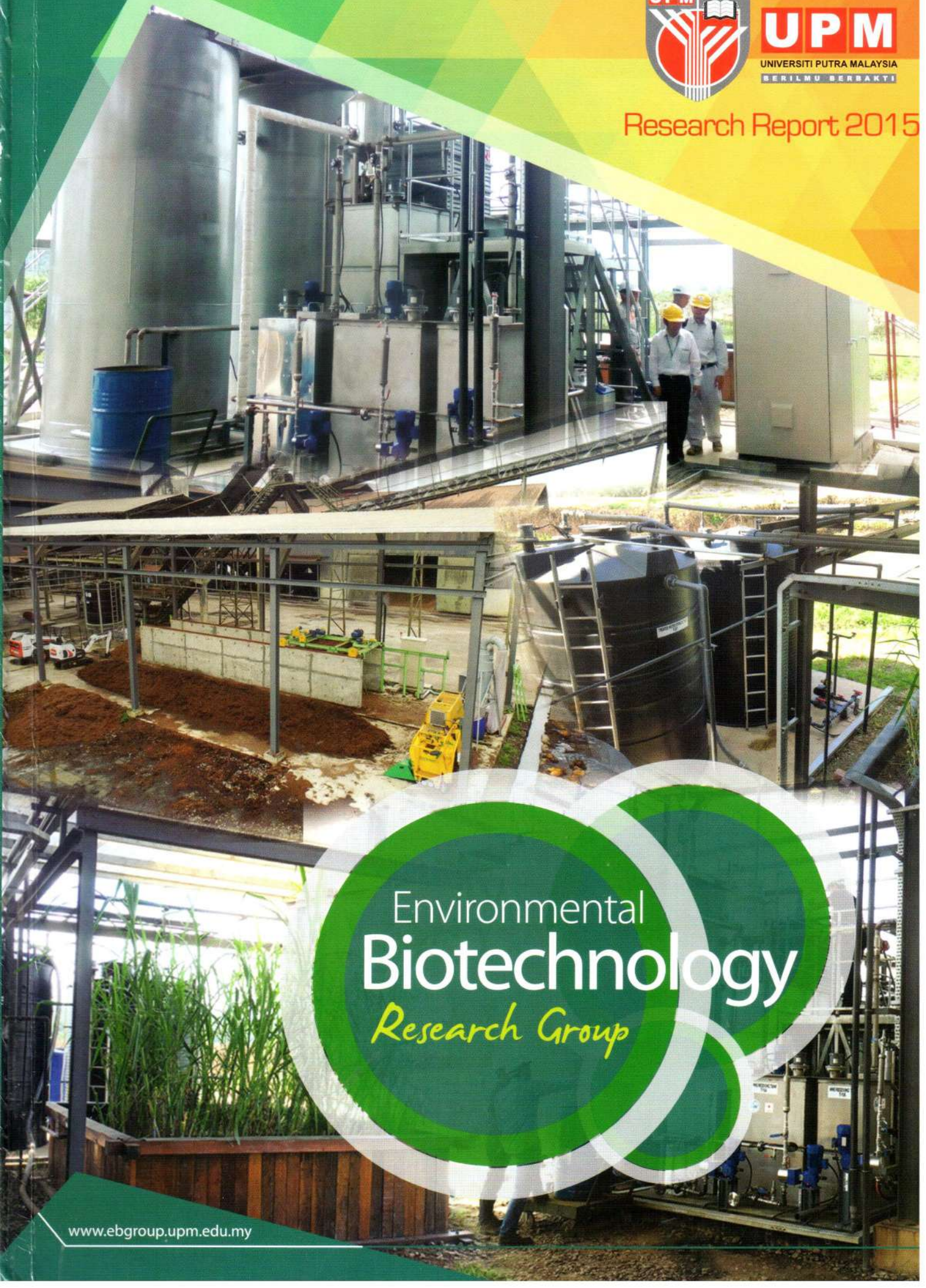
UPM

UNIVERSITI PUTRA MALAYSIA

BERILMU BERBAKTI

Research Report 2015



Environmental Biotechnology

Research Group

www.ebgroup.upm.edu.my

EB GROUP

Environmental Biotechnology Research Group (EB Group), Faculty of Biotechnology and Biomolecular Sciences (FBSB), Universiti Putra Malaysia was officially formed in 2005. Currently, EB Group focuses on four themes which are biocompost, biomaterial, bioenergy and biobased chemicals. EB Group undertakes research in core areas of biomass utilization, specifically in the production of renewable and valuable green bioproducts. Other potential biomass such as kitchen waste, landfill leachate and sago wastes also been studied. There are nine principal researchers, with one post-doctoral fellow, 21 PhD students, 28 Master students, and 3 research assistants. Our facilities include three laboratories and a refinery complex. The Environmental Biotechnology (General & Molecular) Laboratory are located at Biotech 3, FBSB within the main campus area, while the Biomass Technology Centre (BTC) is situated next to the Biorefinery Complex, nearby Bukit Ekspo UPM.

We aim to be a high performance research group conducting research on oil palm biomass and other renewable resources in Malaysia into valuable green products, with our tagline "EB for 3P" (Environmental Biotechnology – for Profit, People and Planet). We conduct collaborative research in close industries locally and internationally such as IWK Sdn. Bhd, FELDA, SIRIM, Ajinamoto Co. (Japan), Kyutech (Japan), AIST (Japan), MOSTI, YPJ Plantation Sdn. Bhd., MITSUBISHI, and CES (Korea).

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Lecturers

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Master Students

Introduction to Biorefinery Complex

Biorefinery complex of Environmental Biotechnology (EB) group is the first pilot processing in UPM that incorporate a holistic approach in exploiting biomass into value added products through green technology. Biochar, biocompost, biodiesel and biogas pilot plants are developed based on our extensive research for 20 years in environmental biotechnology. Pilot plants are majorly equipped with solid biomass processing machines and instrument for generation of lignocellulosic-based products. The pilot plants consist of biocompost machinery including biocompost reactor, mechanical compost turner, grinder, wood chipper as well as other machines such as steam blasting and biodiesel reactor. Serdang Biomass Town launched in January 2012 was a breakthrough project for EB group in collaboration with MPSJ, MARDI, KyuTech (Japan), FELDA, AIST (Japan) and KPKT. Through this project, we promoted zero discharge concepts for Serdang community by converting selected biomass into valuable biomaterials.

Biorefinery complex also includes Biomass Technology Centre (BTC) for analytical purposes to attain research and development requirement. This year, EB Group is proudly marks the first anniversary of BTC. BTC located near to University Agricultural Park (TPU) and UPM golf course, was operated last year starting from January 2014. The whole area of BTC covers 1075 m^2 features laboratories, postgraduate students room that accommodates 30 students, researcher rooms, meeting room and seminar room. The seminar room can accommodate a maximum of 100 people at a time for meetings and presentations. The laboratory of this centre comprises of a chemical room, a culture room, a bioreactor room, an analysis room and a cold room. These rooms are fully equipped with instruments for environmental biotechnology research such as biomass pretreatment, fermentation process and analytical equipments.

Introduction to EB Lab at BioTech 3

Environmental Biotechnology (EB) Research Group has two laboratories in BioTech 3: Environmental Biotechnology Lab and Environmental Biotechnology (Molecular) Lab. There are about 20 students (postgraduates and undergraduates) currently working in both labs. Environmental Biotechnology Laboratory is a general laboratory mainly focusing on research related to biopolymers, biomaterials and biochemicals. The laboratory is equipped with equipment and analytical instruments related to the research such as stirred tank bioreactors (2L & 7L), incubator shaker, freeze-dryer, glass tube oven for pyrolysis, gas-chromatography with Flame Ionization Detector (GC-FID), gel permeation chromatography (GPC) with UV and RI detectors, high performance liquid chromatography with UV and RI detectors, phase-contrast microscope, differential scanning colorimetry (DSC) and UV-VIS spectrophotometer.

Environmental Biotechnology (Molecular) Lab on the other hand is a laboratory dedicated for molecular work focusing on environmental samples. The laboratory is equipped with equipment for molecular analyses such as PCR, RT-PCR, Denaturing Gradient Gel Electrophoresis (DGGE) machine, NanoDrop and Gel Documentation system.

MESSAGE FROM THE EB GROUP LEADER

PROFESSOR DR. MOHD ALI HASSAN

In The Name of ALLAH, Most Gracious, Most Merciful.

AlhamduLillah, praise to ALLAH for His generous favours and blessings on all of us.

I am glad to share with you our Environmental Biotechnology (EB) research report for 2015. We have two operational sub-groups, comprising of EB1- Biomass and Biorefinery, and EB2– Bioenergy and Biochemicals. We have 9 academic staff members, 1 post-doctorate researcher and 15 associate researchers. Our current student enrolments are 21 PhD, 28 MS and 20 undergraduate students. In addition we also have 4 students on the PhD Double-Degree and 5 students on the Split-PhD program with Kyushu Institute of Technology, Japan. We continue to operate the Biorefinery@UPM Complex, comprising of the Biomass Technology Centre and the Pilot Plants for Biocompost, Biochar and Biodiesel and Biogas under the Serdang Biomass Town project, in collaboration with The Ministry of Housing and Local Government (KPKT, Malaysia), The Ministry of Agriculture, Forestry and Fisheries (MAFF, Japan), Malaysia Agricultural Research and Development Institute (MARDI) and The Subang Jaya Municipal Council (MPSJ).

We managed to secure the JICA-JST SATREPS International Grant for the period 2013-2018, with a matching grant from The Ministry of Higher Education Malaysia. In the SATREPS project, we collaborate with Kyushu Institute of Technology, Kyushu University, The Advanced Industrial Science and Technology (AIST) Institute, Japan and University Malaysia Sabah and Sabah State Government. We have set up an integrated zero-emission showcase pilot plant at Keningau Palm Oil Mill in Sabah, which is under testing and commissioning. We also conducted a collaborative research project with the industry, namely Indah water Konsortium (IWK) on biofertilizer pellets. In terms of output, we successfully published 25 research papers in 2015, with 16 in Quartile 1 (Q1) and 5 in Quartile 2 (Q2), with a total of 58.6 Impact Factors. We were awarded 1 patent and filed 1 joint patents with our collaborators.

I really appreciate the hard work from all EB members and our collaborators in maintaining our high-performance culture. We also wish all the best to all EB alumni. May ALLAH give all of us the strength to continue the good work and contribute to the university, the ummah and the nation.

Thank you. Wassalam.

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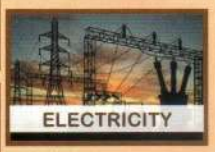
EB GROUP

TRADITIONAL TECHNOLOGY

PALM OIL MILL


FRESH FRUIT


ELECTRICITY


RIVER WATER


OIL PALM TREE

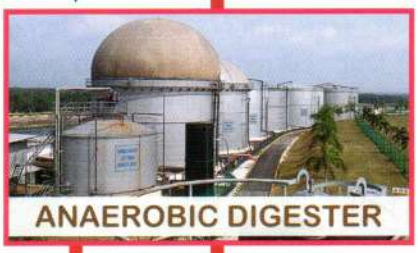
POME final discharge treated with bioadsorbent

Methane for electricity generation


POME


FROND

TRUNK


ANAEROBIC DIGESTER

Sludge

Pressing

BIO SUGAR

BIO GAS

BIO COMPOSITE

BIO COAL

BIO ADSORBANT

BIG PICTURE

Cellulose & hemicellulose → BIOSUGAR

Lignin

BIO COMPOSITE

LIGNINASE & CELLULASE

BIO VANILIN

BIO BUTANOL

BIO ETHANOL

BIO PLASTIC

EMERGING TECHNOLOGY

SERDANG BIOMASS

UNIVERSITI PUTRA MALAYSIA
BERILMU BERBAKTI

Kyutech
Kyushu Institute of Technology

RECYCLEABLE MATERIALS

FOOD WASTE

Biogas Production

BIOGAS

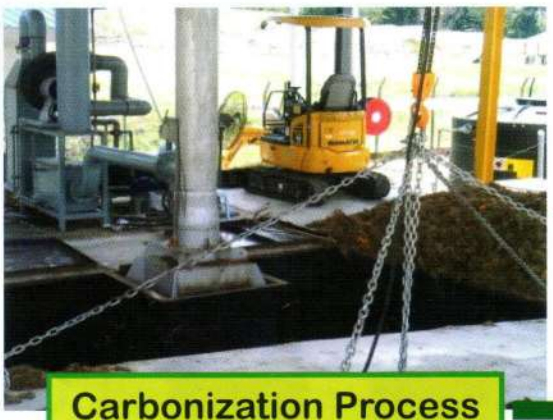
SLUDGE

SEGREGATION

BIOREFINERY COMPLEX

Municipal Solid Waste

Landscaping Waste



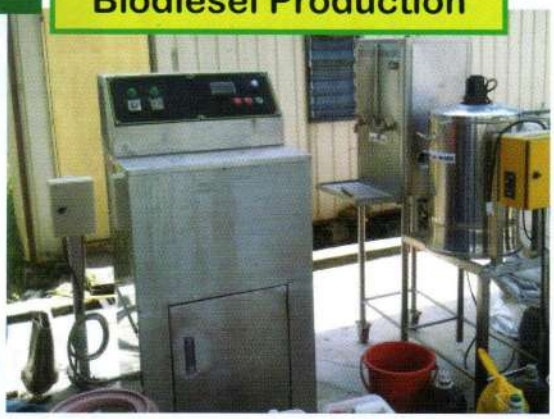
Carbonization Process

BIOCHAR

TOWN BIG PICTURE

National Institute of Advanced Industrial Science and Technology
AIST

BIODIESEL ← Biodiesel Production

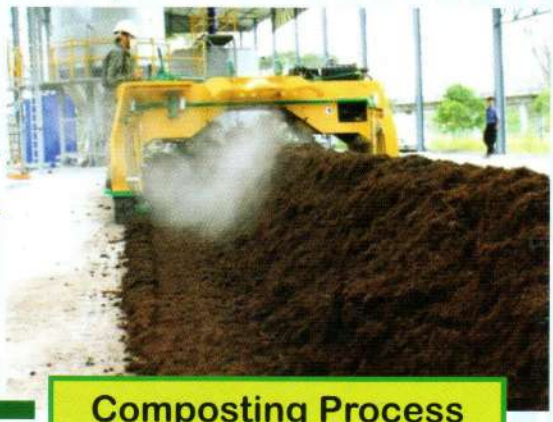


AT UNIVERSITI PUTRA MALAYSIA

Sewage Sludge

Livestock Manure

Used Cooking Oil

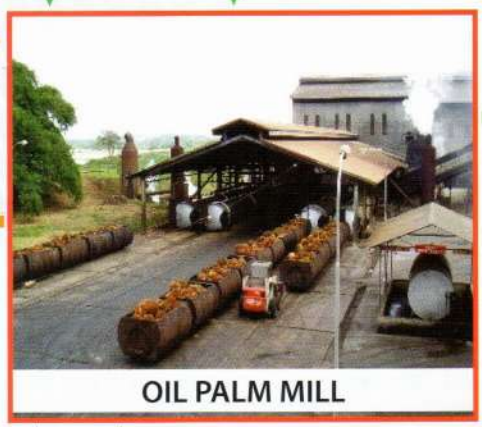


BIOCOMPOST ← Composting Process

SATREPS

RAW MATERIALS

TURBINE



TRADITIONAL PRODUCTS

NO DUST AND SMOKE

NO POME

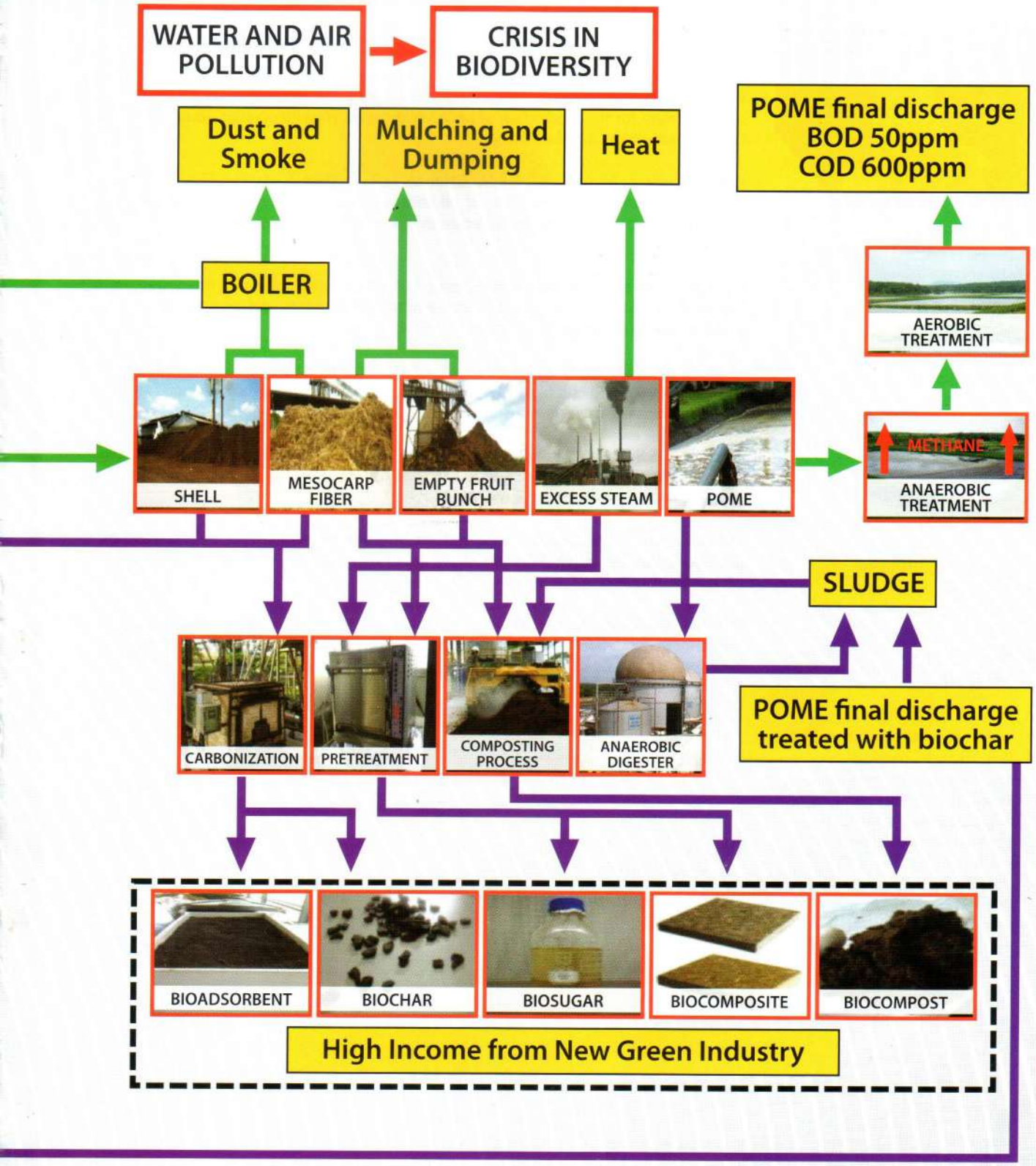
BIODIVERSITY CONSERVATION

NEW BOILER

NEW TURBINE

METHANE

BIG PICTURE


WATER AND AIR POLLUTION
CRISIS IN BIODIVERSITY
Dust and Smoke
Mulching and Dumping
Heat
POME final discharge BOD 50ppm COD 600ppm
BOILER
AEROBIC TREATMENT
SHELL
MESOCARP FIBER
EMPTY FRUIT BUNCH
EXCESS STEAM
POME
METHANE
ANAEROBIC TREATMENT
BUSINESS AS USUAL
SLUDGE
CARBONIZATION
PRETREATMENT
COMPOSTING PROCESS
ANAEROBIC DIGESTER
POME final discharge treated with biochar
NEW BUSINESS MODEL
BIOADSORBENT
BIOCHAR
BIOSUGAR
BIOCOMPOSITE
BIOCOMPOST
High Income from New Green Industry

EB GROUP Researcher

Professor Dr. Mohd Ali Hassan

Specialisation:
Bioprocess engineering and environmental biotechnology

Current research interest:
Treatment and utilization of biomass for the production of biobased products, bioremediation and reduction of greenhouse gases

h-index: 25

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Academic Qualification:

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2. M.Phil. (Chemical Engineering), University of Birmingham, U.K. (1990)
3. M.Sc. (Food Engineering), University of Leeds, U.K. (1982)
4. B.Sc. (Hons) (Chemical Engineering), University of Leeds, U.K. (1980)
5. 'A' Levels (Math., Chem., Physics), Oxford College Further Edu., U.K. (1977)
6. Post-graduate Diploma (Islamic Studies), University Kebangsaan Malaysia (1985)

Selected publications:

Zahari, M.A.K.M., Ariffin, H., Mokhtar, M.N., Salihon, J., Shirai, Y., Hassan, M.A. 2015. Case study for a palm biomass biorefinery utilizing renewable non-food sugars from oil palm frond for the production of poly(3-hydroxybutyrate) bioplastic. Journal of Cleaner Production. 87, 284-290.

Idris, J., Shirai, Y., Ando, Y., Ali, A.A.M., Othman, M.R., Ibrahim, I., Hassan, M.A. 2015. 2015. Self-sustained carbonization of oil palm biomass produced an acceptable heating value biochar with low gaseous emission. Journal of Cleaner Production. 89, 257-261.

Ali, A.A.M., Shirai, Y., Othman, M.R., Hassan, M.A. 2015. Sustainable and integrated palm oil biorefinery concept with value-addition of biomass and zero emission system. Journal of Cleaner Production 91, 96-99.

Idris, J., Shirai, Y., Ando, Y., Ali, A.A.M., Othman, M.R., Ibrahim, I., Husen, R., Hassan, M.A. 2015. Improved yield and higher heating value of biochar from oil palm biomass at low retention time under self-sustained carbonization. J. Clean Prod. 104, 475-479.

Abdullah, S.S.S., Shirai, Y., Bahrin, E.K., Hassan, M.A. 2015. Fresh oil palm frond juice as a renewable, non-food, non-cellulosic and complete medium for direct bioethanol production. Ind. Crops Prod. 63, 357-361.

Harmaen, A.S., Khalina, A., Azowa, I., Hassan, M.A., Tarmian, A., Jawaid, M. Thermal and biodegradation properties of poly(lactic acid)/fertilizer/oil palm fibers blends biocomposites. Polym Composites. 36(3), 576-583.

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Researcher EB GROUP

Prof. Dr Suraini Abd-Aziz

Specialisation:
Biochemical Engineering and Enzyme Technology

Current research interest:
Biomass utilization for the production of bioenergy and biobased chemicals

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2. M.Sc. (Biochemical Engineering), University of Wales, Swansea, United Kingdom (1994)
3. B.Sc. (Hons) (Clinical Biochemistry), Universiti Kebangsaan Malaysia (1992)

Selected publications:

Hussin, H., Md Salleh, M., Siong, C.C., Naser, M.A., Abd-Aziz, S., Al-Junid, A.F.M. (2015). Optimization of biovanillin production of lemongrass leaves hydrolysates through Phanerochaete chrysosporium. J. Teknolog: 77(31): 55-61.

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Zanirun, Z., Bahrin, E.K., Phang, L.Y., Hassan, M.A., Abd-Aziz, S. (2015). Enhancement of fermentable sugars production from oil palm empty fruit bunch by ligninolytic enzymes mediator system. Inter. Biodeter. Biodegrad. 105: 13-20.

Ibrahim, M.F., Linggang, S., Jenol, M.A., Phang, L.Y., Abd-Aziz, S. (2015). Effect of buffering system on acetone-butanol-ethanol fermentation by Clostridium acetobutylicum ATCC 824 using pretreated oil palm empty fruit bunch. BioResources. 10(3): 3890-3907.

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Zuraidah, Z., Bahrin, E.K., Lai-Yee, P., Hassan, M.A., S. Abd-Aziz. (2014). Effect of physical and chemical properties of lignocellulosic biomass on cellulases production by Trichoderma asperellum UPM1 and Aspergillus fumigatus UPM2. Appl. Biochem. Biotechnol. 172:423–435.

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Shankar, R., Madihah, M.S., Shaza, E.M, Nur Aswati, K.O., Suraini, A.A., Kamarulzaman, K. (2014). Application of Different Feeding Strategies in Fed Batch Culture for Pullulanase Production Using Sago Starch. Carbohydrate Polym. 102: 962– 969.

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Abu Samah, R., Zainol, N., Lai Yee, P., Pawing, C.M., Abd-Aziz, S. (2013). Adsorption of Vanillin using Macroporous Resin H103. Adsorpt. Sci. Technol. 31 (7): 599-610.

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Ibrahim, M.F., Razak, M.N.A., Lai-Yee, P., Hassan, M.A., Abd-Aziz, S. (2013). Crude cellulases cocktail from oil palm empty fruit bunch by Trichoderma asperellum UPM1 and Aspergillus fumigatus UPM2 for fermentable sugars production. Appl. Biochem. Biotechnol. 170:1320–1335.

EB GROUP Researcher

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Specialization:
Bioprocess Engineering and Environmental Biotechnology

Current research interest:
Bio-based polymers and chemicals, utilization of biomass for value-added products.

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Selected publications:

Farid, N.F.S.M., Ariffin, H., Zakaria, M.R., Zahari, M.A.K.M., Hassan, M.A. (2015). Non-solvent pretreatment of poly(3-hydroxybutyrate) for high purity biocrotonic acid production. RSC Advan. 5, 33546–33553.

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Nordin, N.I.A.A., Ariffin, H., Hassan, M.A., Ibrahim, N.A., Shirai, Y., Andou, Y. (2015). Effect of milling methods on tensile properties of polypropylene / oil palm mesocarp fiber biocomposite. Pertanika J. Sci. Technol. 23 (2), 325-337.

Then, Y.Y., Ibrahim, N.A., Zainuddin, N., Ariffin, H., Chieng, B.W., Yunus, W.M.Z.W. (2015). Influence of fiber content on properties of oil palm mesocarp fiber/poly (butylene succinate) biocomposites. BioResources. 10 (2), 2949 – 2968.

Then, Y.Y., Ibrahim, N.A., Zainuddin, N., Ariffin, H., Yunus, W.M.Z.W., Chieng, B.W. (2015). Static mechanical, interfacial, and water absorption behaviors of alkali treated oil palm mesocarp fiber reinforced poly(butylene succinate) biocomposites. BioResources. 10 (1), 123-136.

Karuppuchamy, S., Andou, Y., Nishida. H., Nordin, N.I.A.A., Ariffin, H., Hassan, M.A., Shirai, Y. (2015). Superheated steam treated oil palm frond fibers and their application in plastic composites. Adv. Sci. Eng. Med. Vol. 7, 1–6.

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Zahari, M.A.K.M., Abdullah, S.S.S., Roslan, A.M., Ariffin, H., Shirai, Y., Hassan, M.A. (2014). Efficient utilization of oil palm frond for bio-based products and biorefinery. J. Clean. Prod. 65, 252-260.

Rahim, N.F.A., Watanabe, K., Ariffin, H., Andou, Y., Hassan, M.A., Shirai, Y. (2014). Design of Bio-based monomers from oleic and linoleic acids for greener polyester. Chem. Lett. 43 (9), 1517 - 1519.

Then, Y.Y., Ibrahim, N.A., Zainuddin, N., Ariffin, H., Yunus, W.M.Z.W., Chieng, B.W. (2014). The influence of green surface modification of oil palm mesocarp fiber by superheated steam on the mechanical properties and dimensional stability of oil palm mesocarp fiber/poly (butylene succinate) biocomposite. Int. J. Mol. Sci. 15 (9), 15344-15357.

Researcher EB GROUP

Dr. Mohd Rafein Zakaria

Specialization:
Environmental Biotechnology

Current research interest:
Biomass valorization in biorefinery concept

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Academic Qualification:

1. PhD (Environmental Biotechnology), Universiti Putra Malaysia (2012)
2. M.Sc. (Environmental Biotechnology), Universiti Putra Malaysia (2008)
3. B.Sc. (Hons) Biotechnology, Universiti Putra Malaysia (2003)

Selected publications:

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 structures resulting in enhanced enzymatic digestibility. Bioresour. Technol. 193, 128-134.

Zakaria, M.R., Norrrahim, M.N.F., Hirata, S., Hassan. M.A. (2015). Hydrothermal and wet disk milling pretreatment for high conversion of biosugars from oil palm mesocarp fiber. Bioresour. Technol. 181, 263-269.

Zakaria, M.R., Hirata, S., Hassan. M.A. (2015). Hydrothermal pretreatment enhanced enzymatic hydrolysis and glucose production from oil palm biomass. Bioresour. Technol. 176, 142-148.

Abd-Rahim, F., Wasoh, H., Zakaria, M.R., Ariff, A., Kapri, R., Ramli, N., Liew S.L. 2014. Production of high yield sugars from Kappaphycus alvarezii using combined methods of chemical and enzymatic hydrolysis. Food Hydrocolloids 42, 309-315.

Zakaria, M.R., Hirata, S., Hassan, M.A. 2014. Combined pretreatment using alkaline hydrothermal and ball milling to enhance enzymatic hydrolysis of oil palm mesocarp fiber. Bioresour. Technol. 169, 236–243.

Zakaria, M.R., Fujimoto, S., Hirata, S., Hassan, M.A. 2014. Ball Milling Pretreatment of Oil Palm Biomass for Enhancing Enzymatic Hydrolysis. Appl. Biochem. Biotechnol. 173; 7.

Zakaria, M.R., Ariffin, H., Abd-Aziz, S., Hassan, M.A., Shirai, Y.2013. Improved properties of poly(3-hydroxybutyrate-co-3- hydroxyvalerate) produced by Comamonas sp. EB172 utilizing volatile fatty acids by regulating the nitrogen source. BioMed Res. Inter. 1-8.

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Salihan, N.H.A., Ariff, A., Zakaria, M.R., Abd_Aziz, S., Abd Wahab, M.N., Wasoh, H.2013. Performance of B-glucosidase produced by Ganoderma lucidum using waste substrate as carbon source. Journal of Biochemistry, Microbiology and Biotechnology, 1, 17-24.

