SIMULTANEOUS SACCHARIFICATION AND FERMENTATION PROCESS OF BIOETHANOL FROM PALM OIL EMPTY FRUIT BUNCHES

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ABSTRACT

Currently, new renewable energy resources are seek out to substitute fossil fuels in the transportation sector in order to tackle the increasing energy demand. Bioethanol emerge as a potential option in replacing transportation fuels of gasoline. Oil palm empty fruit bunches (EFBs) are one of the promising biomass wastes, which can be utilized as a feedstock for the second generation bioethanol production. Optimal conditions are required for a cost-efficient bioethanol fuel processes from EFBs. Thus, this study aims to optimize the process conditions for bioethanol production from EFBs through simultaneous saccharification and fermentation (SSF) process using Response Surface Methodology (RSM). This study can be divided into two main parts which are the screening of the optimum concentration of enzymes and microorganisms and optimization of fermentation parameters. In this study, EFBs were treated using sequential acid and alkali treatment before being used as substrate. Physical morphologies and structures of the EFBs were analyzed using Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FTIR). The findings revealed that the pretreatment has changed the morphology and EFBs structure by removing silica which act as the chemical composition barrier that causes pores formation. In the first part of this study, the optimum combination of enzymes and microbes for bioethanol production was screened. According to the results, co-cultures of *S. cerevisiae* and *T. harzianum* combined with Cellulase and β-glucosidase was selected for further used in the fermentation steps. This combination produced the highest bioethanol concentration determined at 11.76 mg/mL. Under optimal conditions for enzymatic saccharification, 4% (w/v) of pretreated EFB was completely hydrolyzed and produced 21.14 ± 1.49 mg/mL glucose at 50 °C, 150 rpm and 72 hours operating conditions. In the second part in this study, Central Composite Design of RSM was employed to optimize the SSF process including the fermentation time, temperature, inoculum concentration, and pH. It was found that fermentation for 72 hours duration, 30 °C and pH 4.8 of media using 6.79% (v/v) of inoculum concentration could produce up to 9.72 mg/mL of bioethanol and 0.46 g/g glucose of bioethanol yield with 90.63% conversion efficiency. Fermentation conducted under optimum conditions yielded 9.65 mg/mL of bioethanol, 0.46 g/g glucose of bioethanol yield and 89.56% conversion efficiency which were in close agreement with the model suggested. Overall, this study showed better results for bioethanol production as compared to previous research done using EFBs as the feedstocks.

ABSTRAK

SIMULTANEOUS SACCHARIFICATION AND FERMENTATION PROCESS OF BIOETHANOL FROM PALM OIL EMPTY FRUIT BUNCHES

Pada masa ini, sumber tenaga baru yang boleh diperbaharui untuk menggantikan bahan api fosil dalam sektor pengangkutan dicari untuk menangani permintaan tenaga yang semakin meningkat. Bioetanol muncul sebagai pilihan yang berpotensi untuk menggantikan bahan api pengangkutan petrol. Tandan kosong kelapa sawit (EFBs) adalah salah satu daripada sisa biomas yang berpotensi untuk digunakan sebagai bahan mentah untuk pengeluaran bioetanol generasi kedua. Keadaan optimum diperlukan untuk menghasilkan bioethanol yang kos efektif. Oleh itu, matlamat kajian ini adalah untuk mengoptimumkan pengeluaran bioetanol dari EFBs melalui proses sakcarifikasi dan penapaian serentak (SSF) menggunakan Metodologi permukaan tindakbalas (RSM). Kajian ini boleh dibahagikan kepada dua bahagian utama iaitu pemeriksaan optimum enzim dan mikroorganisma serta pengoptimuman parameter penapaian. Dalam kajian ini, EFBs dirawat dengan menggunakan Pra-rawatan alkali asid berturutan sebelum digunakan sebagai substrat. Morfologi dan struktur fizikal EFBs dianalisis menggunakan Mikroskop Pengimbasan Elektron (SEM) dan Inframerah Transformasi Fourier (FTIR). Dapatan kajian menunjukkan bahawa proses pra-rawatan telah mengubah morfologi dan struktur EFBs dengan membuang silika yang bertindak sebagai komposisi kimia yang menyebabkan pembentukan liang-liang. Pada bahagian pertama kajian ini, gabungan optimum enzim dan mikroorganisma bagi pengeluaran bioetanol telah ditapis. Menurut hasil proses penyaringan, kokultur S. cerevisiae dan T. harzianum digabungkan dengan enzim selulase dan β-glucosidase dipilih untuk digunakan lebih lanjut dalam penapaian proses. Kombinasi ini menghasilkan kepekatan bioetanol tertinggi iaitu 11.76 ± 0.79 g/ L bioethanol. Di bawah keadaan optimum untuk sakcarifikasi enzimatik, 4% (w/v) EFB yang sudah dirawat, dihidrolisis sepenuhnya dan menghasilkan 21.14 ± 1.49 mg/mL glukosa pada 50 °C, 150 rpm dan 72 jam operasi. Dalam bahagian kedua kajian ini, CCD dalam kaedah RSM digunakan untuk pengoptimuman bagi SSF proses termasuk masa penapaian, suhu, kepekatan inoulum dan pH. Ia didapati bahawa penapaian selama 72 jam, 30 °C dan pH 4.8 media menggunakan 6.79% (v/v) kepekatan inokulum boleh menghasilkan 9.72 mg/mL bioetanol, 0.46 g/g glukosa hasil bioetanol dengan 90.63% kecekapan penukaran. Proses penapaian yang dilakukan menggunakan keadaan yang dioptimumkan berjaya menghasilkan 9.65 mg/mL bioetanol, 0.46 g/g glukosa hasil bioetanol dan 89.56% kecekapan penukaran bersesuaian dengan jumlah yang diramalkan oleh model CCD. Secara keseluruhannya, kajian ini telah menunjukkan hasil yang lebih baik dalam penghasilan bioetanol berbanding dengan kajian terdahulu mengunakan buah tandan kosong sebagai sumber utama.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
ATCC	-	American Type Culture Collection
C	-	Carbon
CO_2	-	Carbon Dioxide
CCD	-	Central Composite Design
C.V.	-	Coefficient of Variation
EFBs	-	Empty Fruit Bunches
FTIR	-	Fourier Transform Infrared Spectroscopy
GC-MS	-	Gas Chromatography Mass Spectrophotometer
HCl	-	Hydrochloric Acid
H_2SO_4	-	Sulphuric Acid
HPLC	-	High Performance Liquid Chromatography
PRESS	-	Predicted Residual Sum of Squares
POME	-	Palm Oil Mill Effluent
R^2	-	Correlation coefficient
RPM	-	Rotation per Minute
RSM	-	Response Surface Methodology
SD	-	Standard Deviation
SEM	-	Scanning Electron Microscope
SSF	-	Simultaneous Saccharification and Fermentation

LIST OF SYMBOLS

μm	-	Micromolar
μL	-	Microlitre
%	-	Percentage
° C	-	Degree celcius
g/g	-	Gram per gram
g/L	-	Gram per litre
g/mL	-	Gram per Millilitre
h	-	Hour
s	-	Second
min	-	Minute
U	-	Enzyme unit
mg/mL	-	Milligram per Millilitre
v/v	-	Volume per volume
w/v	-	Weight per volume

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CHAPTER 1

INTRODUCTION

1.1 Research Overview

More and more research are done to discover new renewable energy resources due to the increasing energy security, global energy demand, industrialized economy and continuous growth of world population (Gaurav *et al.*, 2017; Raman and Gnansounou, 2014). Hence, research on the biofuels production is done to overcome this matter since it can be used as a source of energy to meet the world's increasing energy demand. Biofuels had been one of the candidates among the renewable energy resources in replacing fossil fuels in the transportation sector (Raman and Gnansounou, 2014). However, its feedstock becomes an issue as it is mainly used human-food which causes worldwide dissatisfaction due to a shortage of food mainly in developing nations (Alam *et al.*, 2015). To tackle this food versus fuel conflict, the focus of biofuels research has changed towards manipulating agricultural waste and non-crop resource for example biomass wastes for production of bioethanol, and algae and non-edible oil crops for biodiesel (Raman and Gnansounou, 2014). Biodiesel and bioethanol are two most important liquid biofuels which emerged as a potential option in replacing transportation fuels of gasoline and diesel (Luque *et al.*, 2009).

Bioethanol is a renewable and sustainable liquid biofuels which can be produced locally to meet day to day high-energy sources demand (Sudiyani *et al.*, 2013). It is a promising renewable energy sources, but it requires a suitable technology in order for the conversion is economically feasible (Samsudin and Mat Don, 2015). Its production from cellulosic biomass is also rising as one of the essential technologies for the production of sustainable renewable fuels for transportation (Sukumaran *et al.*, 2009). In recent years, extensive expansion and swift growth of bioethanol have produced a terrific amount of ethanol by-products from the fermentation process. Sustainable and renewable bioethanol will limit and reduce the usage of fossil fuels. Consequently, bioethanol will soon become fossil gasoline substitution or replacement as an alternative and renewable energy (Hanif *et al.*, 2016). Prior to that, developments of suitable bioprocesses are needed to convert biomass feedstocks into higher value and yield of bioethanol production. It is important to reduce its production cost by reducing the feedstock and operational cost (Zabed *et al.*, 2017).

