Proceedings of the 1st ASEAN SAGO SYMPOSIUM
Current Trend and Development in Sago Research

October 29–30, 2009
Riverside Majestic Hotel, Kuching

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Universitas Mulawarman
Bogor Agricultural Institute
New Century Fermentation Research Agency
Malaysian Nuclear Agency

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GREETINGS FROM THE CHAIR.

Sago starch is an important commodity for Sarawak with an annual export about of 70,000t. However, the low price of the starch impedes meaningful development in the sago industries. In order for sago starch to be competitive, it has to be modified into a product that is able to command a higher price.

In the early 90's up to mid 2000, financial support for sago research; other than from individual research organisations and countries was primarily provided by the Japan Society for Promotion of Science (JSPS), which actively organised numerous International Sago Seminars (ISS) within the Asean region, including Japan. Scientists from various research groups in JSPS were the key personnel which developed sago research to its current echelon. However, these support dwindled with the demise of JSPS by 2005 with the last 8th ISS at Jayapura, Indonesia in August, 2005. Individual research persists in certain countries, albeit at a smaller level, but these researchers do not have a proper forum to meet and discuss their specific findings and development in sago research.

Universiti Malaysia Sarawak (UNIMAS) is situated in Sarawak, a state which produced over 90% of the sago export from Malaysia. Realising that the research in sago must persist, together with the need for a proper venue for its discussion and dialogue, UNIMAS decided in 2008 to continue with the JSPS tradition for a sago seminar, but at a slightly smaller scale in ASEAN, hence the 1st ASEAN Sago Symposium. We were rather cautious when we first started, unsure of the response from previous (and old) colleagues, but it turn out that we are somewhat overwhelmed by the response, particularly from outside Malaysia.

With that note, I wish to welcome all participants to this symposium.
Thank You.

Prof Dr Kopli Bujang  
Chairman
WELCOMING NOTE FROM THE VICE CHANCELLOR

Sago palm is a starch producer which contributes to the economics of the Asean countries, particularly so for Malaysia and Indonesia. It has been used by the locals for hundreds of years as food, and now is the subject of intense studies as the main option for starch source of the future.

Research on starch and its plant resources is done worldwide. However, research on sago palm and sago starch is only confined to small groups of researchers mainly in South East Asia and Japan. As a major producer of sago, we in Sarawak are proud to be involved in this research field. UNIMAS, in collaboration with other institutions and companies - locally and abroad, is actively involved in all aspects of sago research from upstream to downstream processes. In the upstream research, UNIMAS researchers are involved in genomic studies and molecular biology related to sago starch production with starch biosynthesizing genes and enzymes. We are also involved in the downstream of sago research such as starch fermentation and sago waste utilization. In addition, other areas of research concomitantly being pursued are starch microbiology and biochemistry, engineering aspects of effluent separation and subsequent treatments, product modifications and utilization of sago waste.

In order to enhance our research on sago and to speed up the development process, there is an urgent need for all parties involved to openly discuss their findings with each other. This symposium is an excellent venue where we hope to encourage such discussion and to form new networking among researchers.

I hope that all participants will enjoy their stay, have fruitful discussions, and depart with beautiful memories of this symposium.

Thank You

Prof Dr Khairuddin Ab Hamid
Vice Chancellor
In the 21st century, we have serious crisis of food, energy and environment. These crises are now recognized as the common urgent tasks to be overcome by all humans since we are the residence of the globe. Burst of population makes shortage of food supply, as such increasing the harvest of carbohydrate crops is an effective strategy in addition to the equal distribution of these crops among developed and developing countries. Energy supply is an essential tool for our life. Energy is used in all our activities; transportation, communication, industry, agriculture and fisheries. Almost all of this energy is generated by burning of fossil fuel. However the resource of fossil fuel is limited to 2.2725 x 10^{12} barrels and has been estimated to be fully used up by 2060. It is obvious that sago is an attractive green (renewable) resource which contributes to overcome the above said urgent task. Sago is a photosynthetic product and the plant forms starchy residue in its trunk by fixing solar energy. This means carbon dioxide emitted from various sources, including burning of fossil fuel is converted into available energy. Sago can be used not only for food but also as alternative fuel for automobiles. Some seaweed can also accumulate polymer carbohydrate and it is possible to produce glucose which is then fermented to bioethanol. Ocean is good to store and supply carbon dioxide in the form of bicarbonate as such that seaweed is now focused as a good tool for production of bioethanol. Anyhow we have to produce new energy which is carbon neutral (recycling carbon dioxide), and sago is the best tool for this concept together with its cellulosic residue which is also a valuable renewable resource to produce bioethanol for our region, in very much the same way as corn-cob in the USA.
Sago palm is the highest carbohydrate producer in the World. Unfortunately not much attention has been given to this palm. Up to now only P.T. National Timber and Forest Product has cultivated sago palm as a plantation in Indonesia. Ever since the year 2004 when P.T. National Timber and Forest Product has financial problem, the sago palm has not been maintained properly. Amount of sago palm trunk that can be harvested at Divisions 1, 2, 3 and 4 are only 53%, while other divisions are less than 30%. Some effort has been carried out to rehabilitate the sago plantation such as to restore canals and to clear the weeds. There are three types of canals, i.e. main, collector and branch canals. The canal is not only to support sago palm growth, but is also to overcome forest burning and as transportation. Weeds at some areas had been cut and cleared. As a result of those two activities, some sago leaves have turned green. P.T. National Timber and Forest Product have been cooperating with Bogor Agricultural University in our attempt to rehabilitate the sago palm plantation.

