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INTROPica

INSTITUTE OF TROPICAL FORESTRY AND FOREST PRODUCTS

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LIGNOCELLULOSIC MATERIALS FOR INDUSTRIAL APPLICATION

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Warm greetings to all

Welcome to the 17th issue of INTROPica!

This is the 11th year of publication for INTROPica magazine since the first issue published in 2008! If ten was a perfect number, then eleven would have been an even more amazing number which represents something above and beyond the mundane. Gratefully, our 11-year journey has been eventful and fruitful. For the 17th issue, the Laboratory of Biopolymer and Derivatives (BADs) has been given an honour to publish this biannual INTROP magazine with the theme Lignocellulosic Materials for Industrial Application. Lignocellulose is the most abundant source of organic chemicals on earth, accounting for approximately 50% of the world's biomass, has great potential to serve as an alternative source for the production of renewable fuels and chemicals. Lignocellulose has attracted considerable attention as an alternative feedstock and energy resource due to the large quantities available and also its renewable nature. Actual and potential outlets for lignocellulose are as pulp and paper, food, fuel, chemicals and construction materials.

Lignocellulosic biomass has higher amount of oxygen, and lower fractions of hydrogen and carbon with respect to petroleum resources. Owing to this compositional variety, more classes of products can be obtained from lignocellulosic biorefineries than petroleum based ones. For the production of the other value-added chemicals, the presence of oxygen often provides valuable physical and chemical properties to the product. Thus, the production process requires much less deoxygenation. However, various sources of lignocellulosic biomass need to be considered separately the compositions of lignocellulose vary greatly, depending on the type of plant, cultivation conditions, and the age of the plant.

The development in the valorization of lignocellulosic biomass, however, still remains a big challenge together with many opportunities. Thus, extensive research is needed in modern day to convert lignocellulosic biomass to value-added chemicals and polymers at high selectivities, and yields at economical costs. It can be foreseen that, the future developments in the valorization of lignocellulosic biomass are directly correlated to improvements in the fields of chemical and microbial synthesis. Owing to the recent advancements in these fields, the number and diversity of lignocellulosic biomass based commodity and specialty chemicals have been rapidly increasing. With advancement on the lignocellulose technology and development, lignocellulosic biomass will contribute in building a greener and sustainable industry.

BIOPLASTIC PRODUCTION FROM LIGNOCELLULOSIC BIOMASS TOWARDS SUSTAINABLE FUTURE IN MALAYSIA

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INTRODUCTION

Plastic usage has ultimate number of consumers globally in every sector. In line with the expanding market demand for eco-friendly green products that have been strongly advocated as alternatives to petroleum-based products had leave the big impacts to many industrial sectors and Malaysia is no exception to it (Mohd Yusof et al., 2015). Based on report by Malaysian Plastics Manufacturers Association's (MPMA, 2016) data, the major market segments for plastic product is in packaging area with 45% while electrical and electronic is 26%, automotive 10%, construction 8%, 5% for household, and the remaining is in other industries. Currently, the Ministry of energy, science, technology, environment, and climate change (MESTECC) has put a lot of efforts to ensure that Malaysia would reduce the usage of plastic especially single-use plastic which cannot be reuse once after use. The single-use plastic products are widely utilized in packaging area as a product plastic wrapper, food packaging as well as carrier shopping bag and so on. Most of plastic materials are made up from petroleum-based known as a non-renewable fossil fuel with huge carbon footprint that leads to the global climate change due to carbon emissions. Environmental awareness has increased tremendously in recent years due to many environmental issues involving animals extinction caused by non-biodegradable plastic disposal into the landfills and in natural habitat like marine debris issues, physical problem to wildlife such as entanglement with plastic besides potential chemical transfer to wildlife (Pei & Schmidt, 2011).

An uprising number of policies and national strategies of implementation as well as development of a bio-based economy have emerged in many countries such as US, EU, Australia, Canada, Sweeden, Malaysia and others since 2008. The policies and strategies are more striving towards eco-efficient and sustainable transformation of natural resources into energy, food or other industrial products (Mohd Yusof et al., 2015). Since Malaysia is listed as the second largest oil palm biomass (OPB) resources producer, it is a great opportunity to employ OPB into bio-based products in order to cater the issues regarding the non-biodegradable plastics. Hence, the replacement of conventional synthetic plastics with biodegradable bioplastic (BP) is one of the good alternatives. BP can refer as i) synthetic biodegradable polymers, e.g. PVA, PBS and PCL; 2) conventional plastics; 3) bio-based, non-biodegradable plastics like polyamides and bio-based PE; 4) bio-based and biodegradable plastics like starch acetate, PLA and PHA. The latter would be a great candidate with amazing properties. Therefore, the focus is more towards polyhydroxyalkanoate (PHA) production from OPB to produce sustainable and eco-friendly BP.

LIGNOCELLULOSIC BIOMASS

Lignocellulosic biomass is one of the most natural renewable and available resources in almost every country. Major component of lignocellulosic biomass is cellulose which considered as the strongest promising alternative for petroleum-based polymers due to its environmentally friendly properties such as biodegradable, biocompatible as well as renewable besides it is the most abundant resources in the earth. Lignocellulosic biomass also known for its carbon-neutral property that capable to reduce emission of atmospheric pollution and CO2. Based on previous studies, it also has substantial potential for sustainable production of fuels and chemicals. Even from the economic point of view, a lot of lignocellulosic biomass can be produced or growth quickly and cheaper compared to other agricultural feedstocks like soybean, corn, sugar cane, and starch (Isikgor & Becer, 2015).

Malaysia is often known as one of the largest cultivator or contributor for oil palm *(Elaeis guineensis)* plants besides Indonesia with approximately 5.4 million hectares of plantation area (Chiew and Shimada, 2013). The high global demand of oil palm leads to explosive expansion of oil palm plantation which increase the production of lignocellulosic biomass, namely, oil palm trunk (OPT), fronds (OPF) and empty fruit bunch (OPEFB) which expected to reach 110 million tonnes by year 2020 (Wan Rosli et al., 2017). The increasing of oil palm plantation resulted in the increment of oil palm mill. Malaysia is now among a top world's oil palm exporter for numerous oil palm-based production in line with the large plantation areas and enormous numbers of oil palm mills. As reported by Kong et al. (2014), only about 10% of oil palm produced as oil extraction, while the remaining 90% left as biomass waste. It would be tremendously wasted if this biomass is not exploited to its fullest. This data showed that, the oil palm industry can create many opportunities and social benefits for the locals. In recent years, green, renewable, sustainable, biodegradable, and environmentally friendly materials are receiving explosive interest from both scientific and industrial communities due to several drawbacks from conventional sources such as ecological treats, finite supply and non-renewable petroleum-based sources for bio-based products applications. Cellulose, a biopolymer, which in recent decades have develops into promising value-added end-products (Abdul Khalil et al., 2014; Kargarzadeh et al., 2017).

BIOPLASTIC DERIVED FROM PHA FROM OIL PALM BIOMASS

Commonly, polymers are produced from petrochemical derivatives which generate large amount of wastes that hard to be treated or dispose. Therefore, a lot of efforts in searching for other potential candidates have been done which particularly focus in eco-friendly material that leads to biopolymer referring to polymer materials derived from renewable biomass resources. Biopolymers also known as bioplastics (BPs) are suitable candidate to replace common polymer due to it physicochemical properties similar to those petroleum-derived material. It is more environmentally-friendly compared to normal polymer due to its biodegradability (Boneberg et al., 2016). As aforementioned, not all BPs are biodegradable. Table 1 shows the commercialize bioplastics and biodegradable plastics. Unlike starch-based polymers and chemically synthesized polymers, PHA is more favorable as its environmentally-friendly, biodegradability and sustainability properties (Khanna & Srivastava 2005; Salehizadeh & Van Loosdrecht, 2004).