EB GROUP Researcher

Dr. Norhayati Ramli

Specialization:
Microbial Biotechnology

Current research interest:
Understanding structure and dynamic of microbial communities related to ecological functions; Strain improvement and utilization of biomass for the production of enzymes, bio-based chemicals, bioethanol

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Selected Seminar/ Conferences:

Ramli, N., Hassan, M.A., Sakai, K., Tashiro, Y., Shirai. Y. Molecular analysis of bacterial community structure in the palm oil mill effluent treatment in Malaysia. Proceeding, AFOB Regional Symposium, Universitas Indonesia, Depok, Indonesia. 2015

Sobri, M.F.M., Ramli, N., Abd-Aziz, S., Abu Bakar, F.D., Molecular cloning of β-glucosidase gene into ethanol fermenting yeast for enhancement of bioethanol production from oil palm empty fruit bunch. e-Proceeding, Asian Congress on Biotechnology, Kuala Lumpur, Malaysia. 2015

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Nor, D.M., Ramli, N., Hassan, M.A., Sakai, K., Tashiro, Y., Maeda. T. Shirai. Y. Microbial community changes in different stages of palm oil mill effluent treatment. e-Proceeding, Asian Congress on Biotechnology, Kuala Lumpur, Malaysia. 2015

Nik Pa, N.I.M., Abd-Aziz, S., Ramli, N. Regulation of RNA transcription for production improvement of recombinant cyclodextrin glycosyltransferase. e-Proceeding, Asian Congress on Biotechnology, Kuala Lumpur, Malaysia. 2015

Kenji Sakai, Yukihiro Tashiro, Ramli, N., Hassan, M.A., Vairappan. C.S. Microbial community structure analysis as a tool for monitoring environmental impact. Asian Congress on Biotechnology, Kuala Lumpur, Malaysia. 2015

Kenji Sakai, Yukihiro Tashiro, Ramli, N., Hassan, M.A., Vairappan. C.S. Microbial diversity analysis as a tool for monitoring environmental impact and biodiversity toward sustainability of Sabah, Malaysia. Asian Congress on Biotechnology, Kuala Lumpur, Malaysia. 2015.

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Ibrahim, M.F., Linggang, S., Jenol, M.A., Phang, L.Y., Abd-Aziz, S. (2015). Effect of buffering system on acetone-butanol-ethanol fermentation by Clostridium acetobutylicum atcc 824 using pretreated oil palm empty fruit bunch. BioResources, 10(3), 3890-3907 (IF: 1.425)

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. Renew Energy, 77:447–455. (IF: 3.476)

Jenol, M.A., Ibrahim, M.F., Phang, L.Y., Salleh, M.M., Abd-Aziz, S. (2014). Sago biomass as a sustainable source for biohydrogen production by Clostridium butyricum A1. BioResources 9 (1): 1007-1026. (IF: 1.425)

Ibrahim, M.F., Razak, M.N.A., Phang, L.Y., Hassan, M.A., Abd–Aziz, S. Crude cellulase from oil palm empty fruit bunch by Trichoderma asperellum UPM1 and Aspergillus fumigatus UPM2 for fermentable sugars production. Appl. Biochem. Biotechnol, 170:1320–1335. (IF: 1.735)

Razak, M.N.A., Ibrahim, M.F., Phang, L.Y., Hassan, M.A., Abd–Aziz, S. (2013). Statistical optimization of biobutanol production from oil palm decanter cake hydrolysate by Clostridium acetobutylicum ATCC 824. BioResources 8(2), 1758–1770. (IF: 1.425)

Selected patents:

Abd–Aziz, S., Hassan, M.A., Ismail, M.S., Sarbini, R., Ibrahim, M.F., Abdul Razak, M.N., Abu Bakar, N.K., Yee, P.L., (2011). Crude cellulase cocktail for lignocellulosic material degradation. Patent Pending: PI2011002674.

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Biofuels production through simultaneous acetone-butanol-ethanol fermentation using oil palm empty fruit bunch as substrate. Biotech Mini Symposium 2015, Universiti Putra Malaysia, Malaysia.

Biofuels production through simultaneous acetone-butanol-ethanol fermentation using oil palm empty fruit bunch as substrate. 6th AFOB Regional Symposium. Universitas Indonesia, Indonesia.

Co-production of biobutanol and biohydrogen from pretreated oil palm empty fruit bunch through simultaneous saccharification and fermentation. 2nd International Symposium on Applied Engineering and Sciences (SAES2014). Kyushu Institute of Technology (Kyutech), Japan.

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AFOB Regional Symposium 2014, Kuala Lumpur, Malaysia. February 9-11, 2014

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Ciptanto, A., Yusoff, M.M.Z., Zakaria, M.R., Maeda, T., Hassan, M.A. 2014. 'Biohydrogen generation on thermophilic dark fermentation of palm oil mill effluent usinganaerobic microflora.' AFOB Regional Symposium. Kuala Lumpur, Malaysia. 2014

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Nik Anis Nik Mahmud, Azhari Samsu Baharuddin , Ezyana Kamal Bahrin, Alawi Sulaiman, Mohd Nazli Naim, , Rabitah Zakaria, Mohd Ali Hassan, Haruo Nishida and Yoshihito Shirai (2013). Enzymatic Saccharification of Oil Palm Mesocarp Fiber (OPMF) Treated with Superheated Steam. *BioResources* 8(1): 1320-1331. (IF: 1.348).

Selected seminar/conferences:

Masran, R., Zanirun, Z., Rizal, N. F. A. A., E. K. Bahrin, Ibrahim, M. F., Phang, L. Y. and Abd-Aziz, S. Laccase Enzyme Production by *Pycnoporus sanguineus*. Asian Congress of Biotechnology, 15-19 November 2015 Kuala Lumpur, Malaysia.

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Abdullah, S. S. S., Bahrin, E. K., Hassan M. A. and Shirai, Y. Glucose Preservation In Non-food Juice of Oil Palm Frond at Mild Temperature Storage for Bioethanol Production. Asian Congress of Biotechnology, 15-19 November 2015 Kuala Lumpur, Malaysia.

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Selected seminar/conferences:

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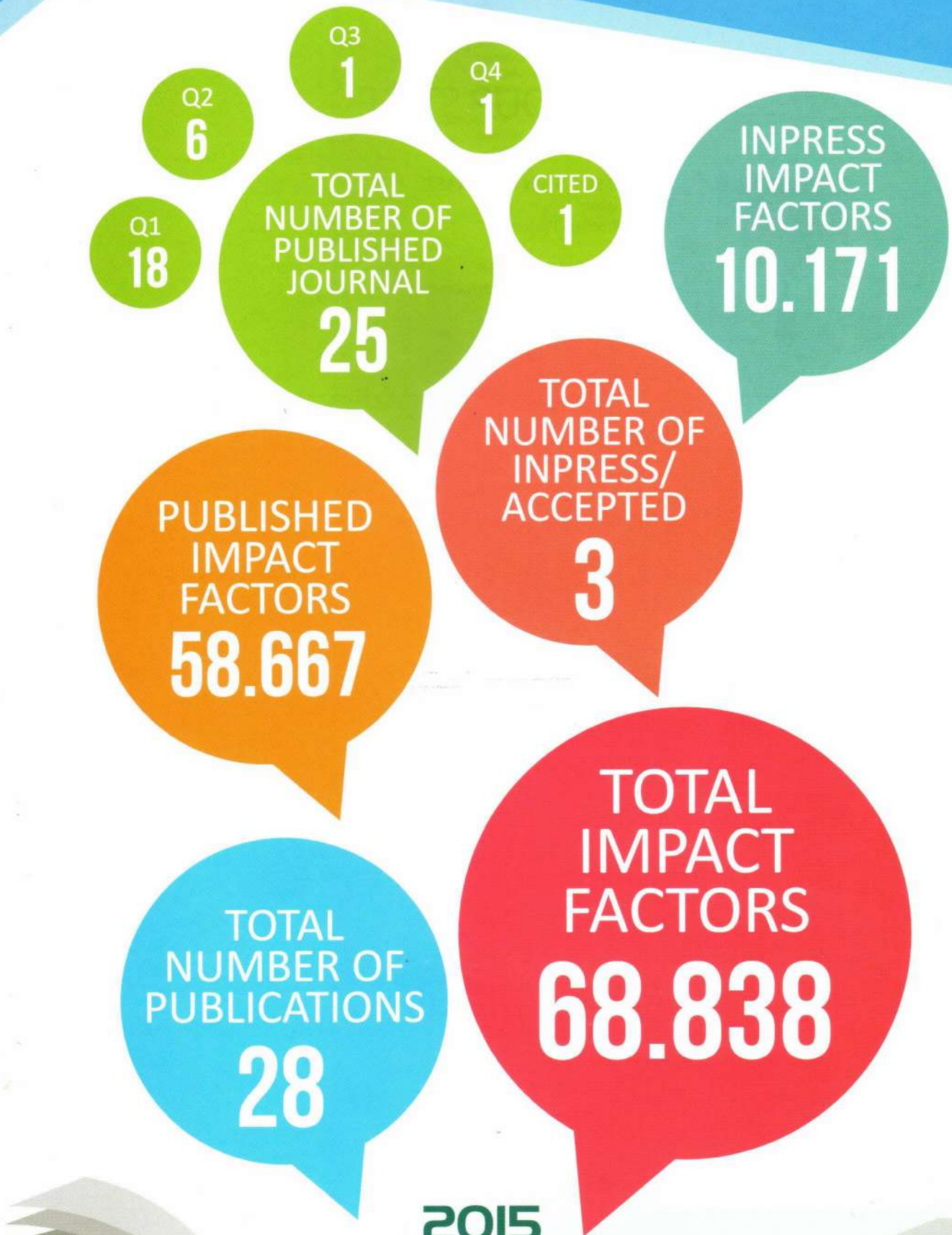

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Hydrothermal pretreatment enhanced enzymatic hydrolysis and glucose production from oil palm biomass

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HIGHLIGHTS

- Hydrothermal pretreatment as suitable method for oil palm biomass.
- Removal of hemicellulose correlated with hydrothermal treatment severities.
- Tannic acid as potential cellulase inhibitor from oil palm treated slurries.
- Specific surface area and pore volume correlated with glucose yield.
- 87.9% and 100% of glucose conversion from OPFF and OPEFB.

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ABSTRACT

The present works investigate hydrothermal pretreatment of oil palm empty fruit bunch and oil palm frond fiber in a batch tube reactor system with temperature and time range from 170 to 250 °C and 10 to 20 min, respectively. The behavior of soluble sugars, acids, furans, and phenols dramatically changed over treatment severities as determined by HPLC. The cellulose-rich treated solids were analyzed by SEM, WAXD, and BET surface area. Enzymatic hydrolysis was performed from both pretreated slurries and washed solid, and data obtained suggested that tannic acid derived from lignin degradation was a potential cellulase inhibitor. Both partial removal of hemicellulose and migration of lignin during hydrothermal pretreatment caused structural changes on the cellulose–hemicellulose–lignin matrix, resulting in the opening and expansion of specific surface area and pore volume. The current results provided important factors that maximize conversion of cellulose to glucose from oil palm biomass by hydrothermal process.

Q1
IMPACT FACTOR
4.494

Mohd Rafein Zakaria et. al., 2015.

Hydrothermal pretreatment enhanced enzymatic hydrolysis and glucose production from oil palm biomass. Bioresource Technology. 176, 142-148.

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Hydrothermal and wet disk milling pretreatment for high conversion of biosugars from oil palm mesocarp fiber

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HIGHLIGHTS

- Combined pretreatment using hydrothermal and WDM was performed on OPMF.
- Maximal H_2O contact and hemicellulose removal were favored under HCW than SHS.
- Defibrillation of OPMF is key factor for higher glucose conversion.
- Optimal combined pretreatment of HCW–WDM was 180 °C, 20 min after 9 cycles of WDM.
- Glucose yield (98%) obtained from HCW–WDM with power requirement 9.6 MJ/kg OPMF.

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Enzymatic hydrolysis

ABSTRACT

Eco-friendly pretreatment methods for lignocellulosic biomass are being developed as alternatives to chemical based methods. Superheated steam (SHS), hot compressed water (HCW) and wet disk milling (WDM) were used individually and with combination to partially remove hemicellulose and alter the lignin composition of recalcitrant structure of oil palm mesocarp fiber (OPMF). The efficiency of the pretreatment methods was evaluated based on the chemical compositions altered, SEM analysis, power consumption and degree of enzymatic digestibility. Hemicellulose removal (94.8%) was more pronounced under HCW compared to SHS, due to maximal contact of water and production of acetic acid which enhanced further degradation of hemicellulose. Subsequent treatment with WDM resulted in defibrillation of OPMF and expansion of the specific surface area thus increasing the conversion of cellulose to glucose. The highest glucose yield was 98.1% (g/g-substrate) when pretreated with HCW (200 °C, 20 min) and WDM which only consumed 9.6 MJ/kg of OPMF.

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IMPACT FACTOR
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Mohd Rafein Zakaria et. al., 2015.

Hydrothermal and wet disk milling pretreatment for high conversion of biosugars from oil palm mesocarp fiber. Bioresource Technology. 181, 263-269.

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4.494

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Combined pretreatment with hot compressed water and wet disk milling opened up oil palm biomass structure resulting in enhanced enzymatic digestibility. Bioresource Technology.

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Combined pretreatment with hot compressed water and wet disk milling opened up oil palm biomass structure resulting in enhanced enzymatic digestibility

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HIGHLIGHTS

- OPEFB and OPFF were hydrothermally treated under isothermal and non-isothermal.
- Hemicellulose dissolution more pronounced at higher temperature.
- Subsequent WDM of HCW-pretreated oil palm biomass unravels fiber structures.
- Fibrillation of pretreated oil palm biomass improved over milling cycles.
- 88.5% and 100% of total sugars obtained from OPEFB and OPFF at 150 °C, 240 min.

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Oil palm empty fruit bunch
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ABSTRACT

Combined pretreatment with hot compressed water and wet disk milling was performed with the aim to reduce the natural recalcitrance of oil palm biomass by opening its structure and provide maximal access to cellulase attack. Oil palm empty fruit bunch and oil palm frond fiber were first hydrothermally pretreated at 150–190 °C and 10–240 min. Further treatment with wet disk milling resulted in nanofibrillation of fiber which caused the loosening of the tight biomass structure, thus increasing the subsequent enzymatic conversion of cellulose to glucose. The effectiveness of the combined pretreatments was evaluated by chemical composition changes, power consumption, morphological alterations by SEM and the enzymatic digestibility of treated samples. At optimal pretreatment process, approximately 88.5% and 100.0% of total sugar yields were obtained from oil palm empty fruit bunch and oil palm frond fiber samples, which only consumed about 15.1 and 23.5 MJ/kg of biomass, respectively.

Q1
IMPACT FACTOR
3.844

Mior Ahmad Khushairi Mohd Zahari et. al., 2015.

Case study for a palm biomass biorefinery utilizing renewable non-food sugars from oil palm frond for the production of poly(3-hydroxybutyrate) bioplastic. Journal of Cleaner Production. 87, 284-290.

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Case study for a palm biomass biorefinery utilizing renewable non-food sugars from oil palm frond for the production of poly(3-hydroxybutyrate) bioplastic

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Renewable sugars
Oil palm biomass

ABSTRACT

In this paper, we assess the economic viability of renewable non-food sugars from oil palm frond (OPF) as fermentation feedstock for the production of the bioplastic, poly(3-hydroxybutyrate), P(3HB) within an integrated palm biomass biorefinery. The production cost of P(3HB) is estimated based on 9900 t/y of the potential amount of renewable sugars that can be produced from OPF in a typical palm oil mill in Malaysia. Based on the case study, approximately 99,780 t/y of renewable sugars could be produced from 10 neighbouring palm oil mills, each with the capacity to process an average of 200,000 t/y of fresh fruit bunch (FFB). With 20,000 t/y of P(3HB) production, the specific production cost of P(3HB) using renewable sugars from OPF is estimated at $ 3.44/kg P(3HB), which is 41% lower compared with that produced from commercial glucose.

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Note from the field

Self-sustained carbonization of oil palm biomass produced an acceptable heating value charcoal with low gaseous emission

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Self-sustained carbonization
Charcoal
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Oil palm biomass
Oil palm empty fruit bunch

ABSTRACT

Charcoal production with higher heating value (HHV) requires high capital investment and high energy requirement for large scale production. In this study, charcoal production under self-sustained carbonization from oil palm biomass was proposed and tested at pilot scale, whereby temperature and exhaust gas flow rate were monitored but not controlled. This proposed system under self-sustained carbonization, whereby oil palm biomass is combusted to provide the heat for carbonization in inadequate oxygen is preferable to the industry due to its simplicity, ease of operation and low energy requirement. Moreover, the gaseous emissions are below the permitted level set by the environmental authorities. The considerable HHV obtained was between 23 and 25 MJ/kg with low gaseous emissions. The results obtained are acceptable and comparable to other studies on oil palm biomass conducted under controlled conditions with electrical heating elements.

Q1
IMPACT FACTOR
3.844

Juferi Idris et. al., 2015.

Self-sustained carbonization of oil palm biomass produced an acceptable heating value biochar with low gaseous emission. Journal of Cleaner Production. 89, 257-261.

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Sustainable and integrated palm oil biorefinery concept with value-addition of biomass and zero emission system

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ABSTRACT

The problem of biomass residues and effluent from the palm oil milling process has become a big concern for the industry, the public and the environment. Furthermore, the modern palm oil mill can no longer rely solely on traditional crude palm oil and palm kernel products for profit generation. In order to remain truly sustainable in the future, we propose the solid biomass residues and liquid effluent to be managed and utilized via a biorefinery concept to generate new value-added products, in-line with zero emission system. Modern and efficient boiler and turbine systems utilizing biomass and biogas captured from the anaerobic effluent treatment can provide the steam and electricity required for the palm oil mill operations. The solid biomass residues can be channeled towards the production of value-added products such as biofertiliser, biochar, biofuels and biomaterials. The liquid final discharge can be further treated to meet river water quality, making it suitable to be recycled - hence achieving zero emission. Such an integrated approach will not only solve the issue of proper biomass disposal and effluent treatment, but also more importantly create a win-win-win situation for profit, people and planet - the three pillars of sustainability.

Q1
IMPACT FACTOR
3.844

Ahmad Amiruddin Mohd Ali et. al., 2015.

Sustainable and integrated palm oil biorefinery concept with value-addition of biomass and zero emission system. Journal of Cleaner Production 91, 96-99.

Q1
IMPACT FACTOR
3.844

Juferi Idris et. al., 2015.

Improved yield and higher heating value of biochar from oil palm biomass at low retention time under self-sustained carbonization. Journal of Cleaner Production. 104, 475-479.

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Improved yield and higher heating value of biochar from oil palm biomass at low retention time under self-sustained carbonization

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Waste management and utilization

ABSTRACT

Oil palm biochar with high yield and higher heating value under low energy requirement is required for improved waste management and utilization in the palm oil industry. This paper presents, a self-sustained carbonization of oil palm empty fruit bunch biomass, without internal heating element, which produced high biochar yield and higher heating value. Three different particle sizes of pressed-shredded oil palm empty fruit bunch biomass, i.e. below 29 mm, 30–99 mm and 100–150 mm, at 8–10% moisture content were used. The carbonization temperature was monitored and used as an indicator to stop the carbonization prior to harvesting. The maximum carbonization temperature recorded was 600 °C. In our previous report, harvested at 300 °C under uncontrolled exhausted air flow rate and found that the higher heating values obtained were 23.0–25.0 MJ/kg. However the biochar yield was only 14–16 %. In order to increase the yield of biochar, the exhaust air flow rate has been fixed at 36 m^3/hr by using an air suction blower to ensure uniform circulation and distribution of hot air from top to bottom before being discharged. The biochar was harvested when the temperature of the bed decreased to 500 °C. The particle size range from 100 to 150 mm produced the highest biochar yield of 26.0 ± 1.2% with higher heating value of 23.0–23.5 MJ/kg within 5–8 h retention time. The gaseous emissions were lower than permitted level set by the environmental authorities. The technology developed in this study should be used to improve the management and utilization of oil palm biomass towards a more sustainable palm oil industry.

Q1
IMPACT FACTOR
3.84

Nur Falia Shazana Manja Farid et. al., 2015.

Non-solvent-based pretreatment of poly (3-hydroxybutyrate) for improved bio-based crotonic acid production. RSC Advances. 5, 33546–33553.

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Non-solvent-based pretreatment of poly(3-hydroxybutyrate) for improved bio-based crotonic acid production

Nur Falia Shazana Manja Farid,[a] Hidayah Ariffin,*[ab] Mohd Rahimi Zakaria Mamat,[a] Mior Ahmad Khushairi Mohd Zahari[c] and Mohd Ali Hassan[a]

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In this study, high purity bio-based crotonic acid was obtained by a non-solvent-based pretreatment of poly(3-hydroxybutyrate), PHB, prior to pyrolysis. PHB was produced by *Cupriavidus necator* KCTC 2649 utilizing heat-treated oil palm frond juice followed by mild alkaline treatment with 0.05 M NaOH. It was found that NaOH-treated PHB was highly converted to its dehydrated monomer to give bio-based crotonic acid with 89% purity; 16% higher than that produced from chloroform-treated PHB. It is believed that pretreatment of PHB with low concentration NaOH assisted in high thermal conversion of PHB into crotonic acid by producing a crotonyl chain-end and Na-binding carboxyl terminal end, which both accelerate the β-chain scission of PHB into biocrotonic acid. The initial molar mass of PHB also played a role in biocrotonic acid production. Overall, improved biocrotonic acid production with high purity is an advantage for industrial production of crotonic acid from renewable resources.

Renewable Energy 77 (2015) 447–455

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Renewable Energy

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Simultaneous enzymatic saccharification and ABE fermentation using pretreated oil palm empty fruit bunch as substrate to produce butanol and hydrogen as biofuel

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Simultaneous saccharification fermentation

ABSTRACT

Simultaneous saccharification and acetone–ethanol–butanol (ABE) fermentation was conducted in order to reduce the number of steps involved in the conversion of lignocellulosic biomass into butanol. Enzymatic saccharification of pretreated oil palm empty fruit bunch (OPEFB) by cellulase produced 31.58 g/l of fermentable sugar. This saccharification was conducted at conditions similar to the conditions required for ABE fermentation. The simultaneous process by *Clostridium acetobutylicum* ATCC 824 produced 4.45 g/l of ABE with butanol concentration of 2.75 g/l. The butanol yield of 0.11 g/g and ABE yield of 0.18 g/g were obtained from this simultaneous process as compared to the two-step process (0.10 g/g of butanol yield and 0.14 g/g of ABE yield). In addition, the simultaneous process also produced higher cumulative hydrogen (282.42 ml) than to the two-step process (222.02 ml) after 96 h of fermentation time. This study suggested that the simultaneous process has the potential to be implemented for the integrated production of butanol and hydrogen from lignocellulosic biomass.

Q2
IMPACT FACTOR
3.361

Ibrahim, M. F. et. al., 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 (May): 447–55.

Industrial Crops and Products 63 (2015) 357–361

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Industrial Crops and Products

journal homepage: www.elsevier.com/locate/indcrop

Fresh oil palm frond juice as a renewable, non-food, non-cellulosic and complete medium for direct bioethanol production

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Oil palm frond juice
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Renewable feedstock

ABSTRACT

Oil palm frond (OPF) is the largest biomass source in the palm oil industry. Fresh OPF juice can be readily obtained by just pressing the fresh OPF, similar to sugarcane juice. OPF juice contains sugars and other nutrients such as nitrogen, magnesium, calcium, zinc, phosphorus and sulphur, making it a potential medium for bioethanol fermentation. In this study, the potential of fresh OPF juice as a complete non-food medium for direct bioethanol production was evaluated. A promising yield of 0.38 g bioethanol per g sugars consumed was obtained after 24 h of fermentation of fresh OPF juice without nutrient supplementation and without pH correction, which is comparable to synthetic medium at 0.40 g/g. This value is also comparable to the 0.4 g/g yield obtained from sugarcane juice in the Brazilian bioethanol industry. Therefore, this study provides an opportunity for the use of fresh OPF juice as a new renewable, non-food and non-cellulosic feedstock for the bioethanol industry.

Q2
IMPACT FACTOR
2.837

Sharifah Soplah Syed Abdullah et. al., 2015.

Fresh oil palm frond juice as a renewable, non-food, non-cellulosic and complete medium for direct bioethanol production. Industrial Crops and Products. 63, 357-361.

Q2
IMPACT FACTOR
2.131

Zuraidah, Z. et. al., 2015.

Enhancement of fermentable sugars production from oil palm empty fruit bunch by ligninolytic enzymes mediator system. International Biodeterioration & Biodegradation. 105: 13-20.

International Biodeterioration & Biodegradation 105 (2015) 13–20

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International Biodeterioration & Biodegradation

journal homepage: www.elsevier.com/locate/ibiod

Enhancement of fermentable sugars production from oil palm empty fruit bunch by ligninolytic enzymes mediator system

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Oil palm empty fruit bunch
Enzymatic hydrolysis

ABSTRACT

The impact of crude ligninolytic enzyme-mediator pretreatment on the bio-modification and partial removal of oil palm empty fruit bunch (OPEFB) lignin prior to cellulose hydrolysis was evaluated. The OPEFB was first treated with ligninolytic enzyme together with mediators and then hydrolysed with commercial cellulase for its fermentable sugars production. Two mediators of laccase, hydroxybenzotriazole (HBT) and azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) were compared in the pretreatment of OPEFB whereas manganese sulphate was used as mediator for manganese peroxidase (MnP). Optimum pretreatment conditions with maximum Klason lignin removal were achieved at concentration of 1.5% HBT, 4 mM ABTS and 2 mM manganese (II) with as much as 8.02%, 8.68% and 3.7% respectively as compared to raw OPEFB. lignin was removed from OPEFB by 8.8% at 50 °C and 8.16% at 10% of substrate loading, respectively. Pretreatment verifications at optimal condition was determined by cellulose hydrolysis of pre-treated OPEFB from the combination of HBT-Mn (II) and ABTS-Mn (II) which increased sugar yield by 16%–17% with approximately 30 g/L of fermentable sugars as compared to crude ligninolytic alone with 19.1 g/L, suggesting that mediators had played important roles in modification and partial removal of lignin, thus improved cellulose accessibility.

Q1
IMPACT FACTOR
1.425

Ibrahim, M.F. et. al., 2015.

Effect of buffering system on acetone-butanol-ethanol fermentation by Clostridium acetobutylicum ATCC 824 using pretreated oil palm empty fruit bunch. BioResources. 10(3): 3890-3907.

PEER-REVIEWED ARTICLE bioresources.com

Effect of Buffering System on Acetone-Butanol-Ethanol Fermentation by *Clostridium acetobutylicum* ATCC 824 using Pretreated Oil Palm Empty Fruit Bunch

Mohamad Faizal Ibrahim, Siren Linggang, Mohd Azwan Jenol, Phang Lai Yee, and Suraini Abd-Aziz*

Change of pH has been identified as the most significant parameter in modulating the transition between the conversions of acids into solvents in acetone-butanol-ethanol (ABE) fermentation by *Clostridia*. Thus, ABE fermentation at various phosphate buffer concentrations and initial pH values was conducted using pure glucose and sugars derived from pretreated oil palm empty fruit bunch (OPEFB). A higher solvent concentration (2.93 g/L) was obtained in the fermentation using 20 g/L of glucose with buffer compared with one without buffer that produced 1.34 g/L of solvents. Approximately 8.77 and 9.15 g/L of solvents were produced from fermentation using 40 g/L of glucose with and without buffer, respectively. In the latter conditions, at an initial pH of 5.5, 8.77 g/L of solvents was obtained, which was the highest concentration compared to other initial pH values. Increasing the buffer concentration to 0.2 M at an initial pH of 6.0 resulted in acid accumulation of 16.83 g/L but reduced the solvent production to 1.36 g/L. In addition, ABE fermentation using 20 g/L of sugars from pretreated OPEFB produced 2.25 g/L of solvents with a yield of 0.13 g/g, which was comparable with fermentation using 20 g/L of glucose conducted in a buffering system.

Keywords: Acetone-butanol-ethanol (ABE) fermentation; Clostridium acetobutylicum ATCC 824; Oil palm empty fruit bunch; Buffer; Biobutanol

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Journal homepage: http://www.pertanika.upm.edu.my/

Effects of Milling Methods on Tensile Properties of Polypropylene / Oil Palm Mesocarp Fibre Biocomposite

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ABSTRACT

The objective of this study was to evaluate the effects of milling methods on tensile properties of polypropylene (PP) / oil palm mesocarp fibre (OPMF) biocomposites. Two types of mills were used; Wiley mill (WM) and disc mill (DM). Ground OPMF from each milling process was examined for its particle size distribution and aspect ratio by sieve and microscopic analyses, respectively. Results showed that DM-OPMF had smaller diameter fibre with uniform particle size compared to the WM-OPMF. Surface morphology study by SEM showed that DM-OPMF had rougher surface compared to WM-OPMF. Furthermore, it was found that PP/DM-OPMF biocomposite had higher tensile strength compared to PP/WM-OPMF, with almost two-fold. Thus, it is suggested that small diameter and uniform size fibre may improve stress transfer and surface contact between the fibre and polymer matrix and cause well-dispersion of filler throughout the polymer resulted in better tensile strength of PP/DM-OPMF compared to PP/WM-OPMF biocomposite. Overall, it can be

SCOPUS

Noor Ida Amalina Ahamad Nordin et. al., 2015.

Effect of Milling Methods on Tensile Properties of Polypropylene / Oil Palm Mesocarp Fiber Biocomposite. Pertanika J. Sci. & Technol. 23 (2): 325 - 337.

energy&fuels

Article

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Potential Uses of Xylanase-Rich Lignocellulolytic Enzymes Cocktail for Oil Palm Trunk (OPT) Degradation and Lignocellulosic Ethanol Production

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Supporting Information

ABSTRACT: In this paper, we reported that oil pam trunk (OPT) can be used as an alternative fermentation feedstock for lignocellulolytic enzyme production and carbon source for bioethanol production. Xylanase production from OPT by locally isolated fungus, *Aspergillus fumigatus* SK1, under solid-state fermentation (SSF), was optimized using central composite design (CCD). Under optimized conditions, a maximum xylanase activity of 1792.43 U/g was produced, which was 4.28-fold higher than before optimization. Significant amounts of CMCase (56.19 U/g), FPase (3.47 U/g), and β-glucosidase (1.55 U/g) were also found concomitantly with xylanase. Subsequently, the effect of solid loading, Tween-80 concentration, and incubation temperature on the saccharification of OPT by the crude enzymes were optimized to enhance the total reducing sugar production. A total of 13.148 g/L of reducing sugar was reported under optimized conditions. Comparisons of physiochemical characteristics between native and hydrolyzed OPT via scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, and X-ray photoelectron spectroscopy (XPS) showed strong degradation capacity of the crude enzymes toward cellulose, hemicellulose, and lignin. Alcoholic fermentation of the hydrolysate by *Candida tropicalis* RETL-Crl produced 3.067 g/L of ethanol. Higher ethanol production at 0.322 g/g with a theoretical ethanol yield of 68.05% indicates that *Candida tropicalis* RETL-Crl has a greater potential to be used in ethanol fermentation process. This result further proved that OPT has the potential to be used as a renewable carbon source.

