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PRODUCTION OF SUGARS FROM SAGO BARK USING SUBCRITICAL WATER TREATMENT

NURHUSNI BINTI M. AMIN

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By

NURHUSNI BINTI M. AMIN

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PRODUCTION OF SUGARS FROM SAGO BARK USING SUBCRITICAL WATER TREATMENT

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December 2019

Chair : Nordin Bin Hj. Sabli, PhD
Faculty : Engineering

Sago bark is one of the solid wastes being discarded in large volume from sago industries and currently being abandoned and underutilized. The effort to valorize this waste is not enlarge due to the technology limitation. Besides, the current practices on the sago wastes left at the sago starch processing industries have raised to various environmental issues. Due to its large in carbon content, sago bark is subjected to subcritical water treatment in this study for producing sugars and other value-added products. Sago bark was differentiated into inner and outer layers and both were treated at 180 - 320 °C for 5 min. It was found that inner layer yielded higher amount of TOC (0.27 g/g-dry sago bark) and total sugar (0.67 g/g-dry sago bark) than the outer layer at 210 °C. Inner layer was also substantially affected with more than 90% solid loss recorded with increasing reaction temperature and maximum tar yield of 0.41 g/g-dry sago bark at T≥280 °C. Besides, inner layer had shown better conversion and solubility in subcritical water thus, it is more susceptible to subcritical water treatment than the outer layer. Inner layer was selected for further experiments under varied reaction times, 1 - 15 min. Temperatures of 180, 210 and 240 °C were selected and made constant at a time. Temperature of 210 °C and reaction time 5 min yielded the highest total sugar yield among the other reaction temperatures. The production of tar was less affected by the prolonged reaction time unlike at higher temperature. It was noticed that polysaccharide in the bark decomposed sequentially from higher to lower degree of polymerization. Hemicellulose decomposed earlier (180 °C, 5 min) than the cellulose portion (≥210 °C, ≥7 min). Among all of reaction temperatures applied, 240 °C showed better monosaccharides yields (glucose = 0.093, xylose = 0.097 g/g-dry sago bark) in shorter time, 5 min. 210 °C was a suitable temperature for arabinose production with the highest yield of 0.015 g/g-dry sago bark at 2 min. The drop of pH combined with increase amount of organic acids generated confirmed that, sugars degradation had happened at higher reaction temperature and time. The six types of organic acid identified were pyruvic, malic, acetic, formic, succinic and lactic acids. The declining thermogravimetric analysis combustion values, from 80 to 60 wt. % for the reaction temperature 180 - 240 °C further supported that sago bark had successfully decomposed during the reaction. The thermogravimetric analysis also revealed that hemicellulose decomposed the most during the reaction rather than the

cellulose and resulted in large contribution to the sugar yields. The increasing crystallinity index obtained, 59.3 - 78.1% when treated at 180 - 240 °C as compared to the raw sago bark, 38.6%, further verified the efficient removal of certain amount of lignin and hemicellulose from the solid sample matrix. The crystallinity index became evident that only amorphous region of cellulose was affected thus, contributed into the cellulose sugars production i.e. glucose at higher temperature and time.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGHASILAN GULA DARIPADA KULIT KAYU SAGU MENGGUNAKAN RAWATAN SUBKRITIKAL

Oleh

NURHUSNI BINTI M. AMIN

Disember 2019

Pengerusi : Nordin Bin Hj. Sabli, PhD
Fakulti : Kejuruteraan

Kulit kayu sagu adalah salah satu sisa pepejal yang dibuang dalam jumlah yang besar dari industri sagu dan kini diabaikan dan kurang digunakan. Usaha untuk mempelbagaikan kegunaan sisa in tidak diperbesar kerana keterbatasan teknologi. Selain itu, amalan meninggalkan buangan sisa sagu di kilang-kilang telah membawa kepada pelbagai isu alam sekitar. Disebabkan kandungan karbonnya yang banyak, kulit kayu sagu telah dirawat dengan air subkritikal dalam kajian ini untuk penghasilan gula dan produk nilai tambah yang lain. Kulit kayu sago dibezakan kepada lapisan dalam dan luar dan kedua-duanya dirawat pada suhu 180 - 320 °C selama 5 minit. Lapisan dalam menghasilkan jumlah TOC (0.27 g/g-kulit sagu kering) dan jumlah gula yang tinggi (0.67g/g-kulit sagu kering) berbanding lapisan luar pada suhu 210 °C. Lapisan dalam juga merekodkan kehilangan pepejal melebihi 90% apabila suhu tindak balas meningkat dan menghasilkan tar maksimum sebanyak 0.41 g/g-kulit sagu kering pada suhu ≥280 °C. Selain itu, lapisan dalam telah menunjukkan keterlarutan yang lebih baik dalam air subkritikal dan lebih mudah terurai dalam air subkritikal berbanding lapisan luar. Lapisan dalam telah dipilih untuk tindak balas seterusnya pada masa tindak balas yang berbeza, 1 - 15 minit. Suhu 210 °C dan masa tindak balas 5 minit telah menghasilkan jumlah gula tertinggi di antara suhu-suhu yang lain. Penghasilan tar kurang dipengaruhi oleh masa tindak balas yang lama tidak seperti pada suhu yang tinggi. Polisakarida dalam kulit kayu terurai secara berurutan dari tahap pepolimeran yang tinggi kepada tahap yang rendah. Hemiselulosa diuraikan lebih awal (180 ° C, 5 min) berbanding selulosa (≥210 ° C, ≥7 min). Di antara suhu tindak balas yang digunakan, 240 ° C menunjukkan hasil monosakarida yang lebih baik (glukosa = 0.093, xylosa = 0.097 g/g-kulit sagu kering) dalam masa yang lebih singkat, 5 minit. 210 ° C adalah suhu yang sesuai untuk pengeluaran arabinosa dengan hasil tertinggi sebanyak 0.015 g/g-kulit sagu selama 2 minit. Penurunan pH dan peningkatan jumlah asid organik mengesahkan bahawa kemerosotan gula berlaku pada suhu dan masa tindak balas yang lebih tinggi. Enam jenis asid organik telah dikenalpasti iaitu asid piruvik, malik, asetik, formik, susinik dan laktik. Nilai pembakaran analisis termogravimetrik yang menurun dari 80 hingga 60 wt. % bagi suhu 180 - 240 °C, menyokong bahawa kulit kayu sagu telah berjaya diuraikan semasa tindak balas. Analisis termogravimetrik juga mendedahkan bahawa hemiselulosa lebih terurai semasa rawatan berbanding selulosa dan banyak menyumbangkan kepada

penghasilan gula. Peningkatan indeks kristaliti yang diperolehi, 59.3 - 78.1% apabila dirawat pada 180 - 240 ° C berbanding dengan kulit kayu sagu mentah, 38.6%, selanjutnya mengesahkan penyingkiran efisien sejumlah lignin dan hemiselulosa dari matriks pepejal sampel. Indeks kristaliti menjadi bukti bahawa hanya selulosa rantau amorf yang terjejas dan telah menyumbang kepada penghasilan gula selulosa seperti glukosa pada suhu dan masa yang lebih tinggi.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Nordin Bin Hj. Sabli, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Shamsul Izhar Bin Siajam, PhD
Associate Professor, Ir.
Faculty of Engineering
Universiti Putra Malaysia
(Member)

____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Name and Matric No.: Nurhusni Binti M. Amin, GS46903

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This is to confirm that:

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Signature: ____________________________

Name of Chairman of Supervisory Committee: Nordin Bin Hj. Sabli

Signature: ____________________________

Name of Member of Supervisory Committee: Shamsul Izhar Bin Siajam

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LIST OF ABBREVIATIONS

SCW	Subcritical water
SB	Sago bark
TOC	Total organic carbon
TGA	Thermogravimetric analysis
TS	Total sugar
XRD	X-ray Diffraction
AS	Acetone soluble
WS	Water soluble
RS	Residual solid

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Sago palm is a starch crop par excellence, as it has a higher starch production capacity, between 20 - 25 tons/ha/year, than that of cassava, rice or corn (Flores, 2008). The world production of starch is approximately about 27.5 million tons. Meanwhile, global consumption of sago starch accounts for about 3% of the total world market which lies between 200,000 to 300,000 tons per annum and the rest is dominated by corn, potato and tapioca (Bujang, 2006). Even though current staple food has been diverged to rice, there are still numerous products derived from sago for it has multitude usage. For instance in food industry, sago is widely used to produce sago pearls, sago flour and syrups in soft drinks. Besides, it is also used in the glue industry involved in plywood manufacture (Singhal et al., 2008).