Table 1. Types of bioplastics and biodegradable plastics

	Biodegradable	**Non-biodegradable**
Bioplastics (BPs)	- Polyhydroxyalkanoate (PHA) - Polylactic acid (PLA) - Starch-based plastics	- Polyamide 11 (PA11) - Bio-derived polyethylene
Petroleum-based plastics	- Polycaprolactone (PCL) - Polyesteramide - Polybutylene succinate adipate (PBSA)	- Polypropylene (PP) - Polyethylene (PE) - Polyethylene terephthalate (PET) - Polystyrene (PS)

Source: Hassan et al. 2013

PHA is naturally accumulated in bacteria through fermentation with materials like sugar, vegetable oils or industrial waste in culture medium and also 100% biodegradable polymer. It is produced under imbalanced growth conditions by bacteria and some of the bacteria are able to produce PHA up to 90% (w/w) of dry cells. Simple fermentation method is utilized in commercial production of PHA to fulfill the BPs criteria. The common industrial microbes that have been used in the process are *Aeromonas hydrophila, Alcaligenes latus,* Recombinant *E.coli*, *Pseudomonas putida*, and *Bacillus* spp. (Varsha & Savitha, 2015). The PHA production cost is expensive compared to synthetic plastics (PE & PP). The carbon substrate contributes almost half in PHA production price. Therefore, renewable biomass material as a carbon source will be an excellent alternative in reducing the PHA production cost substantially and capable to minimize the industrial waste disposal cost (Hassan et al., 2013). Previously reported by Reddy and co-workers (2003), the OPB and its related products are suitable as substrates for PHA production by a different of PHA producers which at least from 75 variety genera has been listed. For OPB, the regular component that always been used are pall oil mill effluent (POME) and OPEFB which are the most abundant residues for OPB. POME will undergo anaerobic treatment to produce organic acids which become a carbon sources for PHA production in bacterial cells (Hong et al., 2009). While, there are two types of pretreatment for OPEFB which are acid hydrolysis and enzymatic saccharification to convert OPEFB into fermentable carbohydrates and subsequently turns it to fermented broth via microbial fermentation, hence it is viable for PHA production. Both of these methods could be an effective way to dispose the POME and OPEFB residues instead of being discharged into the environment as a harmful wastewater or being burned without proper usage, respectively, which will cause greenhouse gas emission (Hassan et al., 2013).

GLOBAL MARKET CHALLENGES IN BIOPLASTIC INDUSTRY

BPs worldwide market is mostly in packaging sector which gradually growth to date. In recent year, with a soaring price in natural gas and crude oil indirectly cause an increment in petroleum-based plastics price. Thus, bio-based plastics are one of the promising alternatives to replace petroleum-based plastics. The most challenging in developing a sustainable BPs industry is that of price competition. Even in the high rank country like United State cannot give lower than five folds prices compared to common thermoplastics. BRICs countries or known as Brazil, Russia, India and China countries are emerging countries where the BPs sectors get a higher demand due to their changing lifestyle, increasing foreign investments in pharmaceutical industry, growth of domestic electronics as well as food and beverage industries which amplifies the market interest for BPs packaging. While in Europe countries, the government has set a few policies like Europe 2020 strategy that promote bio-economy. This policy has reduces taxes for bio-based products and encourage public authorities to support preference towards procurement of bio-based products (Ahmad Saffian & Abdan, 2015).

As some of developing countries like Thailand, Indonesia and Malaysia are putting more efforts in BPs industry and try to improve in terms of its quality and production cost with utilization of renewable biomass. A lot of countries get the government support with this eco-friendly replacement via various types of fund in order to generate a better product and raising awareness among the private sectors and public users. Moreover, oil palm industry will break the country's dependence on fossil fuel. Usually, as fossil fuel cost increase, a substantial proportion of the products related to it will also increase. Unlike the fossil fuel-based products, BPs which is from non-fossil fuel will not be related to fluctuation of the market price like conventional synthetic plastic. The generated bio-based BPs will decrease the dependence on fossil fuel. Thus, automatically can preserve and balance our minerals source in earth. However, the overall cost for commercialization will involve many factors besides the raw materials used. This still need a deep evaluation and studies in order to improve the BPs sustainability (Hassan et al., 2013).

CONCLUSION

Plastic usage is indispensable in many sectors by numerous industries and consumers. Besides, the petroleum-based sources might be depleted in a few centuries as it is not renewable materials and it causes many environmental issues in a long run. Therefore, other potential alternatives should be employed and improved in line with government attempts in this issue. In recent years, BPs production from biorenewable sources came into limelight and it is ensured that the emerging sustainability, biodegradability, and renewability issues can be catered well with improved research development. Last but not least, the products criteria must meet the consumers and manufacturers demand to advance them as a useful material globally.

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CONSTRUCTION AND BUILDING MATERIALS FROM LIGNOCELLULOSIC MATERIALS

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INTRODUCTION

Construction and building materials including a wide variety of materials intended for construction purposes. The materials consist of wood and timber, fired bricks and clay blocks, steel, concrete, cement composites and many more. Lignocellulosic materials are plant dry matters that composed of carbohydrate polymers, namely cellulose and hemicellulose, and an aromatic polymer, which is lignin. These three components play their own role in providing the strength properties to the materials. In concrete terms, hemicellulose is the boding agent or crosslinking material between cellulose and lignin. Cellulose acts as reinforcement that contributes to tension forces and lignin for compression forces (Homan and Jorissen, 2004).

Construction and building materials can be generally categorized as structural and non-structural materials. Major structural materials comprise concrete, wood and steel. On the other hand, glass, plastics, insulator and adhesives are the examples of non-structural materials (Sev and Ezel, 2014). Materials derived from lignocellulosic biomass can be applied in the manufacturing of construction and building materials. Nanomaterials are able to enhance the properties of construction and building materials by acting as a reinforcement to the concrete and steel (Sev and Ezel, 2014). When it comes to the application in the construction and building materials, nanotechnology offers several advantages such as sturdier and stronger but relatively lighter structural composites, cementitious materials with superior properties, thermal and sound insulators with lower thermal transfer rate and better sound absorption capability (Lee *et al.*, 2010). According to Zhu *et al.* (2004), nanomaterials has been applied in the construction sectors aiming to increase the strength and durability of construction materials and components while reducing pollution at the same time.

CONCRETE AND CEMENT COMPOSITE

performance of concrete and cement composite. There are currently a huge number of studies reported the application of lignocellulosic biomass as reinforcement materials in cement and concrete composites. These lignocellulosic biomasses including oil palm shell, coconut shell, palm fibers, date palm fibers, hemp fibers and shives, flax shives, kenaf bast fibers, bamboo and eucalyptus kraft pulps (Vo and Navard, 2016). As a reinforcement materials, better flexural strength and modulus of elasticity of cement mortar composites was recorded when nanofibrillated cellulose were added (Claramunt *et al.*, 2015). Similarly, nanocellulose fiber gel prepared from bleached softwood pulp has reduced the hydration rate of the limestone cement paste as well as improved flexural strength and energy absorption property (Onuaguluchi *et al.*, 2014).

Cement composite reinforced with nanofibrillated cellulose derived from bamboo pulp displayed better mechanical properties even after weathering (Da Costa Correia *et al.*, 2018). Apart from the materials that synthesized from lignocellulosic sources, bacterial nano-cellulose and marine biomass have also been used widely as the reinforcement of concrete and cement. The benefits of marine biomasses over land plants is that they have higher rapid growth rate and are low in natural physicochemical barriers. Therefore, no severe chemical treatment is required to remove their inherently recalcitrant structure in order to enhance the cellulose accessibility (Chen *et al.*, 2016). For a more sustainable development of construction and building materials, application of recycled cellulosic fibers and lignocellulosic aggregates in the production of cement-based mortars shown positive aspect that could be potentially contributed to the environment benefits (Stevulova *et al.*, 2016).