Q1

IMPACT FACTOR 2.79

Y, S. Abd-Aziz et. al., 2015.

Potential uses of xylanase-rich lignocellulolytic enzymes cocktail for oil palm trunk (OPT) degradation and lignocellulosic ethanol production. Energy Fuels. 29: 5103–5116.

Q2
IMPACT FACTOR
1.632

Hassan, M.A. et. al., 2015.

Thermal and biodegradation properties of poly(lactic acid)/fertilizer/oil palm fibers blends biocomposites. Polymer Composites. 36(3), 576-583.

Thermal and Biodegradation Properties of Poly(lactic acid)/Fertilizer/Oil Palm Fibers Blends Biocomposites

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Poly(lactic acid) (PLA) and NPK fertilizer with empty fruit bunch (EFB) fibers were blends to produced bioplastic*fertilizer (BpF) composites for slow release fertilizer. Thermal properties of BpF composites were investigated by thermogavimteric analysis (TGA), differential scanning calorimetry (DSC), and morphological and degradation properties were anlayzed by scanning electron microscopy (SEM), soil burial test, respectively. TGA themogram display that neat PLA, PLA/NPK, and BpF composites degradate at different temperatures. DSC curves of PLA and other composites exhibited same glass transition temperature (T_g) value indicating that both major blend components are miscible. The T_g, crystallization temperature (T_c), melting temperature (T_m) values also decreased with increased amount of fertilizer and fibers. The T_m of BpF composites did not change with an increase in fertilizer content because thermal stability of PLA and PLA/NPK composites was not affected. Soil burial and fungal degradation test of PLA, PLA/NPK, and BpF composites were also carried out. Soil burial studies indicated that BpF composites display better biodegradation as compared with neat NPK. Fungal degradation study indicated that fungi exposure times of BpF composites show higher value of degradation as compared with PLA/NPK. We attribute that developed BpF composites will help oil palm plantation industry to use it as slow release fertilizer. POLYM. COMPOS., 36:576–583, 2015. © 2014 Society of Plastics Engineers

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INTRODUCTION

In the recent years many use of synthetic polymers and plastic materials produced from petroleum based materials which are non-degradable plastics. The residues of plastic wastes have led to the serious environment pollution and widely effecting human life on earth. There are many attempts to solve this problem such as recycling plastics, fighting to decrease demanding to use plastics of human including the production of biodegradable polymers derived from renewable resources. Biodegradable polymers produced from natural biopolymers are innovative for an environmentally-friendly material because it can be converted into the substrates for production of the monomer for polymerization later, as well as the cycle of plastics life. The biodegradation of polymers in nature involves several processes. The natural microorganisms influence abiotic degradation through physical, chemical and enzymatic reactions [1]. Degradation steps of biodegradable polymers started to hydrolyze polymers which are catalyzed by temperature control followed by microorganisms actions on the fragmented residues.

Polylactic acid (PLA) is the one type of biodegradable polymer based on renewable resources, as lactic acid which obtained from microbial fermentation. Under appropriate conditions, PLA can be degraded by the simple action of microorganisms in the environment. Moreover, PLA has been attentive to apply for packaging, clothing and biomedical products due to the good properties such as high-strength, high-modulus, brightness, barrier and good moisture management biocompatible and

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Hidayah Ariffin et. al., 2015.

Influence of Alkaline-Peroxide Treatment of Fiber on the Mechanical Properties of Oil Palm Mesocarp Fiber/Poly(butylene succinate) Biocomposite. BioResources. 10 (1), 1730-1746

PEER-REVIEWED ARTICLE bioresources.com

Influence of Alkaline-Peroxide Treatment of Fiber on the Mechanical Properties of Oil Palm Mesocarp Fiber/Poly(butylene succinate) Biocomposite

Yoon Yee Then,[a] Nor Azowa Ibrahim,[a,*] Norhazlin Zainuddin,[a] Buong Woei Chieng,[a] Hidayah Ariffin,[b] and Wan Md Zin Wan Yunus [c]

In this work, the surface of oil palm mesocarp fiber (OPMF) was modified *via* alkaline-peroxide treatment with hydrogen peroxide under alkaline conditions. The effect of the treatment on the chemical composition and microstructure of the fiber was examined using chemical analysis, Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and X-ray diffraction (XRD) analysis. The treatment resulted in the removal of lignin, hemicellulose, and waxy substances from the fiber and increased its surface roughness and crystallinity. The eco-friendly biocomposite was made from poly(butylene succinate) (PBS) and chemically treated fiber at a weight ratio of 30:70, and was fabricated *via* a melt-blending technique followed by hot-pressed moulding. The results indicated that alkaline-peroxide treatment of the fiber improved the tensile strength, tensile modulus, and elongation at break of the OPMF/PBS biocomposite by 54, 830, and 43%, respectively. The SEM analysis revealed improvement of the interfacial adhesion between the chemically treated fiber and the PBS. This work demonstrates that alkaline-peroxide treatment of fiber is beneficial prior to its use in fabricating biocomposites.

Keywords: Alkaline-peroxide; Biocomposite; Oil palm mesocarp fiber; Poly(butylene succinate)

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Static Mechanical, Interfacial, and Water Absorption Behaviors of Alkali Treated Oil Palm Mesocarp Fiber Reinforced Poly(butylene succinate) Biocomposites

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In this work, oil palm mesocarp fiber (OPMF) was surface-treated with varying NaOH concentrations (1, 3, 5, 7, or 9%) and soaking times (1, 2, 3, or 4 h) at room temperature aiming to enhance its adhesion to the thermoplastic matrix for biocomposite application. The biocomposites from alkali treated OPMFs and poly(butylene succinate) at weight ratios of 70:30 were fabricated by a melt blending technique and hot-pressed moulding. The results indicate that NaOH treatment removed fiber's surface waxes, hemicellulose, and lignin, and produced fiber with rough surface morphology. The tensile results showed that OPMF treated in 5% NaOH solution for 3 h produced biocomposite with enhanced tensile strength (30%), tensile modulus (105%), and elongation at break (16%), as well as reduced water absorption (15%) and thickness swelling (13%) in comparison to that of untreated OPMF. Scanning electron microscopy showed improvement of interfacial adhesion between treated fiber and poly(butylene succinate). These results suggest that NaOH treatment could be an effective form of treatment for OPMF in biocomposites materials.

Keywords: Alkali treatment; Biocomposite; Oil palm mesocarp fiber; Poly(butylene succinate)

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Static mechanical, interfacial, and water absorption behaviors of alkali treated oil palm mesocarp fiber reinforced poly(butylene succinate) biocomposites. BioResources. 10 (1), 123-136

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Tar-free and Benzo[*a*]pyrene-free Hydrothermal Liquefaction of Bamboo and Antibacterial Property of Recovered Vinegar

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Bamboo, which was treated using superheated steam controlled at a low temperature range, gave tar-free and benzo[*a*]pyrene-free vinegar. The vinegar's selective antibacterial activity against *Staphylococcus aureus* concerned with the atopic dermatitis and *Bacillus cereus* causing food poisoning in humans was confirmed, while no effect was found against *Escherichia coli* and *Bacillus subtilis* as being indigenous bacteria in natural environments.

Wood and bamboo vinegars are liquors with strong smoke flavors that have been obtained as a by-product during the traditional carbonization process of wood and bamboo. These vinegars are composed of water and organic compounds such as acetic acid, propionic acid, furfural, 2-cyclopentenone, and 2-hydroxy-3-methyl-2-cyclopentenone.[1] So far, the vinegars have been conventionally used for treatment of atopic dermatitis without any scientific basis.

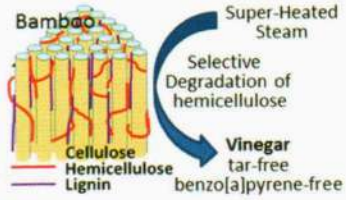

Figure 1. Bamboo vinegar preparation using superheated steam.

Phyllostachys heterocycla f. pubescens (Moso bamboo) (diameter: 10–20 cm, height: 10–20 m) was collected from Yame city in Japan. The bamboo was cut to 40 cm length and treated with superheated steam (SHS) at 210, 220, and 230 °C and a constant flow rate of 6 kg h^{-1} for 5 h in a SHS oven model NHL-

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Hidayah Ariffin et. al., 2015.

Tar-free and Benzo[α]pyrene-free Hydrothermal liquefaction of bamboo and antibacterial property of recovered vinegar. Chemistry Letters.

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Enrichment of anaerobic ammonium oxidation (anammox) bacteria for short start-up of the anammox process: a review. Desalination and Water Treatment. 2015 (1-21).

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Enrichment of anaerobic ammonium oxidation (anammox) bacteria for short start-up of the anammox process: a review

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ABSTRACT

The application of the anaerobic ammonium oxidation (anammox) reaction in a biological nitrogen removal system to treat wastewater has become of great interest since its discovery. The anammox reaction is performed by anammox bacteria that belong to the Planctomycete phylum. The reaction occurs in the presence of ammonium using nitrite as the substrate under anaerobic conditions. However, the bacteria have an extremely slow growth rate and stringent metabolic conditions that cause difficulty in culturing and applying the system for wastewater treatment. Anammox enrichment has a long start-up period for the anammox process that hinders researchers using laboratory and full-scale systems for the first time. Many attempts have been made to culture anammox to establish a successful anammox culture with a shorter start-up period for the anammox reaction and high nitrogen removal activity. This paper reviews previous studies on anammox enrichment with emphasis on (i) inoculum selection, (ii) enrichment techniques and (iii) factors influencing anammox enrichment. This review will assist researchers in planning and designing an appropriate anammox enrichment. The findings should widen the application of anammox in biological nitrogen removal systems for nitrogenous wastewater.

Keywords: Anaerobic ammonium oxidation (anammox); Enrichment; Start-up; Biological nitrogen removal; Nitrogenous wastewater

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Hidayah Ariffin et. al., 2015.

Influence of fiber content on properties of oil palm mesocarp fiber/poly(butylene) succinate biocomposites. BioResources. 10 (2), 2949-2968.

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Influence of Fiber Content on Properties of Oil Palm Mesocarp Fiber/Poly(butylene succinate) Biocomposites

Yoon Yee Then,[a] Nor Azowa Ibrahim,[a,]* Norhazlin Zainuddin,[a] Hidayah Ariffin,[b] Buong Woei Chieng,[a] and Wan Md Zin Wan Yunus [c]

Biodegradable and environmentally friendly biocomposites produced by a combination of biodegradable thermoplastics and natural fiber have gained increasing interest in recent years. In this work, eco-friendly biocomposites made from poly(butylene succinate) (PBS) and different weight percentages (10, 30, 50, and 70 wt%) of oil palm mesocarp fiber (OPMF) were fabricated *via* a melt blending process followed by hot-press molding. The biocomposites showed an improvement in storage and loss moduli with increasing fiber content, as indicated by dynamic mechanical analysis. Also, the water uptake and thickness swelling of the biocomposites increased with fiber content. The presence of fiber improved the biodegradability of the PBS, as evidenced from soil decomposition and scanning electron microscopy studies. Conversely, the presence of fiber lowered the melting and crystallization temperature as well as the thermal stability of neat PBS. The biocomposites from PBS and OPMF could be promising biocomposite materials because of their improved mechanical properties and biodegradability compared to neat PBS.

Keywords: Biodegradability; Dynamic mechanical analysis; Oil palm mesocarp fiber; Poly(butylene succinate); Thermal; Dimensional stability

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Effect of 3-Aminopropyltrimethoxysilane on Chemically Modified Oil Palm Mesocarp Fiber/Poly(butylene succinate) Biocomposite

Yoon Yee Then,[a] Nor Azowa Ibrahim,[a,*] Norhazlin Zainuddin,[a] Buong Woei Chieng,[a] Hidayah Ariffin,[b] and Wan Md Zin Wan Yunus [c]

Consecutive superheated steam-alkali treatment was introduced to modify oil palm mesocarp fiber (OPMF) prior to biocomposite fabrication. The biocomposite made up of 70 wt.% modified OPMF (SNOPMF) and 30 wt.% poly(butylene succinate) (PBS) was prepared by melt blending followed by compression molding. A silane coupling agent of 3-aminopropyltrimethoxysilane (APTMS) was also incorporated into the SNOPMF/PBS biocomposite during the compounding process to impart better adhesion at the SNOPMF-PBS interface. The experimental results revealed that the tensile, flexural, and impact strengths were enhanced by 16, 30, and 15%, respectively, after the introduction of 2 wt.% APTMS to the SNOPMF/PBS biocomposite. Similarly, the resistance to water uptake and thickness swelling of this biocomposite was improved by 34 and 49%, respectively, relative to SNOPMF/PBS biocomposite. The SEM observation of the tensile fracture surface showed that APTMS improved the interfacial adhesion between SNOPMF and PBS. Based on the results, it can be deduced that APTMS could be a good coupling agent for improving the SNOPMF-PBS adhesion and, thereby, lead to a water resistant biocomposite of enhanced mechanical properties.

Keywords: Biocomposite; Oil palm mesocarp fiber; Poly(butylene succinate); Silane; Alkali; Superheated steam

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Chemical Modification of Oil Palm Mesocarp Fiber by Methacrylate Silane: Effects on Morphology, Mechanical, and Dynamic Mechanical Properties of Biodegradable Hybrid Composites

Chern Chiet Eng,[a] Nor Azowa Ibrahim,[a,*] Norhazlin Zainuddin,[a] Hidayah Ariffin,[b] and Wan Md Zin Wan Yunus [c]

Effects of modifying oil palm mesocarp fibers (OPMF) by methacrylate silane on polylactic acid (PLA)/ polycaprolactone (PCL)/clay/OPMF hybrid composites were investigated. The composites were prepared by a melt blending technique and characterized by dynamic mechanical analysis (DMA) and scanning electron microscopy (SEM). The silane-treated OPMF hybrid composites showed better tensile strength, tensile modulus, and elongation at break than unmodified OPMF hybrid composites. DMA analysis showed an increase in storage modulus when silane-treated OPMF was added to a hybrid composite. The loss modulus curve showed that the incorporation of silane-treated OPMF into a hybrid composite shifted the two glass transition temperatures (T_g) of composites closer to each other. The low tan δ peak indicated good fiber/matrix adhesion for the silane-treated OPMF hybrid composites. SEM micrographs revealed that silane-treated OPMF hybrid composites showed better fiber/matrix adhesion than unmodified OPMF hybrid composites because of absence of gap between silane-treated OPMF and the matrix in the composite.

Keywords: Oil palm mesocarp fiber; Chemical modification; Silane coupling agent; Hybrid composites

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Characterisation and Biodegradation of Poly(Lactic Acid) Blended with Oil Palm Biomass….. Bioresources. 2015.

PEER-REVIEWED ARTICLE bioresources.com

Characterisation and Biodegradation of Poly(Lactic Acid) Blended with Oil Palm Biomass and Fertiliser for Bioplastic Fertiliser Composites

Harmaen Ahmad Saffian,[a,*] Khalina Abdan,[b] Mohd Ali Hassan,[c] Nor Azowa Ibrahim,[d] and Mohammad Jawaid [a,*]

This work presents a new technique for producing a slow-release fertiliser with bioplastic polymer coating. Poly(lactic acid) (PLA) was blended with granular NPK fertiliser and empty fruit bunch (EFB) fibres using extrusion technique. The polymer coatings were characterised using thermal gravimetric analyser (TGA) and diffraction scanning calorimetry (DSC). The PLA and EFB fibres complemented each other in terms of their thermal stability in the BpF composites. A homogenous BpF blend was observed under a scanning electron microscope (SEM). In biodegradation the percentages of weight loss for PLA/EFB/NPKC1 and PLA/EFB/NPKC2 were higher due to the presence of EFB fibres, which were 64.3% and 76.3%, respectively.

Keywords: Bioplastic; Oil palm biomass; Fertiliser; Composites; Leaching

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Isolation,screening and identification of potential cellulolytic and xylanolytic producers for biodegrdation of untreated oil palm trunk and its application in saccahrification of lemongrass leaves. Prep Biochem Biotechnol. 45:279–305.2

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Isolation, Screening, and Identification of Potential Cellulolytic and Xylanolytic Producers for Biodegradation of Untreated Oil Palm Trunk and Its Application in Saccharification of Lemongrass Leaves

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This study presents the isolation and screening of fungi with excellent ability to degrade untreated oil palm trunk (OPT) in a solid-state fermentation system (SSF). Qualitative assay of cellulases and xylanase indicates notable secretion of both enzymes by 12 fungal strains from a laboratory collection and 5 strains isolated from a contaminated wooden board. High production of these enzymes was subsequently quantified in OPT in SSF. *Aspergillus fumigates* SK1 isolated from cow dung gives the highest xylanolytic activity (648.448 U g^{-1}), generally high cellulolytic activities (CMCase: 48.006, FPase: 6.860, beta-glucosidase: 16.328 U g^{-1}) and moderate lignin peroxidase activity (4.820 U/g), and highest xylanolytic activity. The xylanase encoding gene of *Aspergillus fumigates* SK1 was screened using polymerase chain reaction by a pair of degenerate primers. Through multiple alignment of the SK1 strain's xylanase nucleotide sequences with other published xylanases, it was confirmed that the gene belonged to the xylanase glycoside hydrolase family 11 (GH11) with a protein size of 24.49 kD. Saccharification of lemongrass leaves using crude cellulases and xylanase gives the maximum reducing sugars production of 6.84 g/L with glucose as the major end product and traces of phenyl-propanic compounds (vanillic acid, *p*-coumaric acid, and ferulic acid).

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Superheated Steam Treated Oil Palm Frond Fibers and Their Application in Plastic Composites

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Surface treatment of the oil palm frond (OPF) fiber was carried out using superheated steam (SHS) in order to increase the compatibility between the OPF fiber and polypropylene. Biocomposites were prepared using polypropylene (PP) and SHS treated or untreated oil palm frond (OPF) fiber by injection molding method to observe the effects of fiber surface treatment on the mechanical properties of the biocomposites. The microstructure of the untreated and SHS treated OPF fiber was characterized by using X-ray diffraction (XRD) and scanning electron microscopy (SEM). XRD results showed that the crystallinity of OPF fiber was increased after SHS treatment indicating tougher fiber properties. The thermal degradation behavior of untreated and SHS treated OPF fiber was studied using thermogravimetric (TG) and derivative thermogravimetric (DTG) analyses. TG/DTG analyses revealed the improved thermal stability of OPF fiber after the SHS treatment. The superior mechanical properties was obtained for the SHS treated fiber reinforced biocomposites as compared with untreated fiber reinforced biocomposites due to the enhanced interfacial interaction between the OPF fiber and the PP matrix.

Keywords: Polymer, Fibre, Composite, Surface Treatment, Mechanical Property.

Non-Cited

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Superheated Steam Treated Oil Palm Frond Fibers and Their Application in Plastic Composites. Advanced Science, Engineering and Medicine. 7(2), 120-125.

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Soluble inhibitors generated during hydrothermal pretreatment of oil palm mesocarp fiber suppressed the catalytic activity of *Acremonium* cellulase

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HIGHLIGHTS

- Oil palm mesocarp fiber was pretreated at isothermal and non-isothermal conditions.
- Enzymatic hydrolysis of both pretreated slurry and solids were performed.
- Inhibitors generated from hydrothermal pretreatment of OPMF were identified.
- Xylooligosaccharide and tannic acid are the most severe inhibitors to cellulase.
- Activated carbon from OPMF is suitable adsorbent for tannic acid removal.

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Acremonium cellulase inhibition

ABSTRACT

Oil palm mesocarp fiber was subjected to hydrothermal pretreatment under isothermal and non-isothermal conditions. The pretreated slurries were separated by filtration, pretreated liquids and solids were characterized. An enzymatic digestibility study was performed for both pretreated slurries and solids to understand the effect of soluble inhibitors generated during the pretreatment process. The highest glucose yield obtained from pretreated slurries was 70.1%, and gradually decreased with higher pretreatment severities. The highest glucose yield obtained in pretreated solids was 100%, after pretreatment at 210 °C for 20 min. In order to study the inhibitory effects of compounds generated during pretreatment with cellulase, technical grade solutions that mimic the pretreated liquid were prepared and their effect on *Acremonium* cellulase activity was monitored using Avicel. Xylo-oligomers and tannic acid were identified as powerful inhibitors of *Acremonium* cellulase, and the lowest hydrolysis rate of Avicel of 0.18 g/g-glucose released/L/h was obtained from tannic acid.

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Case study: Preliminary assessment of integrated palm biomass biorefinery for bioethanol production utilizing non-food sugars from oil palm frond petiole. 2016. Energy Conversion and Management, 108, 233-242.

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Case study: Preliminary assessment of integrated palm biomass biorefinery for bioethanol production utilizing non-food sugars from oil palm frond petiole

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Oil palm biomass

ABSTRACT

In this case study, a preliminary assessment on the bioethanol production from oil palm frond (OPF) petiole sugars within an integrated palm biomass biorefinery was carried out. Based on the case study of 4 neighbouring palm oil mills, approximately 55,600 t/y of fermentable sugars could be obtained from OPF petiole. The integrated biorefinery will be located at one of the 4 mills. The mill has potential excess energy comprising 3.64 GW h/y of electricity and 177,000 t/y of steam which are sufficient to run the biorefinery. With 33.9 million litres/y of bioethanol production, the specific production cost of bioethanol is estimated at $ 0.52/l bioethanol, compared to $ 0.31–0.34/l bioethanol produced from sugarcane and $ 0.49–0.60/l bioethanol from other lignocellulosics. The net energy ratio of 7.48 for bioethanol production from OPF provides a promising alternative for OPF utilization as a non-food sugar feedstock.

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Successful scaling-up of self-sustained pyrolysis of oil palm biomass under pool-type reactor

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Abstract

An appropriate technology for waste utilisation, especially for a large amount of abundant pressed-shredded oil palm empty fruit bunch (OFEFB), is important for the oil palm industry. Self-sustained pyrolysis, whereby oil palm biomass was combusted by itself to provide the heat for pyrolysis without an electrical heater, is more preferable owing to its simplicity, ease of operation and low energy requirement. In this study, biochar production under self-sustained pyrolysis of oil palm biomass in the form of oil palm empty fruit bunch was tested in a 3-t large-scale pool-type reactor. During the pyrolysis process, the biomass was loaded layer by layer when the smoke appeared on the top, to minimise the entrance of oxygen. This method had significantly increased the yield of biochar. In our previous report, we have tested on a 30-kg pilot-scale capacity under self-sustained pyrolysis and found that the higher heating value (HHV) obtained was 22.6–24.7 MJ kg^{-1} with a 23.5%–25.0% yield. In this scaled-up study, a 3-t large-scale procedure produced HHV of 22.0–24.3 MJ kg^{-1} with a 30%–34% yield based on a wet-weight basis. The maximum self-sustained pyrolysis temperature for the large-scale procedure can reach between 600 °C and 700 °C. We concluded that large-scale biochar production under self-sustained pyrolysis was successfully conducted owing to the comparable biochar produced, compared with medium-scale and other studies with an electrical heating element, making it an appropriate technology for waste utilisation, particularly for the oil palm industry.

Keywords

Biochar, self-sustained pyrolysis, oil palm biomass, charcoal

EB GROUP ATTACHMENT 2015 OUTBOUND

Participants	Program	Research Theme	Host/Location	Duration	Sponsor
Muhammad Azman Zakaria	Student Exchange Support Program	Biohydrogen / Pseudogene	Kyushu Institute of Technology (KYUTECH), Japan	September 2014 - February 2015	JASSO
Siti Suliza Salamat	Training MiSeq & Registration for Double Degree Program (DDP-UPM & KTUTECH)	Biocompost	Kyushu Institute of Technology (KYUTECH), Japan	September 2014 - February 2015	JASSO
Nurhajirah Mohamed Biran	Research Attachment	Bioplastic	Kyushu Institute of Technology (KYUTECH), Japan	November 2014 – March 2015	Kyutech
Mohd Rahimi Zakaria@Mamat	Research Attachment	Biomaterial	Kyushu Institute of Technology (KYUTECH), Japan	15 December 2014 - 15 March 2015	UPM & Kyutech
Dhurga Devi Rajaratanam	Research Attachment	Controlled hydrolysis of poly(3-hydroxybyrate-co-3-hydroxyhexanoate) for oligoester production	Kyushu Institute of Technology (KYUTECH), Japan	18 April 2015 – 18 October 2015	JASSO
Mohd Hafif Samsudin	Student Exchange Support Program	Molecular work (Miseq)	Kyushu Institute of Technology (KYUTECH), Japan	18 April 2015 – 18 October 2015	JASSO
Izzudin Ibrahim	JICA Training Program	Biochar and Activated Carbon	Kyushu Institute of Technology (KYUTECH), Japan	3 August 2015 – 18 September 2015	JICA
Mohd Nor Faiz Norrahim	JICA Training Program	Biomass and Composite Samples	Kyushu Institute of Technology (KYUTECH), Japan	15 August 2015 – 30 September 2015	JICA
Tengku Arisyah Tengku Yasim Anuar	Training for Project on Green Economy with Palm Oil Industry	Characterization of biomass and composite samples	Kyushu Institute of Technology (KYUTECH), Japan	15 August 2015 – 30 September 2015	JICA
Ahmad Muhaimin Roslan	Research Attachment	Training on Hydrothermal Treatment of Oil Palm Biomass Using High Pressure Autoclave	National Institute of Advanced Industrial Science & Technology (AIST), Japan	31 August 2015 – 31 October 2015	JICA
Siti Jamilah Hanim Mohd Yusof	Research Attachment	Training on Hydrothermal Treatment of Oil Palm Biomass Using High Pressure Autoclave	National Institute of Advanced Industrial Science & Technology (AIST), Japan	31 August 2015 – 31 October 2015	JICA
Noor Farisha Abd Rahim	Research Attachment	Design of Functionalized Polyester from Palm Oil's Fatty Acids	Kyushu Institute of Technology (KYUTECH), Japan	15 September 2015 – 29 February 2016	JASSO

EB GROUP ATTACHMENT 2015 OUTBOUND

Participants	Program	Research Theme	Host/Location	Duration	Sponsor
Mohd Zulkhairi Mohd Yusoff	Post-doctoral research	Bio-based chemical production from oil palm biomass	National Institute of Advanced Industrial Science and Technology (AIST), Japan	1 October 2015- 31 Mac 2017	AIST and UPM
Diana Mohd Nor	Research Attachment	Training for Bacterial Community Analysis of Palm Oil Mill Effluent (POME) & Final discharge using MiSeq (Illumina) & Real Time PCR	Kyushu Institute of Technology (KYUTECH), Japan	28 November 2015 – 30 January 2016	JICA
Slti Suhailah Sharuddin	Training	Bacterial Community Analysis using MiSeq (Illumina) and Real-Time PCR	Kyushu Institute of Technology (KYUTECH), Japan	29 November 2015 – 30 January 2016	JICA

EB GROUP ATTACHMENT 2015 INBOUND

Participants	Program	Research Theme	Host/Location	Duration	Sponsor
Yuya Hachiguchi	PhD Student	Bio-based chemical production from oil palm biomass	National Institute of Advanced Industrial Science and Technology (AIST), Japan	1 October 2015 - 31 Mac 2017	AIST and UPM
Yuki Yoshikai	PhD Student	Dual / Joint Degree	Biomass Technology Center, UPM	21 June 2014 – 21 June 2017	Kyushu Institute of Technology (KYUTECH), Japan
Azusa Ikegami	Postgraduate Student	Research Attachment	Biomass Technology Center, UPM	16 August 2015 – 2 October 2015	Kyushu Institute of Technology (KYUTECH), Japan
Maho Murakami	Postgraduate Student	Research Attachment	Biomass Technology Center, UPM	13 September 2015 – 17 October 2015	Kyushu Institute of Technology (KYUTECH), Japan
Chayet Worathitanon	Postgraduate Student	Research Attachment	Biomass Technology Center, UPM	26 October 2015 – 26 October 2016	Kyushu Institute of Technology (KYUTECH), Japan
Chawwat Vongfant	Undergraduate Student	Internship	Biomass Technology Center, UPM	June 2015 – July 2015	Kasertsart University, Thailand
Chonlapop Sawangsaensuk	Undergraduate Student	Internship	Biomass Technology Center, UPM	June 2015 – July 2015	Kasertsart University, Thailand

Consultancy

PREVIOUS

RESEARCH THEME	CLIENTS/INDUSTRIAL PARTNER	DURATION
Pilot scale co-composting of sewage sludge and green wastes to bio fertilizer with applications for community benefits	Indah Water Konsortium Sdn. Bhd.	August 2012-July 2013
Treatment of colored wastewater - color removal of final discharge	Microclear Sdn. Bhd.	June-September 2014

CURRENT

RESEARCH THEME	CLIENTS/INDUSTRIAL PARTNER	DURATION
Implementation of readily available technology for bromelain extraction and purification from pineapple wastes for value-added to pineapple plantation industry	Alaf Putra Biowealth Sdn. Bhd.	September 2014 - August 2016
Research study on the effectiveness of biofertiliser pellets for landscape plants	Indah Water Konsortium Sdn. Bhd.	December 2015 - March 2017

Conferences and Workshops

Event name	Date	Venue	Name of participant
Asia Renewable Energy Workshop (AREW2015)	3-4th February 2015	Universiti Putra Malaysia	EB Members
UPM-Sejong University Biotechnology Joint Symposium	13th February 2015	Universiti Putra Malaysia	All lecturers, Muhammad Nazmir Mohd Warid
Biotech Mini Symposium 2015	14th April 2015	Universiti Putra Malaysia	SurainiAbd-Aziz, Mohamad Faizal Ibrahim, Ahmad Muhaimin Roslan, Mohd Zulkhairi MohdYusoff
AFOB Regional Symposium 2015 (ARS 2015)	27-30th May 2015	Universitas Indonesia, Depok, Indonesia	SurainiAbd-Aziz, Hidayah Ariffin, Ezyana Kamal Bahrin, Norhayati Ramli, Mohamad Faizal Ibrahim, Mohd Zulkhairi Mohd Yusoff
23rd European Biomass Conference and Exhibition (EUBCE)	1-4th June 2015	Messe Wien Exhibition & Congress Center, Messeplatz 1, 1021 Wien, Austria	Mohd Rafein Zakaria
2nd Biotech UPM-Prince of Songkla University (PSU) Joint Seminar	13th August 2015	Universiti Putra Malaysia	Nur Sharmila Binti Sharip, Noor Farisha Abd Rahim, Muhammad Nazmir Mohd Warid

Conferences and Workshops

Event name	Date	Venue	Name of participant
Virtual Fermentation Workshop	19-20th August 2015	UniKL MICET, Alor Gajah, Melaka.	Muhamad Yusuf Hasan, Mohd Azwan Jenol, Nurul Hanisah Md Badrul Hisham, Hazwani Husin, Muhammad Siddiq Mohamed Salleh
Pre-conference DGGE Workshop	12-13th November 2015	Universiti Putra Malaysia	Norhayati Ramli, Siti Suhailah Sharuddin, Diana Mohd Nor, Siti Suliza Salamat, Mohamad Farhan Mohamad Sobri, Mohd Hafif Samsudin
Asian Congress on Biotechnology 2015 (ACB2015)	15-19th November 2015.	Hotel Istana, Kuala Lumpur, Malaysia	EB Members
The 3rd UPM-KYUTECH International Symposium on Applied Engineering and Sciences (SAES2015)	23-24th November 2015	Univesiti Putra Malaysia	Nurhajirah Mohamed Biran, Muhammad Azman Zakaria, Muhammad Nazmir Mohd Warid, Diana Mohd Nor, Tengku Arisyah Tengku Yasim Anuar, Yuya Hashiguchi, Mohd Nor Faiz Norrahim
INTROP Research Colloquium	1-2nd December 2015	RHR Hotel @ Uniten, Putrajaya, Malaysia	Hidayah Ariffin, Muhammad Nazmir Mohd Warid, Tengku Arisyah Tengku Yasim Anuar
International Biomass Conference Malaysia 2015	8-9th December 2015	MATRADE Hall, Kuala Lumpur, Malaysia	Nur Fatin Athirah Binti Ahmad Rizal, Nurul Hanisah Md Badrul Hisham, Hazwani Husin, Tengku Arisyah Tengku Yasim Anuar, Nur Atheera Aiza Md Razali, , Ruqayyah Masran, Dhurga Devi Rajaratanam

EB STUDENTS RESEARCH SUMMARY

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Development of a recovery system for biovanillin

Macroporous resins were tested for vanillin adsorption from aqueous solution, which were Amberlite XAD-16, Amberlite XAD-2, Sepabeads SP207, Diaion HP-20, DM11 and H103. All the resins gave more than 95% adsorption except for Amberlite XAD-2 and DM11. Resin H103 was selected for the subsequent work due to high adsorption capacity and low cost. Adsorption parameters were determined in batch mode in order to obtain the preliminary conditions for vanillin adsorption onto resin H103. Tests at different temperatures between 25°C and 55°C yielded almost similar adsorption performance, which led to the selection of 25°C as the reaction temperature. It was also observed that within the range of pH tested (pH 3.0 to 7.0), no considerable different in the amount of vanillin adsorbed. For that reason, pH 6.0 was selected as the reaction pH, mainly due to the pH of freshly prepared vanillin solution was around pH 5.9 to pH 6.1. Kinetics analysis revealed that the adsorption followed pseudo-second order kinetic model and occurred rapidly, after which it reached equilibrium after 90 minutes of reaction. Adsorption isotherm

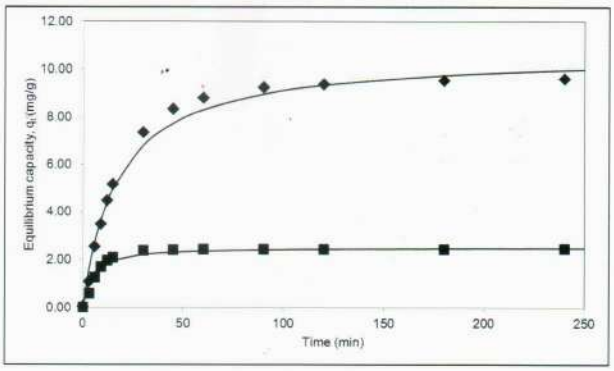

Figure 1. Contact time profile of vanillin adsorption onto resin H103. Kinetics data for 0.5 g of resin (♦), kinetics data for 2.0 g of resin (■).

was also determined at 25°C and it was fitted to Langmuir and Freundlich equations using linear regression and non-linear regression (sum of squares) methods. The regression shows that the vanillin adsorption onto resin H103 followed Langmuir model (R2 of 0.9984), with a maximum capacity of 73.015 mg/g.