In Malaysia, there are more than 90% of all sago-planting areas concentrated in the state of Sarawak, which is one of the world's largest sago exporter, exporting about 25,000 - 40,000 tons of sago products annually to Peninsular Malaysia, Japan, Taiwan, Singapore, etc. (Bujang, 2006; Singhal et al., 2008). In the world, Malaysia is currently the third main sago producer after Indonesia and Papua New Guinea and combined, the three countries produce approximately 94.6% of the world's sago (Naim et al., 2016). Although Indonesia and Papua New Guinea produce more sago than Malaysia, the sago industry in this country is well established and has become one of the important industries contributing to export revenue (Karim et al., 2008). In Malaysia, sago starch ranks fifth in terms of highest agricultural revenue after pepper, palm oil, cocoa, and rubber (Abd-Aziz, 2002). Department of Agricultural Sarawak, DAS reported that the production and export value of sago starch has been increasing 15% to 20% every year (Jenol et al., 2014; Mohamad et al., 2011). As the demand increases, so will sago production, which consequently contributes to the significant amount of waste generated.

In the sago starch processing industries, there are three by-products generated namely sago bark, SB fibrous pith residue or also known as *hampas* and wastewater. Bark and hampas are classified as solid residues whereas wastewater is a liquid residue. In a day, about 237.6 tons of wastewater and 7.1 tons of fibrous hampas are generated from approximately 600 logs of sago palm (Zainab et al., 2014). Meanwhile, about 5 -15 tons SB is produced from the processed logs each day from a factory (Vikineswary et al., 1994). This huge value eventually amounts to more than 20, 000 tons of sago bark being discarded annually from Malaysia's sago industry.

Currently, the SB wastes left behind during the starch processing are destroyed through open or control burning, discarded into the rivers or left to degrade naturally at the factories. These practices pose several serious problems such as threat to the environment through air pollution, shallow the rivers and create unpleasant odor and view (Wahi et al., 2014). Nonetheless, initiatives have been taken by locals when using SB wastes to build a platform around the factory, footpaths of houses, wall materials, and fences. Besides, there are also numerous interior decoration products from SB such as wall tiles, furniture and flower pots recycled from SB in ascribing its natural features and beautiful surface (Abd Rahman, 2005).

Subcritical water (SCW) is a condition when water maintains its liquid form between water boiling temperatures, 100 °C to its critical temperature, 374 °C under adequate pressure. In the last decades, SCW treatment has gained increased attention due to several advantages over other biomass extraction methods including the ability to use wet heterogeneous biomass feedstock without prior dewatering (Pavloviè et al., 2013b). Also, there are several factors that can influence the efficiency of SCW treatment such as reaction temperature, time, pH and etc. Nonetheless, reaction temperature gives a substantial influence on SCW reaction than the other factors.

1.2 Problem Statement

There is an abundant amount of SB being discarded yearly from sago starch processing industries and are not fully utilized. The current practices on the sago wastes left at the sago starch processing industries have raised to an environmental issue as it is loaded in the fields to naturally degrade or practically burnt. Exploitation of SB wastes are not maximize and only minimal efforts have been done either industrially or in research institutions (Abd Rahman, 2005) that rooted from no clear new technology can be adapted for alternative sago bark utilization (Chong et al., 2014). More extensive research on SB should be done pertinent to its large content of cellulose and hemicellulose compositions. According to Ethaib et al. (2016), SB has high in carbohydrate content, accounting for more than 60% of cellulose and hemicellulose. Therefore, it can be used to produce sugars as a feedstock or raw materials in other industries i.e. biofuel industry. This could enhance the usage of SB instead of utilize it for traditional building materials.

Recently, several researches have successfully been done on SB in producing xylitol (Mohamad et al., 2013) via acid hydrolysis and fermentation, and sugars (Ethaib et al., 2016) using microwave-assisted dilute acid pretreatment and enzymatic hydrolysis. Both studies have resulted in a very promising value. Nonetheless, the applications of chemicals and enzymes during reactions are of apathy since awareness towards green solvent and environmental friendly becomes the major concerns. Application of acid is corrosive and required neutralization process while enzymes require very long time to obtain the products and cannot be recycled. Hence, in this research a method known as subcritical water (SCW) treatment is introduced to address the aforementioned problem while maximizing the SB utilization.

SCW treatment used water at high temperature between 100 to 374 °C under an adequate pressure of ~22.0 MPa. However, the high temperature treatment posed in this process may rapidly degrade the products produced, thus, several key parameters should be manipulated and controlled to ensure the maximum product yields are achieved. Besides, the presence of lignin that bound closely around the cellulose and hemicellulose components makes the hydrolysis accessible restricted. This is more prominent at the outer bark where lignin is mostly concentrated over 20% at this region than the inner bark (Pásztory et al., 2016). Therefore, distinguishing and separating the bark layers could enhance the accessibility of hydrolysis process and sugars production. Most of the sugars production from biomass wastes could be contributed from either cellulose or hemicellulose as the major carbohydrate portions in plants. Solid characterization such as TGA and XRD analyses (Ethaib et al., 2016; Mohan et al., 2015) on remaining solid left after hydrolysis may tell the either cellulose or hemicellulose reacted the most and contributed to product yields.

1.3 Objectives

In this study, SB was proposed as the raw material for the production of valuable materials using SCW to enhance the utilization of sago wastes. Therefore, the objectives of this study are as follows:

1. To compare the conversion between inner and outer layers of SB using SCW treatment into any value-added products.
2. To evaluate the effects of SCW treatment process conditions (reaction temperature and time) on SB in producing sugars and other value-added products.
3. To characterize the residual solid left from SB after SCW treatment.

1.4 Scope of Research

To conduct the first objective, the SB was debarked manually and differentiated into inner and outer layers, concerning that the different distance of layers from the center pith could influence the sago trunk anatomically and starch content. Then the samples were chopped into smaller sizes, 2 - 3 cm according to the specified SB wastes usually discarded from sago starch industries. The layers were characterize in terms of moisture and ash content as well as its chemical compositions. Then, the different SB layers were subjected to SCW treatment at varied temperatures, 180 to 320 °C and constant time, 5 min. Size of the sample loaded in the reactor was not manipulated and kept constant for all experiments as it does not give significant effect on the hydrolysis process of a batch system (Prado et al., 2015). Meanwhile, hydrolysis using water at room temperature was used as a control. Three phases were isolated after treatment called WS, AS phases and residual solid. TOC and TS analyses were conducted on WS phase to ensure the decomposition of SB and the presence of sugar after treatment respectively. While, gravimetric analysis done on AS phase and residual solid left to monitor the possible effects of pyrolysis that may take place at high reaction temperature. Solubility of the two layers in SCW treatment was compared, and the layer with high solubility indicates high reactivity and reliability of the material.

For the second objective, the selected layer that produced high TS yield was further reacted with SCW treatment. Three best reaction temperatures were fixed separately to constant at a time under varied reaction time, 1 to 15 min. Similar analyses were done as in previous (in objective 1), with additional HPLC-sugar and HPLC-organic acid analysis to identify the type of sugar and organic acid present as a function of time and temperature respectively. The significance analysis, $p < 0.05$ of reaction temperature and time and its interaction was conducted using two-way ANOVA analysis based on the TS sugar yield. Tar and residual solid collected was limited to only study on its yield.

For the third objective, solid characterization analysis was done in terms of thermal stability and crystallinity of solid residue using thermogravimetric and X-ray diffraction methods respectively. The remaining solid residue left after SCW treatment at 180, 210 and 240 °C and 10 min was categorized as treated SB and analyzed to compare its solid structure with the untreated SB. Solid characterization analysis would give ideas on the extensive effects of SCW on SB and the chemical composition of SB that was affected and contributed to the product yields.

1.5 Significant of The Study

SCW treatment on SB will definitely provide the environmental friendly alternative solution for issues related with sago starch processing industries. Production of valuable materials from SB by fully utilizing the cellulosic materials present will enhance the zero emission from biomass waste and/or agriculture waste in Malaysia. It will reduce wastes being dump into landfills as well as the burning practice that consequently cause increment in the carbon footprint. The production of value-added products such as sugar from SB will harness the generation of bio-based fuel i.e. bioethanol, biobuthanol and etc. Thus, this research will positively affect our society, nation and economy.

1.6 Thesis Outline

This thesis comprised of five chapters. First chapter briefly describes the background of the study, problem statement, objectives and outline of the thesis. The second chapter reviews in details about the sago palm, current status of sago wastes and its utilization, the various hydrolysis techniques including SCW treatment as well as biomass that had been treated with SCW hydrolysis. Chapter three mainly describes in details about the sample preparation, step of procedures, calculations, chemicals and equipment involved throughout the research. Meanwhile, chapter four reports and elaborates all of the results obtained in regards to the experiments done with justification and support from previous studies. Final chapter, chapter five summarizes all the findings according to the research objectives and recommends some suggestions for improvements as for the continuity of future researches.