Agricultural and forestry residues (lignocellulosic biomass), and algae are potential substrates in terms of availability and cost, however, it faces some processing problems as it produce lower yield ethanol with higher production costs (Izmirlioglu and Demirci, 2017). Thus, a more valuable feedstock actually comes from a biomass waste as it does not involve in the "food versus fuel" conflict, cheaper and renewable which can benefit the biofuels industry. Bioconversion of the lignocellulosic waste materials to chemical and biofuel also attracts attention as they are renewable, low cost, and widespread in nature (Sudiyani *et al.*, 2013). In Malaysia, agricultural biomass wastes became very promising alternative resources for production of second generation bioethanol (SGB) since agricultural are one of the major industries contributed to the economy. Malaysian market for bioethanol is larger than the biodiesel market as larger proportion of the transportation vehicle runs on gasoline. Thus, promoting and implementing bioethanol production effectively is a tactical move for Malaysia to become a self-sufficient country in the near future (Tye *et al.*, 2011). Hence, Malaysia has the potential to play a major role in the world of biofuels and food market because of its large and growing palm oil industry, plus with a strong global demand for palm oil (Gan and Li, 2014).

Malaysia is one of the growing economies countries in South-East Asia which is important for its oil palm industry (Basri *et al.*, 2015). Oil palm industry is one of the important agricultural sectors in Malaysia. However, the industry contributed to a major biomass waste production, where empty fruit bunches are discarded after the oil extraction from the fruit bunches. Every million tonnes of oil palm caused another million tonnes of EFBs to be thrown, as each tonne harvested from the palm plantation, 20 % will be the oil while the rest, 80 % became the biomass waste (Hassan *et al.*, 2013). Utilization of sustainable and renewable energy sources, mainly oil palm wastes, has been improved since it is able to lessen the agriculture disposal dilemma in an environmental friendly approach (Al-Zuhair *et al.*, 2011). Oil palm biomass is a promising renewable energy source due to rising price of crude oil. Therefore, converting oil palm biomass into biofuel is not only able to reduce the petrol crisis but also helps to protect the environment by reducing CO_2 and greenhouse gas emission (Shuit *et al.*, 2009). Hence, EFBs is a promising feedstock for bioconversion into bioethanol fuel because it is rich in lignocellulosic content, easily accessible and abundant in Malaysia. Bioethanol production from oil palm industrial wastes has gained attention not only because of the reduced production cost, but also the ethanol production productivity (Izmirlioglu and Demirci, 2017).

Bioethanol production from lignocellulosic biomass requires four main steps: physical and chemical pretreatment of the lignocellulosic biomass, enzymatic hydrolysis of cellulose to sugars, fermentation of the resulting sugars and distillation of ethanol (Kamm and Kamm, 2004). Pretreatment processes are key technologies for generating fermentable sugars based on lignocellulosic biomass. It is necessary to remove the lignin and hemicellulose contents in EFBs (Kim *et al.*, 2012). In hydrolysis, enzymes that are mostly employed to degrade the polysaccharides are cellulases which can be categorized into three main types including β-glucosidase, endo-glucanases and exo-glucanases. Research by Nur Atikah *et al.* (2016) treated the EFBs with combination enzymes of Cellic Ctech2 and Cellic Htech2 in the enzymatic hydrolysis. Hydrolysis and fermentation process can be achieved by several process strategies which include separate hydrolysis and fermentation (SHF), and simultaneous saccharification and fermentation (SSF). According to Chen *et al.*, the SSF process has other benefits such as reduced operation costs, lower enzyme requirement and increased productivity (Chen *et al.*, 2007). A great number of microorganisms can be used for bioethanol production. *S. cerevisiae* (baker's yeast) is the most frequently and traditionally used organism in fermentation (Dahnum *et al.*, 2015; Kim and Kim, 2013; Samsudin and Mat Don, 2015).

Application of microorgansism in biofuels production is believed to be the key in solving problems of environmental pollution associated with fossil fuels (Tang *et al*, 2015). Different microorganisms that are used in the fermentation process can also influence the yield of bioethanol production. Microorganism such as *Saccharomyces cerevisiae* is mainly used for bioethanol production. Kabbashi *et al.*, compared the compatibility of several fungal and yeast to develop direct solid-state bioconversion using the potential mixed culture to produce bioethanol (Kabbashi *et al.*, 2007). Thus, a combination of fungal and yeast such as *Trichoderma harzianum* and *Saccharomyces cerevisiae* can be used if higher ethanol yield is produced than using one strain of microorganisms (Kabbashi *et al.*, 2007). Study by Alam and Al-Khatib (2014) also produced bioethanol from EFBs by using co-culture of *Saccharomyces cerevisiae* and *Aspergillus niger*. Meanwhile, Ali *et al.* (2014) produced higher bioethanol by using co-culture of *Saccharomyces cerevisiae* and *Pichia stipitis*.

To our knowledge, there is no published report yet on the bioethanol production using SSF from empty fruit bunches (EFB) by a combination of two different microorganisms, *Saccharomyces cerevisiae,* and *Trichoderma harzianum*. The aim of this study is to optimize the production of ethanol by two different strains of microorganisms and enzymes during the fermentation process by employing the Response Surface Methodology (RSM). RSM was used in this study, to overcome the limitation of one-at-a-time-parameter optimization.

1.2 Problem Statement

Development of sustainable bioethanol has become a central solution to overcome the issue of fossil fuels demand. However, there are several problems needed to be tackled in order to meet the bioethanol demand. One of the major problems with the bioethanol production is the raw materials availability (Balat *et al.*, 2008). Thus, oil palm empty fruit bunches (EFBs) which is the biomass waste from the oil palm

REFERENCES

Ab Majid, A. H., Zahran, Z., Abd Rahim, A. H., Ismail, N. A., Abdul Rahman, W., Mohammad Zubairi, K. S. & Satho, T. 2015. Morphological and molecular characterization of fungus isolated from tropical bed bugs in Northern Peninsular Malaysia, *Cimex hemipterus* (Hemiptera: *Cimicidae*). *Asian Pacific Journal of Tropical Biomedicine*, **5** (9): 707–713.

Abdullah, N. & Gerhauser, H. 2008. Bio-oil derived from empty fruit bunches. *Fuel*, **87** (12): 2606–2613.

Abo-state, M. A., Ragab, A. M. E., El-Gendy, N. S. & Farahat, L. A. 2014. Bioethanol Production from Rice Straw Enzymatically Saccharified by Fungal Isolates , *Trichoderma viride* F94 and *Aspergillus terreus* F98. *Scientific Research*, **3**: 19–29.

Abo-State, M. A., Ragab, A. M. E., EL-Gendy, N. S., Farahat, L. A. & Madian, H. R. 2013. Effect of different pretreatments on Egyptian sugar-cane bagasse saccharification and bioethanol production. *Egyptian Journal of Petroleum*, **22** (1): 161–167.

Abu Bakar, N. K., Zanirun, Z., Abd-Aziz, S., Ghazali, F. M. & Hassan, M. A. 2012. Production of fermentable sugars from oil palm empty fruit bunch using crude cellulase cocktails with *Trichoderma asperellum* UPM1 and *Aspergillus fumigatus* UPM2 for bioethanol production. *BioResources*, **7**(3): 3627–3639.

Adekunle, A., Orsat, V. & Raghavan, V. 2016. Lignocellulosic bioethanol: A review and design conceptualization study of production from cassava peels. *Renewable and Sustainable Energy Reviews*, **64**: 518–530.

Adela, N. 2014. Bioethanol Production by Fermentation of Oil Palm Empty Fruit Bunches Pretreated with Combined Chemicals. *Journal of Applied Environmental and Biological Sciences*, **4** (10): 234–242.

Aditiya, H. B., Chong, W. T., Mahlia, T. M. I., Sebayang, A. H., Berawi, M. A. & Nur, H. 2016. Second generation bioethanol potential from selected Malaysia's biodiversity biomasses: A review. *Waste Management*, **47**: 46–61.

Ahmad, F. B., Zhang, Z., Doherty, W. O. S. & O'Hara, I. M. 2016. Evaluation of oil production from oil palm empty fruit bunch by oleaginous micro-organisms. *Biofuels, Bioproducts and Biorefining*, **10**(4): 378–392.

Aisyah, M.S., Uemura, Y. & Yusup, S. 2014. The Effect of Alkaline Addition in Hydrothermal Pretreatment of Empty Fruit Bunches on Enzymatic Hydrolysis Efficiencies. *Procedia Chemistry*, **9**: 151–157.

Akhtar, J., Idris, A., Teo, C.L., Lai, L.W. & Hassan, N. 2014. Comparison of delignification of Oil Palm Empty Fruit Bunch (EFB) by Microwave assisted alkali / acid pretreatment and Conventional Pretreatment Method. *International Journal of Advances in Chemical Engineering and Biological Science*, **1**(2): 155–157.

Alam, F., Mobin, S. & Chowdhury, H. 2015. Third generation biofuel from Algae. *Procedia Engineering*, **105**: 763–768.

Alam, M.Z. & Al-Khatib, N.H.Z.F. 2014. Optimization of Bioethanol Production from Empty Fruit Bunches by Co-culture of *Saccharomyces cerevisiae* and *Aspergillus niger* using Statistical Experimental Design. *Journal of Pure and Applied Microbiology*, ***8*** (SPEC. ISS. 1): 731–740.

Alam, M.Z., Kabbashi, N.A. & Tompang, M.F. 2006. Development of single-step bioconversion process for bioethanol production by fungi and yeast using oil palm empty fruit bunches. *20th Symposium of Malaysian Chemical Engineers*, 1–6.

Alam, M.Z., Mamun, A.A., Qudsieh, I.Y., Muyibi, S.A., Salleh, H.M. & Omar, N.M. 2009. Solid state bioconversion of oil palm empty fruit bunches for cellulase enzyme production using a rotary drum bioreactor. *Biochemical Engineering Journal*, **46**(1): 61–64.

