24 h at room temperature before being repulped. The repulping was performed at 2% consistency for 15 min by using a Valley beater (Lorentzen & Wettre Co., Ltd, Sweden). After repulping, the OCC pulp was washed and screened to remove unwanted materials such as the unpulped paper and other non-fibrous materials.

2. Medium consistency refining under alkaline conditions

Refining under alkaline conditions was carried out using a PFI mill (Hamjern Hamar, Norway). OCC recycled fibers were treated with sodium hydroxide of 0, 1, 2 and 3% on oven dry (O.D.) weight of pulp. This stage was done in polyethylene bag at a pulp consistency of 10%, 30^{o}c for 30 min. After treatment with sodium hydroxide, the pulps were refined in the PFI laboratory mill at 1000, 3000 and 5000 revolutions, respectively. The refined pulps were then washed through a 200 mesh screen until the PH of the washing water became neutral and collected for use in making handsheets of paper.

3. Handsheet making and testing

Handsheets of OCC recycled pulp were prepared at a basis weight of 60 g/m^2 and made in a standard handsheet former as described in the TAPP T205 sp-02 standard method. Prior to physical strength tests, the handsheets were conditioned at 23^{o}C and 50% relative humidity according to the ISO 187 standard method for at least 24 h. The strength properties including tensile, burst and tear strength were determined according to the ISO 1924-2, ISO 2758 and ISO 1974 standard method, respectively.

RESULTS AND DISCUSSION

A summary of strength properties of recycled handsheets made from the CC pulp including tensile index, burst index and tear index is listed in Table 1.

Table 1 Strength properties of OCC recycled pulp handsheets

Strength properties	Units	Value
Tensile strength index	Nm/g	16.72±1.59
Burst strength index	kPa·m^2/g	0.23± 0.09
Tear strength index	mN·m^2/g	4.53± 0.63

Figure 1 shows the effect of refining revolutions and alkaline charges on the tensile strength of OCC recycled pulp handsheets. As can be seen, refining at medium pulp consistency (MC) could improve the tensile index of the sheets. By increasing the refining revolutions, the tensile index was increased. This means that the action of MC refining on OCC recycled pulp has increased the fiber bonding potential. According to Levlin (1999), the degree of bonding between fibers is one of the most important factors contributing tensile strength of paper. Therefore, an increase in the bonding capacity of the fibers leads to improvement of tensile strength. In addition, Wang (2006) showed that internal fibrillation of fibers was highly developed when the number of PFI revolutions was increased. The internal fibrillation is generally involved in the breakage of the crosslinks between microfibrils and swelling in amorphous parts of the cell wall. As reported by Wang (2006), fiber becomes more flexible and conformable when the internal fibrillation is higher. The more flexible and conformable fiber tends to improve the interfiber bonding, and thus the strength increases (Wang, 2006).

Based on Figure 1, it also shows that greater improvement of the tensile strength index could be achieved if the pulp refining was performed under alkaline conditions. Therefore, when sodium hydroxide charge of 1% (O.D. weight of pulp) was added in OCC recycled fibers which was then refined in a PFI mill at 1000, 3000 and 5000 revolutions, the tensile strength increased up to 7.46%, 21.44% and 29.11%, respectively, compared to pulp refining without alkali. Adding sodium hydroxide to the pulp refining process may increase fiber swellability and flexibility, which contribute to ease of pulp refining and development of paper strength. However, an increase in sodium hydroxide charge greater than 1% (O.D. weight of pulp) did not result in further improvement of tensile strength as expected. This was possibly because the retention time in during the refining process was very short, which might not result in extending the reaction of cellulose fibers with sodium hydroxide when the percent of NaOH charge increased. According to Brodeur *et al.* (2011), reaction time is essential for alkaline pretreatment process.