REFERENCES

Abd-Aziz, S. (2002). Sago starch and its utilisation. *Journal of Bioscience and Bioengineering*, *94*(6), 526–529. https://doi.org/10.1016/S1389-1723(02)80190-6

Abd Rahman, K. A. A. (2005). Utilizing Sago (Metroxylon spp) Bark Waste for Value Added Products. *Proceedings - Fourth International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Eco Design 2005, Tokyo Japan*, 102–106. https://doi.org/10.1109/ECODIM.2005.1619175

Abdelmoez, W., Nage, S. M., Bastawess, A., Ihab, A., & Yoshida, H. (2014). Subcritical water technology for wheat straw hydrolysis to produce value added products. *Journal of Cleaner Production*, *70*, 68–77. https://doi.org/10.1016/j.jclepro.2014.02.011

Abdelmoez, W., & Yoshida, H. (2006). Simulation of Fast Reactions in Batch Reactors Under Sub-Critical Water Condition. *American Institute of Chemical Engineers Journal*, *52*(10), 3600–3611. https://doi.org/10.1002/aic

Abdullah, S., Yusup, S., Ahmad, M., Ramli, A., & Ismail, L. (2010). Thermogravimetry study on pyrolysis of various lignocellulosic biomass for potential hydrogen production. *International Journal of Chemical and Biological Engineering*, *3*(3), 137–141. https://doi.org/10.1016/j.jsbmb.2009.08.001

Agbor, V. B., Cicek, N., Sparling, R., Berlin, A., & Levin, D. B. (2011). Biomass pretreatment : Fundamentals toward application. *Biotechnology Advances*, *29*(6), 675–685. https://doi.org/10.1016/j.biotechadv.2011.05.005

Ahmed, M. Z. (2014). *Evaluation of moistre content in wood fiber and recommendation of the best method for its determination*. https://doi.org/10.13140/RG.2.1.4795.4648

Akhtar, J., & Amin, N. A. S. (2011). A review on process conditions for optimum bio-oil yield in hydrothermal liquefaction of biomass. *Renewable and Sustainable Energy Reviews*, *15*, 1615–1624. https://doi.org/10.1016/j.rser.2010.11.054

Akmar, P. F., & Kennedy, J. F. (2001). The potential of oil and sago palm trunk wastes as carbohydrate resources. *Wood Science and Technology*, *35*(5), 467–473. https://doi.org/10.1007/s002260100107

Allen, S. G., Schulman, D., Lichwa, J., Antal, M. J., Laser, M., & Lynd, L. R. (2001). A Comparison between hot liquid water and steam fractionation of corn fiber. *Industrial & Engineering Chemistry Research*, *40*, 2934–2941.

Amin, N., Sabli, N., Izhar, S., & Yoshida, H. (2020). Production of valuable materials from sago bark using subcritical water treatment. *Internationl Journal of Engineering Research and Technology*, *13*(1), 1–11.

Anwar, Z., Gulfraz, M., & Irshad, M. (2014). Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy : A brief review. *Journal of Radiation Research and Applied Sciences*, *7*, 163–173. https://doi.org/10.1016/j.jrras.2014.02.003

Asghari, F. S., & Yoshida, H. (2010). Conversion of Japanese red pine wood (Pinus densiflora) into valuable chemicals under subcritical water conditions. *Carbohydrate Research*, *345*(1), 124–131. https://doi.org/10.1016/j.carres.2009.10.006

Asif, M. (2009). Sustainability of timber, wood and bamboo in construction. In *Sustainability of construction materials* (pp. 31–54). Woodhead Publishing Limited. https://doi.org/10.1533/9781845695842.31

Asl, H. A., & Khajenoori, M. (2013). *Subcritical water extraction*.

Awaluddin, S. A., Thiruvenkadam, S., Izhar, S., Hiroyuki, Y., Danquah, M. K., & Harun,

R. (2016). Subcritical water technology for enhanced extraction of biochemical compounds from Chlorella vulgaris. *BioMed Research International*, 1–10.
Awg-Adeni, D. S., Abd-Aziz, S., Bujang, K., & Hassan, M. A. (2010). Bioconversion of sago residue into value added products. *African Journal of Biotechnology*, *9*(14), 2016–2021. https://doi.org/10.5897/AJBx10.009
Awg-Adeni, D. S., Bujang, K. B., Hassan, M. A., & Abd-Aziz, S. (2013). Recovery of glucose from residual starch of sago hampas for bioethanol production. *BioMed Research International*, *2013*, 1–8. https://doi.org/10.1155/2013/935852
Bhagwat, S., Ratnaparkhe, S., & Kumar, A. (2015). Biomass pre-treatment methods and their economic viability for efficient production of biofuel. *British Biotechnology Journal*, *8*(2), 1–17. https://doi.org/10.9734/BBJ/2015/18284
Bhuiyan, M. T. R., Hirai, N., & Sobue, N. (2000). Changes of crystallinity in wood cellulose by heat treatment under dried and moist conditions. *Journal of Wood Science*, *46*, 431–436.
Bobleter, O. (1994). Hydrothermal degradation of polymers derived from plants. *Polymer Science*, *19*, 797–841.
Brunner, G. (2014). Processing of biomass with hydrothermal and supercritical water. In *Hydrothermal and Supercritical Water Processes* (Vol. 5, pp. 395–509). https://doi.org/10.1016/B978-0-444-59413-6.00008-X
Bujang, K. (2006). Potentials of bioenergy from the sago industries in Malaysia. In *EOLSS - Encyclopedia of Life Support Systems* (Vol. 14). UNESCO-IOBB, Brisbane, Australia. Retrieved from http://www.eolss.net/sample-chapters/c17/E6-58-12-12.pdf
Bukhari, N. A., Loh, S. K., Nasrin, A. B., & Maizan, I. (2017). Hydrolysis of residual starch from sago pith residue and its fermentation to bioethanol. *Sains Malaysiana*, *46*(8), 1269–1278.
Cai, W., Gu, X., & Tang, J. (2008). Extraction, purification, and characterization of the polysaccharides from Opuntia milpa alta. *Carbohydrate Polymers*, *71*, 403–410. https://doi.org/10.1016/j.carbpol.2007.06.008
Cardenas-toro, F. P., Alcazar-alay, S. C., Forster-carneiro, T., & Meireles, M. A. A. (2014). Obtaining Oligo- and Monosaccharides from Agroindustrial and Agricultural Residues Using Hydrothermal Treatments, *4*(3), 123–139. https://doi.org/10.5923/j.fph.20140403.08
Carr, A. G., Mammucari, R., & Foster, N. R. (2011). A review of subcritical water as a solvent and its utilisation for the processing of hydrophobic organic compounds. *Chemical Engineering Journal*, *172*(1), 1–17. https://doi.org/10.1016/j.cej.2011.06.007
Cecil, J. E. (1992). *Small-, medium-, large-scale starch processing*.
Chen, K., Hao, S., Lyu, H., Luo, G., Zhang, S., & Chen, J. (2017). Ion exchange separation for recovery of monosaccharides , organic acids and phenolic compounds from hydrolysates of lignocellulosic biomass. *Separation and Purification Technology*, *172*, 100–106. https://doi.org/10.1016/j.seppur.2016.08.004
Chen, Z., & Wan, C. (2017). Biological valorization strategies for converting lignin into fuels and chemicals. *Renewable and Sustainable Energy Reviews*, *73*, 610–621.
Chew, T. A., Isa, A. H. M., & Mohayidin, M. G. (1999). Sago (Metroxylon sagu Rottboll), the forgotten palm. *Journal of Sustainable Agriculture*, *14*(4), 5–17. https://doi.org/10.1300/J064v14n04_03
Chew, T., Hassan, A., Ghazah, M., & Ghazah, I. (1998). The sago industry in Malaysia : Present status and future prospects. In *Proceedings of the 7th international Working Conference on Stores-product protection* (Vol. 2, pp. 1720–1728).

Chong, K. H., Law, P. L., Rigit, A. R. H., Baini, R., & Shanti, F. S. (2014). Sago bark as renewable energy. *UNIMAS E-Journal of Civil Engineering*, *5*(2), 29–34.

Demirbas, A. (2008). Products from lignocellulosic materials via degradation processes. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *30*, 27–37. https://doi.org/10.1080/00908310600626705

Deng, W., Wang, Y., & Yan, N. (2016). Production of organic acids from biomass resources. *Current Opinion in Green and Sustainable Chemistry*, *2*, 54–58. https://doi.org/10.1016/j.cogsc.2016.10.002

Deniel, M., Haarlemmer, G., Roubaud, A., Weiss-hortala, E., & Fages, J. (2017). Hydrothermal liquefaction of blackcurrant pomace and model molecules : understanding of reaction mechanisms model molecules: understanding of reaction mechanisms. *Royal Science of Chemistry*, *1*(3), 555–582.

Dransfield, J., Uhl, N. W., Asmussen, C. B., Baker, W. J., Harley, M. M., & Lewis, C. E. (2005). A new phylogenetic classification of the palm family , Arecaceae. *KEW Bulletin*, *60*(4), 559–569.