Ali, I.W., Aziz, K.K. & Syahadah, A.A.H. 2014. Bioethanol Production from Acid Hydrolysates of Date Palm Fronds Using a Co-culture of *Saccharomyces cerevisiae* and *Pichia stipitis*. *International Journal of Enhanced Research in Science Technology and Engineering*, **3**(5): 35–44.

Al-Shorgani, N.K.N., Shukor, H., Abdeshahian, P., Mohd Nazir, M.Y., Kalil, M.S., Hamid, A.A. & Wan Yusoff, W.M. 2015. Process optimization of butanol production by *Clostridium saccharoperbutylacetonicum* N1-4 (ATCC 13564) using palm oil mill effluent in acetone-butanol-ethanol fermentation. *Biocatalysis and Agricultural Biotechnology*, **4**(2): 244–249.

Alsuhaim, H., Vojisavljevic, V. & Pirogova, E. 2012. Effects of Non-thermal Microwave Exposures on the Proliferation Rate of *Saccharomyces Cerevisiae* yeast. *Research Gate*, 1–5.

Alvira, P., Tomás-Pejó, E., Ballesteros, M. & Negro, M.J. 2010. Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis: A review. *Bioresource Technology*, **101**(13): 4851–4861.

Al-Zuhair, S., Ramachandran, K.B., Farid, M., Aroua, M.K., Vadlani, P., Ramakrishnan, S. & Gardossi, L. 2011. Enzymes in Biofuels Production. *Enzyme Research*, 1–2.

Annie, D. 2006. *Biofuels Production, Trade and Sustainable Development: Emerging Issues.*, pp. 2-5. United Kingdom: International Institute for Environment and Development.

Ariffin, H., Hassan, M., Umi Kalsom, M., Abdullah, N., Shirai, Y. & Ariffin, H. 2008. Effect of physical, chemical and thermal pretreatments on the enzymatic hydrolysis of oil palm empty fruit bunch (OPEFB). *Journal of Trop. Agric. and Fd. Sc*, **36**(2): 1–100.

Ashokkumar, V., Razman, M., Salam, Z., Sivakumar, P., Tung, C., Elumalai, S. & Nasir, F. 2017. Production of liquid biofuels (biodiesel and bioethanol) from brown marine macroalgae *Padina tetrastromatica*. *Energy Conversion and Management*, **135**: 351–361.

Ask, M., Olofsson, K., Di, T., Ruohonen, L., Penttilä, M., Lidén, G. & Olsson, L. 2012. Challenges in enzymatic hydrolysis and fermentation of pretreated *Arundo donax* revealed by a comparison between SHF and SSF. *Process Biochemistry*, **47**(10): 1452–1459.

Aunsbjerg, S.D., Andersen, K.R. & Knøchel, S. 2015. Real-time monitoring of fungal inhibition and morphological changes. *Journal of Microbiological Methods*, **119**: 196–202.

Awalludin, M.F., Sulaiman, O., Hashim, R. & Nadhari, W.N.A.W. 2015. An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion, specifically via liquefaction. *Renewable and Sustainable Energy Reviews*, **50**: 1469–1484.

Aziz, A.A., Husin, M. & Anis, M. 2002. Preparation of cellulose from oil palm empty fruit bunches via ethanol digestion: Effect of acid and alkali catalysts. *Journal of Oil Palm Research*, **14**: 9–14.

Baharuddin, A.S., Nor, A.A.R., Umi, K.M.S., Mohd, A.H., Minato, W. & Yoshihito, S. 2011. Evaluation of pressed shredded empty fruit bunch (EFB)-palm oil mill effluent (POME) anaerobic sludge based compost using Fourier transform infrared (FTIR) and nuclear magnetic resonance (NMR) analysis. *African*

Journal of Biotechnology, **10**(41): 8082–8089.

Baharuddin, A.S., Sulaiman, A., Kim, D.H., Mokhtar, M.N., Hassan, M.A., Wakisaka, M. & Nishida, H. 2013. Selective component degradation of oil palm empty fruit bunches (OPEFB) using high-pressure steam. *Biomass and Bioenergy*, **55**: 268–275.

Balat, M., Balat, H. & Öz, C. 2008. Progress in bioethanol processing. *Progress in Energy and Combustion Science*, **34**(5): 551–573.

Barlianti, V., Dahnum, D., Hendarsyah, H. & Abimanyu, H. 2015. Effect of Alkaline Pretreatment on Properties of Lignocellulosic Oil Palm Waste. *Procedia Chemistry*, **16**: 195–201.

Basri, N.A., Ramli, A.T. & Aliyu, A.S. 2015. Malaysia energy strategy towards sustainability: A panoramic overview of the benefits and challenges. *Renewable and Sustainable Energy Reviews*, **42**: 1094–1105.

Ben-Iwo, J., Manovic, V. & Longhurst, P. 2016. Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. *Renewable and Sustainable Energy Reviews*, **63**: 172–192.

Bergman, L.W. 2001. Growth and Maintenance of Yeast. In P. N. MacDonald (Ed.). *Methods in Molecular Biology, Two Hybrid Systems: Methods and Protocols* (Vol. **177**, pp. 9–39). Humana Press Inc.

Bhadwal, A.S., Le, A., Le, T.T., Shrivastava, S. & Bera, T. 2013. *Trichoderma koningii* assisted biogenic synthesis of silver nanoparticles and evaluation of their antibacterial activity. *Advances In Natural Sciences: Nanoscience And Nanotechnology*, **2013**: 4.

Bibi, R., Ahmad, Z., Imran, M., Hussain, S., Ditta, A., Mahmood, S. & Khalid, A. 2017. Algal bioethanol production technology: A trend towards sustainable development. *Renewable and Sustainable Energy Reviews*, **71**: 976–985.

Bouza, R.J., Gu, Z. & Evans, J.H. 2016. Screening conditions for acid pretreatment and enzymatic hydrolysis of empty fruit bunches. *Industrial Crops and Products*, **84**: 67–71.

Brethauer, S. & Studer, M.H. 2014. Consolidated bioprocessing of lignocellulose by a microbial consortium. *Energy and Environmental Science*, **7**: 1446–1453.

Burhani, D., Putri, A.M.H., Waluyo, J., Nofiana, Y. & Sudiyani, Y. 2017. The effect of two-stage pretreatment on the physical and chemical characteristic of oil palm empty fruit bunch for bioethanol production. *AIP Conference Proceedings*, **1904**: 0020016 (2017).

Cardona, C.A., Sanchez, O.J. & Gutierrez, L.F. 2009. *Process Synthesis for Fuel Production.*, pp. 1-19. New York, USA: CRC Press.

Carneiro, M.L.N.M., Pradelle, F., Braga, S.L., Gomes, M.S.P., Martins, A.R.F.A., Turkovics, F. & Pradelle, R.N.C. 2017. Potential of biofuels from algae: Comparison with fossil fuels, ethanol and biodiesel in Europe and Brazil through life cycle assessment (LCA). *Renewable and Sustainable Energy Reviews*, **73**: 632–653.

Chang, S.H. 2014. An overview of empty fruit bunch from oil palm as feedstock for bio-oil production. *Biomass and Bioenergy*, **62**: 174–181.

Chen, H.Z., Xu, J. & Li, Z.H. 2007. Temperature cycling to improve the ethanol production with solid state simultaneous saccharification and fermentation. *Applied Biochemistry and Microbiology*, **43**(1): 57–60.

Cheng, J., Leu, S. Y., Zhu, J. Y. & Jeffries, T.W. 2014. Ethanol production from non-detoxified whole slurry of sulfite-pretreated empty fruit bunches at a low cellulase loading. *Bioresource Technology*, **164**: 331–337.

Chiesa, S. & Gnansounou, E. 2014. Use of empty fruit bunches from the oil palm for bioethanol production: A thorough comparison between dilute acid and dilute alkali pretreatment. *Bioresource Technology*, **159**: 355–364.

Chin, S.X., Chia, C.H. & Zakaria, S. 2013. Production of reducing sugar from oil palm empty fruit bunch (EFB) cellulose fibres via acid hydrolysis. *BioResources*, **8**(1): 447–460.

Chin, S.X., Chia, C.H., Zakaria, S., Fang, Z. & Ahmad, S. 2015. Ball milling pretreatment and diluted acid hydrolysis of oil palm empty fruit bunch (EFB) fibres for the production of levulinic acid. *Journal of the Taiwan Institute of Chemical Engineers*, **52**: 85–92.

Choi, W.I., Park, J.Y., Lee, J.P., Oh, Y.K., Park, Y.C., Kim, J.S. & Lee, J.S. 2013. Optimization of NaOH-catalyzed steam pretreatment of empty fruit bunch. *Biotechnology for Biofuels*, **6**(1): 170.

Chong, P.S., Jahim, J.M., Harun, S., Lim, S.S., Mutalib, S.A., Hassan, O. & Nor, M.T.M. 2013. Enhancement of batch biohydrogen production from prehydrolysate of acid treated oil palm empty fruit bunch. *International*

Journal of Hydrogen Energy, **38**(22): 9592–9599.

Christia, A., Setiowati, A.D., Millati, R., Karimi, K., Cahyanto, M.N., Niklasson, C. & Taherzadeh, M.J. 2016. Ethanol production from alkali- pretreated oil palm empty fruit bunch by simultaneous saccharification and fermentation with mucor indicus. *International Journal of Green Energy*, **13**(6): 566–572.