In addition to the tensile strength, the burst strength of the sheets was improved by increased refining revolutions (Figure 2). The enhanced burst strength was likely the result of increased bond strength arising from the fiber structure modification due to the effect of mechanical actions on the fibers during refining. Based on the results obtained, the OCC pulp refining under alkaline conditions provided better improvement of the burst strength than the non-alkali process. The trend to higher burst strength for OCC recycled pulp refined under alkaline conditions was maintained after sodium hydroxide charge of 1% (O.D weight of pulp) was used. This showed that increasing alkaline charge during pulp refining did not have an appreciable effect on burst strength development.

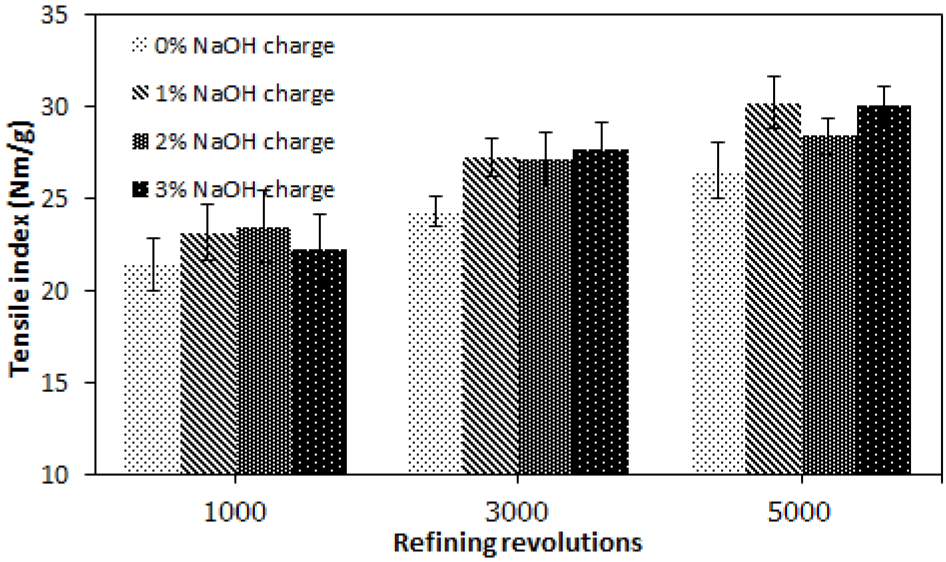

Figure 1 Tensile index of the sheets as function of refining revolutions and alkaline conditions

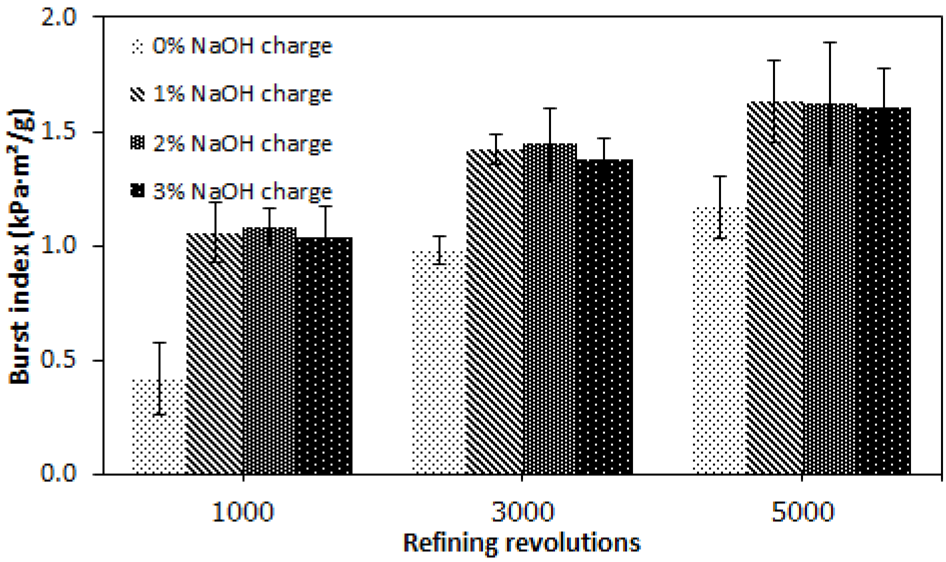

Figure 2 Burst index of the sheets as function of refining revolutions and alkaline conditions