Duval, A., & Lawoko, M. (2014). A review on lignin-based polymeric , micro- and nano-structured materials. *Reactive and Functional Polymers*, *85*, 78–96. https://doi.org/10.1016/j.reactfunctpolym.2014.09.017

Ehara, K., & Saka, S. (2005). Decomposition behavior of cellulose in supercritical water, subcritical water , and their combined treatments. *Journal of Wood Science*, *51*, 148–153. https://doi.org/10.1007/s10086-004-0626-2

Ellen, R. (2006). Local knowledge and management of sago palm (Metroxylon sagu Rottboell) diversity in South Central Seram , Maluku , eastern Indonesia. *Journal of Ethnobiology*, *26*(2), 258–298. https://doi.org/10.2993/0278-0771(2006)26

Erabee, I. K., Ahsan, A., Nik Daud, N. N., Idrus, S., Shams, S., Md Din, M. F., & Rezania, S. (2017). Manufacture of low-cost activated carbon using sago palm bark and date pits by physiochemical activation. *BioResources*, *12*(1), 1916–1923. https://doi.org/10.15376/biores.12.1.1916-1923

Ethaib, S., Omar, R., Mazlina, M. K. S., Radiah, A. B. D., & Syafiie, S. (2016). Microwave-assisted dilute acid pretreatment and enzymatic hydrolysis of sago palm bark. *BioResources*, *11*(3), 5687–5702. https://doi.org/10.15376/biores.11.3.5687-5702

Ethaib, S., Omar, R., Mazlina, M. K. S., Radiah, A. B. D., Syafiie, S., & Harun, M. Y. (2016). Microwave-assisted pretreatment of sago palm bark. *Journal of Wood Chemistry and Technology*, *0*, 1–17. https://doi.org/10.1080/02773813.2016.1224249

Fan, S., Zhang, P., Li, F., Jin, S., Wang, S., & Zhou, S. (2016). A review of lignocellulose change during hydrothermal pretreatment for bioenergy production. *Current Organic Chemistry*, *20*, 1–11. https://doi.org/10.2174/1385272820666160513154

Fang, Y., Zeng, X., Yan, P., Jing, Z., & Jin, F. (2012). An acidic two-step hydrothermal process to enhance acetic acid production from carbohydrate biomass. *Industrial & Engineering Chemistry Research*, *51*, 4759–4763.

Fang, Z., & Fang, C. (2008). Complete dissolution and hydrolysis of wood in hot water. *AIChE Journal*, *54*(10), 2751–2758. https://doi.org/10.1002/aic

Flach, M., & Schuiling, D. L. (1988). Revival of an ancient starch crop: A review of the agronomy of the sago palm. *Agroforestry Systems*, *7*(3), 259–281. https://doi.org/10.1007/BF00046972

Flach, Michiel. (1997). *Sago palm*. *International Plant Genetic Resource Institute*.

Flores, D. M. (2008). The versatile sago (Metroxylon sagu Rottb.) and its green potential for Mindanao. *Banwa*, *5*(1), 8–17. Retrieved from http://ojs.upmin.edu.ph/index.php/banwa-archives/article/viewFile/34/39

Gao, Y., Wang, H., Guo, J., Peng, P., Zhai, M., & She, D. (2016). Hydrothermal degradation of hemicelluloses from triploid poplar in hot compressed water at 180 C-340 C. *Polymer Degradation and Stability*, *126*, 179–187. https://doi.org/10.1016/j.polymdegradstab.2016.02.003

Gong, Y., Zhang, X., He, L., Yan, Q., Yuan, F., & Gao, Y. (2015). Optimization of subcritical water extraction parameters of antioxidant polyphenols from sea buckthorn (Hippophaë rhamnoides L .) seed residue. *Journal of Food Science Technologyechnology*, *52*(3), 1534–1542. https://doi.org/10.1007/s13197-013-1115-7

Hashim, R., Nadhari, W. N. A. W., Sulaiman, O., Kawamura, F., Hiziroglu, S., Sato, M., … Tanaka, R. (2011). Characterization of raw materials and manufactured binderless particleboard from oil palm biomass. *Materials and Design*, *32*, 246–254. https://doi.org/10.1016/j.matdes.2010.05.059

Hoch, G., Richter, A., & Körner, C. (2003). Non-structural carbon compounds in temperate forest trees. *Plant, Cell and Environment*, *26*, 1067–1081.

Hosseini, S. D. (2013). *Evaluation of various new technologies for valuable materials production from green macroalgae*.

Hu, Y., Wang, S., Wang, Q., He, Z., Lin, X., Xu, S., … Li, Y. (2017). Effect of different pretreatments on the thermal degradation of seaweed biomass. In *Proceedings of the Combustion Institute* (Vol. 36, pp. 2271–2281). Elsevier Inc. https://doi.org/10.1016/j.proci.2016.08.086

Ilyas, R. A., Sapuan, S. M., & Ishak, M. R. (2018). Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata). *Carbohydrate Polymers*, *181*, 1038–1051.

Inagaki, T., Siesler, H. W., Mitsui, K., & Tsuchikawa, S. (2010). Difference of the crystal structure of cellulose in wood after hydrothermal and aging degradation: A NIR spectroscopy and XRD study. *Biomacromolecules*, *11*(9), 2300–2305. https://doi.org/10.1021/bm100403y

Ishak, H., Yoshida, H., Muda, N. A., Halim, M., & Ismail, S. (2019). Rapid processing of abandoned oil palm trunks into sugars and organic acids by sub-critical water. *Processes*, *7*(9), 1–16.

Isikgor, F. H., & Becer, C. R. (2015). Lignocellulosic biomass: A sustainable platform for the production of bio-based chemicals and polymers. *Polymer Chemistry*, *6*(25), 4497–4559. https://doi.org/10.1039/C5PY00263J

Janggu, U., & Bujang, K. (2009). Development of pre-treatment of sago fibers for recovery of bio-convertible polysaccharides (cellulose) for ethanol fermentation. In *Proceedings of the 2nd Biotechnology Colloquium 14th-15th April 2009* (pp. 85–90). UNIMAS, Sarawak: Department of Molecular Biology Faculty of Resource Science and Technology.

Jena, U., Das, K. C., & Kastner, J. R. (2011). Effect of operating conditions of thermochemical liquefaction on biocrude production from Spirulina platensis. *Bioresource Technology*, *102*, 6221–6229. https://doi.org/10.1016/j.biortech.2011.02.057

Jenol, M. A., Ibrahim, M. F., Yee, P. L., Md Salleh, M., & Abd-Aziz, S. (2014). Sago biomass as a sustainable source for biohydrogen production by Clostridium butyricum A1. *BioResources*, *9*(1), 1007–1026. https://doi.org/10.15376/biores.9.1.1007-1026

Jin, F., Zhou, Z., Enomoto, H., Moriya, T., & Higashijima, H. (2004). Conversion mechanism of cellulosic biomass to lactic acid in subcritical water and acid-base catalytic effect of subcritical water. *Chemistry Letters*, *33*(2), 3–4. https://doi.org/10.1246/cl.2004.126

Jintana, W., & Shuji, A. (2008). Extraction of functional substances from agricultural products or by-products by subcritical water treatment: A review. *Food Science and Technology Research*, *14*(4), 319–328.

Jones, D., Ormondroyd, G. O., Curling, S. F., Popescu, C., & Popescu, M. (2017). Chemical compositions of natural fibres. In *Advanced High Strength Natural Fibre in Construct* (pp. 23–58). https://doi.org/10.1016/B978-0-08-100411-1.00002-9

Ju, Y. H., Huynh, L. H., Tsigie, Y. A., & Ho, Q. P. (2013). Synthesis of biodiesel in subcritical water and methanol. *Fuel*, *105*, 266–271. https://doi.org/10.1016/j.fuel.2012.05.061

Ju, Y., Huynh, L., Srihartati, N., Guo, T., Wang, J., & Eid, A. (2011). Analysis of soluble and insoluble fractions of alkali and subcritical water treated sugarcane bagasse. *Carbohydrate Polymers*, *83*, 591–599. https://doi.org/10.1016/j.carbpol.2010.08.022

Kalderis, D., Kotti, M. S., Méndez, A., & Gascó, G. (2014). Characterization of hydrochars produced by hydrothermal carbonization of rice husk. *Solid Earth*, *5*, 477–483. https://doi.org/10.5194/se-5-477-2014

Kamal, S. M. M., Mahmud, S. N., Hussain, S. A., & Ahmadun, F. R. (2007). Improvement on sago flour processing. *International Journal of Engineering and Technology*, *4*(1), 8–14.

Kamio, E., Sato, H., Takahashi, S., Noda, H., Fukuhara, C., & Okamura, T. (2008). Liquefaction kinetics of cellulose treated by hot compressed water under variable temperature conditions. *Journal of Material Science*, *43*, 2179–2188. https://doi.org/10.1007/s10853-007-2043-6

Kamio, E., Takahashi, S., Noda, H., Fukuhara, C., & Okamura, T. (2006). Liquefaction of cellulose in hot compressed water under variable temperatures. *Industrial & Engineering Chemistry Research*, *45*, 4944–4953.