WOOD

As one of the renewable resources for construction and building materials, application of wood is always constraint by its poor dimensional stability and biological durability nature. However, coating derived from lignocellulosic materials could help in mitigate the problems faced by wood. Nanocomposite coating could be used to protect the wood from the elements apart from improved its mechanical properties and abrasion resistance (Kaboorani *et al.*, 2017). Nanocellulose-filled coatings could improve the thermal properties, dimensional stability, stiffness, hydrophobicity and surface hardness of maple wood (Cataldi et al., 2017). Waterborne polyurethane coating exhibited high compatibility with TEMPO-oxidized cellulose nanofibers which in turn enhanced the properties of the waterboard wood coating (Cheng *et al.* 2016).

POLYMER COMPOSITES

The growing public's awareness around the world have lessened the dependency on petroleum-based polymers. Demand for greener and renewable polymers are in the rise. Nevertheless, renewable polymers have inferior thermo-mechanical properties compared to that of the conventional petroleum-based polymers. Modification is therefore needed to enhance its performance. Nanofillers could be act as a reinforcement to enhance the properties of the composite. Clay minerals, carbon nanotubes and silica nanoparticles are among the nanofillers that often used in enhancing the physical, mechanical and thermal properties of polymers (González-Irún et al., 2007). Table 1 summarised the nanomaterials derived from various lignocellulosic sources and its uses in the construction and building materials.

Table 1. Nanomaterials derived from various lignocellulosic biomass sources and its uses in the construction and building materials

Biomass source	Nanomaterial	Application	Reference
Green algae (*Cladophora* sp)	cellulose nanofiber	Reinforcement in concrete.	Cengiz et al. (2017)
Softwood pulp	nanocellulose fiber gel	Reinforcement in cement composites	Onuaguluchi et al. (2014)
Bacteria (*Gluconacetobacter xylinus*)	bacterial nanocellulose powder, gel and coated onto bagasse fibers	Reinforcement in fiber-cement composites	Mohammadkazemi et al. (2015)
Bacterial cellulose extracted from *nata-de-coco*	bacterial nanocellulose	Reinforcement in soy polyol-based polyurethanes nanocomposites	Ozgur Seydibeyoglu et al. (2013)
Balsa tree (*Ochramapyramidale Cav*)	nanofibrillar cellulose	balsa wood fibers - castor bean cake – glycerol matrix composites	Nishidate Kumode et al. (2017)
Rachis of date palm tree (*Phoenix dactylifera* L.)	Nanofibrillar cellulose	hybrid composites aerogels made with combinations of cellulose microfibers, cellulose nanofibers and nanozeolites	Bendahou et al. (2015)
Bamboo pulp	Nanofibrillated cellulose and cellulosic pulp	Reinforcement of the extruded cement-based materials	da Costa Correia et al. (2018)
Raw jute fibers	Nanocellulose fiber	Reinforcement in natural rubber nanocomposite	Thomas et al. (2015)
Waste jute fibers	Nanocellulose suspension	Coating for woven jute fabric to produce green epoxy composites	Jabbar et al. (2017)
By-products from pulp and paper industries	Lignin nanoparticles - Lignosulfonate	Substitution of phenol in the synthesis of phenol-formaldehyde (PF) wood adhesive	Akhtar et al. (2011) Dominguez et al. (2013)
Sugarcane bagasse	Lignin acetate	Water resistance surface coating	Park et al. (2008)

CHALLENGES AND LIMITATIONS

The production cost for nanomaterials is very high and consume a lot of energy. Therefore, in developing countries that are facing financial constraints, they are still stick to traditional building industry that incurs lesser production cost to them. Apart from that, lack of exposure to the nanotechnology is also a major reason that inhibited the growth of application of nanomaterials in construction and building sector (Yousef Mohamed, 2015). Lacking of specific standard in some countries has made application of nanomaterials least favoured. In addition, low confidence from users towards its biological impacts is another one of the biggest barriers for the development and promotion of lignocellulosic nanomaterials. All stages in a life cycle of producing nanomaterials pose potential human exposure with inhalation and skin exposure being the main two exposure routes to human (Camarero-Espinosa et al., 2016). However, there is currently lack of understanding and information to the biological impacts of these lignocellulosic nanomaterials upon exposure. Such information is vital for the future determination of biocompatibility and hazard assessment of the lignocellulosic nanomaterials. Although some preliminary studies on the toxicity of unmodified nanocellulose revealed low-to-minimal adverse health effects from oral or dermal, the health risks associated with nanomaterials are remain uncertain. Contradict results has been reported particularly on the health effects on the respiratory system and cytotoxicity (Moon et al., 2016). Absence of the information inevitably restricted the application of these lignocellulosic nanomaterials. In order to convince the user in using nanomaterials, the biological impacts and it's on the human health must be studied thoroughly. A comprehensive report or reference regarding to this topic must be readied for the viewing of public. Apart from that, exposure of the researchers to the needs of the marketplace and product value chain is also a vital future topic.

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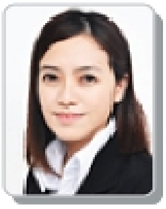
HIGH QUALITY SOLID FUEL PRODUCTION FROM OIL PALM BIOMASS USING COMBINATION OF TORREFACTION AND LEACHING TREATMENTS



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INTRODUCTION

Biomass pretreatment has been recognized as a potential key player in both logistic and handling on. Pretreatment of biomass using torrefaction improves the heating value and it is a promising method to convert low quality biomass into high energy density solid biofuel with consistent and uniform physical and chemical characteristics. Although torrefaction has been shown to improve the biomass fuel properties in terms of energy density, a challenge remains because a large amount of alkali metals, is retained in the char and therefore mitigate their adverse impact on the heat transfer and corrosion rates in the boiler (Chin *et al.* 2013, Saddawi *et al.* 2012). On the other hand, leaching method has been proven to significantly reduce the ash content and increase the ash melting temperature of biomass. Only a slight increment in heating value was observed due to total ash reduction. Thus, leaching does not essentially increase the heating value as in using torrefaction method. In general, both torrefaction and leaching benefit only in one respective factor, i.e. heating value and ash sintering characteristic, respectively, but neglected the other factor.

Nature provides diversity of biomass with different characteristics. To achieve a highly efficient biomass-to-energy chain, a method to overcome logistic economics in large-scale sustainable energy solutions, better energy density and combustion efficiency has to be established. A combination of leaching and torrefaction may be an ideal pretreatment method for both biofuels and biopower. The following work explores the possibility of combining leaching and torrefaction treatment to create an improved fuel from oil palm biomass to achieve high energy density and low ash percentage. Laboratory studies were conducted to evaluate the process sequence of both methods: a torrefaction followed by leaching or leaching followed by torrefaction. The purpose of the work is to determine the effects of the combination treatments on ash removal efficiency, as well as ash melting characteristic of the treated oil palm lignocellulosic biomass.

COMBINED TREATMENT PROCESS

For the AB combination treatment, the oil palm biomass; empty fruit bunch (EFB) and oil palm trunk (OPT) were torrefied before undergo leaching treatment. The lignocellulosic biomass was dried at 105 °C for 24 h before torrefaction in order to remove the residual water remaining in the biomass. The dried lignocellulosic biomass fines (10 g) was placed in a furnace and torrefied under the optimized torrefaction conditions obtained by Chin *et al.* 2013. After torrefaction, the oil palm biomass fines were left to cool in desiccators. After cooling process, 10 gram samples were soaked and submerged in 100 ml of 1% acetic acid under the optimized leaching conditions obtained by Chin *et al.* 2015. After acetic acid leaching, the solutions were filtered and washed with 100 ml distilled water and the leached samples were oven dried at 105 °C over 24 h.