In conventional ethanol production processes for starchy material (rice, maize, potatoes, sago, cassava, etc.), production of glucose by liquefaction followed by saccharification in a cooking process is essential prior to fermentation. For this process, two kinds of enzyme and heat energy are required. Newly developed yeast strain that possessed two kinds of enzyme (a-amylase and gluco-amylase) on the surface may shortened this process. The strain was developed by Dr. Kondo, a Professor at Kobe University, Japan and Director of Bio-energy Corporation. Some results of grounded and cracked rice fermented using this armed yeast under non-cooking condition is detailed here. The concentration of ethanol produced together with fermentation time was almost the same as the conventional process.
Furthermore, the new methodology does not require cooking or extra enzymes, thus ensuring the new process in ethanol production as simpler and energy saving than the conventional method.

Prof. Dr. Dulce M. Flores
University of the Philippines Mindanao, Mindanao, Philippines

FROM THE SAGO LOG TO THE TABLE: AN ALTERNATIVE METHOD OF SAGO FLOUR PROCESSING

Several studies have been done to improve the processing and optimization of quality sago flour production, specifically, modernization of the sago processing plants in this region. Research, however, has been focused on the efficiency of starch extraction, more towards producing the highest purity/quality starch for the export market, particularly mechanization. This paper will report, perhaps for the first time, a strictly dry process primarily for food and subsequently to process it further for industrial purposes. This was aimed to improve on the traditional sago flour extraction by the natives of Argao, Cebu, Philippines, called the Argao Dry Process. In the next phase, the project aims to study its feasibility using minimal mechanization, fully recognizing the environmental benefits behind it. This will start a new sago flour industry which will empower the natives in the far-flung barrios where the wild sago stands are located.
PROGRAM FOR 1st ASEAN SAGO SYMPOSIUM
29 - 30 OCTOBER 2009

SARAWAK CHAMBER
RIVERSIDE MAJESTIC HOTEL, KUCHING, SARAWAK, MALAYSIA

Wednesday 28th October 2009
6.30pm - 9.00pm : Early Registration

Day 1 Thursday
29th October 2009

8.00am Late Registration
8.45am Arrival of guests and participants
9.00am Arrival of Prof. Dr. Peter Songan, Deputy Vice Chancellor (Research and Innovation) representing the Vice Chancellor, Deputy Vice Chancellors, Deans and Directors of UNIMAS and invited guests
9.15am Recitation of Doa
9.20am Welcoming Address by Prof. Dr. Kopli Bujang Organizing Chairman of 1st ASAS 2009
9.45am Speech and Official Opening by Prof. Dr. Peter Songan Deputy Vice Chancellor (Research and Innovation)

10.00am Refreshment followed by viewing of Posters

Keynote Session
Chairperson : Prof. Dr. Zin Zawawi Zakaria

11.00am Keynote Speaker
Prof. Emeritus Dr. Ayaaki Ishizaki
NECFER Corporation, Kurume, Japan.

12.30pm Lunch

Scientific Session 1
Chairperson : Dr. Zulkafli Ghazali
Co-Chairperson : Dr. Lesley Maurice Bilung

2.00pm Plenary Speaker 1
Prof. Dr. H. Mochamad Hasjim Bintoro Djoefrie
Bogor Agricultural University, Bogor, Indonesia.
Some Efforts to Rehabilitate Sago Palm Plantation at Meranti District, Riau Province, Indonesia

2.30pm Paper 1
Utilizing Sago Waste For Sound Absorber Panel Design
Assoc. Prof. Dr. Khairul Aidil Azlin Abd. Rahman
Universiti Malaysia Sarawak, Malaysia.

2.45pm Paper 2
Preliminary Study of Ethanol Production: Optimization of Saccharification Process of Sago Starch into Sugars
Assoc. Prof. Dr. Maizirwan Mel
International Islamic University Malaysia, Kuala Lumpur, Malaysia.

3.00pm Paper 3
Acetylation of Sago Starch for Edible Film Preparation
Prof. Dr. Haryadi
Gadjah Mada University, Yogyakarta, Indonesia.
3.15pm Paper 4
Study of the Potency and Productivity of Natural Sago Forest in Kaureh District, Jayapura, Papua Province, Indonesia
Prof. Dr. Nadirman Haska
Biotech Center (BPPT), Tangerang, Banten, Indonesia.

3.30pm Coffee break & Poster Session

Scientific Session 2
Chairperson : Assoc. Prof. Dr. Edmund Sim Ui Hang
Co-Chairperson : Dr. Hairul Azman Roslan
4.00pm Paper 5
Trunking and Non-Trunking Sago Palm Show Differing Transcript Profiles Using RT-PCR
Anastasia Shera Edward
Universiti Malaysia Sarawak, Malaysia.

4.15pm Paper 6
The Effect of Period of Immersion into IBA and BAP to the Induction of Root on Sago (Metroxylon sagu Rottb) Sucker for Ex Vitro Propagation
Dr. Teuku Tajuddin
Biotech Center (BPPT), Tangerang, Banten, Indonesia.

4.30pm Paper 7
Study of Sago Plantation in the Sub-Province Sambas West Kalimantan, Indonesia
Prof. Dr. Hidayat
Universitas Tanjungpura, Pontianak, Indonesia.

4.45pm Paper 8
The Effect of Foliar Spray Application on Young Sago Palm Growth at P.T. National Timber and Forest Product, Selat Panjang, Riau, Indonesia
Ratih Kemala Dewi
Bogor Agricultural University, Indonesia.