Kanmaz, E. O. (2018). 5-Hydroxymethylfurfural (HMF) formation during subcritical water extraction. *Food Science and Biotechnology*, *27*(4), 981–986. https://doi.org/10.1007/s10068-018-0328-y

Karim, A. A., Tie, A. P.-L., Manan, D. M. A., & Zaidul, I. S. M. (2008). Starch from the sago (Metroxylon sagu) palm tree properties, prospects, and challenges as a new industrial source for food and other uses. *Comprehensive Reviews in Food Science and Food Safety*, *7*(3), 215–228. https://doi.org/10.1111/j.1541-4337.2008.00042.x

Karimi, K., & Taherzadeh, M. J. (2016). A critical review of analytical methods in pretreatment of lignocelluloses : Composition, imaging, and crystallinity. *Bioresource Technology*, *200*, 1008–1018. https://doi.org/10.1016/j.biortech.2015.11.022

Khalil, H. P. S. A., Alwani, M. S., Ridzuan, R., Kamarudin, H., & Khairul, A. (2008). Chemical composition , morphological characteristics , and cell wall structure of Malaysian oil palm fibers. *Polymer-Plastics Technology and Engineering*, *47*, 273–280. https://doi.org/10.1080/03602550701866840

Khuwijitjaru, P., Watsanit, K., & Adachi, S. (2012). Carbohydrate content and composition of product from subcritical water treatment of coconut meal. *Journal of Industrial and Engineering Chemistry*, *18*, 225–229. https://doi.org/10.1016/j.jiec.2011.11.010

Kim, Y., Kreke, T., Mosier, N. S., & Ladisch, M. R. (2014). Severity factor coefficients for subcritical liquid hot water pretreatment of hardwood Chips. *Biotechnology and Bioengineering*, *111*(2), 254–263. https://doi.org/10.1002/bit.25009

Kirtania, K., Tanner, J., Kabir, K. B., Rajendran, S., & Bhattacharya, S. (2014). In situ synchrotron IR study relating temperature and heating rate to surface functional group changes in biomass. *Bioresource Technology*, *151*, 36–42. https://doi.org/10.1016/j.biortech.2013.10.034

Klinchongkon, K., Khuwijitjaru, P., Wiboonsirikul, J., & Adachi, S. (2015). Extraction of oligosaccharides from passion fruit peel by subcritical water treatment. *Journal of Food Process Engineering*, 1–8. https://doi.org/10.1111/jfpe.12269

Kristiani, A., Effendi, N., Aristiawan, Y., Aulia, F., & Sudiyani, Y. (2015). Effect of combining chemical and irradiation pretreatment process to characteristic of oil palm's empty fruit bunches as raw material for second generation bioethanol. *Energy Procedia*, *68*, 195–204. https://doi.org/10.1016/j.egypro.2015.03.248

Kshirsagar, S. D., Waghmare, P. R., Loni, P. C., Patil, S. A., & Govindwar, S. P. (2015). Dilute acid pretreatment of rice straw, structural characterization and optimization of enzymatic hydrolysis conditions by response surface methodology. *RSC Advances*, *5*(58), 46525–46533. https://doi.org/10.1039/c5ra04430h

Kumar, A. K., & Sharma, S. (2017). Recent updates on different methods of pretreatment of lignocellulosic feedstocks : A review. *Bioresources and Bioprocessing*, *4*(7), 1–19. https://doi.org/10.1186/s40643-017-0137-9

Kumar, P., Barrett, D. M., Delwiche, M. J., & Stroeve, P. (2009). Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial & Engineering Chemistry Research*, *48*(8), 3713–3729.

Kumar, S., & Gupta, R. B. (2008). Hydrolysis of microcrystalline cellulose in subcritical and supercritical water in a continuous flow reactor. *Industrial & Engineering Chemistry Research*, *47*, 9321–9329.

Kumar, S., & Gupta, R. B. (2009). Biocrude production from switchgrass using subcritical water. *Energy Fuels*, *23*, 5151–5159. https://doi.org/10.1021/ef900379p

Kumar, S., Gupta, R., Lee, Y. Y., & Gupta, R. B. (2010). Cellulose pretreatment in subcritical water: Effect of temperature on molecular structure and enzymatic reactivity. *Bioresource Technology*, *101*(4), 1337–1347. https://doi.org/10.1016/j.biortech.2009.09.035

Kumoro, A. C., Ngoh, G. C., Hasan, M., Ong, C. H., & Teoh, E. (2008). Conversion of fibrous sago (Metroxylon sagu) waste into fermentable sugar via acid and enzymatic hydrolysis. *Asian Journal of Scientific Research*, *1*(4), 412–420. https://doi.org/10.3923/ajsr.2008.412.420

Kurnin, N. A. A., Ismail, M. H. S., Yoshida, H., & Izhar, S. (2016). Recovery of Palm Oil and Valuable Material from Oil Palm Empty Fruit Bunch by Sub-critical Water. *Journal of Oleo Science*, *65*(4), 283–289. https://doi.org/10.5650/jos.ess15209

Lachos-Perez, D., Brown, A. B., Mudhoo, A., Martinez, J., Timko, M. T., Rostagno, M. A., & Forster-Carneiro, T. (2017). Applications of subcritical and supercritical water conditions for extraction, hydrolysis, gasification, and carbonization of biomass : A critical review. *Biofuel Research Journal*, *14*, 611–626. https://doi.org/10.18331/BRJ2017.4.2.6

Lachos-Perez, D., Martinez-Jimenez, F., Rezende, C. A., Tompsett, G., Timko, M., & Forster-Carneiro, T. (2016). Subcritical water hydrolysis of sugarcane bagasse: An approach on solid residues characterization. *Journal of Supercritical Fluids*, *108*, 69–78. https://doi.org/10.1016/j.supflu.2015.10.019

Lachos-perez, D., Tompsett, G. A., Guerra, P., Timko, M. T., Rostagno, M. A., Martínez, J., & Forster-carneiro, T. (2017). Sugars and char formation on subcritical water hydrolysis of sugarcane straw. *Bioresource Technology*, *243*, 1069–1077. https://doi.org/10.1016/j.biortech.2017.07.080

Lal, J. (2003). *Sago palm*. *Encyclopedia of Food Sciences and Nutrition*. Elsevier Ltd.

https://doi.org/10.1016/B0-12-227055-X/01036-1
Lee, K. M., Ngoh, G. C., Seak, A., Chua, M., Yoon, L. W., Ang, T. N., & Lee, M. (2014). Comparison study of different ionic liquid pretreatments in maximizing total reducing sugars recovery. *BioResources*, *9*(1), 1552–1564. https://doi.org/10.15376/biores.9.1.1552-1564
Liang, X., & Fan, Q. (2013). Application of sub-critical water extraction in pharmaceutical industry. *Journal of Materials Science and Chemical Engineering*, *1*, 1–16. https://doi.org/10.1007/BF00203768
Limayem, A., & Ricke, S. C. (2012). Lignocellulosic biomass for bioethanol production: Current perspectives, potential issues and future prospects. *Progress in Energy and Combustion Science*, *38*(4), 449–467. https://doi.org/10.1016/j.pecs.2012.03.002
Lin, R., Cheng, J., Ding, L., Song, W., Qi, F., Zhou, J., & Cen, K. (2015). Subcritical water hydrolysis of rice straw for reducing sugar production with focus on degradation by-products and kinetic analysis. *Bioresource Technology*, *186*, 8–14. https://doi.org/10.1016/j.biortech.2015.03.047
Linggang, S., Phang, L. Y., Wasoh, M. H., & Abd-Aziz, S. (2012). Sago pith residue as an alternative cheap substrate for fermentable sugars production. *Applied Biochemistry and Biotechnology*, *167*(1), 122–131. https://doi.org/10.1007/s12010-012-9592-0
Lu, X., & Saka, S. (2010). Hydrolysis of Japanese beech by batch and semi-flow water under subcritical temperatures and pressures. *Biomass and Bioenergy*, *34*(8), 1089–1097. https://doi.org/10.1016/j.biombioe.2010.02.015
Lv, G.-J., Wu, S., & Lou, R. (2010). Characteristics of corn stalk hemicellulose pyrolysis in a tubular reactor. *BioResources*, *5*(4), 2051–2062.
Ma, Z., Guerra, P., Tyufekchiev, M., Zaker, A., Tompsett, G. A., Mayanga, P. C. T., … Timko, M. T. (2017). Formation of an external char layer during subcritical water hydrolysis of biomass. *Sustainable Energy and Fuels*, *1*(9), 1950–1959. https://doi.org/10.1039/C7SE00260B
Maki-Arvela, P., Salmi, T., Holmbom, B., Willfor, S., & Murzin, D. Y. (2011). Synthesis of Sugars by Hydrolysis of Hemicelluloses: A Review. *Chemical Reviews*, *111*, 5638–5666. https://doi.org/10.1021/cr2000042
Mamun, A. A., Heim, H. P., & Bledzki, A. K. (2015). The use of maize, oat, barley and rye fibres as reinforcements in composites. In *Biofiber Reinforcements in Composite Materials* (pp. 454–487). https://doi.org/10.1533/9781782421276.4.454
Marulanda-Buitrago, P.-A., & Marulanda-Cardona, V.-F. (2017). Production of reducing sugars from lignocellulosic kikuyu grass residues by hydrolysis using subcritical water in batch and semibatch reactors. *Ciencia, Tecnologia Y Futuro*, *7*(1), 137–146.
Mayanga-Torres, P. C., Lachos-Perez, D., Rezende, C. A., Prado, J. M., Ma, Z., Tompsett, G. T., … Forster-Carneiro, T. (2017). Valorization of coffee industry residues by subcritical water hydrolysis: Recovery of sugars and phenolic compounds. *Journal of Supercritical Fluids*, *120*, 75–85. https://doi.org/10.1016/j.supflu.2016.10.015
Mçller, M., Nilges, P., Harnisch, F., & Schrçder, U. (2011). Subcritical Water as Reaction Environment : Fundamentals of Hydrothermal Biomass Transformation. *ChemSusChem*, *4*, 566–579. https://doi.org/10.1002/cssc.201000341
Menon, V., & Rao, M. (2012). Trends in bioconversion of lignocellulose: Biofuels , platform chemicals & biorefinery concept. *Progress in Energy and Combustion Science*, *38*, 522–550. https://doi.org/10.1016/j.pecs.2012.02.002
Meryemoglu, B., Hasanog, A., Irmak, S., & Erbatur, O. (2014). Biofuel production by

liquefaction of kenaf (Hibiscus cannabinus L.) biomass. *Bioresource Technology*, *151*, 278–283. https://doi.org/10.1016/j.biortech.2013.10.085