Fractional factorial screening and response surface methodologies were used in order to explain the effect of several factors affecting the adsorption of vanillin onto resin H103 in batch mode. The factors were contact time, initial vanillin concentration, resin dosage, pH and temperature. With the aid of Design Expert version 7.1.6, initial vanillin concentration and resin dosage were determined as significant. The analysis of variance (ANOVA) gave a very good of determination coefficient (R2) of 0.9996. The two significant factors were further optimized in order to determine the optimum condition, using response surface method (RSM). A good R2 was also obtained for the optimized condition (0.9463). A plot of response surface also gave a minimum point, which indicated that within the range tested, an optimum condition to obtain the lowest equilibrium concentration of vanillin in the aqueous was achieved.

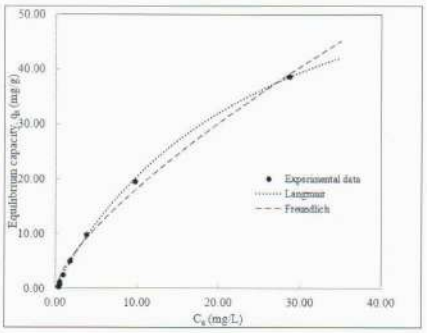

Figure 2: The equilibrium adsorption isotherms at 25°C for vanillin adsorption onto adsorbent resin H103. Langmuir isotherm was best to explain the adsorption of vanillin onto resin H103 (represented by dashed lines, obtained via non-linear regression).

Supervisor
Professor Dr. Suraini Abd Aziz

Objectives

1. To determine the suitable resins on the absorption capacity of vanillin in term of its kinetics and reaction parameters
2. To elucidate vanillin adsorption behaviour in fixed bed column via dynamic adsorption capacity and rate constant
3. To perform scale-up analysis of vanillin adsorption onto fixed bed resin H103

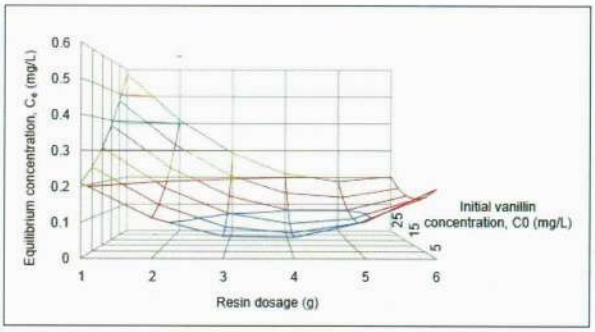

Figure 3: Response surface plot for the effect of resin dosage and initial vanillin concentration on vanillin adsorption onto resin H103.

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Bioethanol production from residual starch of sago hampas

Sago palm which is mostly found in Sarawak usually generated huge amount of solid waste upon the starch extraction process, where starch was accounted to be about 50-58% (dry weight) in this solid waste. This residual starch was used in this study which was converted into glucose via enzymatic hydrolysis process and act as the carbon source for production of bioethanol. Sago hampas initially undergo simple pretreatment steps which were drying, grinding and boiling to render the residual starch more susceptible to enzymatic digestion at the saccharification stage using a commercial enzyme, dextrozyme. Boiling process for at least 30 mins which gelatinized the sago hampas has indicated that 7% (w/v) of the substrate load was sufficient and suitable for enzymatic hydrolysis since residual starch was not observed in the fibrous residue. However in order to increase glucose concentration at the end of hydrolysis process, substrate load need to be increase as well which was not possible due to the complexity and voluminous physical properties of sago hampas. Thus an alternative method was introduced by recycling the hydrolysate upon hydrolysis of the same (7% w/v) amount of sago hamaps during the enzymatic hydrolysis process. The hydrolysate obtained from each cycle was used for subsequent enzymatic hydrolysis, thus the concentration of glucose was increased at the end of each cycle due to total glucose accumulated based on the glucose produced after previous cycles plus the glucose produced in the current cycle. This method was termed as cycle I-II-III, exhibiting the number of cycles that the hydrolysate was re used. A maximum of three cycles was attempted in this project. Greater improvement of glucose concentration (138.45 g/L) and better conversion yield (52.72%) was achieved with the completion of three cycles of hydrolysis. In comparison cycle I and cycle II had glucose concentration of 27.79 g/L and 73.00 g/L, respectively.

The study on pre-germination time of CBY indicated that at 9 h and 12 h, the ethanol fermentation showed complete substrate utilization (100%), good product yield (0.47 – 0.48 g/g) as well as high fermentation efficiency (93.29%) compared to 6 h. Following these, ethanol fermentation was performed utilizing various concentrations of glucose from SHH (g/L: 80, 100, 150, 200, 250.At 100 g/L initial glucose, maximum yield of ethanol fermentation, Yp/s (0.50g/g) and theoretical conversion yield (98%) were obtained compared to other glucose concentrations. The major by-product in this process was glycerol, with lesser amounts of lactic acid and acetic acid. The effects of various nitrogen sources has shown both urea and ammonium sulfate were capable of replacing yeast extract since these alternatives exhibited comparable ethanol yield, ethanol volumetric productivity as well as fermentation efficiency. Supplementations of metal ions did not enhance the fermentation process, as similar profiles of ethanol production and glucose consumption was observed. From the present study it can be concluded that hydrolysate of sago hampas which contain mainly glucose shows high potential to be effective substrate as well as economical fermentation medium for bioethanol production utilizing commercial bakers' yeast (CBY).

Debarked sago logs – ready for starch extraction by rasping.

Bioethanol fermentation using hydrolysate of sago hampas in 3L bioreactor.

Residual starch in sago hampas.

Supervisor
Professor Dr. Suraini Abd Aziz

Objectives

1. To hydrolyse residual starch in sago hampas for glucose production at different substrate load.
2. To obtain high glucose concentration in hydrolysate using commercial enzymes preparation.
3. To evaluate the suitability of sago hampas hydrolysate as fermentation medium for bioethanol production by commercial baker's yeast.
4. To determine the effects of nitrogen and metal ionic compound on fermentability of bioethanol from sago hampas hydrolysate.

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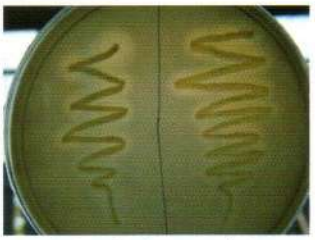
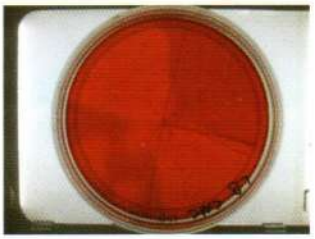
Integrated identification and characterization of microbial diversity from enhanced co-composting of oil palm empty fruit bunch and palm oil mill effluent sludge

One way to promote the zero-discharge system and creating value added product from the oil palm mill by-products is through the co-compositing of oil palm empty fruit bunch (OPEFB) and palm oil mill effluent (POME) anaerobic sludge. In Malaysian oil palm industries, the development for treating oil palm residue such as oil palm empty fruit bunch and palm oil mill effluent anaerobic sludge through co-composting has been of great interest due to its ability to serve as potential renewable resources for production of value added product. OPEFB compost is manageable product which can be use as soil amendment and organic fertilizer. Composting is a natural biological process which is controlled under aerobic condition. In composting, the breakdown of lignocellulose material as well as the organic materials into simpler substance is driven by existence of bacteria community and their association between each others during composting process. The effectiveness of composting process is dependent on the environmental condition such as temperature, oxygen, moisture, material used, size and activity of microbial populations. Recent study of enhanced co-composting of OPEFB and POME anaerobic sludge process has spurred the increased attention into how microbial diversity carryout the degradation process and what microbes are involved during the process. The investigation of microbial diversity of co-composting were generally based on community analysis technique such as culture dependent method through isolation and characterization of cultivable microbe and culture independent method through Polymerase Chain Reaction-Denaturing Gradient Gel Electrophoresis (PCR-DGGE) or small sequence library. The overall objective of this study was to elucidate the microbial community participating in the enhanced composting process through isolation and characterization of cultivated microbe, PCR-DGGE and 16s rRNA clone library technique. The microbial community as well as the patterns of their diversity was then further described by using next generation sequencing; 454-pyrosequencing. The findings of this study expends our knowledge in understanding the collective microbial community in during composting process and in future will help to optimize the composting conditions to increase the quality and productivity of compost.

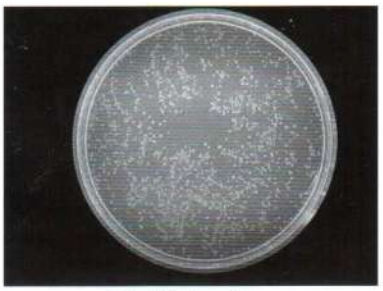
Co-composting of OPEFB with POME anaerobic sludge



Isolation of xylanase producing bacteria on agar plate containing xylan



Isolation of Cellulase producing bacteria on agar plate containing carboxymethyl-cellulose (CMC)



16s rRNA clone library

Supervisor
Professor Dr. Mohd Ali Hassan

Objectives

1. To isolate and characterize the indigenous cellulolytic and hemicellulolytic bacteria of enhanced co-composting of oil palm empty fruit bunch with palm oil mill effluent anaerobic sludge
2. To identify the bacterial community structure and biochemical changes associated with co-composting of lignocellulose oil palm empty fruit bunch
3. To assess in-depth bacterial community during rapid co-composting of OPEFB and palm oil mill effluent anaerobic sludge via pyrosequencing

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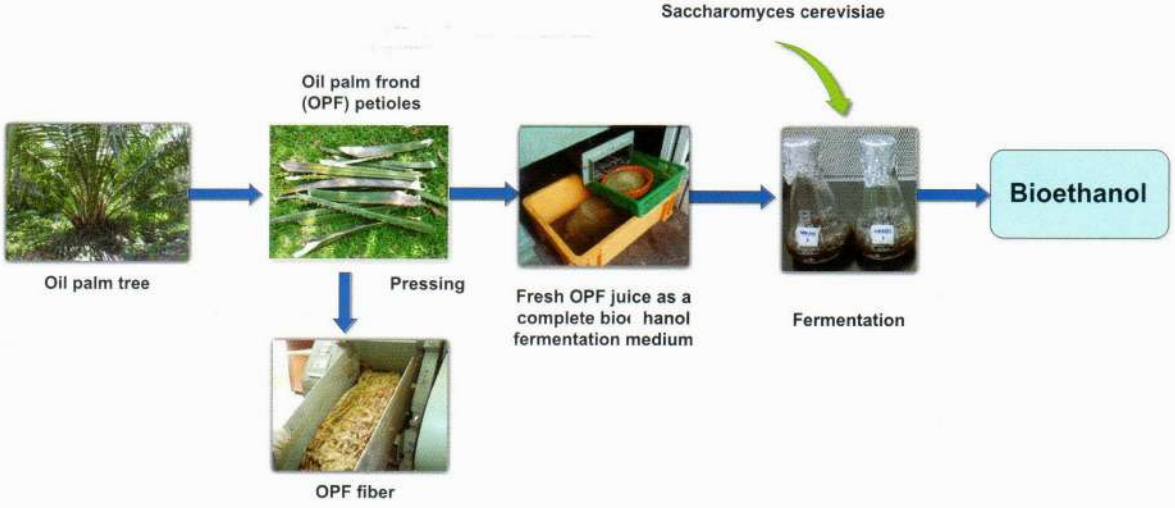
Efficient bioethanol production from oil palm frond petiole

The growing interest in bioenergy and particularly in second generation bioethanol (SGB) is a great challenge as the development of lignocellulose-related technologies are not very well established in the world. Another major constraint is the relatively higher cost of SGB, both in terms of investment costs and final energy costs. This causes the commercialization of research findings on SGB faces stiff competition from fossil fuels. Hence, this study was aimed to produce SGB but using a straight forward technology of first generation bioethanol from sugarcane juice. A newly identified lignocellulosic material having such characteristics is the fresh oil palm frond (OPF). OPF is the largest biomass source in the palm oil industry contributing 61% of total biomass. Fresh OPF juice can be readily obtained by just pressing the fresh OPF petiole, similar to sugarcane. OPF juice was identified rich in fermentable sugars and other nutrients, making it a potential medium for bioethanol fermentation. A promising yield of bioethanol per g sugars consumed was obtained after 24 hours of fermentation of fresh OPF juice without nutrient supplementation and without pH correction, which is comparable to synthetic medium as well as the bioethanol yield from sugarcane juice in the Brazilian bioethanol industry. Therefore, this study provides an opportunity for the use of fresh OPF juice as a new renewable, non-food and non-cellulosic feedstock for the bioethanol industry. However, the major challenge of using liquid feedstock as a fermentation medium is rapid degradation of sugars during storage. Therefore, the effect of OPF juice concentration and mild temperature storage on glucose content were studied.

In order to commercialise the bioethanol production from OPF petiole, the usage of sugars from both OPF juice and OPF pressed fibre were proposed as the percentage of fermentable sugars present in both portions is economically feasible as compared to usage of OPF juice alone. Therefore, a new approach of integrating a biorefinery plant for bioethanol production to an existing palm oil mill (POM) was examined. The concept proposed the production of fermentable sugars from OPF at six neighboring POMs before being transported to the nearest biorefinery plant located at one of the POMs. All the processes was targeted to use the excess energy at the current POM in order to reduce the utility cost. This research expected the low production cost of bioethanol from OPF by integrated approach similar to production cost of corn bioethanol and cheaper than the current SGB cost. This finding suggests that an integrated approach is an economically feasible option to commercialise bioethanol production in the near future, provided that the government make a move towards the commercialisation by introducing a policy on SGB.



Supervisor
Professor Dr. Yoshihito Shirai

Objectives

1. To exploit the OPF juice as a renewable, non-food, non-cellulosic and complete medium for direct bioethanol production
2. To investigate the effects of OPF juice concentration and mild temperature storage on glucose content in OPF juice
3. To evaluate the feasibility of bioethanol commercialization from fresh OPF by introducing integrated technology approach of bioethanol plant to existing palm oil mill (POM).

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Biochar production from empty fruit bunch biomass under self-sustained carbonization for the development of Yamasen carbonization oven

The usage of OPEFB biomass as an alternative source for renewable energy such as biochar has a great potential to overcome the shortage of fossil fuel. Moreover, the utilization of biomass as a source of biofuel can reduce the problem of environmental pollution particularly on the issues related to greenhouse gases. Being the second largest oil palm producer in the world, Malaysia has a great potential to produce clean renewable energy from biomass. The self-sustained carbonization was proposed and tested in this study, whereby oil palm biomass itself was combusted to provide heat for self-carbonization in inadequate oxygen without electrical heating element.

Fig.1 Pilot Scale (30 kg) brick self-sustained carbonization reactor

Temperature profiles and gaseous emission during self-sustained carbonization of OPEFB biomass in a pilot scale reactor (30 kg capacity) has been carried out. Deferent particles sizes (100-150, 30-99 and less than 29 mm) under natural and fixed exhausted gas flow rate were evaluated. For natural and fixed exhausted gas flow rate, the maximum temperatures were ranged 417-580 and 493-564^{o}C, respectively at all particle size tested which was suitable for biochar production. The average concentration of CO_2, CO and CH_4 released during the carbonization process for both natural and fixed exhausted gas flow rate at all particles sizes were low compared to other studies, meanwhile SO_2, HCl, NOx and particulate matter, (PM10) were well below permitted level.

Under natural exhausted gas flow, harvesting carbonization temperature of < 500^{o}C of OPEFB biomass at 100-150 mm particle size produced the highest biochar yield and quality (calorific value, CV) between 23-25 % and 22.6-24.7 MJ/kg, respectively. Meanwhile, under fixed exhausted gas flow rate, the OPEFB biochar at particle size 100-150 mm produced the highest yield (25-27%), harvested at carbonization temperature of < 500 oC with low retention time and higher yield compared to natural exhausted gas flow rate. The CVs were found between 23.0-24.4 MJ/kg and comparable with other studies.

Self-sustained carbonization in a scaled-up pool type reactor using OPEFB biomass (3 tones capacity) for the development of YAMASEN oven was carried out. The maximum temperature for pressed-shredded and whole bunch OPEFB biomass was ranged 583-695^{o}C while CV between 21.9-24.3 and 19.6-22.9 MJ/kg, respectively and comparable to small scale production. This study to produce biochar for fuel usage has been achieved and it is preferable to the industry due to its simplicity, ease of operation and low energy requirement.

Supervisor
Professor Dr. Yoshihito Shirai
Professor Dr. Mohd Ali Hassan

Objectives

1. To evaluate the temperature profiles and gaseous emission during self-sustained carbonization of empty fruit bunch biomass in a pilot scale reactor.
2. To evaluate the effect of exhausted gas flow rate and OPEFB biomass particle size on biochar yield and quality under self-sustained carbonization in a pilot scale reactor.
3. To evaluate OPEFB biochar yield and quality in a scaled-up pool type reactor under self-sustained carbonization.
4. To evaluate energy balance and potential energy saving of raw OPEFB and biochar in a scaled-up pool type self-sustained carbonization reactor.

Fig.2 Pool type (scaled-up) self-sustained carbonization reactor

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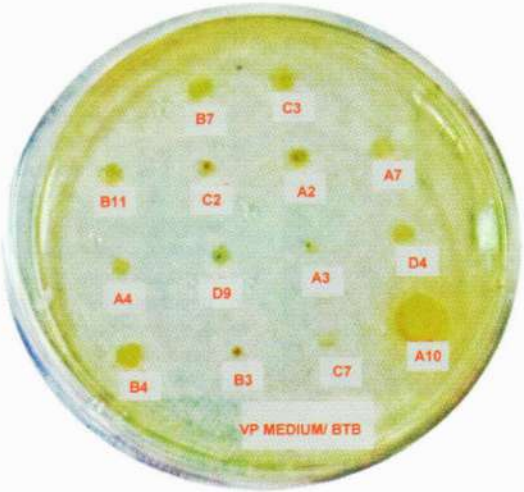
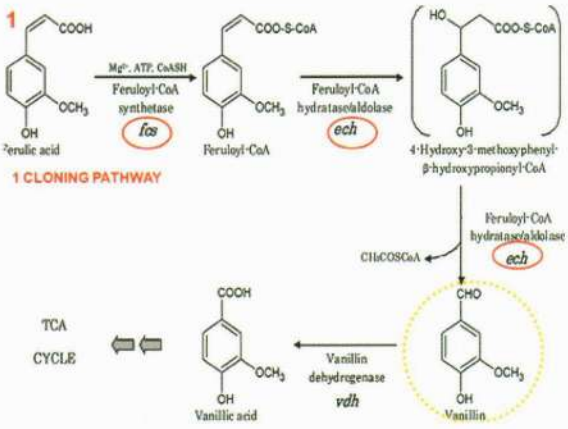
One-step biotransformation of ferulic acid into biovanillin using genetically engineered *Escherichia coli*

Vanillin is the major component of natural vanilla and a secondary metabolite of plant which is an important aromatic component as well as flavouring compound in the industry of food and personal products. It is derived from the tropical Vanilla orchid by the extraction from vanilla beans. Natural vanillin extracted from vanilla pods has a very high price and limited supply in the market due to it involved a time-consuming process which required intensive cultivation, pollination, harvesting and ripening of pods. It is also very dependable on the suitability of soil and climate conditions. Thus, current market demand for vanillin is fulfilled by the chemically synthesized vanillin. However, this artificially derived vanillin flavour could not be referred as a natural product. Therefore, the recent increasing demand for natural flavours and the problem of vanillin derived from Vanilla plant is relatively expensive has move the trends towards investigation of other biotechnological routes to produce vanillin. As a result, vanillin production through biotransformation of potential precursor by microorganism has been proposed towards a sustainable and environmental friendly process.

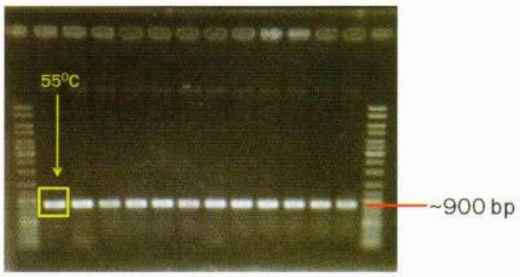
In this study, ferulic acid will be used as biovanillin precursor due to the chemically close relationship to vanillin, low cost, and readily available. It has been reported that the bacterium from *'Pseudomonas'* family have the ability to produce vanillin via biotransformation process involving ferulic acid obtained from biomass. Based on the common pathway of bacteria for biovanillin production, vanillin will be further oxidized into vanillic acid due to oxidation of vanillin was easily occurred in compared to ferulic acid. As a result, vanillin as an intermediate was nearly undetectable at the end of the fermentation process. Thus, the aim of this study is to develop a methodology for biovanillin production using genetically engineered *E. coli* by one step pathway without further oxidation of vanillin into vanillic acid. From this study, bacteria named as *Pseudomonas sp.* AZ10 UPM has been successfully isolated as a potential biovanillin producer using ferulic acid as sole carbon source. By using this strain, isolation of functional genes for biovanillin production can be carried out using DNA walking strategy and later can be cloned and expressed into pRSFDuet vector. The construction of genetically engineered *E. coli* containing biovanillin functional genes is expected to produce biovanillin in one step fermentation without further oxidation of vanillin into vanillic acid.



Rapid colorimetric of vanillic acid producing strain



The pathway of biovanillin production from ferulic acid



PCR optimization of ech gene

Supervisor
Professor Dr. Suraini Abd Aziz

Objectives

1. To screen, isolate and identify potential biovanillin producing bacteria.
2. To isolate the functional genes for biotransformation of ferulic acid into biovanillin and further construct genetically engineered *E. coli*.
3. To produce biovanillin in one step fermentation using genetically engineered *E. coli*.

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Controlled degradation of polyhydroxyalkanoates by high pressure steam hydrolysis for chemical recycling

Saturated steam reactor

Polyhydroxyalkanoate (PHA) has unique characteristics of thermoplastic, biodegradable and biocompatible biopolymer that can be produced intracellularly by microorganism and some plant species. This promising biopolymer has been researched since its discovery in 1920s, remarkably starts the green revolution of non-petrochemical aliphatic polyester that is producible via fermentation biosynthesis and has been commercialized as early as in 1962. The constituent of PHAs, polyhydroxybutyrate acid (PHB) is biocompatible with human as it is also a built compound of blood, made this producible biopolymer able to contribute very significantly in the biomedical applications especially in tissue engineering. This biodegradable carbon reserve plays important role in the environmental carbon storage. Cascade utilization of polymers could be introduced before they are finally being released to the environment. Single use of bioplastics does not support the sustainability of the carbon cycle; therefore a process to depolymerize polymers is needed. Nevertheless, biological production of PHA sometime able to produced ultra-high molecular weight to suit variation of thermo-mechanical properties needed. On the other hand, medium to low-molecular weight PHA are important for slow release and short term coating applications. Medium to low-molecular-weight materials are suitable feedstock for blending and re-polymerization process. Several methods have been used to depolymerize PHA, namely pyrolysis and hydrolysis. Pyrolysis, abiotic hydrolysis and enzymatic hydrolysis of PHA have been extensively studied; however steam hydrolysis of PHA is yet to be studied. Controlled depolymerization of PHA in this study, involved with the concept of the material conversion to molecules that built up of the original material or lowering of its origin molecular weight. This research is aimed at recovering low to medium-molecular weight polymers with hydroxyl and carboxyl chain-ends from polyhydroxyalkanoates (PHA) by steam hydrolysis. These low to medium- molecular weight polymers can be used as feedstock for re-polymerization and other applications. Degradation of PHA by steam hydrolysis will be controlled by several parameters, namely; temperature and retention time. The experiments will be conducted using saturated and superheated steam input. The hydrolysis products will be characterized and the effect of controllable parameters toward the target product formation will be investigated in details. The analysis of molecular weight will be carried out using gel permeation chromatography (GPC) and the depolymerization is projected theoretically to follow autocatalytic random degradation mechanism with the identification of critical point, hydrolysis rate constant and activation energy based on relative molecular weight of polystyrene as the standard. The hydrolyzed products will be characterized by using 1H and 13C NMR, FTIR, DSC, XRD, XPS and AFM. Mass balance for the PHAs hydrolysis will also be studied. At the end of this study, it is expected that the depolymerization mechanisms and kinetics for PHA hydrolysis can be proposed, with the selective formation of targeted products for cascade utilization of PHA.

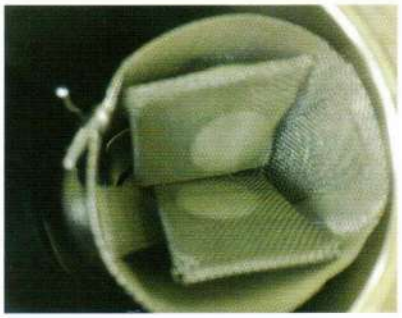
Flow chart of the research project

Supervisor
Dr. Hidayah Ariffin

Objectives

1. Characterization of low to medium molecular weight PHB hydrolyzed by steam.
2. Determination of PHB hydrolysis kinetics in saturated steam.
3. Proposition of mechanism involved in superheated steam hydrolysis of PHB.
4. Evaluation of steam hydrolysis for chemical recycling and surface modification of PHA.

Saturated steam reactor: bottom part



PHB disks arrangement prior to steam hydrolysis

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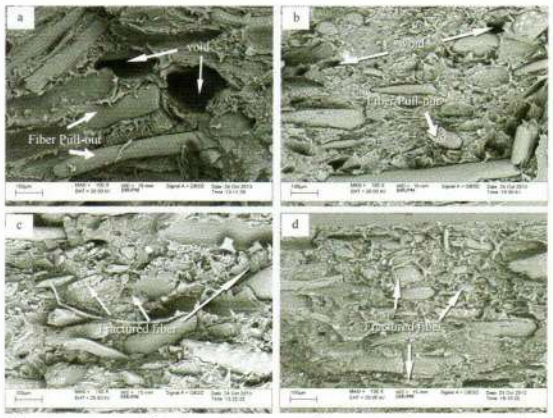
Superheated steam treatment of oil palm mesocarp fiber for biocomposite production

Development of biocomposites reinforced with natural fibers has attracted great interests in the polymer industries. However, incompatibility of hydrophilic natural fibers with non-polar thermoplastics is the main obstacle in the production of biocomposites due to poor adhesion between the two. Steam treatment has been proven to be able to improve the compatibility of plastics and fiber by extracting the most hydrophilic component of the fiber i.e. hemicellulose. This reduced the hydrophilicity of the fiber and hence provides better adhesion between plastics and fiber which results in improved mechanical properties of the biocomposite.