5.00pm End of Scientific Session 1 and Day 1

Day 2 Friday
30th October 2009
Scientific Session 3
Chairperson : Prof. Dr. Kopli Bujang
Co-Chairperson : Abas Said
8.30am Plenary Speaker 2
Dr. Hideo Noda
Kansai Chemical Engineering, Osaka, Japan.
A Novel Ethanol Production Process for Starchy Material Using Yeast Displayed Enzymes on the Surface

9.00am Paper 9
Maximizing Sugar Production from Enzymatic Hydrolysis of Sago Fiber for Ethanol Fermentation
Ugam Janggu
Universiti Malaysia Sarawak, Malaysia.

9.15am Paper 10
Isolation of Full Length Alcohol Dehydrogenase Gene From Leaves of Sago Palm
Wee Ching Ching
Universiti Malaysia Sarawak, Malaysia.

9.30am Paper 11
Rheological and Molecular Properties of Sago (Metroxylon sagu) Starch Modified Using Ionizing Radiation
Zainon Othman
NUCLEAR Malaysia, Selangor, Malaysia.
9.45am Paper 12
The Effect of Storage Method on Sago (*Metroxylon sagu* Rottb.) Sucker in *Ex Vitro*
Propagation Technique
K. Karyanti
Biotech Center, BPPT, Tangerang, Banten, Indonesia.

10.00am Paper 13
Influence of Water Table on Early Vegetative Growth of Sago Palm (*Metroxylon sagu*
Rottb.)
Albertus Fajar Irawan
Ehime University, Matsuyama, Japan.

10.15am Paper 14
Chemical Characteristics of Compost and Humic Acid from Sago (*Metroxylon sagu*) Waste
in Three Different Treatments
Auldry C.P.
Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak, Malaysia.

10.30am Coffee break and Poster Session

Scientific Session 4
Chairperson: Prof. Dr. H. Mochamad Hasjim Bintoro Djoefrie
Co-Chairperson: Safarina Ahmad

11.00am Paper 15
Efficacy of Radiation Processed SAGO Hydrogel Facial Mask
Dr. Khairul Zaman Hj. Mohd. Dahlan
Malaysian Nuclear Agency, Bangi, Selangor, Malaysia

11.15am Paper 16
Actual Experience in Transforming Peat Land into a Sago Estate in Riau, Indonesia
Dr. Jong Foh Shoon

11.30am Paper 17
Cross-Linking and Alcoholic-Alkaline Treatment of Sago Starch
Dr. Lee Jau Shya
Universiti Malaysia Sabah, Sabah, Malaysia.

11.45am Paper 18
Glucose Recovery From Sago ‘Hampas’ For Ethanol Fermentation
Dayang Salwani Awang Adeni
Universiti Putra Malaysia, Selangor, Malaysia.

12.00 Lunch

Scientific Session 5
Chairperson: Prof. Dr. Sulaiman Hanapi
Co-Chairperson: Fazia Mohd. Sinang

2.30pm Plenary Speaker 3
Prof. Dr. Dulce M. Flores
University of the Philippines Mindanao, Philippines.

From the Sago Log to the Table: An Alternative Method of Sago Flour Processing

3.00pm Paper 19
Rapid Amplification of cDNA Ends of Dienelactone Hydrolase Gene from *Metroxylon sagu*
Nurzainizul Julaii @ Julaihi
Universiti Malaysia Sarawak, Malaysia.

3.15pm Paper 20
Weeding on Sago Plantation at PT. National Timber and Forest Product, Tebing Tinggi
Island, Meranti, Riau, Indonesia
Shandra Amarillis
Bogor Agricultural University, Indonesia.

3.30pm Coffee break and Poster Session
4.00pm Paper 21
Maximizing Production of Sugars from Enzymatic Hydrolysis of Various Starch Sources, Compared to Sago Starch
Hafizah Booty
Universiti Malaysia Sarawak, Malaysia.

4.15pm Paper 22
Preliminary Evaluation of Extended Aeration (EA) System for Sago Effluent Treatment
Wahi Abd. Rashid
Universiti Putra Malaysia Bintulu Campus, Sarawak, Malaysia

4.30pm Closing Ceremony of 1st ASEAN Sago Symposium (ASAS) 2009
Prof. Dr. Kopli Bujang
Dean, Centre for Postgraduate Studies
Universiti Malaysia Sarawak, Malaysia.

4.45pm Photography Session

5.00pm End of 1st ASEAN Sago Symposium
ORAL PRESENTATIONS

CO-ORGANISERS

UNIVERSITI MALAYSIA SARAWAK
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In the 21st century, we have serious crises of food, energy and environment. These crises are now recognized as the common urgent tasks which need to be overcome by all human since we are the residence of the globe. Eruption of the human population induces shortage of food supply, so that increase harvest of carbohydrate crops is the effective strategy in addition to the equal distribution of the crop among developed and developing countries. Energy supply is essential for our life. Energy is being used in all of our activities; for transportation, communication, industry, agriculture and fisheries. Almost all of this energy is generated by burning of fossil fuel. However the resource of fossil fuel is limited to $2.2725 \times 10^{12}$ barrels and has been estimated to be fully used up by 2060. It is obvious that sago is an attractive green (renewable) resource which contributes to overcome the above said urgent task. Sago is a photosynthetic product and the plant forms starchy residue in its trunk by fixing solar energy. This means carbon dioxide emitted from various sources, including burning of fossil fuel is converted into available energy. Sago can be used not only for food but also for alternative fuel for automobiles. Some seaweed can also accumulate polymer carbohydrate and it is possible to produce glucose which is then fermented to bioethanol. Ocean is good to store and supply carbon dioxide in the form of bicarbonate as such that seaweed is now focused as a good tool for production of bioethanol. Anyhow we have to produce new energy which is carbon neutral (recycling carbon dioxide), and sago is the best tool for this concept together with its cellulosic residue which is also a valuable renewable resource to produce bioethanol for our region, in very much the same way as corn-cob in the USA.