Minowa, T., Fang, Z., Ogi, T., & Varhegyi, G. (1998). Decompostion of cellulose and glucose in hot-compressed water under catalyst-free conditions. *Journal of Chemical Engineering Japan*, *31*(1), 131–134.

Mohamad, N. L., Kamal, S. M. M., & Abdullah, A. G. L. (2011). Optimization of xylose production from sago trunk cortex by acid hydrolysis. *African Journal of Food Science and Technology*, *2*(5), 102–108.

Mohamad, N. L., Kamal, S. M. M., Abdullah, N., & Ismail, I. (2013). Evaluation of fermentation conditions by candida tropicalis for xylitol production from sago trunk cortex. *BioResources*, *8*(2), 2499–2509.

Mohan, D., Pittman, C. U., & Steele, P. H. (2006). Pyrolysis of wood/biomass for bio-oil : A critical review. *Energy & Fuels*, *20*(3), 848–889.

Mohan, M., Banerjee, T., & Goud, V. V. (2015). Hydrolysis of bamboo biomass by subcritical water treatment. *Bioresource Technology*, *191*, 244–252. https://doi.org/10.1016/j.biortech.2015.05.010

Mohan, M., Timung, R., Deshavath, N. N., Banerjee, T., V.Goud, V., & V. Dasu, V. (2015). Optimization and hydrolysis of cellulose under subcritical water treatment for the production of total reducing sugars. *The Royal Society Chemistry*, *5*, 103265–103275. https://doi.org/10.1039/c5ra20319h

Mok, W. S., & Antal, M. J. (1992). Uncatalyzed solvolysis of whole biomass hemicellulose by hot compressed liquid water. *Industrial & Engineering Chemistry Research*, *31*, 1157–1161.

Moller, M., Harnisch, F., & Schroder, U. (2013). Hydrothermal liquefaction of cellulose in subcritical water — the role of crystallinity on the cellulose. *RSC Advcances*, *3*, 11035–11044. https://doi.org/10.1039/c3ra41582a

Muda, N. A., Yoshida, H., Ishak, H., & Shah, M. H. (2019). Conversion of oil palm trunk into bio-oil via treatment with subcritical water. *Journal of Wood Chemistry and Technology*, *39*(4), 255–269. https://doi.org/10.1080/02773813.2019.1578375

Nagamori, M., & Funazukuri, T. (2004). Glucose production by hydrolysis of starch under hydrothermal conditions. *Journal of Chemical Technology and Biotechnology*, *79*, 229–233. https://doi.org/10.1002/jctb.976

Naim, H. M., Yaakub, A. N., & Awang Hamdan, D. A. (2016). Commercialization of sago through estate plantation scheme in Sarawak: The way forward. *International Journal of Agronomy*, *2016*, 1–6. https://doi.org/10.1155/2016/8319542

Nakayama, T., Nitta, Y., & Matsuda, T. (2006). Structure and function of intercellular spaces of sago palm (Metroxylon sagu Rottb.) stem-Electrion microscopic study. In *The 15th Conference of The Society of Sago Palm Studies* (pp. 21–24).

Nanda, S., Kozinski, J. A., & Dalai, A. K. (2016). Lignocellulosic biomass : A review of conversion technologies and fuel products. *Current Biochemical Engineering*, *3*(1), 24–36.

Ngaini, Z., Wahi, R., Halimatulzahara, D., & Yusoff, N. A.-N. (2014). Chemically modified sago waste for oil adsorption. *Journal of Science and Technology*, *22*(1), 153–161.

Nielsen, S. S. (2010). Phenol-sulfuric acid method for total carbohydrates. In *Food Analysis Laboratory Manual* (pp. 47–53). https://doi.org/10.1007/978-1-4419-1463-7

Ozturk, I., Irmak, S., Hesenov, A., & Erbatur, O. (2010). Hydrolysis of kenaf (Hibiscus cannabinus L .) stems by catalytical thermal treatment in subcritical water. *Biomass and Bioenergy*, *34*, 1578–1585. https://doi.org/10.1016/j.biombioe.2010.06.005

Pandey, M. P., & Kim, C. S. (2011). Lignin depolymerization and conversion : A review of thermochemical methods. *Chemical Engineering Technology*, *34*(1), 29–41. https://doi.org/10.1002/ceat.201000270
Parthasarathy, P., & Narayanan, S. K. (2013). Determination of kinetic parameters of biomass samples using thermogravimetric analysis. *Environmental Progress & Sustainable Energy*, *0*(0), 1–11. https://doi.org/10.1002/ep
Pásztory, Z., Mohácsiné, I. R., Gorbacheva, G., & Börcsök, Z. (2016). The utilization of tree bark. *BioResources*, *11*(3), 7859–7888. https://doi.org/10.15376/biores.11.3.Pasztory
Pavloviè, I., Knez, Ý., & Škerget, M. (2013a). Hydrothermal reactions of agricultural and food processing wastes in sub- and supercritical water : A review of fundamentals , mechanisms and state of research. *Journal of Agricultural and Food Chemistry*, *61*(34), 8003–8025. https://doi.org/10.1021/jf401008a
Pavloviè, I., Knez, Ý., & Škerget, M. (2013b). Subcritical water – A perspective reaction media for biomass processing to chemicals : Study on cellulose conversion as a model for biomass. *Chemical and Biochemical Engineering Quarterly*, *27*(1), 73–82.
Perez, J., & Munoz-Dorado, J. (2002). Biodegradation and biological treatments of cellulose, hemicellulose and lignin : An overview. *International Microbiology*, *5*, 53–63. https://doi.org/10.1007/s10123-002-0062-3
Peterson, A. A., Vogel, F., Lachance, R. P., Froling, M., Antal, M. J., & Tester, J. W. (2008). Thermochemical biofuel production in hydrothermal media : A review of sub- and supercritical water technologies. *Energy & Environmental Sciences*, *1*, 32–65. https://doi.org/10.1039/b810100k
Pettersen, R. C. (1984). *The Chemical Composition of Wood*. American Chemical Society.
Pinkowska, H., Wolak, P., & Adrianna, Z. (2011). Hydrothermal decomposition of xylan as a model substance for plant biomass waste-Hydrothermolysis in subcritical water. *Biomass and Bioenergy*, *35*, 3902–3912. https://doi.org/10.1016/j.biombioe.2011.06.015
Pińkowska, H., Wolak, P., & Oliveros, E. (2013). Production of xylose and glucose from rapeseed straw in subcritical water - Use of Doehlert design for optimizing the reaction conditions. *Biomass and Bioenergy*, *58*, 188–197. https://doi.org/10.1016/j.biombioe.2013.09.005
Pourali, O., Salak, F., & Yoshida, H. (2009). Sub-critical water treatment of rice bran to produce valuable materials. *Food Chemistry*, *115*(1), 1–7. https://doi.org/10.1016/j.foodchem.2008.11.099
Prado, Juliana M., Forster-Carneiro, T., Rostagno, M. A., Follegatti-Romero, L. A., Maugeri Filho, F., & Meireles, M. A. A. (2014). Obtaining sugars from coconut husk, defatted grape seed, and pressed palm fiber by hydrolysis with subcritical water. *Journal of Supercritical Fluids*, *89*, 89–98. https://doi.org/10.1016/j.supflu.2014.02.017
Prado, Juliana M, Carneiro, T. F., Gigo, M. A., Celestrino, R. C. C., Follegatti-Romero, L. A., Filho, F. M., & Meireles, M. A. A. (2013). Subcritical water hydrolysis of sugarcane bagasse. In *III Iberomerican conference on supercritical fluids cartegena de Indias (Colombia)* (pp. 1–9).
Prado, Juliana M, Lachos-perez, D., Forster-carneiro, T., & Rostagno, M. A. (2015). Sub- and supercritical water hydrolysis of agricultural and food industry residues for the production of fermentable sugars : A review. *Food and Bioproducts Processing*, *98*, 95–123. https://doi.org/10.1016/j.fbp.2015.11.004
Prado, Julianaa M, Lachos-Perez, D., Foster-Carneiro, T., & Rostagno, M. A. (2015).