In this study, Superheated Steam (SHS) treatment was used to treat Oil Palm Mesocarp Fiber (OPMF). Tensile, flexural and impact strength of the biocomposite were then evaluated.

It was found that SHS-treated OPMF biocomposite had better mechanical properties compared to untreated. Tensile strength of 50 % SHS-treated OPMF biocomposite was 2 times higher compared to untreated OPMF biocomposite. It is also interesting to note that mechanical properties of biocomposites were affected by fiber loading. Mechanical properties of untreated and SHS-treated biocomposites were reduced as the fiber loading was increased. At higher fiber loading, mechanical properties of untreated OPMF biocomposite sample was largely affected. The reduction in mechanical properties upon increasing the fiber loading was due to interruption caused by the fiber in transferring the stress along applied force. Meanwhile, SHS-treated OPMF biocomposites was able to possess higher tensile strength even at 50 % fiber addition.

Project achievement: Biocomposite products and Silver medal won in MTE 2014



SEM micrographs of fractured biocomposite samples from untreated and SHS-treated OPMF

Our results demonstrate that SHS-treated OPMF biocomposites had better mechanical properties compared to untreated OPMF biocomposites. The findings from this study revealed that SHS-treatment was able to improve the adhesion between fiber and polymer due to the removal of hydrophilic moieties from the fiber. Thus, it is concluded that SHS could be an effective treatment process for fiber preparation for biocomposites production.

Supervisor
Dr. Hidayah Ariffin

Objectives

1. Characterization of superheated steam treated mesocarp fiber in comparison with untreated mesocarp fiber
2. Production and characterization of polypropylene/superheated steam treated OPMF biocomposite on mechanical and thermal properties with respect to SHS temperature, fiber loading and the use of compatibilizer
3. The effect of fiber treatment and its chemical composition on properties of PP/OPMF biocomposite

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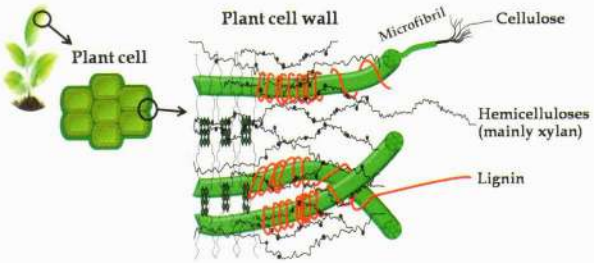
Production of fermentable sugars from oil palm empty fruit bunch using crude lignocellulolytic enzyme cocktail

Worldwide lignocelulosic residues generation every year with inefficient waste management resulted with environmental pollution and loss of valuable materials that can be bio-converted to many of value-added products. Oil palm empty fruit bunch were produced extensively in Malaysia and Indonesia particularly which contributes to the largest fraction of agricultural wastes in the country. The utilization of these agricultural wastes has been seen as promising substrates to be used in various areas of application. As part of the wealth generation strategy, government support to the use and its utilization as well as the incentives given has made it possible to be implemented.

The basic fundamental of the utilization of lignocellulosic residue may arise from the knowledge deals with the rigid structure of lignin and involvement of cellulose and hemicellulose that entail the valued disaccharide and monosaccharide of sugar. Theoretically, lignin gave a strong structure to plants whilst the component of cellulose and hemicellulose were scaffold in between. Thus, the utilization of cellulose and hemicellulose was blocked by the present of lignin. The responsible enzyme was classified into two categories which is ligninolytic enzyme (lignin peroxidase, laccase and mangan peroxidase) and cellulolytic enzyme (FPase, CMCase and β-glucosidase). All of the enzymes were secreted in nature by the ascomycetes and basidiomycetes species of fungi and the manipulation of enzyme to be used in targeted process are very useful. A lot of research together with the fungi in the process took a long time to achieve a specific target of partial lignin removal or modification. Many experiments have been made and a lot of efforts have been invested using fungi for technical lignin removal in the pulping process and for biobleaching. However, the incubation time has to be extended to attain a satisfactorily lignin removal. Incubation time and conditions is still an obstacle to a broad commercial application. Today's goals of fungal pretreatment have changed from the lignin removal (as much is possible) in the beginning, to a modification of lignin. Latest improvement has been made to the use of only enzyme to implementing the removal or modification of lignin instead of fungal pretreatments.



General structure of biomass

Through this research, we are aiming to fulfill the gaps in bringing more environmentally approach by using enzymatic pretreatment using ligninolytic enzyme at the early stage of lignin modification with addition of mediators compound to improve the efficiency and followed by the actions of crude cellulolytic enzyme for the production of sugars which both produced by local isolates to replace the current practices of using list of chemical catalyst as a favorite choices.

This research study will covers the screening and isolation of locally isolated white rot fungi for the production of the best selected ligninolytic producer. The enzyme extracted was used to carry out the effect of enzymes with the addition of mediators on the partial removal of OPEFB and further effect on the enzymatic hydrolysis of cellulose was also studied. In another section, cellulase improvement from locally isolated ascomycetes *Trichoderma asperrellum* UPM1 and *Aspergillus fumigatus* UPM2 was done through solid state and submerged fermentation using oil palm empty fruit bunch, sago pith residue and oil palm decanter cake. Physical and chemical characteristic of each substrates were studied in relation to the effects on the cellulase production. Holocellulose content, cellulose crystallinity and water solubility and absorption were determined. At the final part, both enzymes from the white rot and ascomycetes fungi were applied to studied substrate of OPEFB and the potential sugars produced obtained.

Supervisor
Professor Dr. Suraini Abd Aziz

Objectives

1. To delignify OPEFB using crude ligninolytic enzymes from locally isolated fungi
2. To improve cellulases enzyme production by *Trichoderma asperellum* UPM1 and *Aspergillus fumigatus* UPM2
3. To produce fermentable sugar from OPEFB by two step of enzymatic degradation and hydrolysis using crude lignocellulolytic enzyme cocktail

Type of white rot fungi

Shredded OPEFB

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Compost hybrid modeling of organic waste

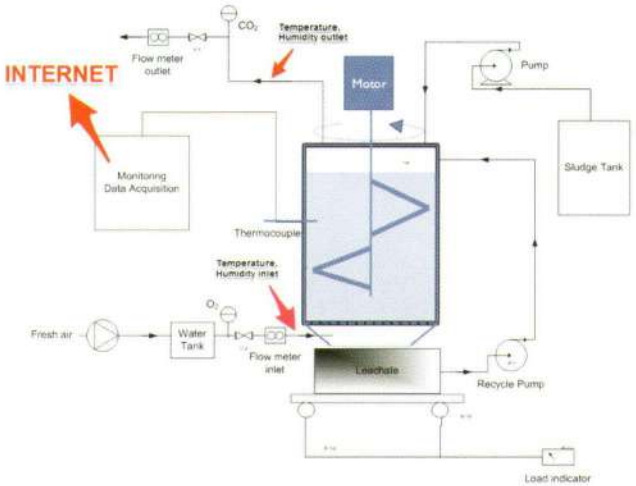
The findings of literature review in the mathematical model type, in composting. It shows the current status of research and several gap automatically proposed research suitable to execute. Example of gap available are validation for the mathematical model was not thoroughly done and tested, rare of hybrid mathematical model in composting and lack of important parameters in modeling. Experiment has to be made to fulfill the parameter data required in the modeling. Research design proposed such as factorial design to run real experiment. The aim is to validate the previous model, to test experiment with different raw material input and process parameter range, and established data for neural network model training dataset and testing. Physical model of to run the experiment already justified base on review made on design, size and capacity.

Temperature and Humdity Sensor with Datalogger

Composter

Compost

Several process factor commonly included in compost mathematical model have known. There are about six common process factor has been applied in. Most popular is a deterministic model example growth factor limiting process to imitate limitiation of actual process. Knowledge of process factor limiting fusion (incorporated into a single model) and direct inclusion of the possible interactions between the states as part of the model's structure could comprehend composting process. Composting is most dynamic type of process hence incorporation factor limiting modeling could gain new insight which compensates vague understanding and flexibility to first principle mathematical model (deterministic).This study could introduce practicality in modeling for dynamic behavior such as composting.



Composter Schematic Diagram

Supervisor
Professor Dr.Mohd Ali Hassan

Objectives

1. To assess mathematical model for composting.
2. To investigate model sensitivity analysis of different ratio organic wastes towards microbial population dynamics.
3. To progress mathematical model by categorizing substrate, basic microbiological approach, physical transport and output compost as a stable product using first principle.

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Design of functionalized polyester from palm oil's fatty acids

This study focuses on the production of polyester from bio-based resource, i.e. palm oil. The beauty of palm oil as raw material for polyester production is due to its fatty acids composition, which has a mixture of unsaturated and saturated fatty acids, and this may produce polyester with versatile properties. The synthesis of bio-based polyester started with dicarboxylic acid production which can be derived from metathesis of unsaturated fatty acids. Dicarboxylic acid produced was then used as monomer for condensation polymerization with aliphatic and aromatic diol in the presence of Lipase N435 and isopropyl titanate as catalyst. Subsequently, a simple and efficient method of chemical modification called olefin epoxidation was applied in order to introduce a new reactive group which will cause the polyester produced to have versatile properties which will lead to the wider applications of the polymer. Lipase N435 was used for epoxidation of the olefin groups present in the original monomers and resulted polymeric material. Produced polymer is subjected to ^{1}H NMR, ^{13}C NMR, FT-IR, GPC, TGA, DSC analyses for further characterization of the polymer.

Synthesis of dicarboxylic acid monomers from metathesis of oleic acid by 2nd generation Grubbs catalyst.

Synthesis of polyester from dicarboxylic acid monomers with aliphatic / aromatic diols by using isopropyl titanate.

Supervisor
Dr.Hidayah Ariffin

Objectives

1. To synthesize dicarboxylic acids monomer by using Grubbs catalyst 2nd generation.
2. To produce palm oil-based polyester from dicarboxylic acids and to evaluate the effect of co-monomers on the characteristics of polyester.
3. To study on enzymatic degradation properties of the polyester and re-polymerize the monomers.

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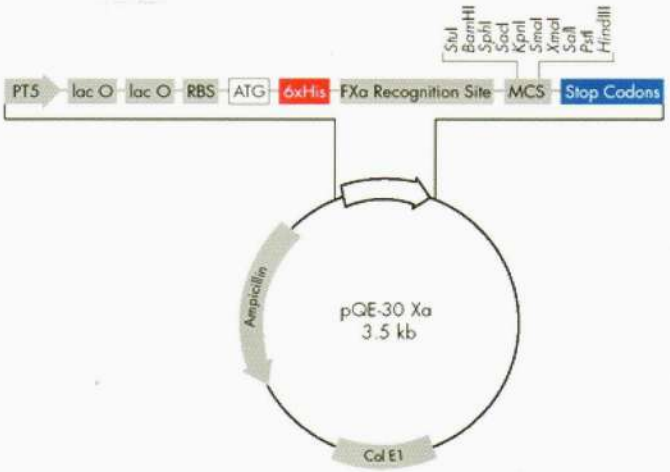
Expression, purification and characterization of polyhistidine-tagged recombinant cyclodextrin glycosyltransferase from *Escherichia coli*

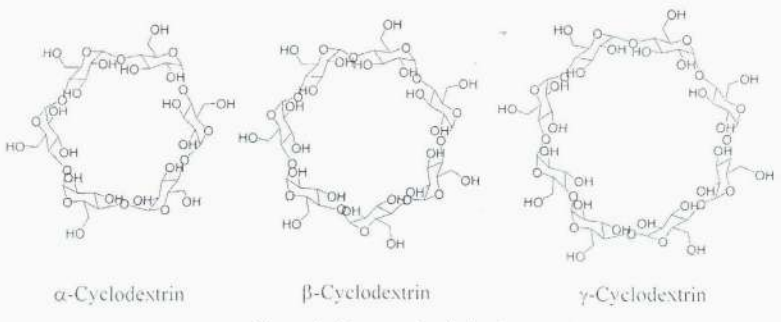
Cyclodextrin glycosyltransferase (CGTase) (EC 2.4.1.19) represents one of the most important groups of microbial amylolytic enzymes. This enzyme is a member of alpha-amylase family or glycosidase hydrolase family 13, which forms circular α-(1, 4)-linked oligosaccharide substrates via a covalent intermediate. The non-reducing end of this intermediate is subsequently used as the acceptor that cleaves the covalent enzyme-substrate bond, and a cyclodextrin (CD) is released. Currently, the productivities of CGTases from wild strains are relatively low, resulting in high costs for production of cyclodextrin. Thus, the increase in CGTase productivity is considered as a major priority for the reduction of cyclodextrin production.

The over expression of CGTase gene using bacterial expression system offers a great advantage in the enhancement of the product yield and provide a straightforward way of satisfying the anticipated expansion of the CD market. Given the potential uses of recombinant CGTase, fermentation process of recombinant microorganism has been developed for production of high value product and the development of low cost industrial media formulation.

The aim of this study is to express and purify the recombinant CGTase from *E. coli*. The polyhistidine-tagged vector will be used to simplify the process of purifying recombinant proteins from crude cell lysates using affinity chromatography. The pure CGTase obtained after enhancement of the production will be characterized in terms of thermostability and tested for its capability in releasing CD. Codon optimization will adjust the codons in a target sequence to high-frequency codons preferred by the selected expression host to enhance CGTase productivity. Since CD shows capability in forming inclusion complex, the properties of the materials with which they complex can be modified significantly. As a result of molecular complexation phenomenon CDs are widely used in many industrial products, technologies and analytical methods.



Schematic representation of the expression vector (pQE-30 Xa)



Schematic diagram of cyclodextrins

Supervisor
Dr Norhayati Ramli

Objectives

1. To express, purify and characterize the N-terminal his-tagged cyclodextrin glycosyltransferase (CGTase) from *Escherichia coli*.
2. To optimize the systematic codon usage for enhancement of CGTase production in *Escherichia coli*.
3. To enhance secretion of recombinant CGTase into the culture media of *Escherichia coli* by medium additives

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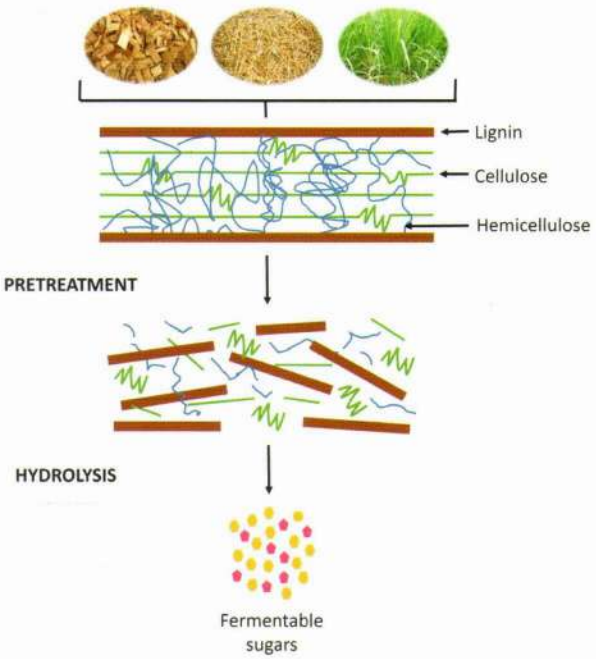
Development and optimization of lignocellulolytic enzyme cocktail for fermentable sugars production from oil palm empty fruit bunch

To date, Malaysia rank in the second place as a global palm oil producer. However, a non-systematic biomass management system despite the rapid growth of oil palm plantation in Malaysia contributes a lot to biomass accumulation in huge amount. Oil palm empty fruit bunch (OPEFB) can be categorized as one of the toughest lignocellulosic biomass to be degraded naturally due to its complexity in structure. Common industrial practice used chemical and physical treatment to treat the OPEFB as it performs faster in hydrolyzing the biomass than biological treatment does. However, as the world is moving towards green concept, chemical treatment is no longer suitable to be practiced because it produce harmful by-product and it give low yield of fermentable sugars. The idea of converting the unwanted OPEFB into value-added products came up due to the biomass pile up from oil palm plantation activity and palm oil refinery industry. In this study, the OPEFB was treated biologically using crude enzyme extract due to environmental concern. The OPEFB is subjected to enzymatic hydrolysis by crude lignocellulolytic enzymes to produce a fermentable sugars. Hence, the biological approach for delignification and saccharification process is expected to results in high lignin removal and consequently produces high fermentable sugars concentration.



Overview of lignocellulosic biomass hydrolysis

Shredded oil palm empty fruit bunch

Pycnoporus sanguineus

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives

1. To improve the ligninolytic enzymes production using Pycnoporus sanguineus through the effect of inducers.
2. To optimize the parameters for delignification and saccharification of oil palm empty fruit bunch using statistical approach for higher fermentable sugars production.

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Controlled hydrolysis of poly (3-hydroxybutyrate-co-3-hydroxyhexanoate) for oligoester production

Polyhydroxyalkanoate (PHA) is a type of biodegradable plastic that belongs to the family of microbial polyesters. These natural polymers are being produced by many types of bacteria as an intracellular energy reserve material under the condition of substrate limitation and in the presence of excessive carbon source. However, the intracellularly produced PHAs have high molecular weight (200 - 3000 kDa) and this feature makes them undesirable for the production of specialty polymers for biomaterials, which require a low, specific range of molecular weight (1 - 5kDa). Therefore, an effective degradation method is necessary to produce oligoesters with desired low range of molecular weight. In the present study, controlled degradation of PHA by superheated steam (SHS) is being studied using two types of PHA, namely poly(3-hydroxybutyrate), PHB and poly(3-hydroxybutyrate-co-3-hydroxyhexanoate), PHBHHx. Effect of SHS temperature and reaction time on the characteristics of hydrolyzed PHA is determined and kinetic parameters of PHA hydrolysis in SHS is also evaluated by adapting kinetic model by Yoon et al. (1997) for non-autocatalytic and Nishida et al. (2000) for autocatalytic hydrolysis mechanisms. The influence of HHx unit composition in PHBHHx SHS hydrolysis is also clarified. It is postulated that controlled SHS condition will cause the hydrolysis to occur specifically at the ester bond to produce PHA oligoesters.

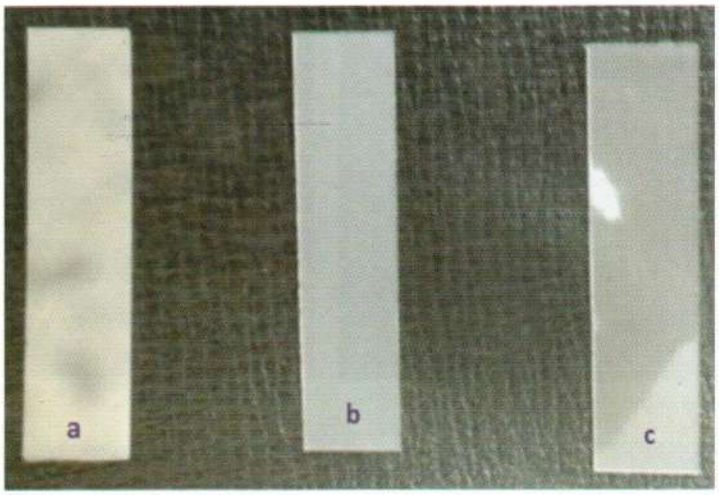

Figure 1: Hot-pressed PHA films for superheated steam (SHS) treatment (a=PHB, b=PHB-co-6%HHx and c=PHB-co-11%HHx)

Figure 2: Superheated steam (SHS) oven used for depolymerization of PHA

Supervisor
Dr. Hidayah Binti Ariffin

Objectives

1. To depolymerize polyhydroxyalkanoates (PHA) by superheated steam (SHS) and to characterize the produced PHA oligoesters.
2. To determine the mechanism of PHA hydrolysis by SHS
3. To determine the functionality of PHA oligoesters as biomaterials

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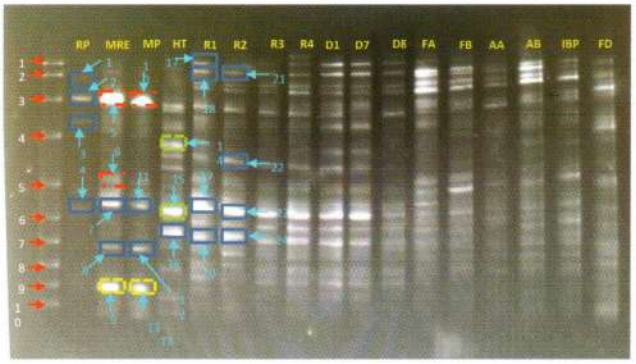
Microbial community adaptation and Its community changes in different stages of palm oil mill effluent treatment

The growing demand for palm oil has caused a substantial increase in the generation of palm oil mill effluent (POME). POME has been known to give the adverse environmental impacts including land and aquatic ecosystem contamination and the biodiversity loss if it is not properly treated. However, the current wastewater treatment system for POME regularly fails to treat the effluent efficiently. To meet the standard discharge limit proposed by the Malaysian Department of the Environment, the POME must be treated effectively before being released into the receiving water bodies. In Malaysia, the ponding system is commonly being used to treat POME because of the low cost and less maintenance is required. To date, only few studies have been conducted on the microbial aspects of POME and little is known about microbial diversity involved in POME treatment, either in terms of their community structure and function or their response to the environment. Therefore, the study on the microbial community structure during POME treatment is proposed. Additionally, the microbial community from POME will be assessed after implementation of zero discharge concept. To achieve these objectives, culture-independent approaches such as PCR-Denaturing Gradient Gel Electrophoresis (DGGE) and Next Generation Sequencing will be applied. In addition, the correlation between microbial community compositions and compounds will be investigated. As a conclusion, the microbial community and its changes during POME treatment is expected to be explored and identified, thus will bring to the microbial community rebound after implementation of zero discharge system.



DGGE Fingerprinting

POME

Cooling Pond

Mixing Pond

Illumina MiSeq

Supervisor
Dr. Norhayati Ramli

Objectives

1. To assess microbial community profiles in different stages of palm oil mill effluent (POME) treatment.
2. To assess the biodiversity rebound in terms of microbial community after POME treatment with zero discharge.

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The use of oil palm empty fruit bunch and palm oil mill effluent compost in oil palm plantations: Nutrients recycling system for oil palm industry

Oil palm (Elaeis guineesis Jacq.) is a tropical crop planted in 43 countries over a total land area of 16.4 million ha (FAO, 2014). Oil palm is the world's highest yielding oil crop, producing nearly 5 tonne ha 1- of oil per year which is 13 times more than the oil produced from soybean (Moradi et al., 2014). In 2015, Indonesia produced the highest production of palm oil with approximately 33 million metric tonnes followed by Malaysia 19.8 million metric other ASEAN countries with 4.7 million metric tonnes and Thailand with 2 million metric tonnes (World Palm Oil Production. com, 2015). Oil palm industry in Malaysia plays a vital role for oil production since early 1980s. Malaysia has expanded the oil palm plantation rapidly from 55,000 ha in 1960 to 5.23 million ha in 2013 (equivalent to 16% of Malaysia's total land area). Malaysian government only owned 8% of the overall plantation area while the private sectors dominated the industry by possessing 52% (IMA, 2010). Although oil palm industry is a strong driver for economic development in Malaysia by providing jobs and incomes to millions of people (USDA, 2007). However, an environmental issue related to oil palm plantation is also associated with the excessive usage of fertilizer. Long-term impact of inorganic fertilizer usage is more pronounced on soil properties specifically on chemical and physical composition of the agriculture soil (Masto et al., 2007). The pH of the soil will decrease when inorganic fertilizer is applied frequently (Liu et al., 2012), resulted in the reduction of nutrient availability and microbial biomass (Bardgett, 2005). Identifying the factors that most affects soil properties and microbial community composition is important for developing sustainable agriculture (Bending, 2004). Maljanen et al, (2003) found that organic C was rich soils emitted very high N_20, was derived from the N mineralized from SOC. Inorganic fertilizer many advantage according to avaible mineral, high solubility, nutrient uptake of plant, easy storage and handling (Jensen et al., 2011). The application of inorganic fertiliser could reduce soil productivity in the long run (Yudavashi, 2001). Low soil productivity and high soil degradation are threatening food security (Oldeman et al., 1990) and will increase the emission of CO^2. Therefore, soil quality and its importance for sustainable agricultural development has received growing attention in recent years (Dumanski and Pieri, 2000). Oil palm requires regular inputs of nutrients to maintain high yields of palm oil following removal of nutrient, particularly where plantations are established on soils with low inherent fertility. Application of inorganic fertiliser is generally required in any oil palm plantation and this contributes to a major component of plantation expenditure (Rankine et al, 1999). The best practise for fertiliser management at oil palm plantation is based on nutrient balance principle by estimating the total demand of the palm and matches with the supplemented nutrient and fertiliser (Goh et al., 1999).

Figure 1: FELDA field triped at Ladang 10 (nursery project), Universiti Putra Malaysia

Figure 2: After 2 years apply treatment in oil palm plantation at FELDA Serting Negeri Sembilan, Malaysia.

Figure 3: Progress oil palm trees a (year one) and b(years two) at Felda Serting Hilir Negeri Sembilan.

Supervisor
Professor Dr. Mohd Ali Hassan
Professor Dr. Yoshihito SHIRAI

Objectives
1. To conduct baseline study, characterize macro-micronutrient and microbial profile of soil planted with oil palms
2. To evaluate the effect of organic and inorganic fertilizer on changes of oil yield, the physical characteristics of oil palm and the soil microbial profile.
3. To observe effects of compost as media to reduce inorganic fertilizer used at nursery stage.

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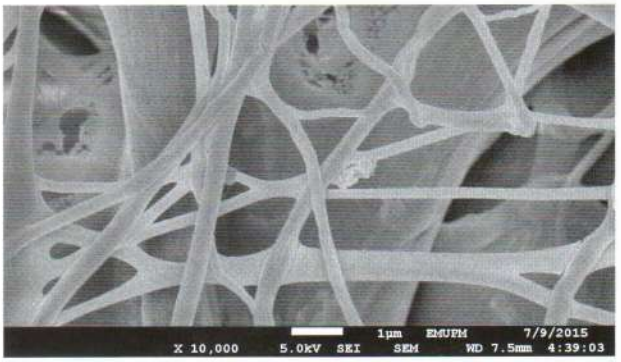
Nanofiber and nanocomposite production from super heated steam treated oil palm biomass

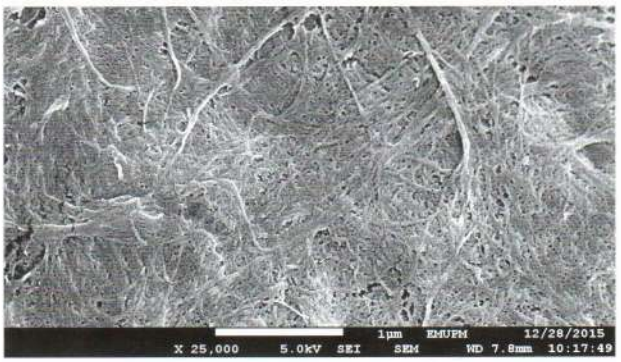
In Malaysia, oil palm biomass annually generates 19.8 million tonnes of biomass on a wet basis and 6.93 million tonnes on a dry basis. This provides huge resources for the conversion into value added products such as biogas, organic acids, bioplastic, cellulose, biocomposite and cellulose nanofiber production. Oil palm biomass (OPB) such as oil palm mesocarp fiber (OPMF) and oil palm empty fruit bunch (OPEFB) are potential materials for nanofiber and nanocomposite production due to their abundance and renewability. However, the complex structure of this lignocellulosic material making its processing into nanofibers difficult and hence, pretreatment is required. The main purpose of pretreatment is to separate cellulose from other components and thus improving processability of nanofibers and subsequently, nanocomposite production. Superheated steam (SHS) treatment has been proven as a superior pretreatment method in order to remove high amount of hemicellulose. In this work,

Wet Disk Milling

lignocellulosic material of OPMF and OPEFB will be pretreated using SHS pretreatment. This will be followed by delignification using sodium chlorite ($NaClO_3$). Control sample was prepared by treating the OPB with potassium hydroxide (KOH) and $NaClO_3$ to produce cellulose-only sample. Nanofibrillation of the pretreated samples will be later conducted using electrospinning and wet disk milling (WDM). For electrospinning, fiber samples will be dissolved in mixture of 1-ethyl-3-methylimidazolium acetate and dimethylformamide (DMF). It is postulated that dissolution of cellulose samples in ionic liquid is affected by pretreatment of fiber and the use of co-solvent. These two parameters also will be evaluated for their effect on nanofiber formation and characteristic. Another nanofibrillation method will be tested which is by mechanical pretreatment using WDM. WDM pretreatment will be carried out to facilitate fibrillation of OPB. The effectiveness of pretreatments will be characterized from the chemical composition of nanofiber produced and number of WDM cycles. Scanning electron microscopy will be used as a core method to compare the structural integrity and morphology between raw and treated OPB nanofiber produced from both methods. Besides that, crystallinity and thermal properties of the nanofiber will be analysed by X-ray Diffraction (X-RD) chromatography and Thermal Gravimetric Analyser (TGA) respectively. Nanocomposite will be subsequently prepared by blending nanofiber with polyurethane (PU) at different proportions of fiber through solvent casting method. Performance of nanocomposite will be characterized by mechanical properties, visibility, morphology and coefficient of thermal expansion. Overall, it is expected that nanofiber can be produced from treated OPB through electrospinning and WDM. Better mechanical properties of composite could be obtained as compared to neat PU.



Nanofiber produced by electrospinning



Nanofiber produced by wet disk milling

Nanofiber slurry (Different cycles)

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To pre-treat oil palm biomass for isolation of cellulose fiber.
2. To produce cellulose nanofiber from pre-treated oil palm biomass using wet disk milling and electrospinning.
3. To develop and characterize nanocomposite of oil palm biomass nanofiber with polyurethane.