Another important strength property for paper products is the tear strength, which depends on the interfiber bonding and fiber length (Levlin, 1999). As seen in Figure 3, increasing the refining revolutions had a positive impact on the tear strength of the sheets, which indicated that MC refining increased the bonding strength between the fibers without reduction in the fiber length. Moreover, the tear strength could be highly improved by the refining under alkaline conditions. However, there was no enhancement of the tear strength when the OCC pulp was refined under alkaline conditions with increased charge of sodium hydroxide. Therefore, it could be concluded that refining under alkaline charge of 1% (O.D. weight of pulp) was the most suitable treatment for the strength development.

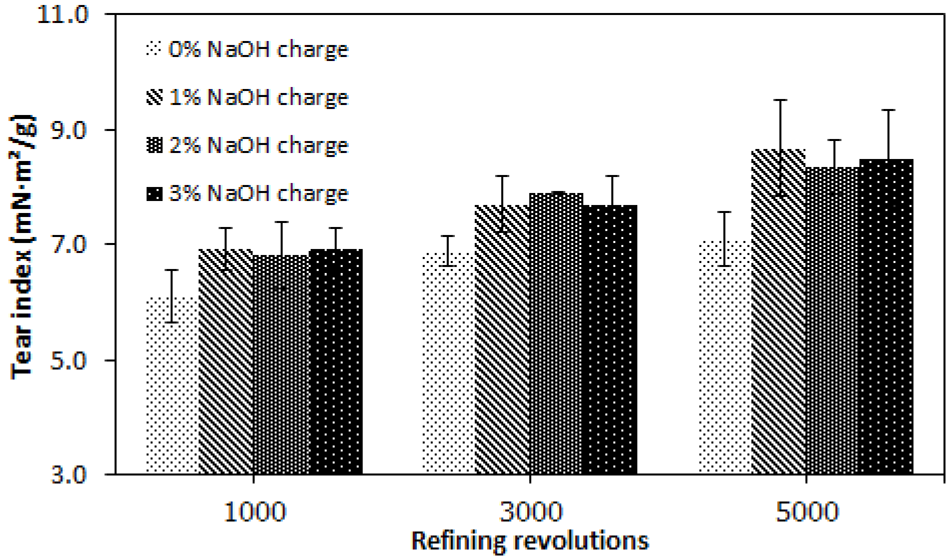

Figure 3 Tear index of the sheets as function of refining revolutions and alkaline conditions

CONCLUSION

This study showed that the strength properties of OCC recycled fibers including tensile, burst and tear strength could be improved by refining at medium consistency. By increasing the refining revolutions, the strength properties were increased. The results also showed that refining at medium consistency refining under alkaline conditions provided higher efficiency in improving of the strength properties of the OCC pulp compared to the refining under condition without the addition of sodium hydroxide. Based on the results, the pulp refining under alkaline charge of 1% (NaOH based on O.D. weight of pulp) was the most suitable condition for enhancing the strength properties.

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Development of Pongamia oil Extraction Technique for Biodiesel Production

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ABSTRACT

Pongamia pinnata (L.) Pierre is a leguminous tree with oil-rich seeds containing 30-40% of non-edible oil. This study was thus focused on the development of oil extraction technique from pongamia seed for commercial production and to compare an efficiency of extraction techniques between the screw press and the hydraulic press technique. The result revealed that screw press technique was more efficient than another. Seed cake of pongamia clogged the hydraulic cylinder and spoiled the extracted crude oil while extracting by hydraulic press method. In this study, a screw press prototype for pongamia oil extraction with capacity of 1 kg of seed/hour was developed. It comprised of 1 hp motor and operated with rotation speed at 50 rpm. Regarding double pressing, this prototype yielded 20.5% of oil (w/w) from pongamia seed. However, there was some residue from the cake approximately 10% in extracted pongamia oil from this prototype. The study also found that it was not able to extract the oil from the fresh pongamia seed. The extracted oil from pongamia seed after 3 weeks of air drying was 13% and increased up to 20% in those after air-drying for 4 weeks. Therefore, pretreatment of pongamia seed under air dry condition for more than 4 weeks was necessary and recommended for the oil extraction. Furthermore, dry pongamia seed with brownish color from either green or brown pod was preferred for the oil extraction.