For the BA combination treatment, the dried samples were leached followed by torrefaction treatment. Ten gram samples were soaked and submerged in 100 ml of 1% acetic acid under selected leaching conditions obtained by Chin et al. 2015. After acetic acid leaching, the solutions were filtered and washed with 100 ml distilled water. The leached samples were oven dried at 105 °C over 24 h before torrefaction in order to remove the residual water remaining in the biomass. The dried wood fine (10 g) was placed in a furnace and torrefied under the optimized torrefaction conditions obtained by Chin et al. 2013. After torrefaction, the lignocellulosic biomass fines were left to cool in desiccators.

ASH REMOVAL

From Table 1, it can be clearly seen that leaching followed by torrefaction (BA combination) generated the acceptably low ash content. These values however are still higher when compared with those recorded for when using leaching alone, 0.21 – 0.82%. Carrier et al. (2011) conducted an experiment by combining leaching and pyrolysis treatment. From the study Carrier et al. (2011) found that the total ash reductions are contributed partially by the leaching pretreatments and further reduce through devolatilization (vaporized inorganic elements such as potassium, chlorine, phosphorus n sulphur) during the pyrolysis process.

The extent of leaching diminishes as the biomass undergone thermal treatment prior to leaching in the AB combination treatment (torrefaction followed by leaching). Comparing the ash yield of raw and torrefied (AB treatment) oil palm biomass revealed higher removal efficiencies were observed for raw lignocellulosic biomass using acetic acid leaching treatment. The ash yield reduction from raw biomass ranged 60 – 86%, whereas the ash yield reduction from torrefied biomass ranged 47 – 68%. The reduction of ash removal efficiency from torrefied biomass can be due to the physicochemical changes which affects the char matrix and to a different mode of occurrence of ash forming elements as soon as the thermal degradation occurred. Following torrefaction treatment, the originally leachable ash is most probably transformed into increasingly stable forms such as carbonates and/or oxides which reduce the solubility in mild acid (Li et al. 2004). From the observations by Raveendran and Ganesh (1998), lignin and hemicelluloses undergo a phase change during the thermal degradation process, forming a molten phrase intermediate which traps the ash components thus making ash removal more difficult as char is formed. Microscopic analysis by Jensen et al. (1999) also proved that ash forming elements such as potassium is bound to the organic matrix after thermal treatment.

Table 1. Ash content of oil palm biomass after pretreatment

Lignocellulosic biomass	Ash Content (%)				
	Untreated	Torrefaction[1] (A)	Leaching[2] (B)	Torrefaction-Leaching (AB)	Leaching-Torrefaction (BA)
EFB	5.96	6.36	0.82	2.04[b]	0.96[a]
OPT	1.33	2.05	0.53	1.08[b]	0.63[a]

[1] Values are taken from optimum pretreatment condition by Chin *et al.* 2013
[2] Values are taken from optimum pretreatment condition by Chin *et al.* 2013.
Note: *Means followed by the different letter in the same row of a species are significantly

HIGHER HEATING VALUE (HHV)

Slightly lower heating value was observed for samples treated with combined treatment process compared to samples that solely undergone torrefaction as shown in Table 2. Significantly higher HHV was obtained using BA combination treatment for all types of lignocellulosic biomass used in this study. Thermal pretreatment split and decompose a significant part of the lignocellulosic biomass fraction into soluble and less complex molecules (Haug et al. 1983). In AB combination treatment process, torrefaction was positioned before the leaching treatment with most of the ash forming elements (inorganic materials) were strongly locked in the biomass due to the physicochemical changes of the organic and inorganic materials during thermal treatment (Li et al. 2004; Jensen et al. 1999 and Raveendran Ganesh, 1998). This results a higher concentration of inorganic materials which have no contribution to the HHV and this directly reduced the HHV of the lignocellulosic biomass from AB combination treatment.

Table 2. Higher heating value of oil palm biomass after pretreatment

Lignocellulosic biomass	Higher Heating Value (Mj/kg)				
	Untreated	Torrefaction[1] (A)	Leaching[2] (B)	Torrefaction-Leaching (AB)	Leaching-Torrefaction (BA)
EFB	18.06	23.08	18.47	22.55[b]	22.82[a]
OPT	17.18	22.22	16.53	22.13[a]	22.50[b]

[1] Values are taken from optimum pretreatment condition by Chin *et al.* 2013
[2] Values are taken from optimum pretreatment condition by Chin *et al.* 2015.
Note: *Means followed by the different letter in the same row of a species are significantly different at $P \leq 0.05$.

ASH MELTING CHARACTERISTIC

Comparison of the ash melting characteristic of the combination treatments to the torrefied biomass demonstrates the benefits of incorporating the leaching treatment with the torrefaction process. As shown in Table 3, oil palm biomass treated with both combination treatments display a substantial improvement in ash melting characteristic compared to oil palm biomass that solely undergone torrefaction.

Table 3. Ash sintering characteristics for pretreated oil palm biomass under high heating temperature[1]

Ash Heating Temperature	Torrefaction[2] (A)	Leaching[3] (B)	Torrefaction-Leaching (AB combination)	Leaching-Torrefaction (BA combination)
EFB				
700	molten	loose	loose	loose
800	molten	loose	loose	loose
900	molten	loose	Slightly sintered	loose
1000	molten	Slightly sintered	Strongly sintered	Slightly sintered
OPT				
700	Strongly sintered	loose	loose	loose
800	molten	loose	loose	loose
900	molten	loose	Slightly sintered	loose
1000	molten	loose	Slightly sintered	loose

[1]Note: Refer to Chin et al, 2018 for the ash classification
[2]Values are taken from optimum pretreatment condition in Chapter 4
[3]Values are taken from optimum pretreatment condition in Chapter 5

Torrefied EFB and OPT will cause severe problems during combustion. However, combining the leaching and torrefaction treatment had reduced the risk of ash sintering. It is anticipated that oil palm biomass will require pretreatment, and that a combined leaching and torrefaction are now predicted not to be problematic in terms of fouling when combusted at temperature below than 1000 °C, except for EFB. EFB treated with torrefaction followed by leaching treatment (AB combination treatment) vastly improved the ash sintering but still potentially problematic if combusted above 900 °C. OPT ash were in a loose form even after heated at temperature 1000°C. By applying the BA combination treatment, EFB resulted in a better ash melting characteristic. At 1000°C, ash from EFB treated with AB combination treatment was strongly sintered but upon way BA combination treatment, a slightly sintered ash was generated. This can be attributed partly to the trapping of ash components inside the char matrix in AB combination treatment, following the formation of a molten phase of EFB during combustion due to the changes undergone by the alkali metals under high temperature.

CONCLUSION

The study shows that by applying leaching procedure followed by torrefaction treatment generated an improved quality of biomass solid biofuel particularly in HHV, ash content and ash melting temperature compared to the fuel treated with singular treatment; torrefaction or leaching alone. Leaching gives rise to a remarkable increment in the ash melting temperature of torrefied oil palm biomass. This suggests that acetic acid leaching is an important treatment for the preparation of torrefied fuels. Acetic acid leaching on torrefied oil palm biomass was less effective than on raw lignocellulosic biomass. Most ash forming elements in the torrefied samples may had transformed into increasingly stable forms that are difficult to be leached. Thus, lower ash content was observed on samples undergone leaching followed by torrefaction (BA combination treatment). Leaching prior to torrefaction proved to be a better combination; significantly increased the HHV of the lignocellulosic biomass and improved the ash melting characteristic.