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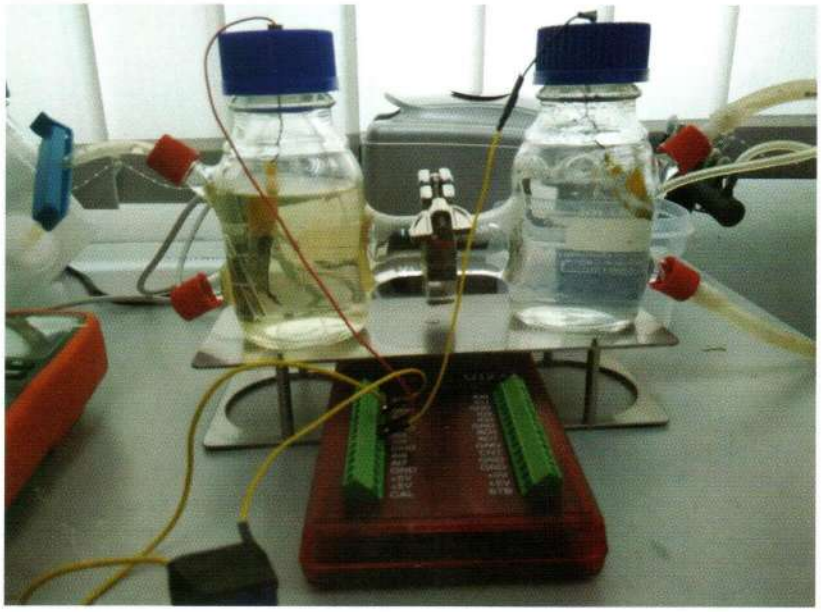
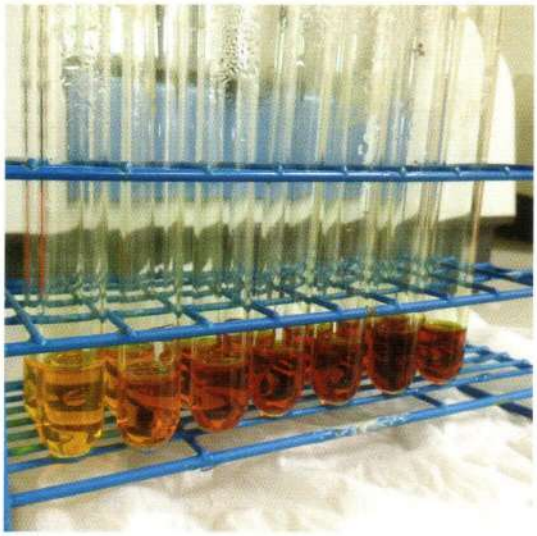
Bioelectricity production from oil palm empty fruit bunch hydrolysate by *Clostridium butyricum* A1 using microbial fuel cell

Recently, microbial fuel cell (MFC) has gained attention due to its ability to transform chemical energy into electricity. MFC has been considered as an expensive technology, thus makes it challenging for commercialization in the near future. Therefore, one of the possible approaches in order to overcome the aforementioned problem is to utilize the readily available biomass as an alternative cheap substrate for MFC. The lignocellulosic biomass, such as oil palm empty fruit bunch (OPEFB) has a great potential to be utilize in MFC. The OPEFB composed of cellulose and hemicellulose that can be hydrolysed by cellulase into fermentable sugars. These fermentable sugars are possible to be used as electron donor in MFC. The fact that Clostridium sp. has few knowledge in MFC field, this study has great opportunity in the development and better understanding for future MFC. The utilization of fermentable sugars obtained from OPEFB and local isolated *Clostridium butyricum* in MFC have expected to give positive and great impact the advancement of MFC system.





Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives

1. To produce bioelectricity by locally isolated *Clostridium butyricum* A1 using microbial fuel cell
2. To utilize the OPEFB hydrolysate as a substrate for bioelectricity production by *Clostridium butyricum* A1 using microbial fuel cell
3. To increase the power density of bioelectricity production from oil palm empty fruit bunch hydrolysate using multi-stacked microbial fuel cell system

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Development of biorefinery process for the production of bioethanol from oil palm frond

Lignocellulosic materials consist mainly of three polymers; namely cellulose, hemicellulose and lignin. In the National Biomass Strategy 2020 published by Malaysia Innovation Agency (2013), it was reported that Malaysia generated approximately 80 million tonne of dry solid biomass from the oil palm industry in 2010 and it is predicted to increase up to 110 million tonnes by 2020. Oil palm empty fruit bunch, oil palm mesocarp fiber and oil palm frond are among the main oil palm wastes produced, with oil palm frond being the largest. The main concern in the application of lignocellulosic materials is that it requires aggressive pretreatment which contributes to high production cost. In recent years, researchers are looking at more efficient, environmental friendly methods which results in more lignin removal and higher surface area for enzymatic reaction. Hydrothermal pretreatment appeared to effectively improve the digestibility of lignocellulosic biomass. The advantage of hydrothermal pretreatment is that the system only use water and hydronium ion from water ionization acts as catalyst during reaction. The low concentrations of solubilized product produced and less severe treatment condition reduce the generation of degradation products which act as fermentative inhibitors.

Figure 1 Sand bath reactor

In this study, hydrothermal hydrolysis of oil palm biomass will be conducted at various combined severity factor and held at selected pressure to assess the influence of these operating conditions on the physical properties, apart from sugar recovery following enzymatic hydrolysis. Findings of this study are expected to provide better understanding on hydrothermal hydrolysis thus further support the potential of hydrothermal pretreatment for improved sugar recovery from biomass.

Supervisor
Professor Dr. Mohd Ali Hassan

Objectives

1. To evaluate the effect of hydrothermal pretreatment at combined severity factors in enhancing enzymatic hydrolysis for sugar recovery from oil palm frond fiber (OPFF)
2. To study the kinetics of hemicellulose and cellulose hydrolysis for hydrothermal pretreated OPFF
3. To develop an integrated biorefinery process for bioethanol production from renewable sugars of oil palm frond

Figure 2 Pretreated OPFF slurry

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Improvement of conventional palm oil mill effluent treatment system for environmental sustainability

Palm oil industry is one of the leading agriculture industry in Malaysia. This industry contributed a lot in Malaysia economic growth. Being the 2nd largest palm oil producer, Malaysia is now facing environment problems due to massive production of effluent from oil palm mill. The production of highly polluting palm oil mill effluent (POME) has resulted in serious environmental hazards. Despite treatment using open ponding systems, the final discharge still contains high level of chemical oxygen demand (COD) and suspended solids (SS), which are higher than river. Since organic compounds are harmful to the environment, it becomes necessary that effluent generated should be treated before discharged into the water courseways. However, less research was done focusing on toxicity level in final discharge. Whether the residue contained in final discharge can lead to toxicity or not is still unknown since the toxicity related parameters are still not regulated. According to the reported journals by 2013, many mills have still discharged over limit for biochemical oxygen demand (BOD), with high COD values as well. We have to consider introducing valuable treatment system or novel idea to keep final discharge for significant parameter limits.

Facultative pond

Supervisor
Dr.Mohd Rafein Zakaria

Objectives
1. To determine the toxicity presence and identify their compounds in final discharge.
2. To investigate parameters changes at three zones in facultative pond.
3. To identify sunlight effect during POME treatment.

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Simultaneous carbonization and activation of oil palm kernel shell for activated carbon production

Biochar and activated carbon are the most important and immediate application for environmental clean-up. Bio-char and activated carbon can adsorb unwanted components in water systems, especially toxic substances such as heavy metals and organic compounds. Production of bio-char and activated carbon from oil palm biomass has been gaining some interest lately. Bio-char from oil palm biomass has been successfully produced high yield and higher heating value under low energy requirement for waste management and utilization in the palm oil industry. Currently, the industry obtains the bio-char by purchasing it from the locals or from the backyard industry, which is producing it domestically using the conventional drum kiln or pit kiln methods. For carbonization and activation processes contributes to energy and time consumption under separated process, and the cost for materials and apparatus. Any combinations of these processes into a single step or step that can be carried out simultaneously can reduce the production cost, energy and time. In addition, the carbonization of oil palm shell as a bio-char and activated carbon also provides some advantages to the industry. This an appropriate technology can help the industry to manage their abundant oil palm shell waste, as well as generating extra profit and at the same time reducing the release of gaseous pollutants and particulate matter emissions into the atmosphere.

Supervisor
Professor Dr. Suraini Abd Aziz

Objectives

1. To evaluate and characterize activated biochar of oil palm shell at different activation temperature and steam flow rate under simultaneous self-sustained carbonization and activation reactor.
2. To evaluate and characterize activated bio-char of oil palm shell at optimum activation temperature and steam flow rate under simultaneous microwave carbonization and activation reactor.

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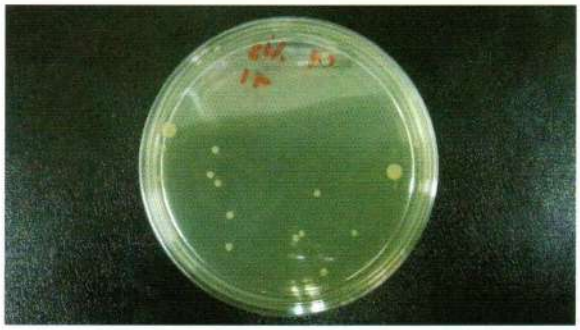
Feasibility of oil palm frond Petiole as fermentation substrate

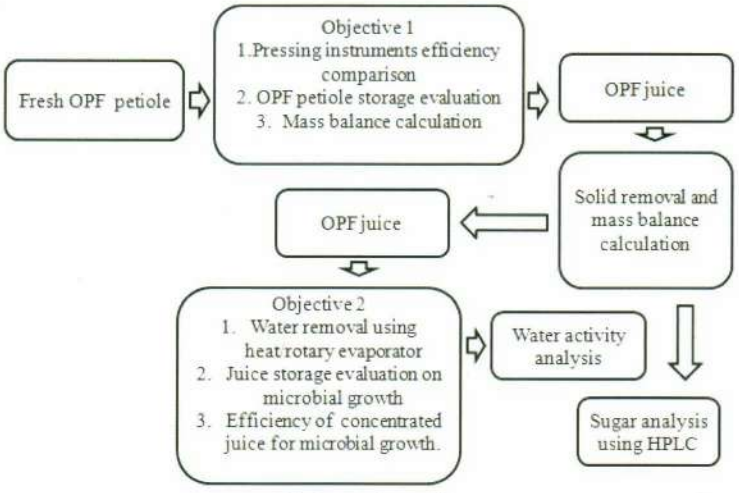
Palm oil is the most profoundly traded vegetable oil in the world, leading approximately 60% of vegetable oil market volume in 2008 (Oil World, 2009). It is majorly planted in South East Asia and Malaysia being as second largest of global palm oil producer which contributing 40% of world production and lead by Indonesia which currently contribute 45% of total oil palm production in the world. Current strategies of managing the residues are by formulating it into ruminant feed. Ongoing research found that the OPF juice contain high sugar composition that can be developed for another rising industries like fermentation, biohydrogen and other high end products. Depolymerizing cellulose using enzyme is a known way to extract sugars. Rather using enzyme for extraction, the sugars is obtained directly from the oil palm frond petiole by using conventional sugarcane press machine. Storage evaluation was also been done to examine the critical sugar degradation in OPF prior to pressing. Besides, this study research was proposed to optimize the production of the juice extraction with the means of pre-treatments as well as techniques to preserve the juice after extraction. The pre-treatment involve including shredding, direct pressing with hydraulic pressing machine and applied optimizing of OPF petiole storage evaluation for preserving the juice. As much as 38 g/kg of free sugars extracted from OPF using the hydraulic pressing machine. Currently, the juice storage was evaluated using water removal technique via heat treatment. Removing water was found to inhibit the microbial growth due to the severe conditioned caused by reduction of water activity. This kind of treatment suffices to preserve the juice within short times 10 days prior to be used as fermentation substrate with merely 8-10% sugar degradation due to the high heat exposure. This study is part of a growing research on oil palm field and economically beneficial to the country. It will explore the potential available on fermentation industry.



Microbial colony capable to grow on OPF juice incorporated to agar.

Fresh OPF after pruning.

OPF juice extracted from the petiole.



Big picture of research.

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To investigate the effect of OPF petiole storage period and physical pretreatments on recovery and characteristics and fermentable sugars from OPF petiole.
2. To concentrating OPF juice by heat treatment and determine storage stability of concentrated OPF juice at ambient temperature.

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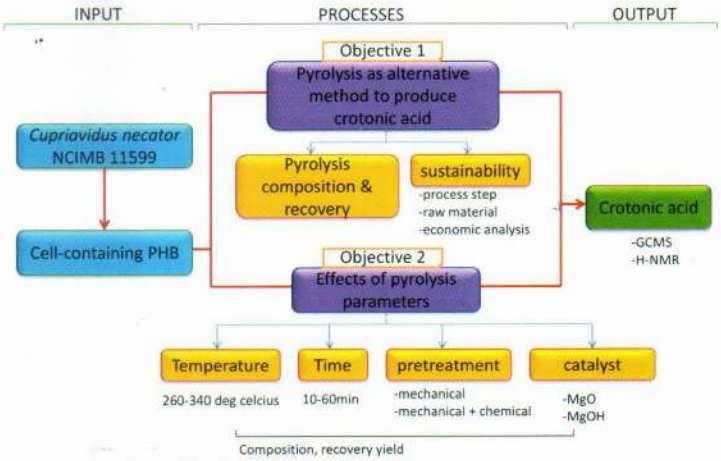
Development of bio-based production of crotonic acid via pyrolysis of Polyhydroxybutyrate (PHB) biomass

Fermentation of PHB by C.necator NCIMB 11599 in 20L bioreactor

BIG PICTURE



Crotonic acid is a short chain unsaturated carboxylic acid. Crotonic acid and its derivatives have various specific applications; for example as a component in dental materials, cosmetics, hair styling products, plasticizers, herbicides, compatibilizers, paints and hydrogels. Current production of crotonic acid is via petrochemical synthesis. However, it has several drawbacks. The chemical synthesis of crotonic acid involves many steps. Furthermore, purification of crotonic acid by crystallization may contribute to the environmental pollutions as it causes the formation of about one ton of highly contaminated effluents per ton of processed crotonic acid. This is accompanied by about 1500m^3 of contaminated air per ton of crotonic acid from the drying process. Moreover, the crystallization process also causes product loss. The present proposed research provides an alternative route to crotonic acid production which involves biological synthesis and eco-friendly methods. This can be done by the use of PHB-producing bacteria biomass. The bacteria accumulate PHB as energy reserve materials under suitable conditions during fermentation. PHB can later be converted into its dehydrated monomer which is crotonic acid via thermal degradation. In this research, recovery of crotonic acid from PHB biomass will be conducted by mean of pyrolysis. Pyrolysis process will be conducted in a glass tube oven, and pyrolyzate collected will be analyzed by GC-MS and ^{1}H-NMR. This study is expected to contribute to new method for green route for crotonic acid production.

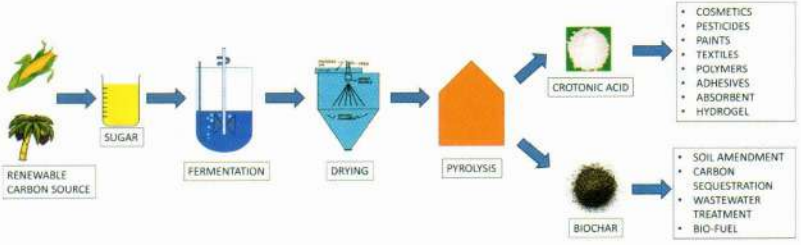
Method	Petrochemical	Bio-based
Feedstock	Non-renewable	Renewable
No. of production steps	5	3
Crotonic acid yield (%)	30	87
Estimated selling price (USD)	6.57-13.13	7.80-11.05

Table. Comparison between petrochemical-based and bio-based crotonic acid production

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To develop environmental friendly method for crotonic acid production via pyrolysis of PHB biomass
2. To evaluate the effect of pyrolysis parameters, pretreatment and catalyst on the composition and recovery of crotonic acid



Schematic diagram of bio-based crotonic acid production

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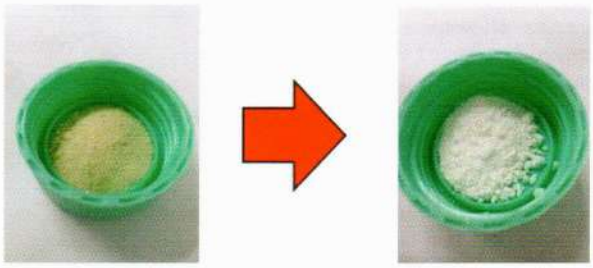
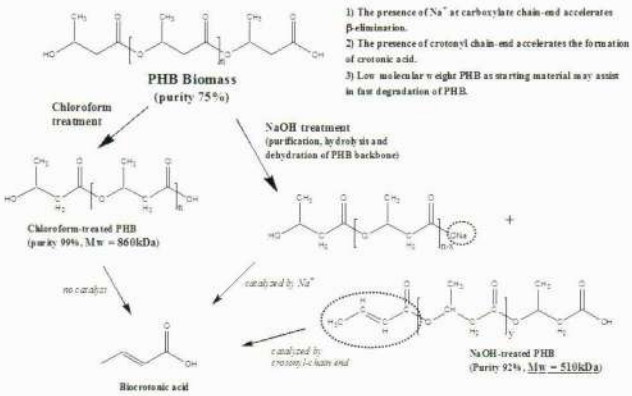
Improved Production of Bio-Based Crotonic Acid

Crotonic acid is an unsaturated carboxylic acid conventionally derived from petroleum resource through multiple-step chemical processes. Nevertheless, research has showed that crotonic acid is also dehydrated monomer of poly(3-hydroxybutyrate) (PHB) which is a bio-based and biodegradable microbial polymer. It has been demonstrated that pyrolysis of PHB under controlled temperature and retention time yielded crotonic acid. Direct pyrolysis of PHB inclusions in bacterial cell has been recently studied, and it was exhibited that low purity of crotonic acid at around 54% was obtained from the process which could be contributed by the presence of other organic compounds in the cell that volatilized together with the crotonic acid during pyrolysis. In this study, improved crotonic acid production and recovery was achieved by introducing a pre-treatment step prior to pyrolysis of PHB inclusions. PHB inclusions obtained from fed-batch fermentation of *Cupriavidus necator* KCTC 2649 utilizing glucose were treated with mild alkali (0.05M NaOH). This treatment saponified lipid layer of the bacterial cell and increased the cell wall permeability, resulted in PHB isolation from bacterial cell. PHB isolated from cell had purity of 90 %, compared to the original untreated PHB with purity of 75 %. Isolated PHB was then pyrolyzed in a glass tube oven and the pyrolyzates were analyzed by GC-MS and 1H-NMR. A marked increase of crotonic acid purity was observed when isolated PHB was used in pyrolysis compared to the original PHB inclusions. Overall, it is concluded that pre-treatment of PHB inclusions with mild alkali assisted the isolation of PHB which resulted in the production of higher purity crotonic acid.



Recovery of PHB Biomass by 0.05 M NaOH



Pathway of biocrotonic acid production from chloroform-treated and NaOH-treated PHB

Collected pyrolyzate (crotonic acid)

Supervisor
Dr. Hidayah Ariffin

Objectives
1. Effect of PHB recovery method on purity of crotonic acid.
2. Effect of alkali earth compounds catalyst on the production and diastereoselectivity of crotonic acid.

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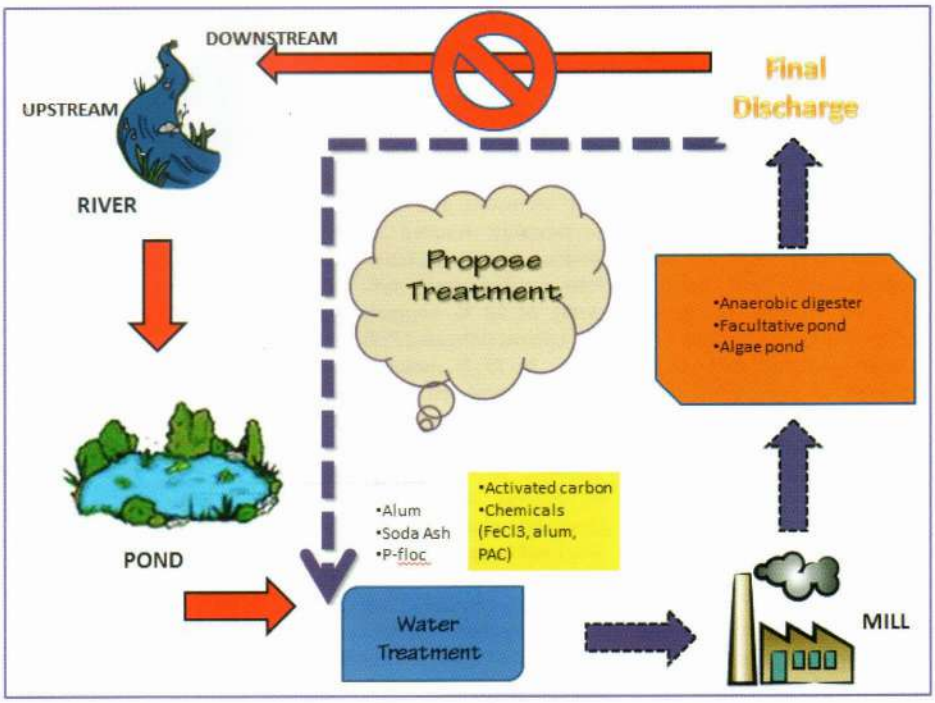
Treatment of effluents from palm oil mill process to achieve river water quality for reuse as recycled water in a zero emission system

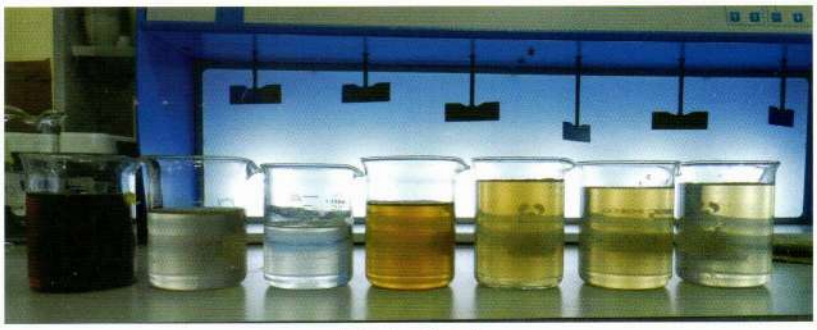
In palm oil industry, huge amount of water have been utilized for palm oil sterilization and extraction process. The processing system has been applying widely in Malaysia for year. It has been estimated that around one tonne of fresh water was needed for processing every tonne of fresh fruit bunch (FFB). As a return, huge amount of wastewater has been generated, treated and discharged to river every day. Current treatment system applying in oil palm industry is using river water, treated and use for mill.

In this study, the effect of chemical coagulant and activated carbon application as appropriate treatment of palm oil mill final discharge wastewater have been evaluated in order to recycled water for the mill to achieve zero discharge. Current chemical treatment used at the mill will be used to treat final discharge wastewater. Activated carbon or biochar is used as absorbent material due to its large number of cavernous pores that provide a large surface area relative to the size of the actual carbon particle and its visible exterior surface.

A jar test method is used to stimulate the coagulation and flocculation process that encourage the removal of COD and suspended solids in final discharge wastewater which can lead to turbidity, color, odor and taste problem. In this research, jar test is used to determine the optimum operating conditions for final discharge wastewater by optimizing dosage of coagulant and activated carbon, mixing and sedimentation time and pH value of existing treatment system to reduce capital expenditure on new treatment system.



Overall big picture of current project



Jar test equipment

Supervisor
Professor Dr. Mohd Ali Hassan

Objectives

1. To study the effectiveness of chemical coagulants for the treatment of palm oil mill final discharge wastewater.
2. To investigate the potential of biochar to polish treated palm oil mill final discharge wastewater.

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Bioconversion of selected phenolic compounds into biovanillin using formulated alkaline hydrolysate of oil palm empty fruit bunch

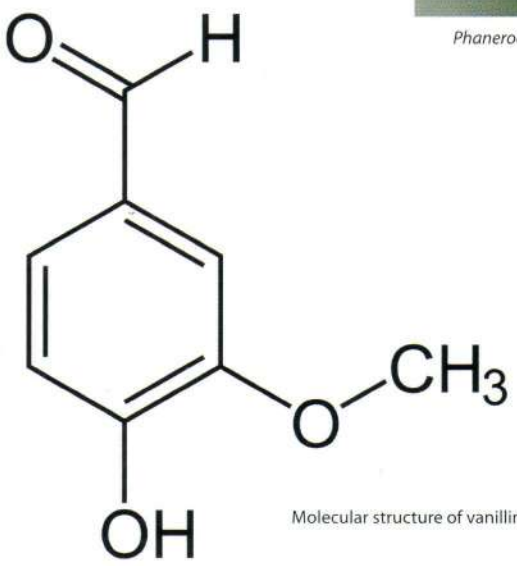
Vanillin is one of the most commonly used flavours in food, beverages, perfumes and pharmaceutical products which normally extracted from the beans of Vanilla planifolia. It is known that natural vanillin has high demand and high market price than synthetic vanillin. Due to these factors, extensive studies are carried out on the production of biovanillin via microbial bioconversion. *Aspergillus niger, Pycnoporus cinnabarinus* and *Phanerochaete chrysosporium* are the common fungi used for the biovanillin production. Phenolic compounds such as ferulic acid, vanillic acid and eugenol or isoeugenol have been proved as precursors for biovanillin production. Instead of using synthethic biovanillin precursors, researchers now had found an alternative to use the phenolic compounds extracted from lignocellulosic biomass. In this study alkaline hydrolysate of oil palm empty fruit bunch (OPEFB) had been used as a substrate for biovanillin production. Based on the composition of phenolic compounds in alkaline hydrolysate of OPEFB, there are five major phenolic compounds selected which are syringic acid, syringaldehyde, p-hydroxybenzoic acid, p-coumaric acid and ferulic acid. The interactions of those compounds are studied in order to see the significance of each phenolic compound towards vanillic acid production using two level full factorial designs. The imitation of alkaline hydrolysate of OPEFB is carried out using synthetic phenolic compounds.

Oil palm empty fruit bunch

Vanilla planifolia

Aspergillus niger

Phanerochaete chrysosporium



Molecular structure of vanillin

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives

1. To determine the potential of alkaline hydrolysate of OPEFB as substrate for biovanillin production via two steps of bioconversion using *Aspergillus niger* ATCC6275 and *Phanerochaete chrysosporium*.
2. To determine the interactions of major phenolic acids in formulated alkaline hydrolysate of OPEFB towards vanillic acid production using two level factorial design approach.

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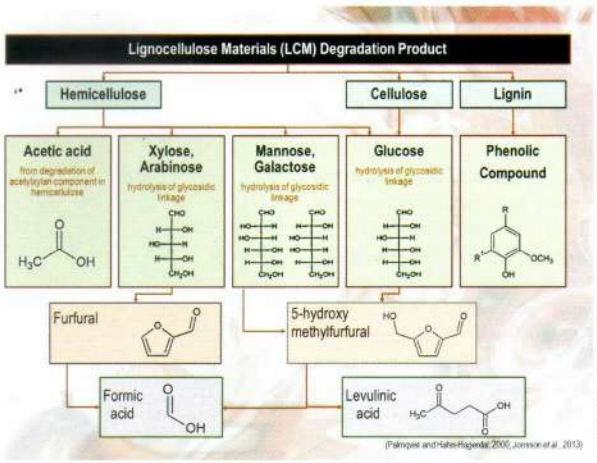
Characterization and antimicrobial properties of oil palm mesocarp fiber superheated steam condensate

Superheated steam (SHS) treatment has been recently used as a method for hydrolyzing lignocellulose material. It is postulated that superheated steam hydrolysis of hemicellulose, low molecular weight lignin and some amount of cellulose in lignocellulose material (LCM) by superheated steam (SHS) produces acidic, furanic and phenolic compounds. These compounds have antimicrobial properties which are useful to be used as antifungal agents.

This study aims to investigate the chemical composition and antimicrobial activity of oil palm mesocarp fiber (OPMF) superheated steam (SHS) condensate. Preliminary work has shown that OPMF condensate obtained from SHS temperature at 240°C showed 5.5±0.17, 4.5±0.0, 5.2±0.1 and 8.0±0.4 inhibition ratio on *Bacillus cereus, Bacillus subtilis, Escherichia coli* and *Staphylococcus aureus,* respectively.

In order to understand the inhibitory activity by the condensate, detailed analysis on the composition of the condensate was conducted. Major product from the hydrolysis of OPMF obtained in the condensate was acetic acid from hemicellulose, followed by phenolic compounds from lignin, for all reaction temperatures tested. Additionally, the number of hydrolysis products produced from SHS treatment of OPMF was increased with increasing of SHS temperature. OPMF condensate from treatment temperature of 240°C was found to have 68 compounds, followed by condensate from 230°C, 220°C, 210°C , 200°C and 190°C which had 66, 61, 58,16 and 9 compounds, respectively. Complex phenolic compounds were found when the SHS treatment conducted at temperature 220°C and above, indicating more hydrolysis of lignin component occurred at that temperature as compared with the treatment at 190°C and 210°C. Increased in reaction temperature also caused the increment in the concentration of hydrolysis products.

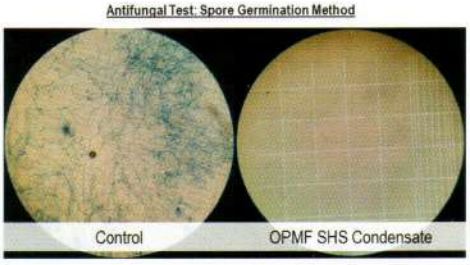
Finally, the effect of antimicrobial activity was tested on several fungal species by agar dilution method. It was found that the growth of fungi species *Ganoderma boninense* UPM13 was fully inhibited while *Aspergillus fumingatus* UPM2 and *Trichoderma asperellum* UPM1 were suppressed to 51.8%, and 45.49%, correspondingly. Higher concentration of condensate sample in growth media was found to inhibit spore germination of all types of fungi tested.



Lignocellulose degradation product

Antibacterial test; Agar disc diffusion method

Superheated steam treatment of oil palm mesocarp fiber



Spore Germination of *Aspergillus fumingatus* UPM2 after 72 hours (40x magnification)

Antifungal test; Spore Germination Test

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To determine the characteristics and antifungal properties of oil palm mesocarp fiber (OPMF) superheated steam condensate.
2. To determine the effect of superheated steam treatment temperature on OPMF condensate composition and its antifungal activity.

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Co-composting of municipal sewage sludge with landscaping wastes by pilot scale

Composting is one of the effective ways of recycling biomass that been generated from the natural environment since decades ago.

Landscaping waste is defined as the accumulation of biodegradable waste as the result of care of the landscape area that normally be disposed into the landfill sides, or sometimes burn them in open burning. On the other hands, municipal sewage sludge is the wastes generated during treatment of domestic sewage (primary, secondary or advanced wastewater treatment) before being released back into the nature, usually in form of solid, slurry, or liquid residue. Renewable materials such as municipal sewage sludge, landscaping wastes, and others are examples of biomass that can be utilized to produce high value product with nutrient-rich organic matter such as biocompost. However, based on current research, these material are still not being utilized completely in Malaysia. With the nutrient availability present within both materials, biocompost production can be established directly by aerobic fermentation.