Coral Medina, J.D., Woiciechowski, A., Zandona Filho, A., Noseda, M.D., Kaur, B.S. & Soccol, C.R. 2015. Lignin preparation from oil palm empty fruit bunches by sequential acid/alkaline treatment - A biorefinery approach. *Bioresource Technology*, **194**: 172–178.

Cui, X., Zhao, X., Zeng, J., Loh, S.K., Choo, Y.M. & Liu, D. 2014. Robust enzymatic hydrolysis of Formiline-pretreated oil palm empty fruit bunches (EFB) for efficient conversion of polysaccharide to sugars and ethanol. *Bioresource Technology*, **166**: 584–591.

Dahnum, D., Tasum, S.O., Triwahyuni, E., Nurdin, M. & Abimanyu, H. 2015. Comparison of SHF and SSF processes using enzyme and dry yeast for optimization of bioethanol production from empty fruit bunch. *Energy Procedia*, **68**: 107–116.

De Azevedo, A.M.C., De Marco, J.L. & Felix, C.R. 2000. Characterization of an amylase produced by a *Trichoderma harzianum* isolate with antagonistic activity against *Crinipellis perniciosa*, the causal agent of witches' broom of cocoa. *FEMS Microbiology Letters*, **188**(2): 171–175.

Delabona, P.S., Farinas, C.S., Da Silva, M.R., Azzoni, S.F. & Pradella, J.G.C. 2012. Use of a new *Trichoderma harzianum* strain isolated from the Amazon rainforest with pretreated sugar cane bagasse for on-site cellulase production. *Bioresource Technology*, **107**: 517–521.

Demirbas, A. 2008. *Biofuels: Securing the Planet's Future Energy needs*, pp. 89. London: Springer Science and Business Media.

Demirbas, A. 2009. *Biorefineries: For biomass upgrading facilities*, pp 58-75. London: Springer Science and Business Media.

Derman, E., Abdulla, R., Marbawi, H. & Sabullah, M.K. 2018. Oil palm empty fruit bunches as a promising feedstock for bioethanol production in Malaysia. *Renewable Energy*, **129**: 285–298.

Dien, B.S., Cotta, M.A. & Jeffries, T.W. 2003. Bacteria engineered for fuel ethanol production: current status. *Applied Microbiology and Biotechnology*, **63** (3):

258–266.

Do, T.X., Lim, Y., Jang, S. & Chung, H. 2015. Hierarchical economic potential approach for techno-economic evaluation of bioethanol production from palm empty fruit bunches. *Bioresource Technology*, **189**: 224–235.

Duangwang, S. & Sangwichien, C. 2015. *Utilization of Oil Palm Empty Fruit Bunch Hydrolysate for Ethanol Production by Baker's Yeast and Loog-Pang. Energy Procedia*, **79**: 157-162.

Eliza, M.Y., Shahruddin, M., Noormaziah, J. & Rosli, W.D.W. 2015. Carboxymethyl Cellulose (CMC) from oil palm empty fruit bunch (OPEFB) in the new solvent dimethyl sulfoxide (DMSO)/tetrabutylammonium fluoride (TBAF). *Journal of Physics: Conference Series*, **622**(1).

Elshahed, M.S. 2010. Microbiological aspects of biofuel production: Current status and future directions. *Journal of Advanced Research*, **1**(2): 103–111.

Evcan, E. & Tari, C. 2015. Production of bioethanol from apple pomace by using cocultures: Conversion of agro-industrial waste to value added product. *Energy*, **88**: 775–782.

Fei, H., Abudureheman, A. & Vessey, J.K. 2017. Improving a "Generation 1.5" biofuel feedstock crop: Colonization and growth enhancement of energy beet (*Beta vulgare* L. Beta 5833R) by inoculation with *Gluconacetobacter* spp. *Biocatalysis and Agricultural Biotechnology*, **10**: 247–255.

Financie, R., Moniruzzaman, M. & Uemura, Y. 2016. Enhanced enzymatic delignification of oil palm biomass with ionic liquid pretreatment. *Biochemical Engineering Journal*, **110**: 1–7.

Gan, P.Y. & Li, Z.D. 2014. Econometric study on Malaysias palm oil position in the world market to 2035. *Renewable and Sustainable Energy Reviews*, **39**: 740–747.

Gaurav, N., Sivasankari, S., Kiran, G.S., Ninawe, A. & Selvin, J. 2017. Utilization of bioresources for sustainable biofuels: A Review. *Renewable and Sustainable Energy Reviews*, **73**: 205–214.

Gavahian, M., Farahnaky, A. & Sastry, S. 2016. Ohmic-assisted hydrodistillation: A novel method for ethanol distillation. *Food and Bioproducts Processing*, **98**: 44–49.

Goh, C.S. & Lee, K.T. 2010. A visionary and conceptual macroalgae-based third-generation bioethanol (TGB) biorefinery in Sabah, Malaysia as an underlay for renewable and sustainable development. *Renewable and Sustainable Energy Reviews*, **14**(2): 842–848.

Goh, C.S., Tan, H.T., Lee, K.T. & Brosse, N. 2011. Evaluation and optimization of organosolv pretreatment using combined severity factors and response surface methodology. *Biomass and Bioenergy*, **35**(9): 4025–4033.

Goh, C.S., Tan, K.T., Lee, K.T. & Bhatia, S. 2010. Bio-ethanol from lignocellulose: Status, perspectives and challenges in Malaysia. *Bioresource Technology*, **101**(13): 4834–4841.

Gupta, R.B. & Demirbas, A. 2010. *Gasoline, Diesel, and Ethanol Biofuels from Grasses and Plants*, pp. 73-84. New York, USA: Cambridge University Press - Technology & Engineering.

Hallenbeck, P.C., Grogger, M., Mraz, M. & Veverka, D. 2016. Solar biofuels production with microalgae. *Applied Energy*, **179**: 136–145.

Hamouda, H.I., Nassar, H.N., Madian, H.R., Amr, S.S.A. & El-Gendy, N.S. 2015. Response Surface Optimization of Bioethanol Production from Sugarcane Molasses by *Pichia veronae* Strain HSC-22. *Biotechnology Research International*, **2015**: 10.

Hamzah, F., Idris, A. & Shuan, T.K. 2011. Preliminary study on enzymatic hydrolysis of treated oil palm (Elaeis) empty fruit bunches fibre (EFB) by using combination of cellulase and β, 1-4 glucosidase. *Biomass and Bioenergy*, **35**(3): 1055–1059.

Han, M., Kim, Y., Kim, S.W. & Choi, G. 2011. High efficiency bioethanol production from OPEFB using pilot pretreatment reactor. *Journal of Chemical Technology and Biotechnology*, **86**(12): 1527–1534.

Hanif, M., Mahlia, T.M.I., Aditiya, H.B., Chong, W.T. & Nasruddin. 2016. Techno-economic and environmental assessment of bioethanol production from high starch and root yield Sri Kanji 1 cassava in Malaysia. *Energy Reports*, **2**: 246–253.

Hassan, O., Ling, T.P., Maskat, M.Y., Illias, R.M., Badri, K., Jahim, J. & Mahadi, N.M. 2013. Optimization of pretreatments for the hydrolysis of oil palm empty fruit bunch fiber (EFBF) using enzyme mixtures. *Biomass and Bioenergy*, **56**: 137–146.

Herskowitz, I. 1988. Life Cycle of the Budding Yeast Saccharomyces cerevisiae. *Microbiological Reviews*, **52**(4): 536–553.

Hossain, M.N.B, Basu, J.K. & Mamun, M. 2015. The Production of Ethanol from Micro-Algae Spirulina. *Procedia Engineering*, **105**: 733–738.

Ibrahim, M.F., Abd-aziz, S. & Hassan, M.A. 2012. Oil Palm Empty Fruit Bunch as Alternative Substrate for Acetone – Butanol – Ethanol Production by *Clostridium butyricum* EB6. *Applied Biochemistry and Biotechnology*, **166**: 1615–1625.

Ibrahim, M.F., Abd-Aziz, S., Yusoff, M.E.M., Phang, L.Y. & Hassan, M.A. 2015. Simultaneous enzymatic saccharification and ABE fermentation using pretreated oil palm empty fruit bunch as substrate to produce butanol and hydrogen as biofuel. *Renewable Energy*, **77**: 447–455.

Isroi, Cifriadi, A., Panji, T., Wibowo, N.A. & Syamsu, K. 2017. Bioplastic production from cellulose of oil palm empty fruit bunch. *International Conference on Biomass: Technology, Application and Sustainable Development*, **65**: 012011.

Isroi, Ishola, M.M., Millati, R., Syamsiah, S., Cahyanto, M.N., Niklasson, C. & Taherzadeh, M.J. 2012. Structural changes of oil palm empty fruit bunch (OPEFB) after fungal and phosphoric acid pretreatment. *Molecules*, **17**(12): 14995–15012.

Izmirlioglu, G. & Demirci, A. 2017. Simultaneous saccharification and fermentation of ethanol from potato waste by co-cultures of *Aspergillus niger* and *Saccharomyces cerevisiae* in biofilm reactors. *Fuel*, **202**: 260–270.

Jahan, N., Sultana, S., Adhikary, S.K., Rahman, S. & Yasmin, S. 2013. Evaluation Of The Growth Performance Of *Trichoderma harzianum* (Rifai.) on Different Culture Media. *Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, **3**(4): 44–50.

Jambo, S.A., Abdulla, R., Azhar, S.H., Marbawi, H., Gansau, J.A. & Ravindra, P. 2016. A review on third generation bioethanol feedstock. *Renewable and Sustainable Energy Reviews*, **65**: 756–769.