Keywords: fossil fuel, sago starch, renewable energy, ethanol fermentation, biofuel.

INTRODUCTION

In the 21st century, we have serious crises of food, energy and environment. These crises are now recognized as the common urgent tasks which need to be overcome by all human since we are the residence of the globe. Eruption of the human population induces shortage of food supply, so that increase harvest of carbohydrate crops is the effective strategy in addition to the equal distribution of the crop among developed and developing countries. Energy supply is essential tools for our life. Energy is being used for all of our activity, for transportation, communication, industry, agriculture and fishing boat. Almost all of this energy is generated by burning of fossil fuel however the resource of fossil fuel is limited to $2.2725 \times 10^{12}$ barrel and was estimated to be used up by 2060.

It is obvious that sago is attractive green (renewable) resource to contribute to overcome the above said urgent tasks. Sago is the photosynthetic product and the plant forms starchy crops in trunk by fixing solar energy. This means carbon dioxide emitted from various sources, including burning of fossil fuel converted into available energy. Sago can use not only for food but also for alternative fuel for automobile. Another potential of sago is alternative material for plastic production. Plastics are the major product of petrochemical industry, and this industry consumes huge amount of petroleum. Petrochemical plastics have ecological problems due to the non-degradability of petrochemical plastics which affects the life of wild animals resulting in the inverse effects of the globe ecosystem. Sago starch is a suitable feedstock for lactate fermentation which is converted to poly-lactate, degradable plastics. This strategy can cut a large amount of petroleum consumption. Thus, sago is very useful tool to help for solving human crisis of food, energy and industry.

CO2 ACCUMULATION AND RECYCLING IN GLOBE

The world average temperature is increasing about 1°C for 120 years duration from 1890 to now. This increase is believed due to increase of green house gas particularly carbon dioxide emitted from burning of fossil fuel for human’s life for transportation,
communication, heating and cooling the house and industry.

Carbon dioxide accumulation and recycling in the globe is shown in Figure 1. As shown here, the total tonnage of carbon dioxide recycling through land to atmosphere is 50 giga tons and another 25 giga tons is the recycling through ocean. Some seaweed accumulates polymer carbohydrate which is convertible to glucose, and applicable in fermentation to produce bioethanol.

Ocean is a good tool to store and supply carbon dioxide in the form of bicarbonate; as such that seaweed is now seen as the feasible material for production of bioethanol. Half of the 50giga tons CO$_2$ recycling from land to atmosphere originated from metabolism of heterotrophic living beings, including human. Recycling of CO$_2$ by autotrophic and heterotrophic metabolism shares half of the total CO$_2$ recycling on land area of the globe. All of CO$_2$ recycling in ocean is from life activity of seaweed, plankton and fishes.

![Figure 1: Accumulation and recycling of CO$_2$](image)

**IMPACT OF POPULATION GROWTH**

Comparison of population increase and bacterial cell growth is demonstrated in Figure 2. Current population has reached 6.8 billion. As seen in this graph, the population growth curve from the year 1600 up to now is exactly the same as a bacterial growth curve. When bacterial growth reaches stationary phase, cells lost their activity and freshness and suffered due to reducing nutrition. Population growth curve shows that our population on the globe is reaching this stationary level. This means our globe has reached an almost limiting level for our ecosystem to support existing numbers of the human population which eventually leads to food crisis. Human needs 2,000 kcal/day as food energy and carbohydrate contains 4 kcal/g. Thus the human requirement of food energy is equated by the following equations:

\[
2,000 = 500g/\text{day}, \text{ or } 500g \times 365 = 182.5kg/\text{year}
\]

Therefore carbon dioxide emission from human per capita is 255 kg/year. At the current population of 6.8 billion, the CO$_2$ emission from human respiration in the whole world is $255 \times 6.8 \times 10^9 = 1.734 \times 10^9$ kg/year, or 1.73 giga tons (approx. 7% of total CO$_2$ for life). One hectare of sago plantation produces 20 tons of edible carbohydrate (starch) and one person needs 2,000 kcal/day of food energy. It is possible to supply 182.5 kg of starch for one year, thus one hectare of sago plantation can provide food for 110 people. This means one million hectare of sago plantation can supply food 111 million people. This clearly illustrate that sago can be used for food to solve the shortage of food and a good tool to minimize starvation.

![Figure 2: Comparison between population increase and bacterial cell growth](image)

**IMPACT OF THE AUTOMOBILES**

The current total number of automobiles in the world is 897 million. Driving a car for a year requires approximately 1kL of fuel, as such the annual demand for these automobiles is estimated at 897 million kL, emitting a total of 2.817 giga tons of CO$_2$ (approx. 10% of total CO$_2$ emission from the industries). CO$_2$ from human is not so small and it shares about 7% of total life cycle CO$_2$.