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NANOFIBRILLATED CELLULOSE AS A COMPOSITE FILLER

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NANOFIBRILLATED CELLULOSE (NFC)

Nanofibrillated cellulose (NFC) are long entangled cellulose fibrils that consist of both amorphous and crystalline regions. This is unlike CNCs that are almost perfectly crystalline (Cao *et al.*, 2016). They also have extremely high aspect ratio

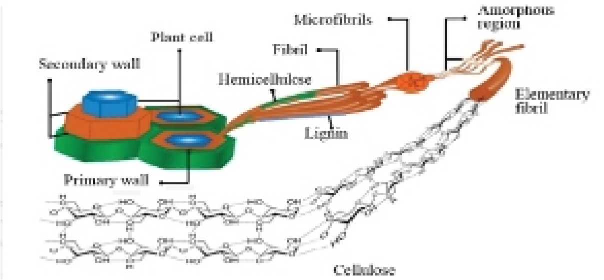

Fig. 1. Structural hierarchy of cellulose.

with lengths up to 2000nm and widths of 4-20nm making them fall within the nanoscale range (Moon, Martini, Nairn, Simonsen, & Youngblood, 2011). The long structures of NFC allow them to form colloidal dispersions in water even when in low concentrations below 1wt% due to the entanglement of the fibers (Cao et al., 2016). Therefore, besides microscopy techniques, the viscosity of the cellulose suspension can be a good indication of the aspect ratio of NFC (Henriksson & Berglund, 2007). In order to extract NFC from plant biomass, the hierarchical structure of cellulosic fibers must be known (Figure 1). NFC is produced by breaking down microfibrillated cellulose or the larger cellulose fibrils by means of mechanical shearing with optional enzymatic pre-treatments (Vilarinho, Sanches Silva, Vaz, & Farinha, 2018). In contrast to the aggressive acid hydrolysis method used to develop CNC, production of NFC employs a milder approach using cellulase enzymes which modify the cellulose without degrading it (Siró & Plackett, 2010). There is another reason as to why enzymatic pre-treatments are used in conjunction with mechanical shearing and this is due to the high amounts of energy consumed when producing NFC. Spence et al., reported that up to 4,000kJ of energy was needed per pass to make 1kg of NFC when using homogenization as a shearing method. Subsequently, microfluidization was also pointed out by the author to consume roughly 630kJ/kg/pass at 30kpsi. Micro-grinding, another shearing technique, uses up about 620kJ/pass/kg of NFC (Nakagaito & Yano, 2004). The high energy consumption is also accompanied by a problem of entanglement of the plant fibers on the equipment, causing plugging and potential damage. Enzymatic pre-treatments have the advantage of loosening up the fibers by decreasing their length and reducing the total energy consumption of the shearing process (Spence *et al.*, 2011).

NFC AS A COMPOSITE MATERIAL

When it comes to choosing a suitable material to be used as a filler, many parameters have to be considered. Mechanical properties such as tensile strength, elastic modulus and flexibility have to be assessed. The thermal properties of the materials are also vital information that contributes to the overall durability of these composites. Research has shown that nanocellulose-based films have potentially high tensile strengths. Qing et al. and Yano and Nakahara have found that NFC has the ability to withstand over 230 MPa of tensile stress when formed properly.

The tensile strength of a material is the amount of tension the material can withstand before breaking. Flexural strength, on the other hand, is the tensile strength of a material when subjected to force across its depth. According to the compilation of mechanical test results in Table 1, it seems that the addition of NFC to thermoplastic polymers would generally increase their tensile strengths. This has been attributed to the extremely high aspect ratios of NFC which allow them to form strong interactions with the polymer matrices (Farahbakhsh et al., 2017; Perić et al., 2019).

Another important parameter to consider when observing material properties is the elongation at break. The elongation at break of a material is the percentage of length the polymer stretches before breaking. It is an indication of the ductility of the polymer. According to Yasim-Anuar et al., a decrease in the elongation at break of the polymers is due to the rigid nature of the CNF fillers. That being said, Zimmermann *et al.*, mentions that is is possible to improve both the tensile properties of a polymer without sacrificing its ductility through proper interfacial interaction and crosslinking between the CNF and the polymer matrix.

Polymers with high elastic moduli or Young's moduli have many uses and applications. The Young's modulus of a polymer or composite is directly related to the tensile strength and the strain of the polymer. In fact, it is the ability of the polymer to resist a change in length when under tension. Fortunately, as shown in Table 1, there are evidence that nanocellulose has the potential to increase the Young's modulus when added to polymer blends as a filler (Zimmermann *et al.*, 2004; Tomé *et al.*, 2013; Kurihara and Isogai, 2014; Farahbakhsh et al., 2017; Igarashi *et al.*, 2018; Norrahim *et al.*, 2018; Samarasekara *et al.*, 2018; Perić *et al.*, 2019; Yasim-Anuar *et al.*, 2019)

Table 1: Effect of NFC on the properties of various polymers. PE, polyethylene; PLA, polylactic acid; PP, polypropylene; HDPE, high density polyethylene; LDPE, low density polyethylene; PVA, polyvinyl acetate

Polymer matrix	Properties Improved	Properties Worsened	Source
PE	Young's modulus, tensile strength, flexural strength, flexural modulus crystalinity, hydrophilicity	Thermal stability, elongation at break, toughness	(Yasim-Anuar et al., 2019)
PLA	Young's modulus, impact strength, elongation at break, crystalinity		(Perić et al., 2019)
PP	Tensile strength, Young's modulus, flexural modulus, crystalinity, thermal stability	Elongation at break	(Norrahim et al., 2019)
PP	Tensile strength, impact strength, hardness, water absorption		(Samarasekara et al., 2018)
HDPE	Tensile strength, Young's modulus, coefficient of thermal expansion	Elongation at break	(Igarashi et al., 2018)
LDPE	Thermal stability, crystalinity, Young's modulus, tensile strength	Transparency, elongation at break	(Farahbakhsh et al., 2017)
Poly(acrylamide)	Young's modulus, tensile strength, yield stress	Elongation at break	(Kurihara and Isogai, 2014)
Corn starch/chitosan	Thermal stability, Young's modulus, tensile strength	Elongation at break	(Tomé et al., 2013)
PVA	Tensile strength, Young's modulus	Elongation at break	(Zimmermann et al., 2004)
Hydroxypropyl cellulose	Tensile strength, Young's modulus, elongation at break		(Zimmermann et al., 2004)

When it comes to the toughness of a material, it is a balancing act. When a material is subjected to a force that exceeds the limit of its strength, one of two things will happen, it will either undergo deformation or fracture. A tough material is able to absorb high amounts of energy and undergo plastic deformation without fracturing. By calculating the area under the stress-strain curve, one can determine the toughness of a polymer or composite. Zimmermann, *et al.*, 2004, found that composites that incorporated cellulose showed a higher degree of toughness. The changes in the thermal stability of the composites depend on the thermal stability of NFC relative to the polymer matrix. For example, in the case of polyethylene (PE), NFC has a relatively lower thermal decomposition temperature as compared to PE.

Therefore, the decrease in thermal stability in the PE/NFC can be attributed to the degradation of NFC at a lower temperature which then triggers the decomposition of the PE matrix (Yasim-Anuar et al., 2019). Improvements to the thermal stability of the composites are suggested to be due to the compatibility of the polymer matrix with the NFC filler and also the interfacial interaction between the two (Farahbakhsh et al., 2017). In fact, for such cases, an additional degradation step appears which is assumed to be due to the degradation of the NFC fractions of the composites (Farahbakhsh et al., 2017; Tomé et al., 2013).