Sub- and supercritical water hydrolysis of agricultural and food industry residues for the production of fermentable sugars: A review. *Food and Bioproducts Processing*, 1–57. https://doi.org/10.1016/j.fbp.2015.11.004

Renninger, H. J., Mcculloh, K. A., & Phillips, N. (2013). A comparison of the hydraulic efficiency of a palm species (Iriartea deltoidea) with other wood types. In *Tree Physiology* (Vol. 33, pp. 152–160). https://doi.org/10.1093/treephys/tps123

Reza, M. T., Andert, J., Wirth, B., Busch, D., Pielert, J., Lynam, J. G., & Mumme, J. (2014). Hydrothermal carbonization of biomass for energy and crop production. *Applied Bioenergy*, *1*, 11–29. https://doi.org/10.2478/apbi-2014-0001

Rogalinski, T., Liu, K., Albrecht, T., & Brunner, G. (2008). Hydrolysis kinetics of biopolymers in subcritical water. *Journal of Supercritical Fluids*, *46*, 335–341. https://doi.org/10.1016/j.supflu.2007.09.037

Sabiha Hanim, S., Norsyabilah, R., Nor Suhaila, M. H., Noraishah, A., & Siti Kartina, A. K. (2012). Effects of temperature, time and pressure on the hemicelluloses yield extracted using subcritical water extraction. *Procedia Engineering*, *42*(August), 562–565. https://doi.org/10.1016/j.proeng.2012.07.448

Saffe, A., Fernandez, A., Mazza, G., & Rodriguez, R. (2018). Prediction of regional agro-industrial wastes characteristics by thermogravimetric analysis to obtain bioenergy using thermal process. *Energy Exploration & Exploitation*, *0*(0), 1–14. https://doi.org/10.1177/0144598718793908

Sarawak Agriculture Statistic. (2013). Retrieved December 20, 2017, from http://www.doa.sarawak.gov.my/modules/web/pages.php?mod=webpage&sub=page&id=712

Savou, V., Grause, G., Kumagai, S., Saito, Y., & Kameda, T. (2018). Pyrolysis of sugarcane bagasse pretreated with sulfuric acid. *Journal of the Energy Institute*, *30*, 1–9. https://doi.org/10.1016/j.joei.2018.06.003

Schuiling, D. L. (2009). *Growth and development of true sago palm (Metroxylon sagu Rottbøll)- A study on morphology, genetic variation, and ecophysiology, and their implications for cultivation*. Wageningen University.

Shahrim, Z., Sabaratnam, V., Rahman, N. A. A., Abd-Aziz, S., Hassan, M. ., & Karim, M. I. . (2008). Production of reducing sugars by Trichoderma sp. KUPM0001 during solid substrate fermentation of sago starch processing waste hampas. *Research Journal of Microbiology*, *3*(9), 569–579.

Shitu, A, Izhar, S., & Tahir, T. . (2015). Sub-critical water as a green solvent for production of valuable materials from agricultural waste biomass : A review of recent work. *Global Journal of Environmental Science and Management*, *1*(3), 255–264.

Shitu, Abubakar, Muhammad, A. I., Yoshida, H., & Izhar, S. (2016). Production of phenolic compounds from durian peel waste using sub-critical water. In *International Conference on Agricultural and Food Engineering* (pp. 59–65).

Sindhu, R., Kuttiraja, M., Binod, P., Sukumaran, R. K., & Pandey, A. (2014). Physicochemical characterization of alkali pretreated sugarcane tops and optimization of enzymatic saccharification using response surface methodology. *Renewable Energy*, *62*, 362–368. https://doi.org/10.1016/j.renene.2013.07.041

Singhal, R. S., Kennedy, J. F., Gopalakrishnan, S. M., Kaczmarek, A., Knill, C. J., & Akmar, P. F. (2008). Industrial production, processing, and utilization of sago palm-derived products. *Carbohydrate Polymers*, *72*(1), 1–20. https://doi.org/10.1016/j.carbpol.2007.07.043

Smith, K. (2015). *The sago palm: The food and environmental challenges of the 21st century*.

Somerville, C. (2006). Cellulose Synthesis in Higher Plants. *The Annual Review of Cell* *and Developmental Biology*, *22*, 53–78. https://doi.org/10.1146/annurev.cellbio.22.022206.160206

Sorek, N., Yeats, T. H., Szemenyei, H., Youngs, H., & Somerville, C. R. (2014). The implications of lignocellulosic biomass chemical composition for the production of advanced biofuels. *Bioscience*, *64*(3), 192–201. https://doi.org/10.1093/biosci/bit037

Sukiran, M. A., Chin, C. M., & Bakar, N. K. A. (2009). Bio-oils from pyrolysis of oil palm empty fruit bunches. *American Journal of Applied Science*, *6*(5), 869–875.

Sulaiman, O., Salim, N., Nordin, N. A., Hashim, R., Ibrahim, M., & Sato, M. (2012). The potential of oil palm trunk biomass as an alternative source for compressed wood. *BioResources*, *7*(2), 2688–2706.

Sun, S., Sun, S., Cao, X., & Sun, R. (2016). The role of pretreatment in improving the enzymatic hydrolysis of lignocellulosic materials. *Bioresource Technology*, *199*, 49–58.

Szczerbowski, D., Pitarelo, A. P., Filho, A. Z., & Ramos, L. P. (2014). Sugarcane biomass for biorefineries : Comparative composition of carbohydrate and non-carbohydrate components of bagasse and straw. *Carbohydrate Polymers*, *114*, 95–101. https://doi.org/10.1016/j.carbpol.2014.07.052

Taherzadeh, M. J., & Karimi, K. (2007). Acid-based hydrolysis processes for ethanol from lignocellulosic materials: A review. *BioResources*, *2*(3), 472–499.

Tanaka, M., Takamizu, A., Hoshino, M., Sasaki, M., & Goto, M. (2012). Food and Bioproducts Processing Extraction of dietary fiber from Citrus junos peel with subcritical water. *Food and Bioproducts Processing*, *90*, 180–186. https://doi.org/10.1016/j.fbp.2011.03.005

Tangkhavanich, B., Kobayashi, T., & Adachi, S. (2012). Properties of rice straw extract after subcritical water treatment. *Bioscience, Biotechnology, and Biochemistry*, *76*(6), 1146–1149. https://doi.org/10.1271/bbb.110983

TAPPI. (1997a). T 204 cm-97. Solvent extractives of wood and pulp. *Technical Association of the Pulp and Paper Industry*. https://doi.org/10.5772/916

TAPPI. (1997b). T 264 cm-97. Preparation of wood for chemical analysis.

TAPPI. (1998). T 222 om-98. Acid-insoluble lignin in wood and pulp. *TAPPI standard test methods*. https://doi.org/10.1023/a:1019003230537

TAPPI. (1999). T 203 cm-99. Alpha-, beta- and gamma-cellulose in pulp.

TAPPI. (2002). T257 cm-02. Sampling and preparing wood for analysis.

Toor, S., Rosendahl, L., & Rudolf, A. (2011). Hydrothermal liquefaction of biomass : A review of subcritical water technologies. *Energy*, *36*(5), 2328–2342. https://doi.org/10.1016/j.energy.2011.03.013

Toor, S. S., Rosendahl, L., & Rudolf, A. (2011). Hydrothermal liquefaction of biomass : A review of subcritical water technologies. *Energy*, *36*(5), 2328–2342. https://doi.org/10.1016/j.energy.2011.03.013

Vek, V., Oven, P., & Poljansek, I. (2016). Review on lipophilic and hydrophilic extractives in tissues of common beech. *Dvrna Industrija*, *67*(1), 85–96. https://doi.org/10.5552/drind.2016.1511

Vikineswary, S., Shim, Y. L., Thambirajah, J. J., & Blakebrough, N. (1994). Possible microbial utilization of sago processing wastes. *Resources, Conservation and Recycling*, *11*(1–4), 289–296. https://doi.org/10.1016/0921-3449(94)90096-5

Vincent, M., Senawi, B. R., Esut, E., Muhammad Nor, N., & Awg-Adeni, D. S. (2015). Sequential saccharification and simultaneous fermentation (SSSF) of sago hampas for the production of bioethanol. *Sains Malaysiana*, *44*(6), 899–904.