One hectare of sago plantation can produce 12.5kL of bioethanol from starch, which can supply 125 cars with the E10 (10%) formula of ethanol mixed with gasoline. Tentatively, one million hectare of sago plantation can produce approx. 12.5 million kL of bioethanol per year, sufficient to supply 125 million cars on E10 gasoline (about 14% of the world cars). USA’s strategy of biofuel growth is to increase cellulolic bioethanol.
According to the ACS (2009), by the year 2022, production of cellulosic bioethanol will be increased to 45 million kL/year while starchy bioethanol will be maintained at 25 million kL. It is possible to utilize sago waste and sago fiber as suitable feedstock for cellulosic ethanol; however it needs further development and procedures.

**IMPACT OF PLASTICS**

Main products of the petrochemical industry are shown in Figure 3. More than half of the product from the petrochemical industries is plastic. Total market of plastics in the world is 100 million ton/year. Petroleum required to produce plastics is estimated to be about 100 million tons. Plastic is a very essential commodity material; however plastic made from petroleum has problems due to its non-degradability which affects our wildlife. In order to maintain the diversity of living things and to protect wild animals and birds on earth, undegradable plastics should be replaced with bio-degradable materials for the plastic markets.

![Graph showing plastic compared to other products](image)

**Figure 3:** Amount of plastic compared to other product from the petrochemical industries

To seek the new material for development of degradable plastics, ACS (American Chemical Society) issued the policy of green chemistry. This consists of 12 principles. To confer this principles, lactate industry and production of poly-lactic acid (PLA) is the best choice. Lactic acid fermentation does not loss any atom during fermentation as shown in the stoichiometry below:

\[ C_6H_{12}O_6 \text{(Glucose)} = 2C_3H_6O_3 \text{(Lactate)} \]

Lactic acid is then formed into PLA by the synthetic processes. Sago starch is available for PLA production and sago plastics can reduce petroleum consumption for production of petrochemical plastics. The author proposed the concept of lactate industry as early as in the 1990's and also at the 7th International Sago Symposium.

**SAGO INDUSTRIES**

Sago has very high potential for various uses. Sago palms can accumulate large quantity of starch in its trunk at an average of 20 ton of starch per hectare, per year of land productivity. It is purely the product of photosynthesis and the results of carbon dioxide assimilation by solar energy. The concept of the sago industries as the savior to environmental pollution and production of CO₂ is presented in Figure 4.

![Diagram showing sago industries](image)

**Figure 4:** The concept of sago industries in relation to food, energy and environmental management

In starch production, harvested sago palms are transported to sago mills to produce fine starch flour. Refined sago flour is then distributed to worldwide market for food processing. For alternative fuel for gasoline, sago starch must first be converted into glucose by enzymatic saccharification. Saccharified sago starch is then fermented to form bioethanol. Different from alcohol for consumption, ethanol for fuel must be anhydrous. The absolute ethanol (bioethanol) is sent to gasoline stands as a 10% mixture (called E10) of ethanol and petrol, and sold to car drivers as an E10 gasoline. In future, sago waste such as sago fiber or 'hampas' can be utilized as raw materials for cellulosic bioethanol production.

For production of bioplastic, saccharified sago starch is used in anaerobic fermentation to lactic acid without any atom loss. Lactic acid produced by this efficient process is then polymerized to large molecular PLA which is the basis for biodegradable plastics. Used bioplastics will be collected for composting and carbon dioxide will be recycled in the globe's ecosystem. This process benefits from the reduction of petroleum usage for plastic production together with new recycling of carbon dioxide through decomposing plastics and from the sago palm.

Comparison of overall CO₂ reduction among various uses of sago starch is presented in Table 1. For food uses, CO₂₆ absorption for formation of starch is...
29.3tons/ha/yr, and CO₂r absorption for tree growth (fiber, woody part and leaves) is 36.4tons/ha/yr. A total of 65.7ton of CO₂ is recycled by natural succession of carbon dioxide through land and atmosphere. For plastics from sago, total CO₂r recycling is the same as in food uses. However, reduction of petroleum as raw material for production of plastic is large. In the use of sago for bioethanol production, formation of CO₂ during ethanol fermentation should be considered. The reversed effect is (-)9.78tons/ha of sago plantation. Merit of CO₂ cutting by use of ethanol replaced with gasoline is estimated at 23.6tons/ha/yr due to oil savings. Thus the overall CO₂r reduction for sago bioethanol is 79.52tons/ha/yr.

Table 1: Overall CO₂ reduction from various uses of sago and oil palm for BDF

<table>
<thead>
<tr>
<th>Description</th>
<th>Sago for Food</th>
<th>Sago for Plastics</th>
<th>Sago for Bio-</th>
<th>Oil Palm for Biodiesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses</td>
<td>Starch 20 t/ha</td>
<td>Starch 20 t/ha</td>
<td>Ethanol 10 t/ha (12.5 t/h)</td>
<td>BDF 5.3 t/ha (Palm oil 5 t/ha)</td>
</tr>
<tr>
<td>CO₂r recycling</td>
<td>29.3 t/ha</td>
<td>29.3 t/ha</td>
<td>29.3 t/ha</td>
<td>15.7 t/ha</td>
</tr>
<tr>
<td>CO₂ during processing</td>
<td>0</td>
<td>(-)19.78 t/h</td>
<td>LPG for methyl-ester</td>
<td></td>
</tr>
<tr>
<td>Oil saving as CO₂</td>
<td>20 t/h</td>
<td>23.6 t/ha (oil 7.5 t)</td>
<td>15.7 t/ha (oil 5 t)</td>
<td></td>
</tr>
<tr>
<td>CO₂ absorption for tree growth</td>
<td>36.4 t/ha</td>
<td>36.4 t/ha</td>
<td>36.4 t/ha</td>
<td></td>
</tr>
<tr>
<td>Total CO₂r cutting effect</td>
<td>65.7 t/ha</td>
<td>65.7 t/ha</td>
<td>79.52 t/ha</td>
<td>66.8 t/ha</td>
</tr>
</tbody>
</table>

As a comparison, effects of CO₂ reduction from the use of oil palm for production of biodiesel are presented. In this case, methanol made from LPG (liquid petroleum gas) is used for methylation. Including CO₂ from LPG, the overall effects of CO₂ from oil palm is 66.8tons, almost the same amount of CO₂r reduction from food and production of bio-plastic.