Jeon, H., Kang, K.E., Jeong, J.S., Gong, G., Choi, J.W., Abimanyu, H. & Choi, G.W. 2014. Production of anhydrous ethanol using oil palm empty fruit bunch in a pilot plant. *Biomass and Bioenergy*, **67**: 99–107.

Jung, Y.H., Kim, I.J., Kim, H.K. & Kim, K.H. 2013. Dilute acid pretreatment of lignocellulose for whole slurry ethanol fermentation. *Bioresource Technology*,

132: 109–114.

Jusuf, M. & Ginting, E. 2014. The prospects and challenges of sweet potato as bio-ethanol source in Indonesia. *Energy Procedia*, **47**: 173–179.

Kabbashi, N.A., Alam, M.Z. & Tompang, M.F. 2007. Direct Bioconversion of Oil Palm Empty Fruit Bunches for Bioethanol Production by Solid State Bioconversion. *IIUM Engineering Journal*, **8**(2): 25–36.

Kamm, B. & Kamm, M. 2004. Principles of biorefineries. *Applied Microbiology and Biotechnology*, **64**(2): 137–145.

Kamoldeen, A.A., Lee, C.K., Wan Abdullah, W.N. & Leh, C.P. 2017. Enhanced ethanol production from mild alkali-treated oil-palm empty fruit bunches via co-fermentation of glucose and xylose. *Renewable Energy*, **107**: 113–123.

Kang, Q., Appels, L., Tan, T. & Dewil, R. 2014. Bioethanol from lignocellulosic biomass: Current findings determine research priorities. *Scientific World Journal*, **2014**.

Kannangara, S., Dharmarathna, R.M.G.C.S. & Jayarathna, D.L. 2017. Isolation, Identification and Characterization of *Trichoderma* Species as a Potential Biocontrol Agent against Ceratocystis paradoxa. *The Journal of Agricultural Sciences*, **12**(1): 51–62.

Karimi, K., Emtiazi, G. & Taherzadeh, M.J. 2006. Ethanol production from dilute-acid pretreated rice straw by simultaneous saccharification and fermentation with *Mucor indicus*, *Rhizopus oryzae*, and *Saccharomyces cerevisiae*. *Enzyme and Microbial Technology*, **40**(1): 138–144.

Kassim, M.A., Loh, S.K., Bakar, N.A., Aziz, A.A. & Mat Som, R. 2011. Bioethanol production from Enzymatically Saccharified Empty Fruit Bunches Hydrolysate using *Saccharomyces cerevisiae*. *Reseach Journal of Environmental Sciences (Academic Journals Inc.)*, 1–14.

Kelly-yong, T.L., Lee, K.T., Mohamed, A.R. & Bhatia, S. 2007. Potential of hydrogen from oil palm biomass as a source of renewable energy worldwide. *Energy Policy*, ***35***: 5692–5701.

Khawla, B.J., Sameh, M., Imen, G., Donyes, F., Dhouha, G., Raoudha, E.G. & Oumèma, N.E. 2014. Potato peel as feedstock for bioethanol production: A comparison of acidic and enzymatic hydrolysis. *Industrial Crops and Products*, **52**: 144–149.

Khor, C.S. & Lalchand, G. 2014. A review on sustainable power generation in Malaysia to 2030: Historical perspective, current assessment, and future strategies. *Renewable and Sustainable Energy Reviews*, **29**: 952–960.

Kim, D.Y., Kim, Y.S., Kim, T.H. & Oh, K.K. 2016. Two-stage, acetic acid-aqueous ammonia, fractionation of empty fruit bunches for increased lignocellulosic biomass utilization. *Bioresource Technology*, **199**: 121–127.

Kim, S. & Kim, C.H. 2013. Bioethanol production using the sequential acid/alkali-pretreated empty palm fruit bunch fiber. *Renewable Energy*, **54**: 150–155.

Kim, S., Park, J.M., Seo, J.W. & Kim, C.H. 2012. Sequential acid-/alkali-pretreatment of empty palm fruit bunch fiber. *Bioresource Technology*, **109**: 229–233.

Komonkiat, I. & Cheirsilp, B. 2013. Felled oil palm trunk as a renewable source for biobutanol production by *Clostridium* spp. *Bioresource Technology*, **146**: 200–207.

Kovačević, M. 2015. *Morphological and physiological characteristics of the yeast Saccharomyces cerevisiae cells differing in the life span*. Master Thesis, Faculty of Pharmacy and Biochemistry. Croatia: University of Zagreb.

Kricka, W., Fitzpatrick, J. & Bond, U. 2014. Metabolic engineering of yeasts by heterologous enzyme production for degradation of cellulose and hemicellulose from biomass: A perspective. *Frontiers in Microbiology*, **5**: 1–11.

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.

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

Kumneadklang, S., Larpkiattaworn, S., Niyasom, C. & Sompong, O. 2015. Bioethanol Production from Oil Palm Frond by Simultaneous Saccharification and Fermentation. *Energy Procedia*, **79**: 784-790.

Kusfanto, H.F., Maggadani, B.P. & Suryadi, H. 2017. Fermentation of Bioethanol from the biomass hydrolyzate of oil palm empty fruit bunch using selected yeast isolates. *International Journal of Applied Pharmaceutics*, **9**: 49–53.

Lai, C.M.T., Chua, H.B., Danquah, M.K. & Saptoro, A. 2017. Isolation of Thermophilic Lignin Degrading Bacteria from Oil-Palm Empty Fruit Bunch (EFB) Compost. *IOP Conference Series: Materials Science and Engineering*, **206**: 1–11.

Law, K.N., Daud, W.R.W. & Ghazali, A. 2007. Morphological and chemical nature of fiber strands of oil palm empty-fruit-bunch (OPEFB). *BioResources*, **2**(3): 351–362.

Lebaz, N., Cockx, A., Spérandio, M. & Liné, A. 2016. Application of the Direct Quadrature Method of Moments for the modelling of the enzymatic hydrolysis of cellulose : I . Case of soluble substrate. *Chemical Engineering Science*, ***149***: 306–321.

Lecault, V., Patel, N. & Thibault, J. 2009. An image analysis technique to estimate the cell density and biomass concentration of Trichoderma reesei. *Letters in Applied Microbiology*, **48**(4): 402–407.

Lee, J.H., Lee, J.H., Kim, D.K., Park, C.H., Yu, J.H. & Lee, E.Y. 2016. Crude glycerol-mediated liquefaction of empty fruit bunches saccharification residues for preparation of biopolyurethane. *Journal of Industrial and Engineering Chemistry*, **34**: 157–164.

Libardi, N., Ricardo, C., Góes-neto, A., Oliveira, J., De Porto, L. & Vandenberghe, D.S. 2017. Domestic wastewater as substrate for cellulase production by *Trichoderma harzianum*. *Process Biochemistry*, **57**: 190–199.

Lim, S. & Lee, K.T. 2012. Implementation of biofuels in Malaysian transportation sector towards sustainable development: A case study of international cooperation between Malaysia and Japan. *Renewable and Sustainable Energy Reviews*, **16**(4): 1790–1800.

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.

Lin, Y. & Tanaka, S. 2006. Ethanol fermentation from biomass resources: Current state and prospects. *Applied Microbiology and Biotechnology*, **69**(6): 627–642.

Lindh, W.Q., Pooler, M., Tamparo, C.D. & Dahl, B.M. 2009. *Delmar's Comprehensive Medical Assisting: Administrative and Clinical Competencies*, 4th edition, pp .1259-1260. New York: Cengage Learning.

Liong, Y.Y., Halis, R., Lai, O.M. & Mohamed, R. 2012. Conversion Of Lignocellulosic Biomass From Grass To Bioethanol Using Materials Pretreated With Alkali And The White Rot Fungus, *Phanerochaete Chrysosporium*. *Bioresources*, **7**: 5500–5513.

Lu, J., Li, X., Zhao, J. & Qu, Y. 2012. Enzymatic saccharification and ethanol fermentation of reed pretreated with liquid hot water. *Journal of Biomedicine and Biotechnology*, **Volume 2012**: 9.

Luque, R., Pinzi, S., Campelo, J.M., Ruiz, J.J., Lopes, I., Luna, D. & Dorado, M.P. 2009. Chapter 8 Biofuels for transport: Prospects and challenges. In V. Shah (Ed.), *Emerging environmental technologies* (pp. 172–211). New York: Springer Science Business Media.

Malaysian Palm Oil Board. (2016). Overview of the Malaysian Oil Palm Industry. *Malaysian Palm Oil Board*, 1–4.

Malaysian Palm Oil Board: Economics & Industry Development Division (Malaysia Oil Palm Planted Area). 2017. http://bepi.mpob.gov.my/index.php/en/statistics/area/176-area-2016. Last visited on 13 September 2017

Malaysian Palm Oil Board: Economics & Industry Development Division (Malaysia palm oil yield). 2017. http://bepi.mpob.gov.my/index.php/en/statistics/yield/181-yield-2017/817-yield-2017. Last visited on 21 September 2017.

Mansa, R.F., Chen, W.F., Yeo, S.J., Farm, Y.Y., Bakar, H.A. & Sipaut, C.S. 2013. Chapter 13 Fermentation Study on Macroalgae *Eucheuma cottonii* for Bioethanol Production via Varying Acid Hydrolysis. In Pogaku R. & Hj Sarbatly (Eds.). *Advances in Biofuels* pp. 219–240. New York: Springer Science and Business Media.

Mansouri, A., Rihani, R., Laoufi, A.N. & Özkan, M. 2016. Production of bioethanol from a mixture of agricultural feedstocks: Biofuels characterization. *Fuel*, **185**: 612–621.