Visakh, P. M., & Thomas, S. (2010). Preparation of bionanomaterials and their polymer nanocomposites from Waste and Biomass. *Waste and Biomass Valorization*, *1*, 121–134. https://doi.org/10.1007/s12649-010-9009-7

Wahi, R., Chuah, L. A., Ngaini, Z., Nourouzi, M. M., & Choong, T. S. Y. (2014). Esterification of M. sagu bark as an adsorbent for removal of emulsified oil. *Journal of Environmental Chemical Engineering*, *2*(1), 324–331. https://doi.org/10.1016/j.jece.2013.12.010

Wahyudi, & Arifudin, M. (2017). Flexural strength properties of glulam made from combining of sago bark and two wood species from West Papua. *European Journal of Wood and Wood Products*, 1–4. https://doi.org/10.1007/s00107-017-1229-0

Wan, Y. K., Sadhukhan, J., & Ng, D. K. S. (2016). Techno-economic evaluations for feasibility of sago-based biorefinery , Part 2 : Integrated bioethanol production and energy systems. *Chemical Engineering Research and Design*, *107*, 102–116. https://doi.org/10.1016/j.cherd.2015.09.017

Wang, H., Gurau, G., & Rogers, R. D. (2012). Ionic liquid processing of cellulose. *The Royal Society Chemistry*, *41*, 1519–1537. https://doi.org/10.1039/c2cs15311d

Wang, L., Liu, H., Xie, A., Zhu, C., & Qin, G. (2018). Dietary Fiber Extraction from Defatted Corn Hull by Hot-Compressed Water. *Polish Journal of Food and Nutrition Sciences*, *68*(2), 133–140. https://doi.org/10.1515/pjfns-2017-0015

Wang, Y., Yao, G., & Jin, F. (2014). Hydrothermal Conversion of Cellulose into Organic Acids with a CuO Oxidant. In *Application of Hydrothermal Reactions to Biomass Conversion, Green Chemistry and Sustainable Technology* (pp. 31–59). https://doi.org/10.1007/978-3-642-54458-3

Warashina, S., Nitta, Y., Matsuda, T., Nakayama, T., & Sasaki, Y. (2007). Formation portion f intercellular spaces and feature of starch accumulation in sago palm (Metroxylon sagu Rottb.). *Japanese Journal of Cropscience*, *76*, 356–357.

Wiboonsirikul, J., Mori, M., Khuwijitjaru, P., & Adachi, S. (2013). Properties of extract from okara by its subcritical water treatment. *International Journal of Food Properties*, *16*(5), 974–982. https://doi.org/10.1080/10942912.2011.573119

Windsor-Collins, A., Cutler, D., Atherton, M., & Collins, M. (2007). The palm – a model for success ? In *Design and informtion biology: From molecules to system* (Vol. 27, pp. 303–326). https://doi.org/10.2495/978-1-85312-853-0/10

Yan, Y., Zhang, C., Lin, Q., Wang, X., Cheng, B., Li, H., & Ren, J. (2018). Microwave-assisted oxalic acid pretreatment for the enhancing of enzyme hydrolysis in the production of xylose and arabinose from bagasse. *Molecules*, *23*, 1–13. https://doi.org/10.3390/molecules23040862

Yang, B., Tao, L., & Wayman, C. E. (2017). Strengths, challenges, and opportunities for hydrothermal pretreatment in lignocellulosic biorefineries. *Biofuels, Bioproducts and Biorefining*, 1–14. https://doi.org/10.1002/bbb.1825

Yao, X., Xu, K., & Liang, Y. (2017). Assessing the effects of different process parameters on the pyrolysis behaviors and thermal dynamics of corncob fractions. *BioResources*, *12*(2), 2748–2767.

Yoshida, H., Izhar, S., Nishio, E., Utsumi, Y., Kakimori, N., & Feridoun, S. A. (2014). Recovery of indium from TFT and CF glasses in LCD panel wastes using sub-critical water. *Solar Energy Materials and Solar Cells*, *125*, 14–19. https://doi.org/10.1016/j.solmat.2014.02.009

Yoshida, H., & Katayama, Y. (2004). Production of Useful Substances from Wood Wastes by Sub-critical Water Hydrolysis. In *Asian Pacific Confederation of Chemical Engineering congress program and abstracts* (pp. 1–9).

Yoshida, H., & Tavakoli, O. (2004). Subcritical Water Hydrolysis Treatment for Waste Squid Entrails and Production of Amino Acids , Organic Acids , and Fatty ... *Journal of Chemical Engineering Japan*, *37*(2), 253–260.

https://doi.org/10.1252/jcej.37.253

Yoshida, H., Terashima, M., & Takahashi, Y. (1999). Production of Organic Acids and Amino Acids from Fish Meat by Sub-Critical Water Hydrolysis. *Biotechnology Progress*, *15*, 1090–1094.

Yoswathana, N., & Eshtiaghi, M. N. (2013). Optimization for subcritical water extraction of phenolic compounds from rambutan peels. *World Academy of Science, Engineering and Technology*, *7*(6), 323–327.

Yu, P., Damiran, D., Azarfar, A., & Niu, Z. (2011). Detecting molecular features of spectra mainly associated with structural and non-structural carbohydrates in co-products from bioethanol production using DRIFT with uni- and multivariate molecular spectral analyses. *International Journal Oof Molecular Sciences*, *12*, 1921–1935. https://doi.org/10.3390/ijms12031921

Yu, Y., Lou, X., & Wu, H. (2008). Some recent advances in hydrolysis of biomass in hot-compressed water and its comparisons with other hydrolysis methods. *Energy & Fuels*, *22*, 46–60. https://doi.org/10.1021/ef7002969

Yu, Y., & Wu, H. (2010). Significant differences in the hydrolysis behavior of amorphous and crystalline portions within microcrystalline cellulose in hot-compressed water. *Industrial & Engineering Chemistry Research*, *49*, 3902–3909.

Zarrinbakhsh, N., Wang, T., Rodriguez-uribe, A., Misra, M., & Mohanty, A. K. (2016). Characterization of wastes and coproducts from the coffee industry for composite material production. *BioResources*, *11*(3), 7637–7653.

Zazalli, M., Yoshida, H., Halim, M., Ismail, S., Sabli, N., & Izhar, S. (2017). Recovery of Oil from Waste Palm Kernel Cake by Sub-Critical Water. *International Journal of Applied Engineering Research*, *12*(24), 14574–14579.

Zhang, Bide, Heidari, M., Regmi, B., Salaudeen, S., Arku, P., Thimmannagari, M., & Dutta, A. (2018). Hydrothermal carbonization of fruit wastes: A promising technique for generating hydrochar. *Energies*, *11*, 1–14. https://doi.org/10.3390/en11082022

Zhang, Bo, Keitz, M. Von, & Valentas, K. (2009). Thermochemical liquefaction of high-diversity grassland perennials. *Journal of Analytical and Applied Pyrolysis*, *84*, 18–24. https://doi.org/10.1016/j.jaap.2008.09.005

Zhao, Y., Lu, W., Chen, J., Zhang, X., & Wang, H. (2014). Research progress on hydrothermal dissolution and hydrolysis of lignocellulose and lignocellulosic waste. *Frontiers of Environmental Science and Engineering*, *8*(2), 151–161. https://doi.org/10.1007/s11783-013-0607-z

Zhong, C., & Wei, X. (2004). A comparative experimental study on the liquefaction of wood. *Energy*, *29*, 1731–1741. https://doi.org/10.1016/j.energy.2004.03.096

Zhu, G., Zhu, X., Fan, Q., & Wan, X. (2011). Production of reducing sugars from bean dregs waste by hydrolysis in subcritical water. *Journal of Analytical and Applied Pyrolysis*, *90*, 182–186. https://doi.org/10.1016/j.jaap.2010.12.006

BIODATA OF STUDENT

The student, Nurhusni binti M. Amin was born on February 16th, 1993 in Kuala Lumpur. Her first education wat at SK. Taman Koperasi Polis (SKTKP) Fasa II from 2000 to 2006. Her secondary school was SMA. Persekutuan Kajang (SMAPK), 2006 to 2010. She completed her foundation studies in Agricultural Science, at Universiti Putra Malaysia, (UPM) in 2012. She obtained her degree in Bachelor of Engineering (Chemical) in 2016 from UPM. Later on the same year, she furthered her study in Master of Science (Major in Chemical Engineering) at the same institution, UPM.

LIST OF PUBLICATIONS

Journal

Amin, N., Sabli, N., Izhar, S., & Yoshida, H. (2020). Production of valuable materials from sago bark using subcritical water treatment. *Int. J. Eng. Res. Technol*, *13*(1), 1-11.

Amin, N., Sabli, N., Izhar, S., & Yoshida, H. (2019). Sago wastes and its applications. *Pertanika J. Sci. & Technol*, *27*(4), 1841-1862.

Conference

1. Nurhusni M. Amin, Nordin Sabli, Shamsul Izhar and Hiroyuki Yoshida (2017). Production of Valuable Materials from Sago Bark Using Subcritical Water Treatment. Oral Presentation. *The Asian Conference on Oleo Science 2017,* 11th - 13th September 2017. Tokyo University of Science, Japan

2. Nurhusni M. Amin, Nordin Sabli, Shamsul Izhar and Hiroyuki Yoshida (2017). Extraction of Sago Bark Using Sub-critical Water Treatment. Oral Presentation. *Wood and Biofiber International Conference (WOBIC2017)*, 21st - 23rd December 2017. Hotel-Bangi Putrajaya, Malaysia

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