Among the various advantages of sago, sago bioethanol gains the largest merit for CO₂ reduction, rendering bioethanol production from of sago biomass as the best choice. Comparison has also been done in the ethanol productivity per unit land for one year, as shown in Table 2. It is clearly that sago is the highest land productivity among the common feedstock for bioethanol production in the world.

The individual parts of sago palm involved in fixation of solar energy for formation of biomass by photosynthesis is shown in Table 3, where starch formation accounts for 43.7% of the solar energy absorbed.

Table 2: Bioethanol productivity per hectare of various feed stocks

<table>
<thead>
<tr>
<th>Crop</th>
<th>Production (t/ha/yr)</th>
<th>Available carbo.</th>
<th>Carbo. Prod/yr</th>
<th>Bio-EtOH KI/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugarcane</td>
<td>70</td>
<td>15%</td>
<td>10.5</td>
<td>6.4</td>
</tr>
<tr>
<td>Cassava</td>
<td>25</td>
<td>25% starch in root</td>
<td>6.25</td>
<td>3.8</td>
</tr>
<tr>
<td>Maize</td>
<td>5</td>
<td>St</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Sago palm</td>
<td>20</td>
<td>250kg per trunk</td>
<td>20</td>
<td>12.2</td>
</tr>
</tbody>
</table>

Table 3: Sago Palm Solar Energy Fixation

<table>
<thead>
<tr>
<th></th>
<th>t/ha/yr</th>
<th>10⁶ Kcal/ha/yr</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch</td>
<td>20</td>
<td>80</td>
<td>43.7</td>
</tr>
<tr>
<td>Bunch</td>
<td>7.6</td>
<td>31</td>
<td>16.9</td>
</tr>
<tr>
<td>Others</td>
<td>17.2</td>
<td>72</td>
<td>39.3</td>
</tr>
<tr>
<td>Total</td>
<td>44.8</td>
<td>183</td>
<td>100</td>
</tr>
</tbody>
</table>

CONCLUSION

In this paper, it is emphasized that CO₂ diffused to air can be trapped and recycled by photosynthesis. Tropical zone is an efficient place for photosynthesis. Sago palm can produce starch at approximately 20 ton/ha year and 24.8 ton/ha year of biomass. Bioethanol from sago is the best choice which will contribute to the improvement of the globe ecosystem. Productivity of bioethanol per hectare is the highest among most the other feed stocks. Sago is a good supplier of food and 1 million hectare of sago plantation can supply food to 111 million people.

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SOME EFFORTS TO REHABILITATE SAGO PALM PLANTATION AT MERANTI DISTRICT, RIAU PROVINCE, INDONESIA

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ABSTRACT

Currently, sago palm is the highest carbohydrate producer in the world. Unfortunately not much attention was paid on this palm, so until today, only P.T. National Timber and Forest Product has cultivated sago palm as a commercial plantation in Indonesia. However, since 2004, P.T. National Timber and Forest Product experienced some financial difficulties and therefore was not able to manage the sago palm plantation properly. As a result, harvestable sago palms in Divisions 1, 2, 3 and 4 are only approximately 53%, while other divisions are harvested at less than 30%. Some efforts have been carried out to rehabilitate the sago plantation such as rehabilitating canals and getting rid of the weeds growing within the plantation. There are three types of canals: main, collector and branch canals. The purpose of these canals is not only to support sago palm growth, but also to overcome forest burning and to be used as transportation. Weeding has also been done in some areas. These two activities have shown positive results evidenced by some sago leaves turning green. P.T. National Timber and Forest Product has started this rehabilitation works in cooperation with the Bogor Agricultural University.

Key words: Sago palm, rehabilitate, water management, weed control.

INTRODUCTION

Sago palm is the highest carbohydrate producer in the world. The palm can produce around 25-30 tons of starch ha/year, which can be used not only as a staple food, but also as an agro-industry raw material. Under natural conditions, each trunk can contain between 200-400 kg of starch. Saitoh et al (2004) found that approximately 838 kg starch can be obtained per trunk from Sentani, Jayapura District. Indonesia has the largest sago palm forest in the world. According to Flach (1983), there are 2.2 million ha of sago palm forest in the world, and 1.2 million ha of this is in Indonesia. Kertopermono (1996) reported that there are more than 1.5 million ha of sago palm forest in Indonesia, of which about 1,406,469 ha is in Papua, 41,000 ha in Maluku, 45,540 ha in Sulawesi, 2,795 ha in Kalimantan, 292 ha in West Java and 31,872 in Sumatra. The Forest Agency in Irian Jaya Province, put the value as more than 6 million ha of sago forest in Papua Province (Bintoro, 1999).

Sago palms are also known to be an environmental friendly palm because they absorb CO₂ gas emission from the atmosphere as much as 25 - 200 mg/m²/hr (Bos and Flassche, 2003). Although sago starch can be used as a staple food alternative therefore ensuring food stability, but unfortunately, so far only P.T. National Timber and Forest Product has cultivated sago palm as a commercial plantation in Indonesia. The company has cultivated sago palm since 1996, which up till today, has cultivated around 11,000 ha in Meranti District, Riau Province, Indonesia (Asmara, 2005; Junaidi, 2005).