Key words: *Pongamia pinnata* (L.), screw press, hydraulic press, biodiesel, Pongamia oil

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INTRODUCTION

Pongamia pinnata (L.) Pierre [Syn. *Pongamia glabra* (Vent); *Derris indica* (Lamk.)] is a fast-growing leguminous and native tree of the Indian subcontinent and Southeast Asia. *P. pinnata* is a medium-sized evergreen or briefly deciduous, glabrous shrub or tree 10-25 m high, Bark grey-brown, smooth or faintly vertically fissured. Leaves alternate, pinnately compound, hairless, pinkish-red when young, Leaflets 5-9, ovate elliptical or oblong, 5-25 x 2.5-15 cm, slightly thickened. Inflorescence raceme-like, axillary, 6-27 cm long, bearing pairs of strongly fragrant flowers; Pods borne in quantities, smooth, oblique oblong to ellipsoid, 3-8 x 2-3.5 x 1-1.5 cm, flattened but slightly swollen, slightly curved with short, 1-2 seeded, short stalked. Seed compressed ovoid or elliptical, bean-like, 1.5-2.5 x 1.2-2 x 0.8 cm, with a brittle coat long, flattened, dark brown, oily (Sangwan *et al*.,2010). *P. pinnata* is a preferred species for controlling soil erosion and binding sand dunes because of its dense network of lateral roots. Root, bark, leaves, flower and seeds of this plant also have medicinal properties and traditionally used as medicinal plants. All parts of the plant have been used as crude drug for the treatment of tumors, piles, skin diseases, wounds and ulcers (Tanaka *et al*.1992). In the traditional system of medicines, such as Ayurveda and Unani, the *P. pinnata* plant is used for anti-inflammatory, anti-plasmodial, anti-nonciceptive, anti-hyperglycamic, anti-lipidperoxidative, anti-diarrhoeal, anti-ulcer, anti- hyperammonic and antioxidant activity (Chopade *et al*. 2009). The *P. pinnata* seeds contain about 40 % oil, which can be converted to biodiesel by transesterification method (Meher *et al*. 2006). *P. pinnata* will impact most significantly through the extraction of seed oil for use in the manufacture of biodiesel. The potential of *P. pinnata* oil as a source of fuel for the biodiesel industry is well recognized (Scott *et al.,* 2008).Moreover, the use of vegetable oils from plants such as *P. pinnata* has the potential to provide an environmentally acceptable fuel, the production of which is greenhouse gas neutral, with reductions in current diesel engine emissions. Importantly, the successful adoption of biofuels is reliant on the supply of feedstock from non-food crops with the capacity to grow on marginal land not destined to be used for the cultivation of food crops. In this regard *P. pinnata* is a strong candidate to contribute significant amounts of fuel feedstock, meeting both of these criteria. The objectives of this study to develop a suitable oil extraction technique from Pongamia seed for commercial production and to compare an efficiency of extraction techniques between screw press and hydraulic press techniques.