The aim in this research is to obtain the optimum condition for the production of biocompost from landscaping wastes and municipal sewage sludge. This research is focusing on the co-composting process of landscaping wastes and municipal sewage sludge that been carried out using windrow system and bioreactor system, which can be considered as semi-pilot scale for producing the compost products in the industry. The composting process was monitored for the crucial parameters for composting i.e. temperature, oxygen level, moisture content and pH. Compost performance was being determined using proximate and ultimate analysis of the product produced as well as the maturity test for compost product.

Other than that, this research is done to evaluate the potential of biocompost from landscaping wastes and municipal sewage sludge on the growth performance of *Tagetes erecta* as an indicator of ornamental plant. With the information obtained from this research, it can be considered as the indicator for other ornamental plants usage and also environmental purposes.

Landscaping wastes

Municipal sewage sludge (wet)

Municipal sewage sludge (dried)

Compost product

Supervisor
Professor Dr. Mohd Ali Hassan

Objectives

1. To obtain the optimum condition for the production of biocompost from landscaping wastes and municipal sewage sludge.
2. To evaluate the potential of biocompost from landscaping wastes and municipal sewage sludge on the growth performance of ornamental plant.

Physical comparison of Tagetes erecta by different types of biocompost

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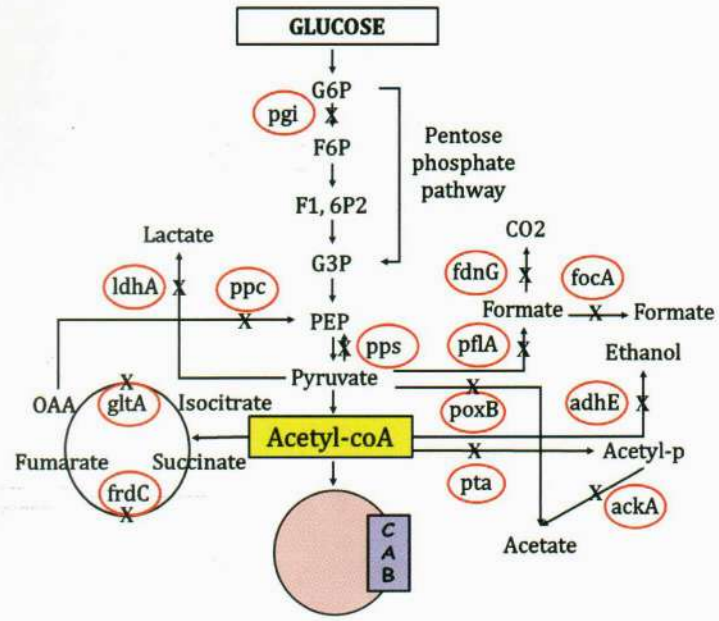
Enhancement of polyhydroxyalkanoates production from *Escherichia coli* through molecular biotechnology approaches

Polyhydroxyalkanoates (PHA) are biodegradable, water-insoluble polyesters that are accumulated intracellularly as carbon storage compounds in the cytoplasm (Steinbuchel and Fuchtenbusch 1998; li et al., 2009). PHA biosynthesis in bacteria mainly involves three basic enzymatic steps (Naik et al., 2008). There are three genes responsible for the biosynthesis of PHA which are PHA synthase (phaC), acetyl-CoA acetyltransferase (phaA) and acetoacetyl-CoA reductase(phaB) enzymes (Figure 1). PHA biosynthetic process is initiated by the condensation of two acetyl-CoA molecules to produce acetoacetyl-CoA and this is catalyzed by phaA. Next, acetoacetyl-CoA is then reduced to (R)-3-hydroxybutyryl-CoA by the phaB and finally, PHA is synthesized by phaC (Rehm and Steinbuchel, 1999).



Metabolic pathway which lead to accumulation of PHA

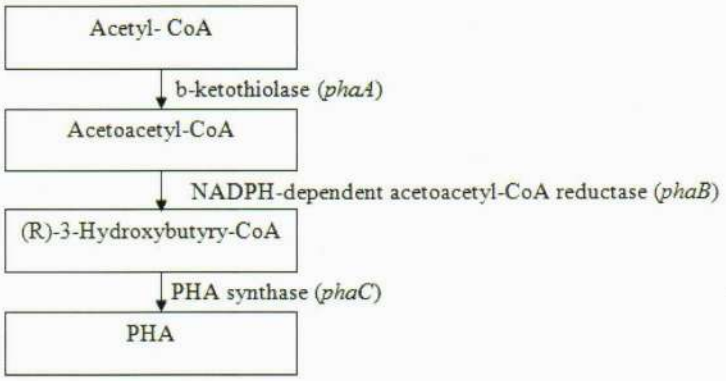


Figure 1 PHA biosynthesis

PHA biosynthesis operon has been introduced into a new host to produce recombinant strain and *E. coli* is one of the most widely used as hosts. PHA production using recombinant strain has advantages over wild-type PHA producers due to an easier manipulation for higher productivity, lack of native degradation machinery and easy purification and recovery process (Aldor and Keasling. 2003). Yee et al. (2012), has introduced PHA biosynthesis operon of *Comamonas sp.* EB172 (phaCAB) in *E. coli* JM109 and about 45.4 % of PHA produced with 1% (w/v) glucose as the carbon source. In previous studies, inactivation of a certain gene will help to improve the PHA production. For example, inactivation of pta gene, which encodes a phosphotransacetylase, *E. coli* will accumulate more PHA than the wild type *E. coli* (Miyake et al., 2000). Thus, this study aimed to improve the PHA production by modifying *E. coli* metabolic pathway which harbouring the PHA biosynthesis operon of *Comamonas sp.* EB172.

Supervisor
Dr. Mohd Zulkhairi Mohd Yusoff

Objectives
1. To construct a new engineered *E. coli* strain for higher PHA production.
2. To produce polyhydroxyalkanoates from the newly engineered *E. coli* strain.

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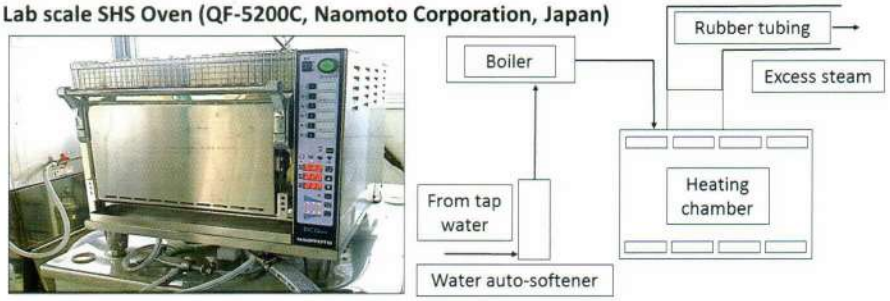
Optimization of superheated steam treatment for oil palm biomass to be used in biocomposite

Incompatibility between hydrophilic lignocellulose fiber and hydrophobic polymer has become the resistance in producing biocomposite with good mechanical properties. Recent research has demonstrated that a green, non-chemical superheated steam (SHS) treatment is an effective method for surface modification of lignocellulose, whereby removal of hemicellulose from fiber can be achieved, making the fiber more hydrophobic, thus improving its compatibility with polymer. Nevertheless, the current temperature and time used for SHS treatment causing significant degradation of cellulose, which is an important component to provide high crystalline fiber. This study was aimed at optimizing SHS treatment conditions for Oil Palm Biomass (OPB) fibers in such a way hemicellulose can be removed while retaining cellulose content. Optimization was done using a type of Response Surface Methodology (RSM) which is Central Composite Design (CCD) with 2 factors (temperature and time) and 2 responses (hemicellulose content and cellulose content). Three types of OPB fibers were used, namely Oil Palm Mesocarp Fiber (OPMF), Oil Palm Empty Fruit Bunch (OPEFB) and Oil Palm Frond (OPF).

Different parts of oil palm biomass produced after palm oil extraction

Lab scale SHS Oven (QF-5200C, Naomoto Corporation, Japan)



Lab-scale superheated steam oven used for this study

The optimized-SHS treatment temperature/retention time for OPMF, OPEFB and OPF is 265°C/5mins, 280°C/5mins and 300°C/9mins, respectively. Hemicellulose removal after treated using optimized SHS treatment conditions was within 60-70% with degradation of cellulose which is less than 5%, for all types of OPB fibers. It is proven that using shorter retention time with high temperature of SHS can get better result in term lignocellulose component compared to previous study, apart from reducing treatment time of fiber which can be beneficial to the industry. Optimized-SHS-treated OPB fibers were then used for biocomposite production by reinforcing with polypropylene (PP). Water absorption, thermal stability and mechanical properties of PP/optimized-SHS-treated OPB biocomposites were improved compared to the PP/untreated OPB biocomposite. PP/optimized-SHS-treated OPF biocomposite shows slightly better properties compared to OPMF and OPEFB. In overall, optimized SHS treatment conditions improved the properties of the fibers and eventually improved the properties of the biocomposites.

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To optimize SHS treatment temperature and retention time for producing fiber with high cellulose and low hemicellulose content prior to biocomposite production.
2. To characterize PP/optimized-SHS-treated OPB biocomposite for its mechanical, thermal and water absorption properties in comparison with PP/untreated OPB biocomposite.

Optimized SHS Treatment of OPB Fibers		
Type of Fiber	**Temperature**	**Time**
Oil Palm Mesocarp Fiber (OPMF)	265°C	5 mins
Oil Palm Empty Fruit Bunch (OPEFB)	280°C	5 mins
Oil Palm Frond (OPF)	300°C	9 mins

Optimized SHS treatment of OPB fibers obtained via Central Composite Design (CCD)

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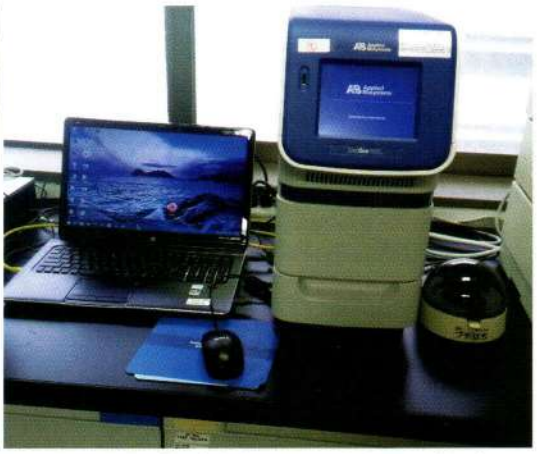
Escherichia coli yqiG pseudogene in hydrogen production

In recent trends, world depends on fossil fuels as source of energy. Continues usage of fossil fuel as main energy sources is not sustainable due to limited world fuel reserved. Moreover, since the world depend so much on natural resources for generation of energy, environment need to bear the consequences where the air is polluted, global warming, wastes from nuclear plant and others.

Hydrogen considered as environmentally friendly fuel and renewable energy if it produced from renewable sources. Hydrogen contains higher energy content and only produce water and energy from hydrogen oxidation compared to fossil fuel and methane gas. Hydrogen production through dark fermentation considered as an effective biological approach which brings several advantages such as easy operation of bioreactor, higher production rate, and may utilize various substrates. *Escherichia coli* has been extensively used in hydrogen production. *E. coli* is well characterized bacteria and the metabolic engineering best-studied. Mutant strain can be constructed by genetically manipulate their metabolic pathway so called metabolic engineering

Small serum bottles and anaerobic flask was used for fermentation purpose



Transcriptional analysis (gene expression) was analyzed by using RT PCR.

Inoculum was transferred into vials containing media in anaerobic chamber.

Pseudogenes are from active genes which turn into junk genes because of transcription and translation disruption. The presence of stop codons, repetitive element frame shift and lack of transcription might interrupt the gene to function well. However, the function of pseudogenes is still unknown. In our preliminary study, we found out that yqiG pseudogene is essential for hydrogen production. Thus, in this study, we try to characterize the function of *yqiG* pseudogene in *Escherichia coli* for hydrogen evolution. Knock-out of *yqiG* gene in E. coli resulted in less hydrogen formation in complex glucose compared to complex formate media. Without the presence of *yqiG* gene, the hydrogen metabolic pathway was interrupted. Hence, *yqiG* pseudogene is important for hydrogen production and prove that some of the pseudogenes are functions in *E. coli*.

Supervisor
Dr. Mohd Zulkhairi Bin Mohd Yusoff

Objectives
1. To characterize the function of *yqiG* pseudogene in hydrogen production

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Production of activated carbon from oil palm biomass for treatment of palm oil mill final discharge

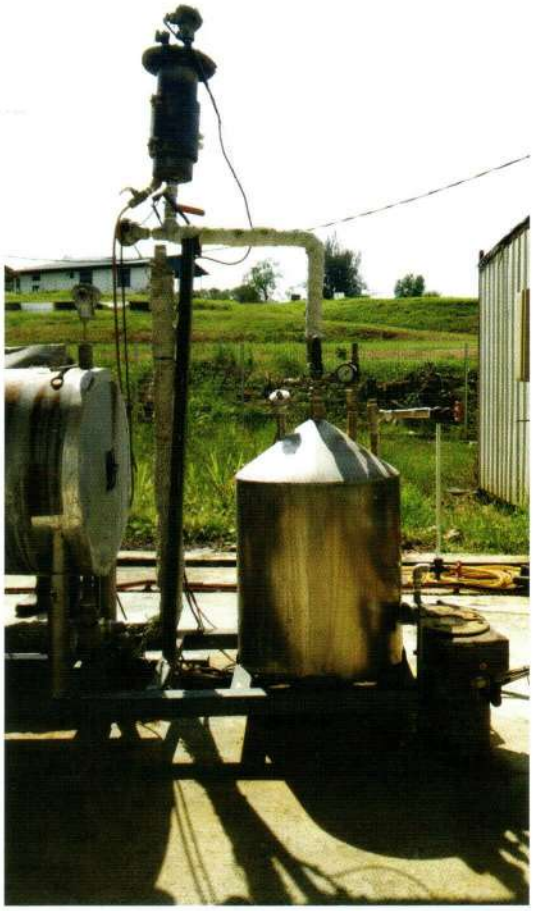
Activated carbon from biomass gain interest as an abundant, cheap and renewable substitute of commercial activated carbon. Conventional activated carbon production uses non-renewable sources such as coal and renewable sources such as peat, coconut shell and pine wood. Feasibility of activated carbon production from oil palm biomass on small scale has been proven, but the ability of activated carbon produced in treating palm oil mill final discharge is not yet researched. Oil palm biomass activated carbon is expected to reduce the color, chemical oxygen demand and suspended solid of palm oil mill final discharge down to river water quality. All raw materials was first pyrolyzed in low oxygen atmosphere before activated using steam and phosphoric acid. Final activated samples and biochar produced were analyzed and compared in terms of BET surface area. Adsorption capacity and the performance of activated samples in treating palm oil mill final discharge was also inspected. It is expected that the surface area of both chemically and steam activated samples will exceed 500 m2/g with a pore size of about 5-20 nm. It is also expected that the activated carbon produced will be able to treat palm oil mill final discharge to an acceptable level.

From left: Raw mesocarp fiber, mesocarp fiber during impregnation, activated mesocarp fiber

Palm oil mill final discharge before (left) and after treatment (right) with mesocarp fiber activated carbon. Tap water for comparison (right)

Supervisor
Prof. Dr. Mohd Ali Hassan
Prof. Dr. Suraini Abd-Aziz
Prof. Dr. Yoshihito Shirai

Objectives
1. To produce activated carbon with minimum surface area of 500 m2/g and mesoporous surface morphology (2-50 nm) from oil palm biomass using pyrolysis and activation.
2. To determine the characteristics and quality of activated carbon produced in treating palm oil mill final discharge



Reactor used for carbonization and activation

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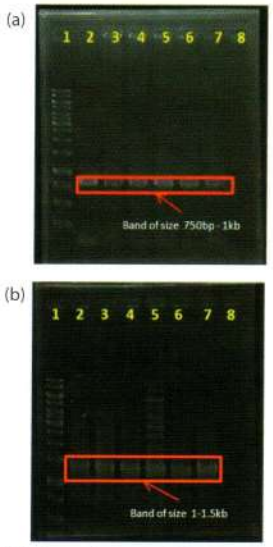
Molecular cloning of β-glucosidase gene into *Candida tropicalis* for enhancement of bioethanol production from oil palm empty fruit bunch

Environmental and economic concerns related to fossil fuel consumption have driven the need for alternative renewable fuel such as bio-ethanol. In Malaysia, abundance of oil palm empty fruit bunch (OPEFB) as waste following oil palm production offers great potential as lignocellulosic substrate. For efficient lignocellulose hydrolysis, high conversion rates from the cellulase enzyme constituents; endoglucanase, exoglucanase and β-glucosidase, are deemed essential. However, common low β-glucosidase expression has resulted in cellobiose buildup, in turn causing feedback inhibition. Thus to achieve increased saccharification rate and reduced inhibition, along with tackling the high cost of enzymes in general, generation of a β-glucosidase expressing yeast strain capable of carrying out simultaneous saccharification and ethanol fermentation would be ideal.

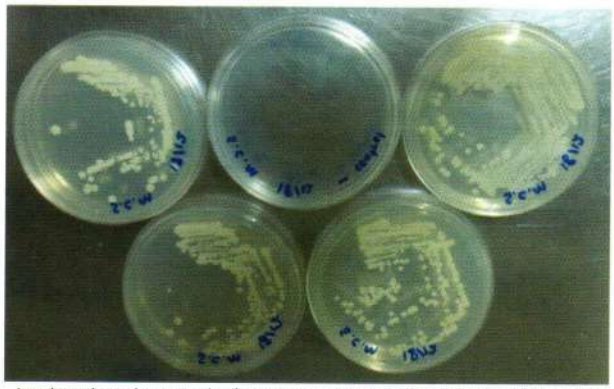
Previous genetic engineering efforts to achieve heterologous β-glucosidase expression in ethanol fermenting yeast has in practice, shown to result in expected increase in cellulose hydrolysis and subsequent ethanol production. However, the use of said strain for ethanol fermentation from OPEFB hydrolysate derived cellobiose has yet proved elusive. In addition, emergence of codon optimization for enhancement of heterologous gene expression has also yet to be demonstrated. Collectively, the effect of codon optimization on cellulase gene expression is expected to result in increased saccharification and ethanol fermentation.

Shredded oil palm empty fruit bunch



Gel electrophoresis of (a) 5' RACE and (b) 3' RACE PCR products

To this effort, isolation and characterization of putative genes from local fungal isolate will be done, where using mRNA as a template, cDNA synthesis and RACE-PCR will be carried out prior to gene sequencing. Synthesis and amplification of native and codon optimized gene variants will be done, prior to molecular cloning and transformation into host yeast strain. Subsequent assays will then quantify enzyme production, substrates liberated and finally resultant ethanol production using gas chromatography. In short, this research demonstrates viability of codon optimization for enhancement of bioethanol production from oil palm biomass hydrolysates.



Incubated aerobic growth of *Saccharomyces cerevisiae* for stock preparation

Supervisor
Dr. Norhayati Ramli

Objectives

1. To isolate and characterize native β-glucosidase from local fungal isolate prior to codon optimization for host *Saccharomyces cerevisiae.*
2. To evaluate expression of native and codon optimized β-glucosidase gene in recombinant yeast strain and evaluate subsequent ethanol production from oil palm empty fruit bunch hydrolysates .

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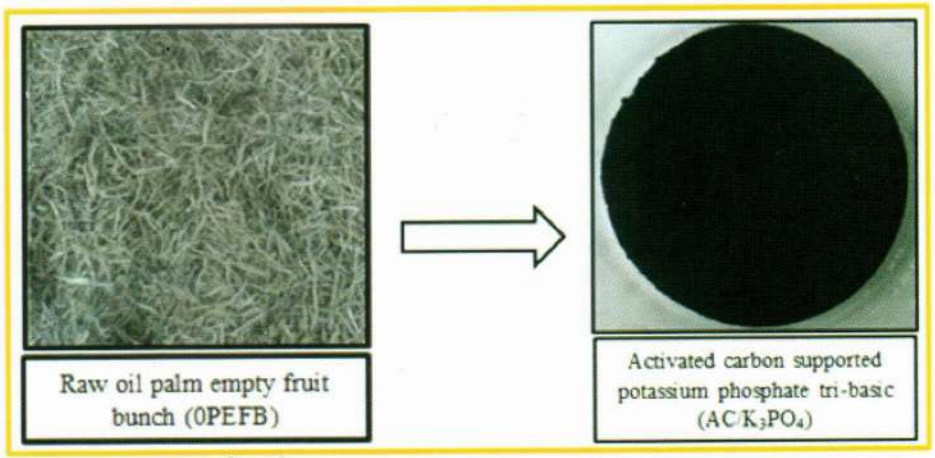
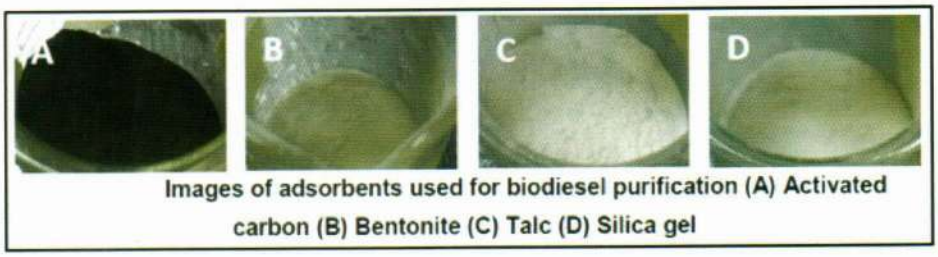
Utilization of activated carbon produced from biomass in biodiesel production using used cooking oil as feedstock

Besides to global warming, gradual growth of world's population and global industrialization has caused an increase in energy requirements and concomitant inevitable depletion of fossil fuels. Apprehensiveness over the ineffectual environmental conservation and energy security issue, however, has encouraged scientific exploitations inducing demand for substitute fuels such as biodiesel.

Lack of policies and inefficient of waste management has led the waste cooking oil been directly disposed into the drainage (Mara & Alam, 2008). Due to cheap in price, some unregulated industries have made profit by recycling the waste cooking oil which definitely harmful to health. Therefore, it is beneficial to utilize this waste into a high-value product such as biodiesel. Recently, carbon based catalyst has gained attention in biodiesel production. Besides owing advantages of reusability and ease of separation, it is green as it could be prepared from biomass. The purity of biodiesel reflects toward the final fuel product's properties (Faccini & Aranda, 2011). The presence of unwanted impurities in biodiesel will lower the quality of fuel and consequently shorten the lifespan of an engine (Ngamlerdpokin et al., 2011). Based on previous studies, dry purification method reveals promising outcomes than water-washing method such as no wastewater produced and less product loss (Berrios et al., 2011).





Images of adsorbents used for biodiesel purification (A) Activated carbon (B) Bentonite (C) Talc (D) Silica gel

Supervisor
Prof. Dr. Mohd Ali Hassan

Objectives

1) To synthesize, characterize and optimize biodiesel production from waste cooking oil using carbon supported potassium phosphate tri-basic (AC/K3PO4) catalyst
2) To study the quality of purified biodiesel from waste cooking oil using activated carbon and compare with other commercial adsorbents such as bentonite, silica gel, and talc.

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Activated carbon as a bioadsorbent produced from oil palm decanter cake by carbonization and physical activation process

Heavy metals were among the prominent hazardous wastes contain in wastewater. Due to rapid growth of population, industrial expansion, and unorganized urbanization, there is great amount of wastewater produced from all of these activities. Therefore, the wastewater needed to be treated adequately to meet the discharge standard. Various treatment processes were used for the treatment of heavy metals, however, adsorption process shown the most efficient treatment. Commercial activated carbon is commonly used for the treatment due to its high effectiveness but involved high cost. This study investigate the usage of oil palm decanter cake (OPDC) as a precursor for alternative activated carbon production. The OPDC will be activated by steam activation process, preceded by carbonization at 700°C and followed by steam activation at temperatures between 600°C to 800°C. The effects of activation temperatures and holding times on the characteristics of the activated carbon produced will also be investigated. Characterization of activated carbon yield, specific surface area, porousity, and heavy metals (Cu(II), Pb(II), Cd(II), Zn(II) and Cr(VI)) adsorption will be conducted and will be compared to commercial activated carbon. It is expected that with carbonization and physical activation process, a quality activated carbon can be produced from the OPDC due to its higher specific surface area and highly porous structure.

Dried raw OPDC

Activated OPDC

Reactor used for carbonization and activation

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives
1. To produce activated carbon from oil palm decanter cake with the minimum surface area of 500 m2/g by carbonization and steam activation

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Pilot scale co-composting of kitchen and garden wastes with addition of biochar

Malaysia is facing a critical solid waste management issue due to population and economic growth, lack of waste management infrastructure and legislation in addition to insufficient awareness among the public. In 2010, the Ministry of Housing and Local Government reported that, Peninsular Malaysia alone has generated an estimated 25,000 metric tonnes of municipal solid waste (MSW) daily. From this, kitchen wastes account for 50% with unconsumed and disposed food alone totaling 930 tonnes. Current management to this is to send the wastes to landfills or incineration at high temperatures.

Composting of kitchen wastes offers a good alternative approach due to its high moisture content, high organics-to-ash ratio, and loose physical structure. However, several limitations remain to be overcome for the process to be sustainable. For example, to improve degradation, researchers are currently looking into the application of activated carbon, such as biochar of which, its unique characteristics; high porosity, sorption capacity and cation exchange capacity. It allows microorganisms to live at the surface and promotes different activity in soil. Recent studies have shown that application of biochar into the composting process improved physico-chemical characteristics of composts. Following this, application of biochar to composting of kitchen waste is expected to result in similar improvements, concomitantly improving the waste recycling system in this country by utilizing biomass produced from local and industry.

kitchen waste collected from Serdang food court

Biochar from coconut shell used as treatment to improve composting process

Compost product

Small scale composter

Supervisor
Prof. Dr. Mohd Ali Hassan

Objectives

1. To determine the effect of biochar on co-composting of kitchen waste and sawdust.
2. To investigate the development of bacterial community in co-composting of kitchen waste and sawdust by using Denaturing Gradient Gel Electrophoresis (DGGE).

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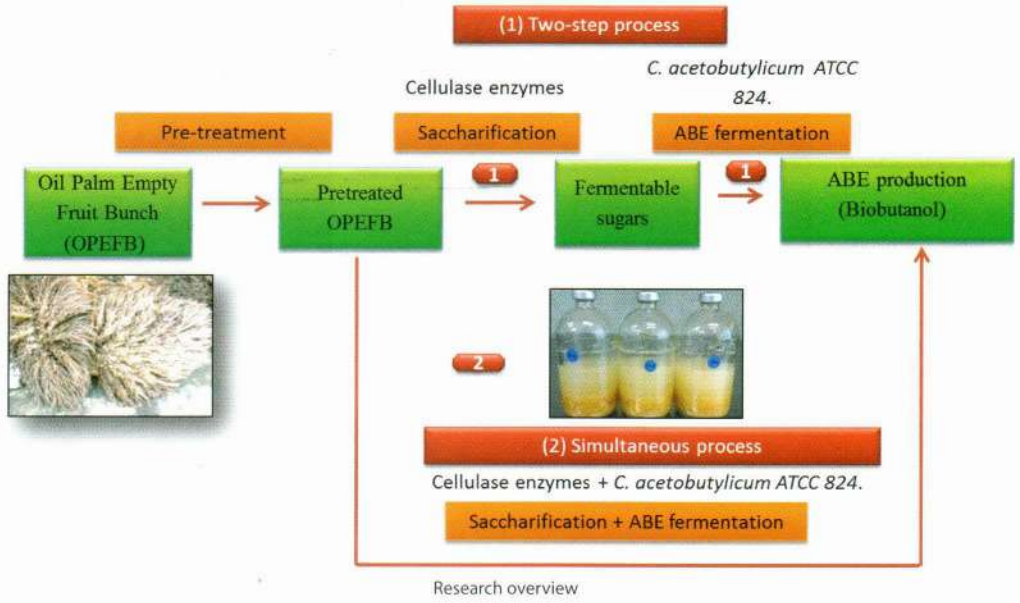
Optimization of simultaneous saccharification and fermentation using oil palm empty fruit bunch for biobutanol production

Biobutanol from lignocellulosic biomass has become one of the potential biofuels which in demands for alternative to fossil fuels. Oil palm empty fruit bunch (OPEFB) is one of the low cost lignocellulosic biomass can be utilized as substrate for biobutanol production. Biobutanol production has been successfully conducted through simultaneous saccharification and, fermentation (SSF) using OPEFB. However, SSF has not been optimized and the capabilities at higher working capacity has not been tested.

This study aim to optimize biobutanol production through SSF using OPEFB. Optimization study is conducted using two statistical softwares tools which are Response Surface Methodology (RSM) and Artificial Neural Network (ANN) to obtain best conditions suitable for high biobutanol production. SSF system is comprised of *Clostridium acetobutylicum* ATCC 824 ,cellulase enzymes and alkali pretreated OPEFB was all added together in one vessel. Various process parameters were tested on the SSF process. This study is expected to get the best condition for biobutanol production through simultaneous saccharification and fermentation.



Research overview

Left (oil palm fresh fruit bunch) and right (oil palm empty fruit bunch)

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives
1. To optimize simultaneous saccharification and fermentation for biobutanol production using response surface methodology and artificial neural network.

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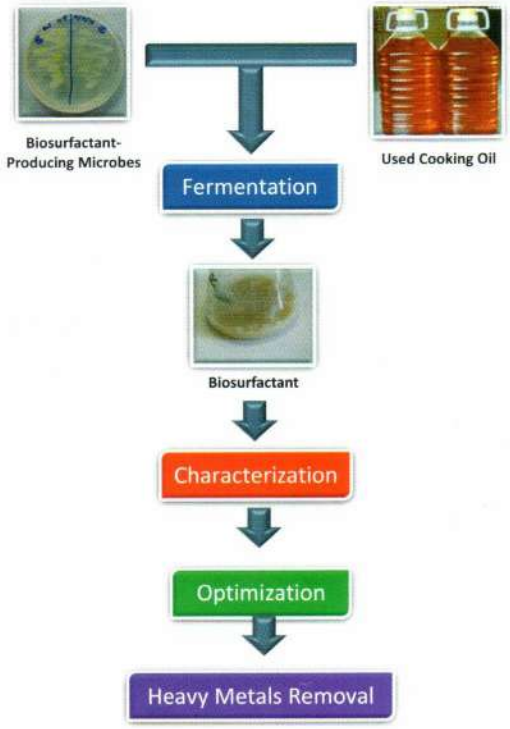
Biosurfactant production from used cooking oil by local isolates for heavy metals removal

The microbial surfactants or biosurfactants have gained attention because of their biodegradability, low toxicity, ecological acceptability, and ability to be produced from renewable and cheaper substrates compared to chemical surfactants. Biosurfactants are amphipathic molecules that partition preferentially at the interface between fluid phases with different degrees of polarity and hydrogen bonding such as oil/water or air/water interfaces. There is an increasing interest in the possible use of biosurfactants in environmental applications such as removal of heavy metals from waste water streams, sewage sludge, and industrial effluents. Biosurfactants spontaneous release and function are often related to hydrocarbon uptake; therefore, they are predominantly synthesized by hydrocarbon-degrading microorganisms. Used cooking oil is a potential substrate for the biosurfactants production, which act as renewable hydrocarbon source. In this study, the production of biosurfactant from used cooking oil by biosurfactant-producing microorganisms was performed. The physical and chemical characterization of biosurfactant obtained includes temperature, pH and salt content. This step is vital as environmental factors are extremely important in the yield and characteristics of the biosurfactant produced in terms of surface tension, interfacial tension, and emulsification index. Optimization study for the biosurfactant production is conducted through Artificial Neural Network (ANN) approach and parameters being tested for this stage are substrate concentration, agitation speed, aeration, temperature, and pH. Further step is to evaluate the capability of the biosurfactant and its ability on enhancing removal of heavy metals in the water systems contaminated with heavy metals.