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DEVELOPMENT OF BIOPLASTIC AND LIGNOCELLULOSIC FOR GREEN COMPOSITES MATERIALS: INDUSTRIAL APPLICATION

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INTRODUCTION

Bioplastics are used in an increasing number of markets, from packaging, catering products, consumer electronics, automotive, agriculture/ horticulture and toys to textiles and a number of other segments. Packaging remains the largest field of application for bioplastics with almost 60 percent (1.2 million tonnes) of the total bioplastics market in 2017. The increase in the use of bioplastics in all market segments is driven by the increasing demand for sustainable products by consumers and brands alike due to a growing awareness of the impact on the environment and the need to reduce the dependency on fossil resources as well as the continuous advancements and innovations of the bioplastics industry in new materials with improved properties and new functionalities. The budding bioplastics industry hast he potential to unfold an immense economic impact over the coming decades. According to a recent job market analysis conducted by (EuropaBio, 2016), the European bioplastics industry could realise a steep employment growth. In 2013, the bioplastics industry accounted for around 23,000 jobs in Europe.

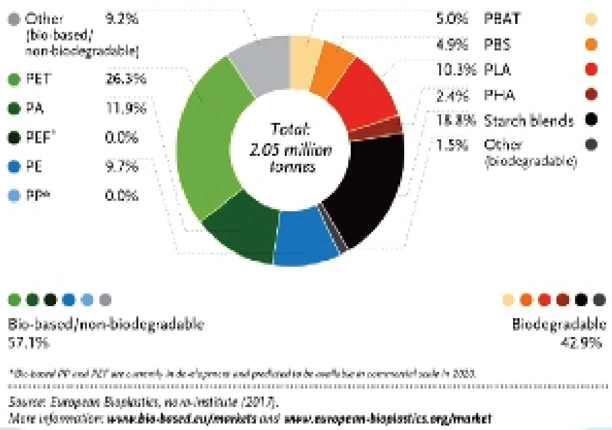


Fig. 1. Global production capacities of bioplastics in 2017 (by material type)

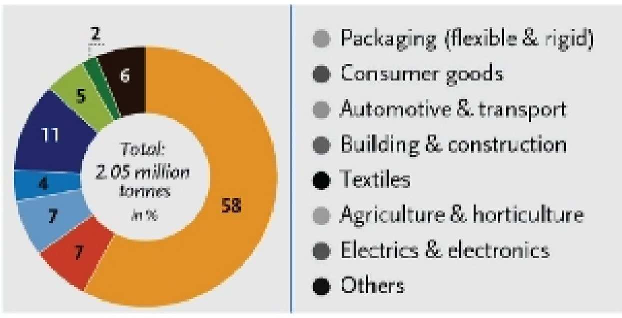


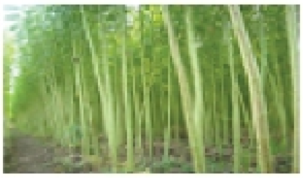
Fig.2. Global production capacities of bioplastics in 2017 (by market segment)

Bioplastics are used in an increasing number of markets, from packaging, catering products, consumer electronics, automotive, agriculture/horticulture and toys to textiles and a number of other segments. Packaging remains the largest field of application for bioplastics with almost 60 percent (1.2 million tonnes) of the total bioplastics market in 2017. Industrial uses of natural fibers increasingly gain attention from various manufacturing sectors. The use of natural fibers for polymer composites is growing rapidly to meet diverse end uses in transportation, low cost building, and other construction industries (Hao et al., 2013). Qualities of natural fibers are strongly influenced by growing environment, age of plant, species, temperature, humidity, and quality of soil. Various fields where natural fibers can be employed are: structural composites, automobile, non-structural composites, geotextiles, packaging, molded products, sorbents, filters, and in combinations with other materials. Apart from the plant-based fibers become other alternatives for producing biodegradable, biomedical and bio-resorbable composite materials for bioengineering and orthopaedic applications.

LIGNOCELLULOSIC FIBRES

Natural fiber is a type of renewable sources and a new generation of reinforcements and supplements for polymer based materials. The development of natural fiber composite materials or environmentally friendly composites has been a hot topic recently due to the increasing environmental awareness. Natural fibers are one such proficient material which replaces the synthetic materials and its related products for the less weight and energy conservation applications. The application of natural fiber reinforced polymer composites and natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials in huge.

Kenaf (*Hibiscus cannabinus* L. family Malvacea) has been found to be an important source of fiber for composites,and other industrial applications. Kenaf is well known as a cellulosic source with both economic and ecological advantages; in 3 month (after sowing the seeds), it is able to grow under a wide range of weather conditions, to a height of more than 3 m and a base diameter of 3 - 5 cm. The kenaf plant is composed of many useful components (e.g., stalks, leaves, and seeds) and within each of these there are various usable portions (e.g., fibers and fiber strands, proteins, oils, and allelopathic chemicals). The yield and composition of these plant components can be affected by many factors, including cultivar, planting date, photosensitivity, length of growing season, plant populations, and plant maturity. Kenaf filaments consist of discrete individual fibers, of generally 2 - 6 mm (Akil et al.,2011). Kenaf is presently being used in paper production on a very limited basis. Various uses of the bast fibers have been explored, such as in the making of industrial socks to absorb oil spills, as well as making woven and non-woven textiles. The kenaf bast fiber is known to have the potential as a reinforcing fiber in thermoplastic composites, because of its superior toughness and high aspect ratio in comparison to other fibers.



Kenaf Tree

Bast Kenaf Fibres

Oil palm (Elaeis guineensis Jacq.) is the highest yielding edible oil crop in the world. It is cultivated in 42 countries in 11 million ha worldwide. West Africa, South East Asian countries like Malaysia and Indonesia, Latin American countries and India are the major oil palm cultivating countries (Shinoj et al., 2011). Oil palm is the largest and important plantation crop in Malaysia. The oil palm trees generally could last between 25-30 years before the next replantation needs to be done. With this replantation cycle, the huge amount of available biomass is available and not being fully utilized and normally left to rot naturally. This readily available renewable resource could be used as a raw material for wood based industry. Empty Fruit Bunch (EFB) is one of the oil palm biomass material. The EFB amounting to 12.4 million t year−1 (fresh weight) and regularly discharged from oil palm refineries (Abdul Khalil et al., 2006). It is a lignocellulosic material and has potential as the natural fibre resource. Moisture content of fresh EFB is very high, about over 60% on a wet EFB basis. As EFB is readily available and abundance in Malaysia, converting them into composite boards can be a way to resolve the scarcity of wood sources.

Oil Palm Tree

Bamboo Fibres

APPLICATION OF LIGNOCELLULOSIC IN INDUSTRY

Automatives part

Natural fibers reinforced composites are emerging very rapidly as the potential substitute to the metal or ceramic based materials in applications that also include automotive, aerospace, marine, sporting goods and electronic industries (Thakur and Thakur, 2014). Natural fiber composites exhibit good specific properties, but there is high variability in their properties. Their weakness can and will be overcome with the development of more advanced processing of natural fiber and their composites. Their individual properties should be a solid base to generate new applications and opportunities for biocomposites or natural fiber composites in the 21st century "green" materials environment. The exploitation of natural fiber composites in various applications has opened up new avenues for both academicians as well as industries to manufacture a sustainable module for future application of natural fiber composites (Gurunathan et al., 2015).

The automobile industry is successfully applying composites reinforced with a variety of natural fiber to replace components such as interior panels and seat cushions originally made of glass mat PMC or polymeric foams (Monteiro et al., 2009). Many automotive components are already produced with natural composites, mainly based on polyester or Polypropylene and fibers like flax, hemp, or sisal. The adoption of natural fiber composites in this industry is led by motives of price, weight reduction, and marketing rather than technical demands (Saravan and Mohar, 2010). Germany is a eader in the use of natural fiber composites. The Germanauto-manufacturers, Mercedes, BMW, Audi and Volkswagen have taken the initiative to introduce natural fiber composites for interior and exterior applications.(Sanjay) The automobile industry is successfully applying composites reinforced with a variety of natural fiber to replace components such as interior panels and seat cushions originally made of glass mat PMC or polymeric foams (Monteiro et al., 2009).