Since 2004, PT National Timber and Forest Product has had some financial difficulties and therefore they have not been managing the plantation properly. During the first four years of cultivation, planting distance between palms was 8 m x 8 m in Divisions 1, 2, 3 and 4. This was increased to 10 m x 10 m in Divisions 5, 6, 7 and 8, during the second four years. Within the following third four years, planting distance between palms was increased again to 10 m x 15 m in Divisions 9, 10 and 11. Therefore the productivity of sago palm in Divisions 1, 2, 3 and 4 are the best mainly because these were planted according to the optimum standards, whereas Divisions 9, 10, 11 are the least productive (Rahman, 2009). The average harvestable sago palm trunk in Divisions 1, 2, 3 and 4 are about 53%, while Divisions 5, 6, 7 and 8 are less than 30% (Wiraguna, 2009). In order to overcome these situations, P.T. National Timber and Forest Product invited P.T. Sampoerna Agri, which since the beginning of this year has taken over P.T. National Timber and Forest Product.
LOCATION, SOIL AND CLIMATE

P.T. National Timber and Forest Product is in Riau Province, Meranti District and Tebing Tinggi Sub District. The sago field is located at Teluk Buntal, Tanjung Gadai, Tanjung Sari, Sungai Tohor, Kayu Ara and Mukun Villages. The total area is approximately 21,000 ha. The annual rainfall in this area is around 2,095 - 2,294mm. May is the driest month while September or October is very humid. Average temperature is around 26 - 27.4°C and the relative humidity is around 82 - 88%. Soil elevation is 0 - 5 m above sea level. Most of its soil type is organosol (peat soil), the pH is around 3.1 – 4.0.

WATER MANAGEMENT

Water is a crucial requirement by plants, especially sago palm, because water is a reagent during photosynthesis. Around 80 - 90% of the plant tissue is made up of water to maintain turgidity. Sago palm needs a lot of water but excessive water will decrease starch content in its trunk. The best water level for sago palm growth is about 30 - 50cm below soil surface. Excessive water can be avoided by making canals surrounding the sago palms. Every divisions is as large as 1,000 ha and it consists of 20 blocks, so every block is 50ha, and each block is surroundly by canal (Figure 1).

During rainy seasons, water level is very high, usually the same level as the soil surface. This condition causes the sago palm plantations to be inaccessible. In contrast, during dry season, the water level is often less than 1m. In order to overcome these conditions, dams with water gate are made (Figure 2).

Water is managed by rebuilding canals in the sago palm plantations. The objectives of doing this are to support sago palm growth, to overcome forest burning and to be used for transportation. Under the former management, canal is only used to overcome forest burning and to support sago palm.

During high water supply in the rainy seasons, the gate will be opened, and will be closed during low water supply in the dry season. The water level can be maintained around 30 – 50cm below the soil surface. Pizzometer is installed to observe the water level condition (Figure 3).

Sometimes local people in the surrounding rural communities disagree to the plantation manager policy and they refuse to grant permission for plantation activities to use road in their area. So, the sago plantation company has to construct a system of canals to connect to each division and to the strait (Figure 4).
Figure 4: Map of Sago Plantation in Meranti Distric

There are three types of canals in the sago plantation: main, collector and branch canals. The main canal is 6m wide and 4m deep. The width of collector and branch canals is 5m and 4m, respectively - while depth of both canals is 3m. All divisions are connected to the main canal. Collector canals connect main canal with branch canals. In cases when the roads cannot be used, the workforce can be transported by using small boat (Amarilis, 2009; Andani, 2009)

WEED CONTROL

Weed is a major problem in any sago palm plantation because weed competes with sago palm for nutrient in the soil, sun light and growing space aside from the possibility of being the host to various pests. Weed is defined as: (a) plants that grow in a certain area which is not welcomed by the farmer; (b) all plants other than cultivated crop; (c) plants that have negative effects to human beings. Weed can also be classified as annual as well as perennial plants (Listio et al., 2008). Weeds can be suppressed either by physical, chemical or by technical plant cultivation. Under the former management of P.T. National Timber and Forest Product, all weeds were cut so its maximum height should be no more than 5 cm. This is different from the current management policy not to cut all weeds. For example, if the first row of palms were cut as usual, the second row are used for placing dead sago palm leaves (Figure 5).

OTHER ACTIVITIES

In rehabilitating the sago palm plantations with the sole purpose of increasing its productivity, P.T. National Timber and Forest Product cooperate with Bogor Agricultural University. The University staffs carry out some research on matters such as germplasm collection, pruning of suckers, proper dosage and applications of fertilizer, studies on effects of water level and the possibilities of multiple cropping. The university also give some recommendations on the rehabilitation works which needs to be done to ensure higher productivity.