Biosurfactant precipitates after left overnight at 4°C in acidic condition

Fatty acids methyl esters of used cooking oil, FAME (upper layer) and hexane (lower layer)



Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives

1. To produce and characterize biosurfactant from used cooking oil by local isolates.
2. To optimize biosurfactant production from used cooking oil using artificial neural network.

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Application of metabolic engineered strain *E.coli* BW25113 for utilization of palm oil mill effluent towards biohydrogen production

Fermentation in 125ml serum vials by using POME

In recent years, many concerns have raised in finding alternatives for energy resources as liquid fossil fuels are depleting due to high consumption of this resource as an energy resource. Hydrogen appears to be one of the promising new energy resources, as it is a renewable, clean and environment-friendly. The key to taking forwards the use of hydrogen as alternative fuels is by producing it at a low cost and sustainable production.

At present, biological approach seems to be a promising way to produce hydrogen at least energy intensive, cheapest production cost and most environmental friendly. However, the yield of hydrogen production in biological method is very low for commercial application as compared to other methods such as hydrolysis and coal-gasification. Therefore, two approaches used in this project to increase biohydrogen production; utilization of different carbon sources and directing microorganism conversion pathway of carbon source into hydrogen. Thus, this study will be carried out to find the opportunity of the microorganism *E. coli* to utilize different carbon source found in palm oil biomass (POME) and also to investigate the application of E. coli engineered strain towards biohydrogen production. The information obtained throughout the study will deliver substantial evidence for the ability to produce hydrogen from various carbon sources found in POME by using *E. coli* and *E. coli* metabolic engineered strain. Hence numerous applications and approaches will be widely available due to the succession of this project.

Fermentation using engineered strain

Fermentation using parental strain

Supervisor
Dr. Mohd Rafein Bin Zakaria

Objectives
1. To establish method in determining substrates such as monomeric and oligomeric sugars from POME.
2. To elucidate the most preferable organic carbon source from POME that contributes to the generation of biohydrogen by *E. coli* strains

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Optimization of simultaneous saccharification and fermentation for biobutanol production from sago hampas

In recent years, there is a high demand towards the biobutanol production instead of bioethanol due to its superior characteristics. Biobutanol has higher energy content, more miscible with diesel, less corrosive and can be shipped in unmodified gasoline pipelines. It is a four carbon atoms alcohol that not only can serve as transportation fuel but can also be used as solvent in manufacturing industry and as an intermediate in chemical synthesis.

Production of biobutanol is commonly done using acetone-butanol-ethanol (ABE) fermentation by solventogenic clostridia species. Nevertheless, one of the major problems in biobutanol production is the cost of substrate. Therefore, alternative substrate like sago hampas that contain both starchy and lignocellulosic biomass can be served as feedstock for ABE fermentation process. Although biomass residue can be used as fermentation substrate, it needs several processes to convert it into sugar and then biobutanol. The problem arises from the potential loss of sugar through varied steps process while producing the biobutanol also become one of the aims in conducting these experiments in a simultaneous process of enzymatic saccharification and ABE fermentation.

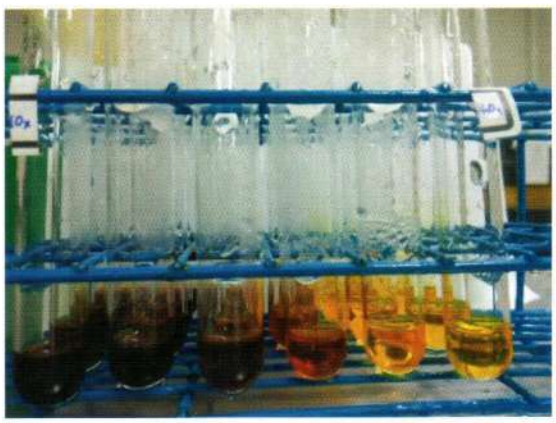
Sago hampas dried under sunlight.

Inoculum Prepared in reinforced clostridia media.

Other important factors that have been kept in preference are the optimal production of biobutanol from sago biomass, which will be evaluated experimentally by testing on different parameters for instance pH and temperature using statistical analysis: response surface methodology (RSM) and artificial neural network (ANN). Biobutanol profiling of simultaneous process using sago hampas is expected to discover the suitable sago biomass that can produce higher yield of biobutanol and optimization of the simultaneous process is expected to give an enhancement of biobutanol production.

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives
1. To optimize the parameters that affect simultaneous process of biobutanol production from sago hampas using statistical approach.



Determination of reducing sugar concentration using DNS Method (Miller,1959).

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In situ recovery of biobutanol produced from simultaneous saccharification and fermentation using gas stripping-distillation techniques

The increased of fossil fuel consumption causes higher carbon being released, thus escalates the concern of environmental problems. This calls for immediate measures to be taken. Hence, the alternative sources from renewable energy can be used to substitute the non-renewable energy. Biobutanol, being one of the renewable energy agents, could be one of the promising sources that can reduce environmental problems as well as being the alternative energy as the reserve of underground fossil fuels is unpredictable. As compared to other sources, biobutanol is the most suitable bioenergy and has less negative impacts on the environment. However, the process of biobutanol extraction is rather challenging whether in form of high biomass, low yield of butanol, low butanol titer, slow fermentations, and with the degeneration of microbes. Therefore, this study is conducted in order to increase the recovery of biobutanol produced from simultaneous saccharification and fermentation by using free pretreated Oil Palm Empty Fruit Bunch (OPEFB) waste as substrate. Free carbon sources such as OPEFB can be utilized by *Clostridium acetobutylicum* through applying the best technique which is in situ recovery. This is to increase the production of biobutanol and concomitantly reduce the toxicity towards the microbes so as to improve the fermentation efficiency. Gas stripping technique, one of the promising in-situ recovery methods, is used since high selectivity of Acetone, Butanol, Ethanol (ABE) is stripped out without interfering the cell, medium, and substrate in the fermentation. Then, further purification of butanol using distillation process will be carried out to release less energy and increase the butanol yield. The gas stripping-distillation recovery system is believed to be one of the future systems for large scale biobutanol processing.

Bioreactor

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives
1. To recover *(in situ)* biobutanol produced from simultaneous saccharification and fermentation using gas stripping technique.
2. To enhance the biobutanol recovery by integrating gas stripping-distillation technique for biobutanol purification.

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Effect of physico-chemical and biological pretreatment of oil palm biomass for fermentable sugars production

Oil palm empty fruit bunch (OPEFB) and oil palm mesocarp fiber (OPMF) are lignocellulosic biomass wastes that abundantly generated in palm oil mills, which provide potential bioresouces for the conversion into value added products such as biosugars, biofuels, biocomposite and others. However, the presence of these oil palm wastes has created a major disposal problem and being wasted through burning of these biomasses. These OPEFB and OPMF reported as suitable raw materials to produce fermentable sugars as a precursor for fermentation process since these materials are rich in carbohydrate. The presence of hemicellulose and lignin hinders the access of cellulose to cellulose thus resulting in low efficiency of the hydrolysis. Effective pretreatments are needed to reduce the recalcitrance of lignocellulosic structures to improve fermentable sugars production. This study proposes an environmental approach by combining of physico-chemical and biological pretreatment of OPEFB and OPMF to obtain high fermentable sugar production. Physico-chemical pretreatment used is superheated steam (SHS) where the unsaturated steam generated by addition of heat to saturated steam during its process. However, from previous studies, SHS treatment alone does not produce high fermentable sugars thus combination with the biological pretreatment will enhance the production of fermentable sugars. Combination of pretreatments has been reported to substantially improve sugar yields. In biological pretreatment, laccase is a ligninolytic enzyme to degrade lignin. It loosened the compact wrap of lignin carbohydrate complex and consequently enhances saccharification efficiency of cellulose. Further improvement on the combination process is expected to enhance fermentable sugars production. Overall, this study will provide another alternatives promising method for pretreatment of lignocellulosic biomass.

SHS pretreatment

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives
1. To optimize the combination of physico-chemical and biological pretreatment to enhance the fermentable sugars production from oil palm empty fruit bunch and oil palm mesocarp fiber.

Untreated OPEFB and SHS pretreated OPEFB after saccharification

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Assessment of physicochemical and community profiles in bacterial ecology of palm oil mill final discharge and polluted river water

Palm oil industry is one of the major industry that contributes significantly to economic growth particularly in Malaysia. The wet palm oil milling process is the most common and typical way of palm oil extraction which giving rises to large amount of waste water known as palm oil mill effluent (POME). POME is classified as a highly polluting wastewater due to its notably high BOD and COD level. Concurrent to the high production of palm oil, an enormous volume of POME is being generated each year. The most common practices of palm oil mills is discharging the highly polluting POME into the nearby river water, and this situation has leads to unfavourable impacts on the water system. Several studies have reported that bacteria are among the essential contributors in the transformation of complex organic compounds in waste water treatment plant. Thus, the discharge of POME will alter the physicochemical properties of effluent-receiving river water and may also introduce a diversity of microorganisms and consequently affecting the indigenous bacterial community structure and function. However, up to this date, there are still too few studies that have been done on the relationship between microbial community and hydrogeochemistry at effluent-receiving river water. The emergence of metagenomic studies which based on the next generation sequencing (NGS) and molecular fingerprinting for particular, has allowed the study of the responses of indigenous microbial community towards environmental perturbations in situ, and revealed an enormous reservoir of uncultured microbes that previously could not be explored due to the limitation of the conventional laboratory culturing method. The discovery of microbial community shifts due to palm oil mill final discharge provides a powerful tool for investigating the effects of industrial activities on the water ecosystem.

Figure 1 : Discharge of treated palm oil mill effluent into river water

Figure 3 : Samples from unpolluted and polluted part of the river.

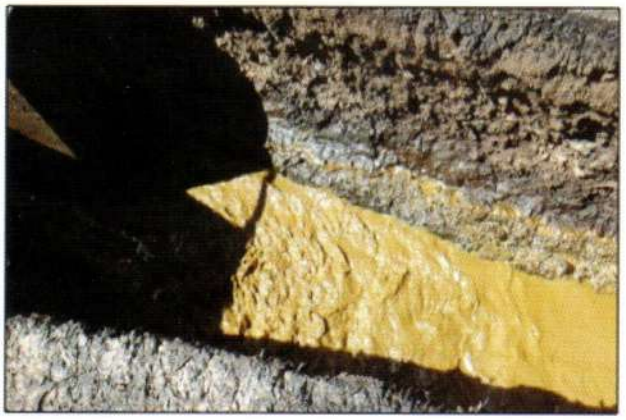

Figure 2 : Mixed Raw Effluent

Supervisor
Dr. Norhayati Ramli

Objectives

1. To correlate the physicochemical properties and structural profiles of bacterial community in the polluted river caused by palm oil mill final discharge in comparison to unpolluted river water.
2. To assess the bacterial community function in polluted river caused by palm oil mill final discharge using Nucleic Acid Double Staining assay based on analytical Flow Cytometry.

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Enzyme-assisted extraction of essential oil from pineapple peels using cellulase

The pineapple canning industry produces a substantial amount of solid waste like peels, cores, stems, crowns and pulp. Pineapple waste disposal can cause to microbial spoilage and environment problems due to the waste material containing high moisture and sugar content. This study is proposed to utilize the pineapple peels, to produce a high value added product of essential oil .Essential oil which is a concentrated volatile compounds extracted from natural sources, has been used widely in the perfumery, aromatherapy, cosmetic, medicine and food flavouring field.

The volatile compounds of pineapple peels can be extracted through a green approach using hydrodistillation method. In order to improve the essential oil yield, pretreatment of the substrate using commercial cellulase is applied prior to the hydrodistillation extraction. The cellulase will act on the substrate's cell wall and hydrolyse them and thus will increase the permeability, expecting to release more essential oil. In addition, several factors are optimized to determine the optimum condition of enzymatic pretreatment and extraction process. The factors that involved are: enzyme loading (FPU/g), hydrolysis time (minutes), substrate to solvent ratio, extraction time (hour) and extraction temperature (°C). With the optimized process condition, it is expected that a higher yield of essential oil can be obtained.

The fatty acid and aromatic compounds of the obtained essential oil are analyzed using GC and GC-MS, respectively. Moreover, the cell wall of the enzymatic pretreated substrate is observed under Scanning Electron Microscopy (SEM) as compared to the untreated substrate. Overall, this study will be promoting a proper way for pineapple waste management by producing a high value added product of essential oil through an optimized green method of enzyme-assisted extraction.

Figure 1: Pineapple Peels collected at Ladang Nenas Sg Telur, Johor

Figure 2: The hydrodistillation set up

Figure 3: Substrate pretreatment using celluse enzyme prior to hydrodistillation

Supervisor
Professor Dr. Suraini Abd-Aziz

Objectives

1. To extract essential oil from pineapple peels through enzyme assisted extraction method using cellulase.
2. To optimize the condition for enzyme-assisted extraction of essential oil from pineapple peels.

Figure 4: Commercial pineapple essential oil in the market

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Production of oil palm mesocarp fiber nanocellulose

Figure 1: Extracted cellulose from OPMF.

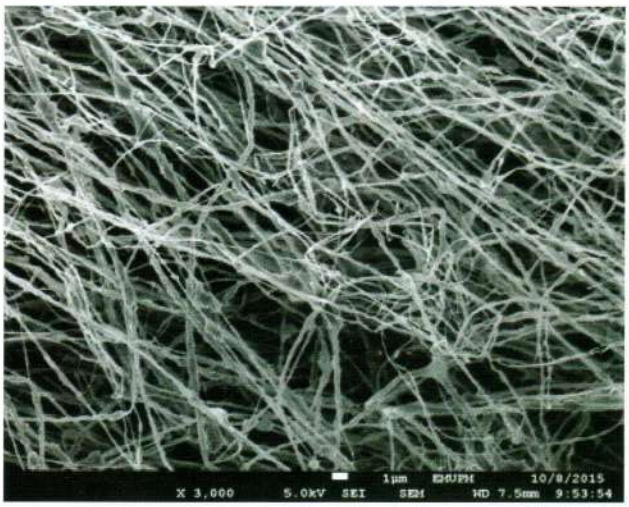

Figure 2: SEM micrograph of OPMF-nanocellulose fiber produced from ultrasonication method.

Oil palm mesocarp fiber (OPMF) is one of the major biomass generated from palm oil industry and it is currently inefficiently burnt at palm oil mill as a mean of disposal. With the growing concern on environmental sustainability and finite supply of non-renewable resources, particular attention has been given to produce value-added materials from OPMF, such as biocomposite and animal feed. Since OPMF contains mainly cellulose, there is high potential for the production of nanocellulose fiber from OPMF. The objectives of this study are to produce OPMF nanocellulose using different nanofibrillation methods and to determine the effect of nanofibrillation methods on the characteristics of OPMF nanocellulose. Prior to any further process, OPMF which is rich with cellulose, hemicellulose and lignin needs to be pretreated first as the presence of hemicellulose and lignin could affect the properties of the nanocellulose fiber. In this study, pretreatment of OPMF was conducted by chemical treatment using 5% (w/v) NaClO3 at 70°C for 90 minutes, followed by 6% (w/v) KOH at room temperature for 24 hours aimed at extracting cellulose from OPMF. OPMF-cellulose obtained was then subjected to nanofibrillation process using three different treatments namely ultrasonication, electrospinning and high pressure homogenization. Chemical compositional analysis of pretreated OPMF showed that hemicellulose and lignin fractions were almost completely removed after $NaClO_3$ and KOH treatments, to leave only cellulose fraction (OPMF-cellulose). Scanning electron microscopy (SEM) micrographs of fiber undergone all nanofibrillation methods confirmed the occurrence of nanocellulose fibers having diameter in the range of 40-110 nm. XRD and TGA studies showed that all nanofibrillation treatments improved the crystallinity and thermal stability of OPMF-nanocellulose fibers. All nanofibrillation methods yielded 60% of nanocellulose after 3 to 9 hours of nanofibrillation process. Future work will be done in order to determine the mechanical properties of OPMF-nanocellulose fibers.

Supervisor
Dr. Hidayah Ariffin

Objectives

1. To produce oil palm mesocarp fiber (OPMF) nanocellulose using different nanofibrillation methods.
2. To determine the effect of nanofibrillation methods on the characteristics of OPMF nanocellulose.

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Production of xylooligosaccharides from mesocarp fiber using hydrothermal pretreatment

Oil palm mesocarp fiber (OPMF) is one of the massive biomass generated from production of palm oil. It is estimated that the palm oil production increased from 8.5 million tons in 2000 to 10.5 million tons on 2010. Therefore a research on utilization of this biomass should be undertaken. OPMF is a lignocellulosic material that consists mainly three polymers; cellulose (20–50%), hemicellulose (20-40%) and lignin (10-28%). Cellulose is the backbone structure, while hemicellulose and lignin are the binding networks. Hemicellulose interacts with cellulose to strengthen the plant cell wall. Meanwhile, xylan is the main component contain in hemicellulose. Many different sources of biomass have been used to produce xylooligosaccharides such as corncorbs, sugarcane bagasse and eucalyptus globulus wood. Pretreatment is carried out to obtain xylooligosacharides (XOs) from hydrolysis of xylan from biomass. This study is carried out to produce xylooligosaccharides from mesocarp fiber. This process is using hydrothermal pretreatment with or without CO_2 assisted under isothermal and non-isothermal condition. Different severity factor will be applied to optimize the production of XOs. Hydrothermal pretreatment is a novelty approach of physical method which is eco-friendly to the environment because it uses water. XOs are intermediate product before all the xylan degrade into xylose, thus medium-severity condition should be performed to get maximum amount of xylooligosaccharides. There are many applications of XOs in food, health and medicinal industry. Xylooligosaccharides can be function as prebiotics when consumed as part of diet since they are non-digestible oligosaccharides (NDO's). Besides that, it also gave improvement in bowel function, calcium absorption, lipid metabolism and reduction of the risk of colon cancer. XOs with lower degree polymerization are preferred for food related product since it can stimulate the sweetness of food compare to sucrose.

Miniclave

Supervisor
Dr Mohd Rafein Bin Zakaria

Objectives

1. To produce xylooligosaccharides from mesocarp fiber using hydrothermal pretreatment. With or without CO_2 assisted for both isothermal and non-isothermal condition.
2. To purify and characterize xylooligosaccharides produced.

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Combined CO_2-assisted steam explosion and wet disk milling pretreatments for bioconversion of fermentable sugar from empty fruit bunch

Differences between untreated (left) and hydrothermal pretreated (right) samples during lignocellulosic compound determination.

Machine used for steam explosion pretreatment (Huber CC-304B Thermostat).

Empty fruit bunch

As one of palm oil producer country, Malaysia generates lots of biomass for example empty fruit bunch fibre, mesocarp fibre, frond, and trunk. Currently, the main dispose method used is through dumping or incineration which then causing pollution towards environment. Hence, in achieving better environment, biomass needs to recycle or reprocess. Biomass consists of high lignocellulosic materials are cellulose, hemicellulose and lignin. Cellulose and hemicellulose are valuable to be converted into fermentable sugar through enzymatic saccharification process. However, the materials are in complex macroscopic form, thus it reduces the enzymatic digestibility. A pretreatment process is required as it alters the lignocellulosic structure to make cellulose more accessible by enzyme. Mainly, there are four approaches of pretreatment available such as physical, chemical, physicochemical and biological. Steam explosion process falls to physicochemical reaction which it loosen up the structure and assisting autohydrolysis reactions within the biomass, while physical appearance will be affected by wet disk milling. Thus, crystalline structure of cellulose will be reduced. Insertion of CO_2 together with steam explosion will decrease final pH and form carbonic acid enhancing disruption of chemical bonds between hemicellulose and lignin; as a result, it helps in enzyme penetration. Enzyme cocktail is used which comprised of cellulase and β-glucosidase. Thus, enzyme penetrating will be easy, therefore low number of enzyme loading required and cost can be reduced. Therefore, the aim of this study is to achieve higher fermentable sugars yield from enzymatic saccharification of OPEFB using CO_2-assisted steam explosion and wet disk milling pretreatments process.

Supervisor
Prof. Dr Mohd Ali Bin Hassan
Dr Ahmad Muhaimin Bin Roslan
Dr Mohd Rafein Zakaria

Objectives
1. To achieve higher fermentable sugars yield from enzymatic saccharification of OPEFB using CO_2-assisted steam explosion and wet disk milling pretreatment processes

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Elucidation of uncharacterized *ydfW* pseudogene, as a functional protein in hydrogen metabolism

Hydrogen holds a promise for a renewable and clean energy source. Molecular of hydrogen gas (H_2) has highest energy content compared to other gaseous fuels. H_2 known as carbon free gas and it is completely oxidizes to water once it is combusted. H_2 can be generated by various methods either chemical or biological approach such as water electrolysis, natural gas, coal, waste material, wastewater and etc. However, hydrogen through biological method (biohydrogen) gain a great interest as it can be produced easily from variety of carbon sources through dark fermentation.

Escherichia coli (E. coli) is the most extensively used bacterium for bio hydrogen production. By screening this strain using chemochromic membranes, ydfW is found as one of the potential pseuodogenes that related during hydrogen metabolism. Based on ecoGene database, 178 pseudogenes are currently annotated including 5 RNA pseudogenes and 116 are y-gene pseudogenes. Pseudogene is a DNA sequence with high homology to a functional gene. However, it is regarded as defunct relatives due to a few types mutation and strain evolution. Biohydrogen production is catalyzed by hydrogenase in mixed-acid fermentation. To date, a comprehensive study of *E. coli* pseudogenes related to hydrogen metabolism has not been conducted. In this study, the actual sequence of pseudogenes *ydfW* was used using single gene knockout method. Then, through transcription gene analysis, the influenced gene in *ydfW* mutant were prevailed. This study was continued by conducting protein comparative modeling in objective to prove the role of *ydfW* pseudogene in hydrogen metabolism. Hence, this research is a fundamental study for enhancing biohydrogen production.

Figure 1 : ydfW mutant streak on LB+Kan medium

Figure 2: ydfW inoculum after 12hours of incubation in LB broth.

Figure 3 : HPLC used for organic acid analysis

Supervisor
Dr Mohd Zulkhairi Mohd Yusoff

Objectives

1. To verify the presence of *ydfW* pseudogene in *Escherichia coli* wild-type BW25113 through molecular biotechnology approach
2. To elucidate the role of *ydfW* pseudogene in *Escherichia coli* wild-type BW25113 during hydrogen production.

RESEARCH **ASSISTANTS**

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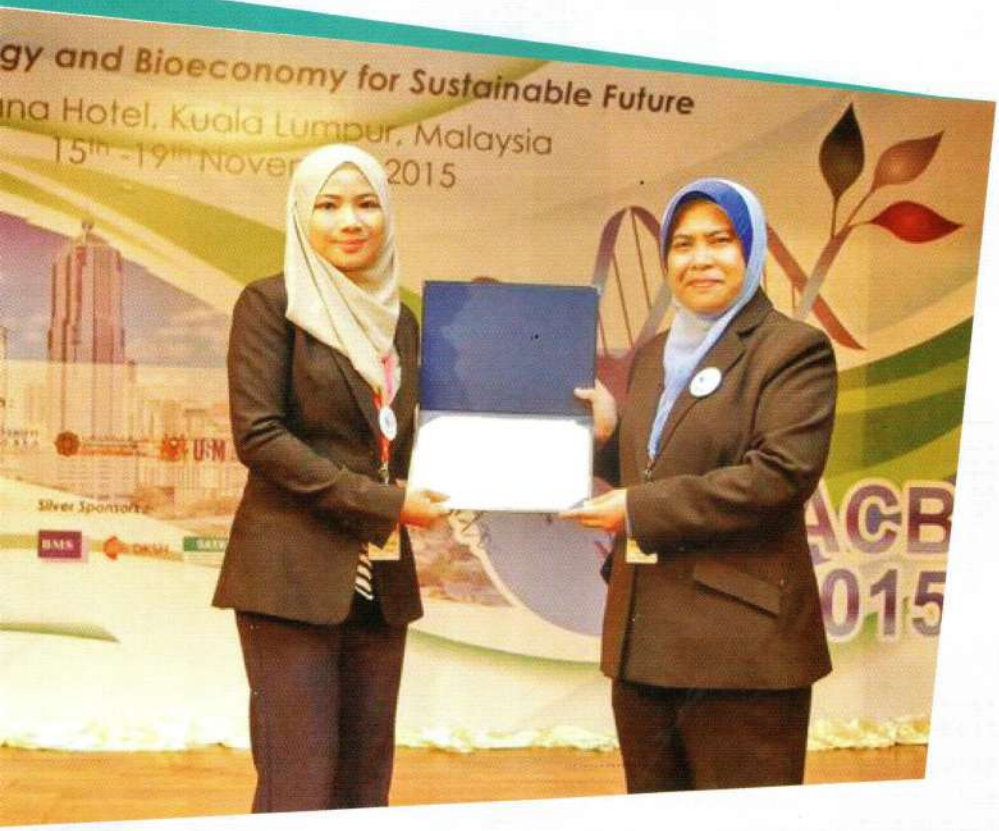
Name : Norainon Maulad Nashir
Supervisor : Dr. Norhayati Ramli

Name : Enis Natasha Noor Arbaain
Supervisor : Prof Dr. Suraini Abd Aziz

AWARD

Tengku Arisyah won as the best poster presenter in INTROP research Colloqium.

Mohd. Nazmir won 2nd place in best poster presenter in INTROP Research Colloqium.



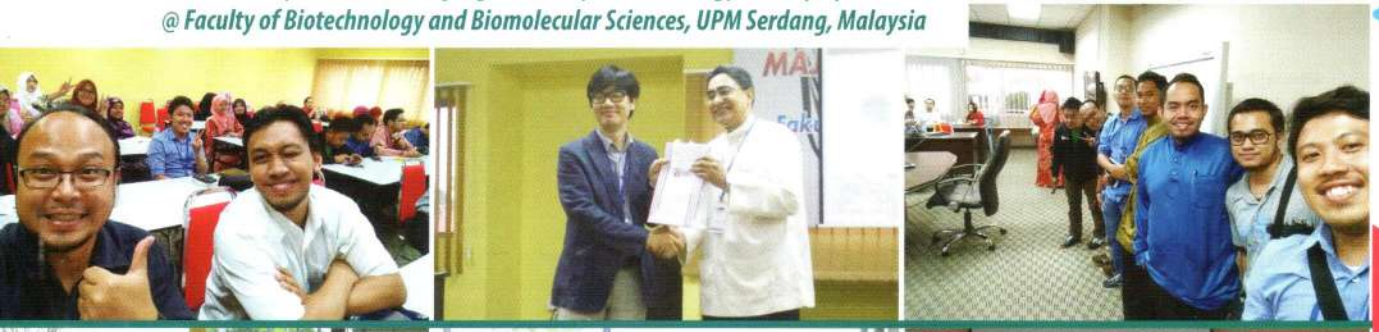
Nurul Hanisah won as the best poster award in ACB2015 for Bioprocess and Bioseparation Engineering Session.

Dr. Rafein won a special gift in WILEY special session on ACB2015.

2015 IN PICTURES

3-4 February 2015 : Asia Renewable Energy Workshop (AREW2015)
@ Faculty of Biotechnology and Biomolecular Sciences, UPM Serdang, Malaysia

13 February 2015 : UPM-Sejong University Biotechnology Joint Symposium
@ Faculty of Biotechnology and Biomolecular Sciences, UPM Serdang, Malaysia



24 February 2015 : Visit From Mulawarman University @ Faculty of Biotechnology and Biomolecular Sciences, UPM Serdang, Malaysia

2015 IN PICTURES



5-6 March 2015 : UPM-KYUTECH MSSC Seminar International Research Collaboration
@ Faculty of Biotechnology and Biomolecular Sciences, UPM Serdang, Malaysia






27-30 May 2015 : AFOB Regional Symposium 2015 (ARS 2015)
@ Universitas Indonesia, Depok, Indonesia



12-13 November 2015 : Pre-conference DGGE Workshop
@ Biotech 3, Faculty of Biotechnology and Biomolecular Sciences, UPM Serdang, Malaysia






15-19 November 2015 : Asian Congress of Biotechnology (ACB2015) @ Hotel Istana, Kuala Lumpur, Malaysia

2015 IN PICTURES

23-24 November 2015 : The 3rd UPM-KYUTECH International Symposium on Applied Engineering and Sciences (SAES2015) @ Faculty of Computer Science and Information Technology, UPM Serdang, Malaysia

8-9th December 2015 : International Biomass Conference Malaysia 2015 @ MATRADE Hall, Kuala Lumpur, Malaysia

2015 IN PICTURES

15 Nov : Serdang Biomass Town Event

AIST training

1 Dec : International Conference on Knowldege Transfer

6 Jun : Iftar Jamaie

Convocation

7 July : EB Raya

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BERILMU BERBAKTI

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Current position:
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Title:
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Former supervisor:
Prof Dr. Suraini Abd Aziz

Juferi Idris

Current work place:
UiTM Sarawak

Current position:
Senior Lecturer

Title:
Biochar production from empty fruit bunch biomass under self-sustained carbonization for the development of Yamasen carbonization oven

Former supervisor:

Che Mohd Hakiman Che Maail

Current work place:
Subang Jaya

Current position:
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Title:
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Former supervisor:
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Mohd Huzairi Mohd Zainudin

Current work place:
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Current position:
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Title:
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Former supervisor:
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Mohd Rahimi Zakaria @ Mamat

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Current position:
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Title:
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Title:
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Former supervisor:
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