Interior part: Dashboard


Interior part: Door frame

Wood Plastic Composites (WPC)

Thermoplastic green composites can be obtained only with limited fiber loading (maximum 50%w/w). This is due to techniques available for thermoplastic composite manufacturing that hinder good fiber dispersion in a high viscosity matrix when the fiber content is higher than 50%. Interestingly, thermoplastic green composites can be processed by means of the standard and economic equipments used for plastic manufacturing such as compounding and injection molding. However, these techniques have the limitation that only relatively short fibers (which impart limited reinforcing effect) can be used. If longer fibers are to be included, compression molding methods need to be used. In the automotive industry, for example, long natural fibers are generally mingled together with fibers of the thermoplastic polymer to form a nonwoven fleece, which is subsequently hot pressed in order to promote melting of the thermoplastic fibers (Fowler et al., 2006).

Food Packaging

Packaging is currently at the centre of intensive research among scientists concerning new technologies that include the development of environmental friendly packaging materials that interact well with foods in terms of preservation. To provide a positive impact on consumer health, the packaging is designed by integrating functional ingredients in the structure of the packaging with the packed food products (Chen, 2014). New developments in packaging technology have been fuelled by developments in materials engineering, electronics and processing technology which involve some key areas including high barrier materials, active packaging, intelligent packaging, nanotechnology, tagging applications and digital print for packaging that are important for the growth of packaging industry (Nomikos, 2005). Most challenging aspect of packaging research is to develop and promote the use of renewable and biodegradable "bio-plastic" which can commercially replace petroleum based plastics and thus help in reducing waste disposal problem. However, biopolymers based packaging has relatively poor mechanical and barrier properties than non-biodegradable counterparts which currently limit their industrial use.

Although extensive research is being undertaken, the nanotechnology approach for packaging applications is still in the development stage. The main focus is to examine the complete lifecycle of the packaging (raw material selection, production, analysis of interaction with food, use and disposal) while integrating and balancing cost, performance and impact on health and environment. Cellulose nanofibre has been considered as a remarkable engineering material because of its high abundance, low weight, high strength, stiffness and biodegradability (Khalil, 2014). The use of cellulose nanofibre adequately enhanced the mechanical and barrier properties of cellulosic fibre based products (e.g., papers, biocomposites). Cellulose nanofibres are derived from natural resources (wood or plant) thus they are almost inexhaustible, renewable and globally abundant (Kalia, 2011). Studies have demonstrated that the use of nanocellulosic based materials as reinfor-cing elements in various bio-based polymeric composites enhanced the mechanical and functional properties of the composite, such as their biodegradability, transparency, gas barrier properties,specific surface area and heat stability (Li, 2014). Beside improvement in properties of food packaging nanomaterials will also prevent the invasion of bacteria and microbes into packed food products through packaging. Polymers with cellulosic fibre/ nanoclay based hybrid materials would provide high barrier, short life, easy disposal and environmentally compatible properties for food packaging materials.

CONCLUSION

Natural fibers are one such proficient material which replaces the synthetic materials and its related products for the less weight and energy conservation applications. The application of natural fiber reinforced polymer composites and natural-based resins for replacing existing synthetic polymer or glass fiber reinforced materials in huge. Cellulose nanofibre neither interferes with the human food chain nor uses petrochemical components for its functionality. Therefore, nanocellulosic fibres have been utilized in a wide range of applications. Packaging sector could be one of the area were cellulose nanofibres can be used for sustainable and green packaging.

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NANO ZINC OXIDE IN PAPER-BASED PRODUCTS

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INTRODUCTION

Zinc oxide having chemical formula, ZnO is a type of inorganic mineral that exists as white powder form and insoluble to water. It has pH 6.95 which cause bitter in taste and high melting point up to 1,975°C. This is the reason of its suitability to be applied in ceramics and electronics products recently. Zinc oxide is a common commercial substance in pharmaceutical industries in instance first-aid tapes and calamine cream for the purpose to treat skin condition problem (rashes and wound) (National Center for Biotechnology Information (NCBI), 2005). The occupation of zinc-oxide at industrial scales production also involved rubber, cosmetics, textile, electronics and electrotechnology, photocatalysis, biosensor and production of zinc silicates as exhibited in Figure 1.

Zinc oxide is eminent as a multi-functional mineral due to its chemical and biological characteristics by having high chemical stability, high photostability, wide range of radiation absorption and high electrochemical coupling coefficient (Segets et al., 2009; Lou et al., 1991). Currently, industries and researchers acquire higher attention in advancing nano-zinc oxide that has been treated as amongst promising nanomaterials owing its unique characteristics such as antimicrobial, photocatalytic, electro conductivity and ultraviolet protection (Kolodziejczak-Radzimska & Jesionowski, 2014)

Researcher has studied the effectiveness of zinc oxide to the extent of nano-sized particles in various products. In obvious research case, nano-zinc can be employed in

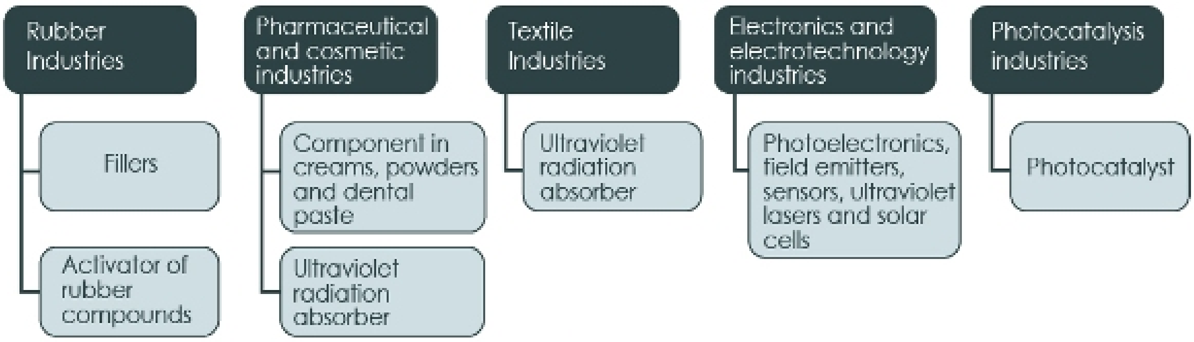

Fig. 1. The application of zinc oxide in industries (Kolodziejczak-Radzimska & Jesionowski, 2014)

treating effluent to reduce microbial load (Nagarajan & Kuppusamy, 2013). As for paper-based application, researcher investigated that nano-zinc oxide coated paper has exhibited higher quality printing paper (Prassad et al. 2010). In addition, the paper brought along the ability of absorbing ultraviolet which can avoid induction of ultraviolet degradation beneath it. A study by Jaisai et al., (2012) also consuming nano-zinc oxide that are grown on paper via hydrothermal method and has shown good antimicrobial activity against Escherichia coli and Staphylococcus aureus. The potential of the antimicrobial paper to inhibit microbes is enhanced by its photocatalysis properties as shown by Baruah et al., (2010) with immobilization of E. coli under visible-light irradiation.

Looking at nano-zinc performance in various application via research and industries persepective therefore it is being treated as amongst promising nanomaterials owing to its unique properties such as antimicrobial substance. This is due to smaller size of zinc oxide particles that can provide larger surface areas to work more efficient. Environmental Working Group (EWG) (2018) applied nano-zinc oxide in their sunscreens product to formulate less white chalky lotion and greater sun protection factor. Besides, the nano-sized zinc oxide is transparent in visible light which make it suitable in certain products like textile, pharmaceutical and cosmetics (DaNa, 2013).