Masum, B.M., Masjuki, H.H., Kalam, M.A., Rizwanul Fattah, I.M., Palash, S. & Abedin, M.J. 2013. Effect of ethanol-gasoline blend on NOx emission in SI engine. *Renewable and Sustainable Energy Reviews*, **24**: 209–222.

Mekhilef, S., Saidur, R., Safari, A. & Mustaffa, W.E.S.B. 2011. Biomass energy in Malaysia: Current state and prospects. *Renewable and Sustainable Energy Reviews*, **15**(7): 3360–3370.

Millati, R., Wikandari, R., Trihandayani, E.T., Cahyanto, M.N. & Niklasson, C. 2011. Ethanol from Oil Palm Empty Fruit Bunch via Dilute Acid Hydrolysis and Fermentation by *Mucor indicus* and *Saccharomyces cerevisiae*. *Agricultural Journal*, **6**(2): 54-59.

Mohammed, M.A.A., Salmiaton, A., Wan Azlina, W.A.K.G., Mohammad Amran, M.S., Fakhru'L-Razi, A. & Taufiq-Yap, Y.H. 2011. Hydrogen rich gas from oil palm biomass as a potential source of renewable energy in Malaysia. *Renewable and Sustainable Energy Reviews*, **15**(2): 1258–1270.

Mohd Zainudin, M.H., Abdul Rahman, N., Abd-Aziz, S., Funaoka, M., Shinano, T., Shirai, Y. & Hassan, M.A. 2012. Utilization of glucose recovered by phase separation system from acid-hydrolysed oil palm empty fruit bunch for bioethanol production. *Pertanika Journal of Tropical Agricultural Science*, **35**(1): 117–126.

Moukamnerd, C., Kawahara, H. & Katakura, Y. 2013. Feasibility Study of Ethanol Production from Food Wastes by Consolidated Continuous Solid-State Fermentation. *Journal of Sustainable Bioenergy Systems*, **3**: 143–148.

Mulyaningtyas, A., Kayati, F.N., Syamsiah, S., Sarto & Sediawan, W.B. 2017. Effects of Various Pretreatment Variables on Hydrolysis of Lignocellulose to Produce Sugar in Bioethanol Production. *Materials Science Forum*, **890**: 141–145.

Muryanto, Sahlan, M. & Sudiyani, Y. 2012. Simultaneous Saccharification and Fermentation of Oil Palm Empty Fruit Bunch for Bioethanol Production by *Rhizopus oryzae*. *International Journal of Environment and Bioenergy*, **3**(2): 111–120.

Musatto, S.I., Dragone, G., Fernandes, M., Milagres, A.M.F. & Roberto, I.C. 2008. The effect of agitation speed , enzyme loading and substrate concentration on enzymatic hydrolysis of cellulose from brewer's spent grain. *Springer Science & Business Media*, **15**: 711–721.

Mushtaq, F., Abdullah, T.A.T., Mat, R. & Ani, F.N. 2015. Optimization and characterization of bio-oil produced by microwave assisted pyrolysis of oil palm shell waste biomass with microwave absorber. *Bioresource Technology*, **190**: 442–450.

Mustafa, A., Khan, M.A., Inam-ul-Haq, M., Pervez, M.A. & Umar, U.D. 2009. Usefulness of Different culture media for in-vitro evaluation of *Trichoderma* spp. against seed borne fungi of economic importance. *Journal of Phytopathology*, **21**(1): 83–88.

Nanda, S., Golemi-Kotra, D., McDermott, J.C., Dalai, A.K., Gökalp, I. & Kozinski, J.A. 2017. Fermentative production of butanol: Perspectives on synthetic biology. *New Biotechnology*, **37**: 210–221.

Narayanaswamy, N., Dheeran, P., Verma, S. & Kumar, S. 2013. *Biological Pretreatment of Lignocellulosic Biomass for Enzyme Saccharification*. In Zhen, F (Editor). Pretreatment Techniques for Biofuels and Biorefineries; Green Energy and Technology, pp. 1-9. New York: Springer.

Neelakandan, T., Usharani, G. & Nagar, A. 2009. Optimization and Production of Bioethanol from Cashew Apple Juice Using Immobilized Yeast Cells by *Saccharomyces cerevisiae*. *American-Eurasian Journal of Scientific Research*, **4**(2): 85–88.

Ng, F.Y., Yew, F.K., Basiron, Y. & Sundram, K. 2011. A Renewable Future Driven with Malaysian Palm Oil-based Green Technology. *Journal of Oil Palm & The Environment*, **2**: 1–7.

Ng, W.P.Q., Lam, H.L., Ng, F.Y., Kamal, M. & Lim, J.H.E. 2012. Waste-to-wealth: Green potential from palm biomass in Malaysia. *Journal of Cleaner Production*, **34**: 57–65.

Nguyen, K., Murray, S., Lewis, J.A. & Kumar, P. 2017. Morphology, cell division, and viability of *Saccharomyces cerevisiae* at high hydrostatic pressure. *Cornell University Library (Quantitative Biology-Cell Behavior)*: 1–19.

Noomtim, P. & Cheirsilp, B. 2011. Production of butanol from palm empty fruit bunches hydrolyzate by *Clostridium acetobutylicum*. *Energy Procedia*, **9**: 140–146.

Norul Izani, M.A., Paridah, M.T., Anwar, U.M.K., Mohd Nor, M.Y. & Ng, P.S. 2013. Effects of fiber treatment on morphology, tensile and thermogravimetric analysis of oil palm empty fruit bunches fibers. *Composites Part B: Engineering*, **45**(1): 1251–1257.

Nurdiawati, A., Novianti, S., Zaini, I.N., Nakhshinieva, B., Sumida, H., Takahashi, F. & Yoshikawa, K. 2015. *Evaluation of Hydrothermal Treatment of Empty Fruit Bunch for Solid Fuel and Liquid Organic Fertilizer Co-Production. Energy Procedia* (**Vol. 79**). Elsevier B.V.

Nurul Adela, B., Nasrin, A.B., Loh, S.K. & Choo, Y.M. 2014. Bioethanol production by fermentation of oil palm empty fruit bunches pretreated with combined chemicals. *Journal Applied Environmental and Biological Sciences*, **4**(10): 234–242.

Nurul Hazirah, C.H., Masturah, M., Osman, H., Jamaliah, M.J. & Shuhaida, H. 2014. Preliminary Study on Analysis of the Chemical Compositions and Characterization of Empty Fruit Bunch (EFB) in Malaysia. *Advanced Materials Research*, ***970***: 204–208.

Ofori-Boateng, C. & Lee, K.T. 2014. Sono-assisted organosolv/H_2O_2 pretreatment of oil palm (*Elaeis guineensis* Jacq.) fronds for recovery of fermentable sugars: Optimization and severity evaluation. *Fuel*, **115**: 170–178.

Otulugbu, K. 2012. *Production of Ethanol from Cellulose (Sawdust)*. Degree Thesis. Arcada: University of Applied Science.

Özçelik, A.E., Aydoğan, H. & Acaroğlu, M. 2015. A Study of the Effects of Bioethanol-Gasoline Blends on Vehicle Emissions. *Journal of Clean Energy Technologies*, **3**(5): 332–335.

Palmqvist, E. & Hahn-Hagerdal, B. 2000. Fermentation of lignocellulosic hydrolysates: Inhibition and detoxification. *Bioresource Technology*, **74**.

Park, E.Y., Naruse, K. & Kato, T. 2012. One-pot bioethanol production from cellulose by co-culture of *Acremonium cellulolyticus* and *Saccharomyces cerevisiae*. *Biotechnology for Biofuels*, **5**: 64.

Park, J.M., Oh, B., Seo, J., Hong, W.K., Yu, A., Sohn, J.H. & Kim, C.H. 2013. Efficient Production of Ethanol from Empty Palm Fruit Bunch Fibers by Fed-Batch Simultaneous Saccharification and Fermentation Using *Saccharomyces cerevisiae*. *Applied Biochemistry and Biotechnology*, **170**: 1807–1814.

Paschos, T., Xiros, C. & Christakopoulos, P. 2015. Simultaneous saccharification and fermentation by co-cultures of *Fusarium oxysporum* and *Saccharomyces cerevisiae* enhances ethanol production from liquefied wheat straw at high solid content. *Industrial Crops and Products*, **76**: 793–802.

Pérez, J., Muñoz-Dorado, J., De La Rubia, T. & Martínez, J. 2002. Biodegradation and biological treatments of cellulose, hemicellulose and lignin: An overview. *International Microbiology*, **5**(2): 53–63.

Piarpuzán, D., Quintero, J.A. & Cardona, C.A. 2011. Empty fruit bunches from oil palm as a potential raw material for fuel ethanol production. *Biomass and Bioenergy*, **35**(3): 1130–1137.

Pradeepkumar, T., Suma Jyothibhaskar, K. & Satheesan, K.N. 2008. *Management of Horticultural Crops*, pp. 641. New Delhi: New India Publishing Science.

Prado, J.M., Lachos-perez, D., Forster-carneiro, T. & Rostagno, M.A. 2015. Food and Bioproducts Processing 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.

Prajankate, P. & Siwarasak, P. 2011. Co-culture of *Trichoderma reesei* RT-P1 with *Saccharomyces cerevisiae* RT-P2: Morphological Study, **4**(2): 75–78.

Pulidindi, I.N., Kimchi, B.B. & Gedanken, A. 2014. Can cellulose be a sustainable feedstock for bioethanol production. *Renewable Energy*, **71**: 77–80.