MATERIALS AND METHODS

Test of Pongamia oil extraction between current available hydraulic press and screw press machines was set to determine their potentials for oil extraction from Pongamia seed (Figure 1). The screw press machine was then invented with modification to maximize its efficiency for Pongamia oil extraction. In order to determine its efficiency, a result from solvent extraction was set as a baseline. Seed Material are collected from Papat beach, Suksamran district, Ranong Province in Fabuary 2015 The pods are transported and deshelled at KAPI, Kasetsart University. For Soxhlet Extraction Method (Solvent extraction method) were grinded the seeds into fine particles and 100 gram of grinded was taken and a thimble was made. The soxhlet apparatus was set up and 300 ml hexane was added to thimble from above. This cycle is allowed to repeat several times within 8 hrs of extraction. After extraction, the solvent is removed, typically by means of a rotary evaporator at 40-50ºC, yielding extracted oil. The nonsoluble portion of the extracted solid remains in the thimble, which is removed separately. The Hydraulic press technique use CARVER Laboratory Press® put the dry pongamia seeds 200 g/batch in the cylinder then put hydraulic pump under pressure 3000-4000 psi. The screw press machine was then invented with modification to suitable for pongamia oil extract. Then put the dry pongamia seeds in the chamber, run the machine and receive crude oil from receiver area.

The study examined the oil yield from Pongamia seed with different storage time under air dry condition. Seed Material are collected from Papat beach, Suksamran district, Ranong Province in Fabuary 2015, the pods are transported and deshelled at KAPI, Kasetsart University. The oil from fresh and air-dry seed from 1 to 10 weeks of drying was extracted by screw press technique with 3 replications and 1 kg of seed each replicate.

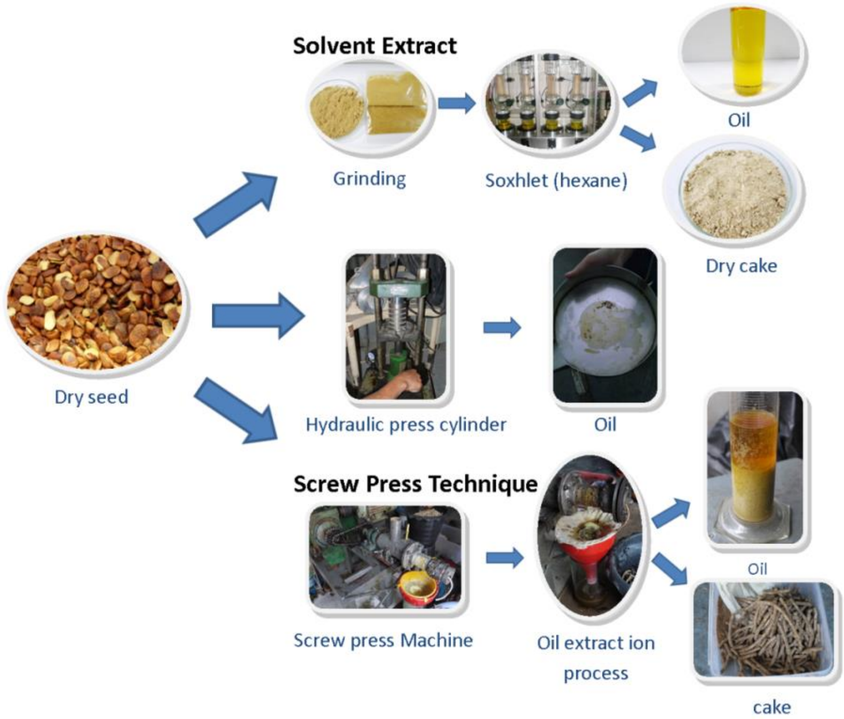

Figure 1 Flow diagram of Pongamia oil extraction test

RESULTS AND DISCUSSION

Three technique of pongamia oil extraction were use in this study (Table 1). The solvent extract used soxhlet extraction method. The quality of crude oil was sediment-free, homogeneous and yellowish red/ brown color. This process was batch production with 100 g/batch in 8 hours ,that was slow process but could extract the oil from pongamia approximate yield 30% that higher than another techniques. The Hydraulic press technique cannot extract the oil from the seed because its clogged hydraulic cylinder by seed cake and impure extracted oil. The screw press machine was then invented with modification to suitable for pongamia oil extract, the Specification of the screw press machine for pongamia oil extract included Moter output 1.0 HP, voltage 220 V, current 5.2 A, speed 1450 r/min, power factor 0.85, speed reducer 60:1 to reduce the final revolution of axis to 24 rpm. The quality of crude oil was sediment in oil but can be separated by sedimentation. This process was continues process with 8-10 liter of extracted oil/day but sometime screw clogged by seed cake. This study consistent with Bobade and Khyade (2012) there were found soxhlet extraction method for best result for extract oil from pongamia (soxhlet extraction method could extract the oil yield 31%, mechanical expeller could extract the oil yield 24%). But for commercial production the screw press techniques should be selected because there are continues process and can extract highest oil volume per day.