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This study is to develop sago waste composite into a high value added product, which can be potentially commercialize in the global high market of music industries. We have successfully developed sound absorber panels from original material of sago waste composite. The composite was applied with various binders and polymers. The function and basic manufacturing of sound absorbers products was aligned with the present products in the market. Fire retardant compound was added in order to comply with the safety requirement for interior product. The panels were tested to validate the suitability and effectiveness of application. Rate testing was also carried out to evaluate the level of sound absorption using ASTM C423 -90a method in collaboration with Standards Institutes and Industrial Research Malaysia (SIRIM). The panels were validated among consumers through consumer preference test to assess the product design suitability according to consumer requirement and commercial value level. This study is one of the environmental strategies to balance the sago waste production by the industries.
PRELIMINARY STUDY OF ETHANOL PRODUCTION: OPTIMIZATION OF SACCHARIFICATION PROCESS OF SAGO STARCH INTO SUGARS

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ABSTRACT

The enzymatic hydrolysis of sago starch was performed by commercially available α-amylase and glucoamylase. In order to attain a higher sugars yield, optimization study of saccharification process was carried out in the shake flask experiment to investigate the effect of main factors of the hydrolysis process, namely, sago concentration, amount of enzyme and time for the maximum production of sugars. As shown in the analysis of variance (ANOVA) result, the sago concentration, and time have contributed more significant effect than amount of the enzyme on hydrolysis process of sago starch.

Keywords: sago, enzyme, hydrolysis, saccharification, sugars, ethanol

INTRODUCTION

The selection of best suitable crops for bioethanol is one of the key factors to reduce the overall cost of the process and maintained the fuel market price. One type of starchy crops that has promising future in bioethanol is sago palm or scientifically known as Metroxylon sagu (Kosaric and Vardar-Sukan, 2001). Sago palm is also known as the starch crops of the 21st century by most scientists. This proves that sago palm has brighter prospect as the source for carbohydrate as well as for bioethanol production. Starch from sago palm is the only commercial starch source that is derived from stem and contains bulky amount of starch in its trunk (Demirbas, 2008).

Sago palm plantations are mainly concentrated in most tropical countries including Malaysia and Indonesia. In Malaysia, approximately 12% of Sarawak total area is mainly covered with sago plantation and good prospect for bioenergy production.

The objective of the study is to optimize the conditions of saccharification for sugar production from sago starch.

MATERIALS AND METHODS

Raw sago materials were obtained from an Indonesian supplier in Riau and were processed to produce sago starch in the Bioprocess Engineering Laboratory of IIUM.

Both α-amylase from Bacillus subtilis and glucoamylase from Aspergillus niger were obtained from the local market. The activities of the two enzymes were identified as 90% each.

A 250ml shake flask was filled with 10 to 20g of sago powder and 100ml of distilled water. Then, 0.1% (v/w) of α-amylase (to the amount of sago) was added and the mixture was cooked at 80°C and agitated at 300rpm for one hour. Then, the mixture was cooled to 50°C and the desired concentration of glucoamylase was added and the mixture was left for the designated time agitated at 250rpm. The solution was then cooled down to 35°C.

The concentration of glucose was determined by centrifuging at 5000rpm for 30 minutes to collect the supernatant which contain the sugars, an analyzed by a Brix analyzer.

Box Behnken Design was used to optimize the hydrolysis process for maximum sugars production. Amount of substrate (A, gram), amount of glucoamylase (B, % (v/w) and saccharification time (C,
hours) were chosen for the independent variables as shown in Table 1. Sugars concentration (Y, % (v/v)) was used as the dependent output variable.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Symbol</th>
<th>Coded levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High (3)</td>
</tr>
<tr>
<td>Amount of substrate, g</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Amount of glucoamylase, % (v/w)</td>
<td>B</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Saccharification time, h</td>
<td>C</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1: Box-Behnken design levels of chosen parameters

RESULTS AND DISCUSSION

The results of the responses for sugars yield (Y) found from experimental work and estimated by the Box-Behnken design are presented in Table 2. An appropriate procedure for analyzing a Box-Behnken design is based on analysis of variance, which is summarized in the ANOVA table, as given in Table 3, to identify significance of effects or interaction of factors on a response. From the ANOVA for response surface quadratic model for surface area, the model p-values of 0.011184 imply that the models are significant.

<table>
<thead>
<tr>
<th>Standard order</th>
<th>A (g)</th>
<th>B (% w/v)</th>
<th>C (h)</th>
<th>Y (% Brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Observed</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0.02</td>
<td>2</td>
<td>20.4</td>
</tr>
<tr>
<td>2</td>
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<td>0.02</td>
<td>2</td>
<td>39.0</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
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<td>20.0</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>0.04</td>
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</tr>
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<td>5</td>
<td>10</td>
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<td>9</td>
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<td>16.6</td>
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<td>14</td>
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<td>0.03</td>
<td>2</td>
<td>28.9</td>
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<td>15</td>
<td>15</td>
<td>0.03</td>
<td>2</td>
<td>28.0</td>
</tr>
</tbody>
</table>

Table 2: The observed and predicted results for sugar yield

Table 3: ANOVA for response surface quadratic model

Figure 1 shows the experimental values versus predicted values using the model equation developed by STATISTICA Software version 8.0. A line of unit slope, the line of perfect fit with points corresponding to zero error between experimental and predicted values is also shown in Figure 1. The coefficient of correlation (R²) is 0.90285. The results in Figure 1 demonstrate that the regression model equation provides an accurate description of the experimental data, indicating that it has successfully captured the correlation between the three parameters to sugar yield.

As shown in the analysis of variance (ANOVA) result, the sago concentration, and time have contributed more significant effect than amount of the enzyme on hydrolysis process of sago starch based on the p-value obtained. The interaction between this two factors can be seen the response plot in the Figure 2. Sago concentration contributes to enhance the total sugars production (percentage of brix). Increasing sago concentration causes the increasing of total sugars drastically. While, time factor not much effect to total sugars production. It may be because amount of this enzyme is enough to convert the sago starch into sugars. It is also this enzyme has a high activity as mentioned by supplier of 90% conversion. The combination factors between sago concentration and time saccharification ion is also significantly effect to