Qi, G., Xiong, L., Luo, M., Huang, Q., Huang, C., Li, H. & Chen, X. 2018. Solvents production from cassava by co-culture of *Clostridium acetobutylicum* and *Saccharomyces cerevisiae*. *Journal of Environmental Chemical Engineering*, **6**(1): 128–133.

Qureshi, N., Cotta, M.A. & Saha, B.C. 2013. Bioconversion of barley straw and corn stover to butanol (A biofuel) in integrated fermentation and simultaneous product recovery bioreactors. *Food and Bioproducts Processing*, **92**(3): 298–308.

Rahman, S.H.A., Choudhury, J.P., Ahmad, A.L. & Kamaruddin, A.H. 2007. Optimization studies on acid hydrolysis of oil palm empty fruit bunch fiber for production of xylose. *Bioresource Technology*, **98**(3): 554–559.

Raman, J.K. & Gnansounou, E. 2014. Ethanol and lignin production from Brazilian empty fruit bunch biomass. *Bioresource Technology*, **172**: 241–248.

Rivera, E.C., Yamakawa, C.K., Saad, M.B.W., Atala, D.I.P., Ambrosio, W.B., Bonomi, A. & Rossell, C.E.V. 2017. Effect of temperature on sugarcane ethanol fermentation: Kinetic modeling and validation under very-high-gravity fermentation conditions. *Biochemical Engineering Journal*, **119**: 42–51.

Rodrigues, B., Lima-Costa, M.E., Constantino, A., Raposo, S., Felizardo, C., Gonçalves, D. & Peinado, J.M. 2016. Growth kinetics and physiological behavior of co-cultures of *Saccharomyces cerevisiae* and *Kluyveromyces lactis*, fermenting carob sugars extracted with whey. *Enzyme and Microbial Technology*, **92**: 41–48.

Saba, N., Jawaid, M., Hakeem, K.R., Paridah, M.T., Khalina, A. & Alothman, O.Y. 2015. Potential of bioenergy production from industrial kenaf (*Hibiscus cannabinus L.*) based on Malaysian perspective. *Renewable and Sustainable Energy Reviews*, **42**: 446–459.

Samsudin, M.D.M. & Mat Don, M. 2015. Assessment of bioethanol yield by *S. cerevisiae* grown on oil palm residues: Monte Carlo simulation and sensitivity analysis. *Bioresource Technology*, **175**: 417–423.

Sangwichien, C. & Duangwang, S. 2013. Fermentation of oil palm empty fruit bunch hydrolysate to ethanol by baker's yeast and loog-pang. *The Sixth PSU-UNS International Conference on Engineering and Technology*, **2013**: 1–3.

Santos Michel, R.J., Canabarro, N.I., Alesio, C., Maleski, T., Laber, T., Sfalcin, P. & Mazutti, M.A. 2016. Enzymatic saccharification and fermentation of rice processing residue for ethanol production at constant temperature. *Biosystems Engineering*, **142**: 110–116.

Santosh, I., Ashtavinayak, P., Amol, D. & Sanjay, P. 2017. Enhanced bioethanol production from different sugarcane bagasse cultivars using co-culture of *Saccharomyces cerevisiae* and *Scheffersomyces (Pichia) stipitis*. *Journal of Environmental Chemical Engineering*, **5**(3): 2861–2868.

Sari, A.A., Ariani, N., Muryanto, Kristiani, A., Utomo, T.B. & Sudarno. 2017. Potential of Oil Palm Empty Fruit Bunches for Bioethanol Production and Application of Chemical Methods in Bioethanol Wastewater Treatment: OPEFB for Bioethanol and Its Wastewater Treatment. *2017 International Conference on Sustainable and Renewable Energy Engineering*, ICSREE 2017: 49.

Saritpongteeraka, K., Chaiprapat, S., Boonsawang, P. & Sung, S. 2015. Solid state co-fermentation as pretreatment of lignocellulosic palm empty fruit bunch for organic acid recovery and fiber property improvement. *International Biodeterioration and Biodegradation*, **100**: 172–180.

Sasikumar, E. & Viruthagiri, T. 2008. Optimization of Process Conditions Using Response Surface Methodology (RSM) for Ethanol Production from Pretreated Sugarcane Bagasse: Kinetics and Modeling. *Bioenergy Resources*, 1: 239–247.

Sassner, P., Galbe, M. & Zacchi, G. 2008. Techno-economic evaluation of bioethanol production from three different lignocellulosic materials. *Biomass and Bioenergy*, **32**(5): 422–430.

Scragg, A. H. 2009. *Biofuels: Production, Application and Development*, pp. 64. Oxford, UK: CAB International.

Shadbahr, J., Khan, F. & Zhang, Y. 2017. Kinetic modeling and dynamic analysis of simultaneous saccharification and fermentation of cellulose to bioethanol. *Energy Conversion and Management*, **141**: 236–243.

Shah, S., Nasreen, S. & Sheikh, P. 2012. Cultural and Morphological Characterization of *Trichoderma* spp. Associated with Green Mold Disease of *Pleurotus* spp. in Kashmir. *Research Journal of Microbiology*, **7**(2): 139–144.

Shah, S.R., Ishmael, U.C., Palliah, J.V., Asras, M.F.F. & Ahmad, S.S.B.N.W. 2016. Optimization of the enzymatic saccharification process of empty fruit bunch pretreated with laccase enzyme. *BioResources*, **11**(2): 5138–5154.

Shamsudin, S., Md Shah, U.K., Zainudin, H., Abd-Aziz, S., Mustapa Kamal, S.M., Shirai, Y. & Hassan, M.A. 2012. Effect of steam pretreatment on oil palm empty fruit bunch for the production of sugars. *Biomass and Bioenergy*, **36**: 280–288.

Shuit, S.H., Tan, K.T., Lee, K.T. & Kamaruddin, A.H. 2009. Oil palm biomass as a sustainable energy source: A Malaysian case study. *Energy*, **34**(9): 1225–1235.

Sindhu, R., Kuttiraja, M., Prabisha, T.P., Binod, P., Sukumaran, R.K. & Pandey, A. 2016. Development of a combined pretreatment and hydrolysis strategy of rice straw for the production of bioethanol and biopolymer. *Bioresource Technology*, **215**: 110–116. 0

Singh, A., Bajar, S. & Bishnoi, N.R. 2014. Enzymatic hydrolysis of microwave alkali pretreated rice husk for ethanol production by *Saccharomyces cerevisiae*, *Scheffersomyces stipitis* and their co-culture. *Fuel*, **116**: 699–702.

Singhania, R.R., Sukumaran, R.K., Patel, A.K., Larroche, C. & Pandey, A. 2010. Advancement and comparative profiles in the production technologies using solid-state and submerged fermentation for microbial cellulases. *Enzyme and Microbial Technology*, **46**(7): 541–549.

Siramon, P., Punsuvon, V. & Vaithanomsat, P. 2017. Production of Bioethanol from Oil Palm Empty Fruit Bunch via Acid Impregnation-Steam Explosion Pretreatment. *Waste and Biomass Valorization*, 1–8.

Siti Aisyah, M.S., Petchpradab, P., Uemura, Y., Yusup, S.S., Kanna, M. & Matsumura, Y. 2014. Ethanol Production from Hydrothermal Pretreated Empty Fruit Bunches. *Advanced Materials Research*, **917**: 80–86.

Sklavounos, E., Iakovlev, M., Survase, S., Granström, T. & Van Heiningen, A. 2013. Oil palm empty fruit bunch to biofuels and chemicals via SO_2-ethanol-water fractionation and ABE fermentation. *Bioresource Technology*, **147**: 102–109.

Sudiyani, Y., Styarini, D., Triwahyuni, E., Sudiyarmanto, Sembiring, K.C., Aristiawan, Y. & Han, M.H. 2013. Utilization of biomass waste empty fruit bunch fiber of palm oil for bioethanol production using pilot - Scale unit. *Energy Procedia*, **32**: 31–38.

Sugiharto, Y.E.C., Harimawan, A., Kresnowati, M.T.A.P., Purwadi, R., Mariyana, R., Andry. & Hosen, H.F. 2016. Enzyme feeding strategies for better fed-batch enzymatic hydrolysis of empty fruit bunch. *Bioresource Technology*, **207**: 175–179.

Sukumaran, R.K., Singhania, R.R., Mathew, G.M. & Pandey, A. 2009. Cellulase production using biomass feed stock and its application in lignocellulose saccharification for bio-ethanol production. *Renewable Energy*, **34**(2): 421–424.

Sumathi, S., Chai, S.P. & Mohamed, A.R.Ã. 2008. Utilization of oil palm as a source of renewable energy in Malaysia. Renewable and Sustainable Energy Reviews, **12**: 2404–2421.

Sun, Y. & Cheng, J. 2002. Hydrolysis of lignocellulosic materials for ethanol production: A review. *Bioresource Technology*, **83**(1): 1–11.

Suzuki, K., Tsuji, N., Shirai, Y. & Mohd Ali Hassan. 2017. Evaluation of biomass energy potential towards achieving sustainability in biomass energy utilization in Sabah , Malaysia. *Biomass and Bioenergy*, **97**: 149–154.

Swain, M.R., Mishra, J. & Thatoi, H. 2013. Bioethanol Production from Sweet Potato (*Ipomoea batatas L*) Flour using Co-Culture of *Trichoderma* sp. and *Saccharomyces cerevisiae* in Solid-State Fermentation. *Brazilian Archives of Biology and Technology*, **56**(2): 171–179.

Tan, H.T., Lee, K.T. & Mohamed, A.R. 2010. Second-generation bio-ethanol (SGB) from Malaysian palm empty fruit bunch: Energy and exergy analyses. *Bioresource Technology*, **101**(14): 5719–5727.