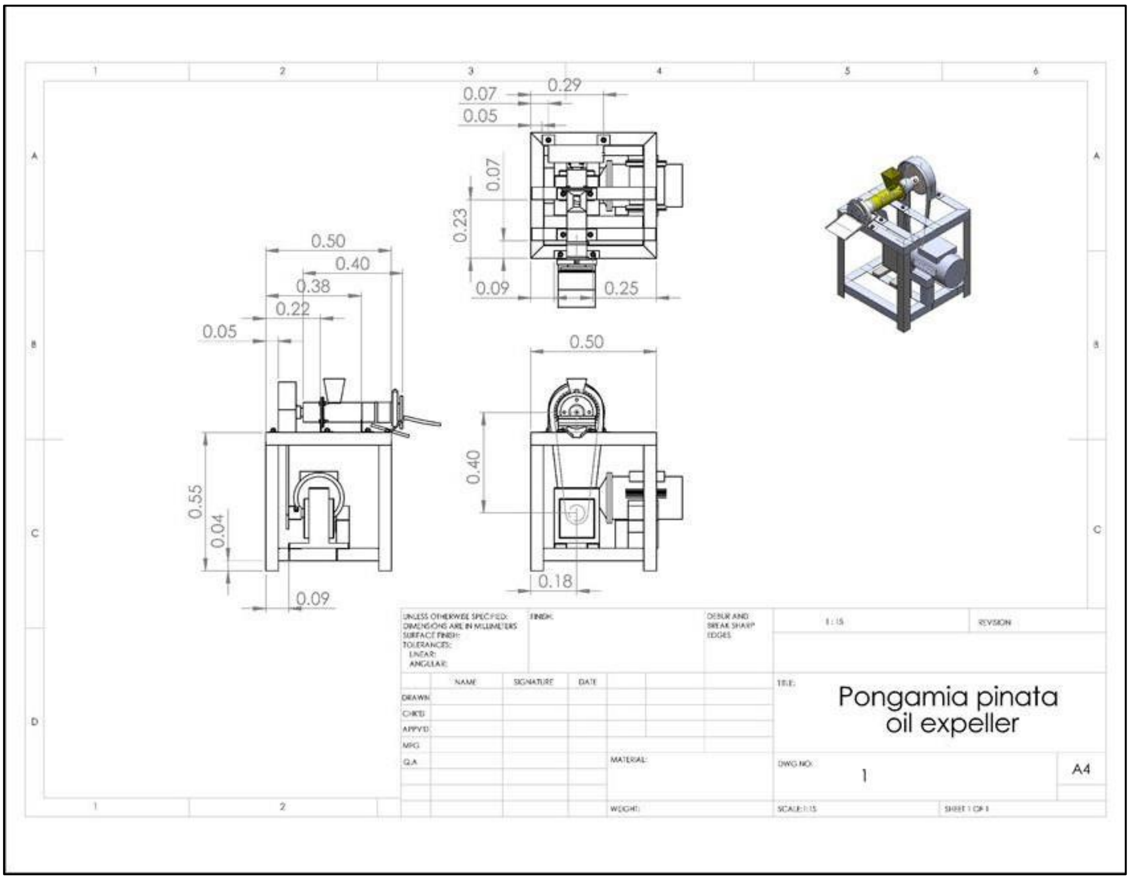

Figure 2 Drawing model of the screw press machine by Solidworks program

Table 1 Comparison of Pongamia oil extraction from solvent extract, hydraulic press and screw press techniques