Tan, I.S. & Lee, K.T. 2014. Enzymatic hydrolysis and fermentation of seaweed solid wastes for bioethanol production: An optimization study. *Energy*, **78**: 53–62.

Tan, K.T., Lee, K.T. & Mohamed, A.R. 2008. Role of energy policy in renewable energy accomplishment: The case of second-generation bioethanol. *Energy Policy*, **36**(9): 3360–3365.

Tan, L., Wang, M., Li, X., Li, H., Zhao, J., Qu, Y., Choo, Y.M. & Loh, S.K. 2016. Fractionation of oil palm empty fruit bunch by bisulfite pretreatment for the production of bioethanol and high value products. *Bioresource Technology*, **200**: 572–578.

Tang, X., Lee, J. & Chen, W.N. 2015. Engineering the fatty acid metabolic pathway in *Saccharomyces cerevisiae* for advanced biofuel production. *Metabolic Engineering Communications*, **2**: 58–66.

Tavva, S.S.M.D., Deshpande, A., Durbha, S.R., Palakollu, V.A.R., Goparaju, A.U., Yechuri, V.R. & Muktinutalapati, V.S.R. 2016. Bioethanol production through separate hydrolysis and fermentation of *Parthenium hysterophorus* biomass. *Renewable Energy*, **86**: 1317–1323.

Tesfaw, A. & Assefa, F. 2014. Current Trends in Bioethanol Production by *Saccharomyces cerevisiae*: Substrate , Inhibitor Reduction , Growth Variables , Coculture , and Immobilization. *International Scholarly Research Notices*, **Volume 2014**: 1–11.

Thakur, A.K., Kaviti, A.K., Mehra, R. & Mer, K.K.S. 2017. Progress in performance analysis of ethanol-gasoline blends on SI engine. *Renewable and Sustainable Energy Reviews*, **69**: 324–340.

Tojo, S. & Hirasawa, T. 2013. *Research Approaches to Sustainable Biomass Systems*, pp. 251-252. Oxford, UK: Academic Press-Technology and Engineering.

Triwahyuni, E., Hariyanti, S., Dahnum, D., Nurdin, M. & Abimanyu, H. 2015. Optimization of Saccharification and Fermentation Process in Bioethanol Production from Oil Palm Fronds. *Procedia Chemistry*, **16**: 141–148.

Triwahyuni, E., Muryanto, Sudiyani, Y. & Abimanyu, H. 2015. The effect of substrate loading on simultaneous saccharification and fermentation process for bioethanol production from oil palm empty fruit bunches. *Energy Procedia*, **68**: 138–146.

Tsai, T.Y., Lo, Y.C. & Chang, J.S. 2014. Effect of Medium Composition and pH Control Strategies on Butanol Fermentation with *Clostridium Acetobutylicum*. *Energy Procedia*, **61**: 1691–1694.

Turgeon, M. L. 2014. *Linne & Ringsrud's Clinical Laboratory Science - E-Book: The Basics and Routine Techniques*, 6th edition, pp. 47. Missouri: Elsevier Health Sciences.

Turhan, O., Isci, A., Mert, B., Sakiyan, O. & Donmez, S. 2015. Optimization of Ethanol Production From Microfluidized Wheat Straw by Response Surface

Methodology. *Preparative Biochemistry and Biotechnology*, **45**(8): 785–795.

Tye, Y.Y., Lee, K.T., Wan Abdullah, W.N. & Leh, C.P. 2011. Second-generation bioethanol as a sustainable energy source in Malaysia transportation sector: Status, potential and future prospects. *Renewable and Sustainable Energy Reviews*, **15**(9): 4521–4536.

Tye, Y.Y., Lee, K.T., Wan Abdullah, W.N. & Leh, C.P. 2014. The Effect of Various Pretreatment Methods on Oil Palm Empty Fruit Bunch (EFB) and Kenaf Core Fibers for Sugar Production. *Procedia Environmental Sciences*, **20**: 328–335.

Ullah Khan, I., Hafiz Dzarfan Othman, M., Hashim, H., Matsuura, T., Ismail, A.F., Rezaei-Dasht Arzhandi, M. & Wan Azelee, I. 2017. Biogas as a renewable energy fuel – A review of biogas upgrading, utilisation and storage. *Energy Conversion and Management*, **150**: 277–294.

Umar, M., Jennings, P. & Urmee, T. 2013. Strengthening the palm oil biomass Renewable Energy industry in Malaysia. *Renewable Energy*, **60**: 107–115.

Verma, G., Nigam, P., Singh, D. & Chaudhary, K. 2000. Bioconversion of starch to ethanol in a single-step process by coculture of amylolytic yeasts and *Saccharomyces cerevisiae* 21. *Bioresource Technology*, **72**: 261–266.

Waghunde, R.R., John, P., Naik, B.M., Solanky, K.U. & Sabalpara, A.N. 2010. Optical density - a tool for the estimation of spore count of *Trichoderma viride*. *Journal of Biopesticides*, **3**(3): 624–626.

Waluyo, B., Roosda, A.A., Istifadah, N., Ruswandi, D. & Karuniawan, A. 2015. Identification of Fifty Sweet potato (*Ipomoea batatas* (*L.*) Lam.) Promising Clones for Bioethanol Raw Materials. *Energy Procedia*, **65**: 22–28.

Waluyo, J., Burhani, D., Hikmah, N. & Sudiyani, Y. 2017. Immobilization of *Saccharomyces cerevisiae* Using Ca-alginate for Bioethanol Production from Empty Fruit Bunch of Oil Palm. *AIP Conference Proceedings*.

Wanderley, M.C.D.A., Soares, M.L. & Gouveia, E.R. 2014. Selection of inoculum size and *Saccharomyces cerevisiae* strain for ethanol production in simultaneous saccharification and fermentation (SSF) of sugar cane bagasse. *African Journal of Biotechnology*, **13**(27): 2762–2765.

Wijaya, Y.P., Putra, R.D.D., Widyaya, V.T., Ha, J.M., Suh, D.J. & Kim, C.S. 2014. Comparative study on two-step concentrated acid hydrolysis for the extraction of sugars from lignocellulosic biomass. *Bioresource Technology*, **164**: 221–231.

Wu, X., Zhang, J., Xu, E., Liu, Y., Cheng, Y., Addy, M. & Ruan, R. 2016. Microbial hydrolysis and fermentation of rice straw for ethanol production. *Fuel*, **180**: 679–686.

Xue, C., Wang, Z., Wang, S., Zhang, X., Chen, L., Mu, Y. & Bai, F. 2016. The vital role of citrate buffer in acetone – butanol – ethanol (ABE) fermentation using corn stover and high-efficient product recovery by vapor stripping – vapor permeation (VSVP) process. *Biotechnology for Biofuels*, **9**: 146.

Yang, J., Kim, J.E., Kim, H.E., Yu, J.H., Cha, Y.L. & Kim, K.H. 2017. Enhanced enzymatic hydrolysis of hydrothermally pretreated empty fruit bunches at high solids loadings by the synergism of hemicellulase and polyethylene glycol. *Process Biochemistry*, **58**: 211–216.

Yue, Z., Ma, D., Peng, S., Zhao, X., Chen, T. & Wang, J. 2016. Integrated utilization of algal biomass and corn stover for biofuel production. *Fuel*, **168**: 1–6.

Yunus, R., Salleh, S.F., Abdullah, N. & Biak, D.R.A. 2010. Effect of ultrasonic pre-treatment on low temperature acid hydrolysis of oil palm empty fruit bunch. *Bioresource Technology*, **101**(24): 9792–9796.

Yusoff, S. 2006. Renewable energy from palm oil - Innovation on effective utilization of waste. *Journal of Cleaner Production*, **14**(1): 87–93.

Zabed, H., Sahu, J.N., Boyce, A.N. & Faruq, G. 2016. Fuel ethanol production from lignocellulosic biomass: An overview on feedstocks and technological approaches. *Renewable and Sustainable Energy Reviews*, **66**: 751–774.

Zabed, H., Sahu, J.N., Suely, A., Boyce, A.N. & Faruq, G. 2017. Bioethanol production from renewable sources: Current perspectives and technological progress. *Renewable and Sustainable Energy Reviews*, **71**: 475–501.

Zainan, N.H., Alam, Z. & Al-khatib, M.F. 2011. Production of sugar by hydrolysis of empty fruit bunches using palm oil mill effluent (POME) based cellulases: Optimization study. *African Journal of Biotechnology*, **10**(81): 18722–18727.

Zakaria, M.R., Hirata, S., Fujimoto, S. & Hassan, M.A. 2015. Combined pretreatment with hot compressed water and wet disk milling opened up oil palm biomass structure resulting in enhanced enzymatic digestibility. *Bioresource Technology*, **193**: 128–134.

Zanirun, Z., Bahrin, E.K., Lai-Yee, P., Hassan, M.A. & Abd-Aziz, S. 2015. Enhancement of fermentable sugars production from oil palm empty fruit bunch by ligninolytic enzymes mediator system. *International Biodeterioration and Biodegradation*, **105**: 13–20.

Zhu, Y., Xin, F., Zhao, Y. & Chang, Y. 2014. An integrative process of bioconversion of oil palm empty fruit bunch fiber to ethanol with on-site cellulase production. *Bioprocess and Biosystems Engineering*, **37**(11): 2317–2324.

Zulkefli, S., Abdulmalek, E. & Abdul Rahman, M.B. 2017. Pretreatment of oil palm trunk in deep eutectic solvent and optimization of enzymatic hydrolysis of pretreated oil palm trunk. *Renewable Energy*, **107**: 36–41.