Indicator	Solvent Extract	Hydraulic Press	Screw Press
Type of oil extraction	Chemical	Mechanical	Mechanical
Oil yield	30%	NA	20.5%
Quality of crude oil	Sediment-free	Sediment in oil	Sediment in oil but can be separated by sedimentation
Efficiency	Batch production with 100 g/batch in 8 hours	Batch production with 200 g/batch	Continuous production with 8 liter of extracted oil/8 hours
Problems	Slow process	Clogged hydraulic cylinder by seed cake and impure extracted oil (mixed with seed cake)	Sometime screw clogged by seed cake

Oil yield of pongamia seed with different storage time were examined in this study. Pongamia seed were air drying for 1-10 weeks were use to determine the effect of storage time on oil production via screw press machine. Stored seed for 1, 2 and 3 weeks could not able to submitted to oil extraction process due to its freshness and high moisture content, the moisture content of the seed is 41 and 32%,respectively. After 3 weeks of air drying can extract the oil 13% at the moisture content 16%. Storage for more than 4 week, the moisture content in pongamia seed was reduce to below 10% w/w which could extract the oil production yield up to 20%.

The moisture content showed similar decrease with Pavithra *et al* (2012) there were found the moisture content of the pongamia seeds collected during 30 – 42 weeks after flowering decreased significantly, but there could use solvent extraction for extract the oil from fresh pongamia seeds (30 weeks after flowering).

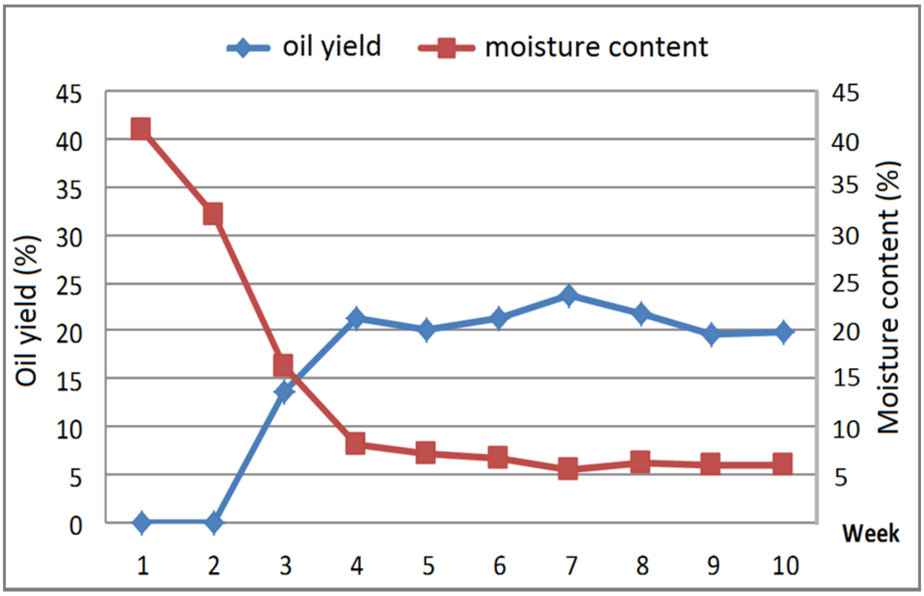

Figure 3 Oil yield and moisture content of the Pongamia seed with different storage time under air dry condition extract by the developed screw press machine

Figure 4 Pongamia seeds after 1-2 weeks drying (A) after 4 weeks drying (B) after 4 month storage (C) Pods and seeds (D)

CONCLUSION

The development of oil extraction technique from pongamia seed for commercial production screw press technique was recommended because that was continues process and can extract oil yield 8-10 liter per day. Dry seed under air dry condition for a minimum of 4 weeks was necessary to obtain the high oil yield. Furthermore, removal of Pongamia seed shell by machine could reduce cost of Pongamia oil production.

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