In papermaking area, there are 2 types of nano-zinc oxide preparation which consist of chemical and biological methodologies. According to Jaisai et al. (2012), nano-zinc oxide that have been hydrothermally-synthesized achieved 250-300 nm and 3,400-4,200 nm in width and length respectively. Catalyst like gold plays important role in defining the nanowires zinc oxide diameter by directing its growth as long as the catalyst remains in liquid state with reactant. Sublimation of zinc oxide powder without catalyst produced nanobelt zinc oxide with typical width for entire length 50-300 nm and 10-30 nm thickness (Wang, 2004). Biological preparation method involves bio-resources and few chemicals as precursor or solvents for extraction process. Plants, algae and fungi are some example of the sources that can be utilized to initiate the growth of nano-zinc oxide. Sutradhar & Saha (2015) used green tea leaf as reducing and stabilizing agent for zinc oxide nanoparticles under microwave irradiation. Nano-zinc oxide can be varied in size and shape for example the sol-gel method with solution-based approach studied by Srivastava, et al., (2013), produced rod-shape zinc oxide nanoparticles in range of 17-50 nm via Transmission Electron Microscopy (TEM).

Nano-zinc oxide has become promising in nanomaterials industries because of its functional properties which can be applied as antiseptic and anti-inflammation due to its antimicrobial property as stated by Prasad et al., (2010). The researchers investigated that no fungal growth was noticed on nano-zinc oxide coated paper while base paper was completely degraded by fungus. Exhibiting strong visible fluorescene was excited by ultraviolet corresponds to wide band gap emission of nano-zinc oxide which makes it good ultraviolet absorber. Photocatalytic activity of nanorods zinc oxide paper studied by Baruah et al., (2010) showed high percentage of photodegradation for methylene blue and methyl orange, and also nominal decrease of efficiency though after several times usage. Sobri et al. (2018) found out that zinc-oxide particles can be produced via in-situ synthesis by using hydrothermal methods which may allow the generation of nano-zinc particles amount and shape that contributes to its characteristics.

In addition, there are few established paper-based products in the market which could provide brighter future for modified nano-zinc oxide paper. The company namely as Paper Products Company (2015) focused on the sanitary and food packaging items. The food packaging items include paper bowls, boxes for cake and pizza, paper cups, paper plates, and facial tissue. Similar to Eco Carton (2016), wide range of food and beverages paper-based packaging has been produced in Malaysia. Being popular for its antimicrobial activity, Wallsauce (2019) has intended to use such particles for wall paper which possible to reduce breeding and minimize spreading of bacteria and mould in moisture and indoor environment respectively. Such paper may be applied for safe and artsy wall for hotels, health institution and even for home and work places. This property could also benefit in health care paper-based products such as face mask, tissue paper and paper for printing and writing bringing along antimicrobial characteristics.

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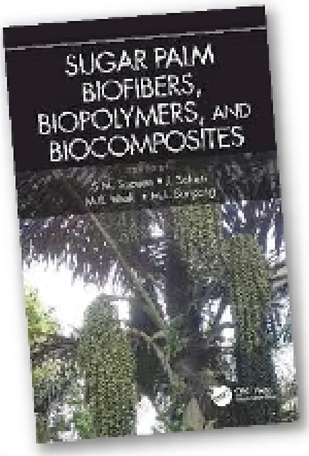
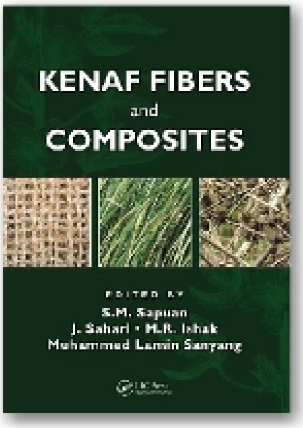
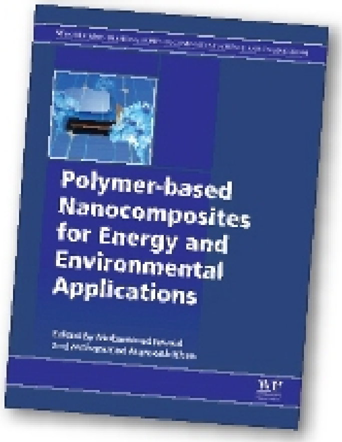
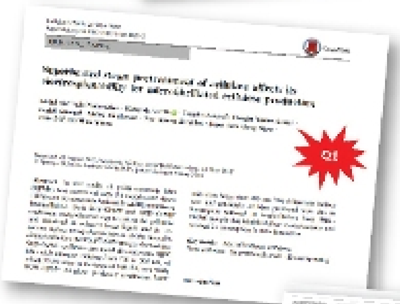
ACHIEVEMENTS 2018

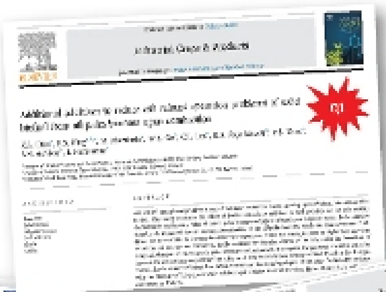
NO	ITEM	ACHIEVEMENTS
1	Publications in CIJ • Journals • Conference and proceeding	 154 (Q1+Q2=85) 26
2	Publications in Others Journals	12
3	Research books • Books • Chapter in books	 10 17
4	Research Grant • Public • Private • International	 RM423,289 RM141,319 RM740,000
5	Innovation • Paten filed • Others IP	 - 3

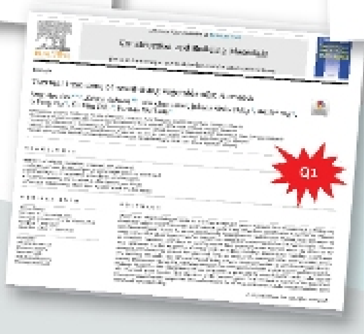












STUDENTS GRADUATED IN 2018

DOCTOR OF PHILOSOPHY

Name : Syeed SaifulAzry Osman Al-Edrus
Matrix No : GS33307
Field of Study : Biocomposite Technology
Thesis Title : Mirco and Nanocrystalline Cellulose Fibre-Reinforced Jatropha Oil-Based Polyurethane Composite Films
Supervisor : Prof. Dr. Luqman Chuah Abdullah

Name : Atiqah Mohd Afdzaluddin
Matrix No : GS44807
Field of Study : Biocomposite Technology and Design
Thesis Title : Properties of Sugar Palm/Glass Fibre-Reinforced Thermoplastic Polyurethane Composites
Supervisor : Prof. Ir. Dr. Mohd Sapuan Salit

Name : Siti Hasnah Kamarudin
Matrix No : GS38064
Field of Study : Nature Tourism
Thesis Title : Development of Kenaf Fibre Poly(Lactic Acid)-Epoxidised Jatropha Oil Biocomposites
Supervisor : Prof. Dr. Luqman Chuah Abdullah

Name : Aida Adnan
Matrix No : GS20878
Field of Study : Biocomposite Technology
Thesis Title : Factors Motivating the Chain of Custody Certification of Malaysian Plywood Mills, Their Certification Cost Components and the Establishment of Property Cost Index for Evaluating Potential Use of Oil Palm Stem as an Alternative Fibre Material
Supervisor : Prof. Dr. Paridah Md Tahir

Name : Zahra Dashtizadeh
Matrix No : GS37600
Field of Study : Biocomposite Technology
Thesis Title : Development and Characterization of Recycled Carbon-Kenaf Filled Cardinol Hybrid Composite
Supervisor : Assoc. Prof. Dr. Khalina Abdan

Name : Tengku Arisyah Tengku Yasim Anuar
Matrix No : GS42494
Field of Study : Materials Science
Thesis Title : Isolation of Cellulose Nanofibers From Oil Palm Mesocarp Fiber and Their Utilization as Reinforcement Material in Low Density Polyethylene Composites
Supervisor : Assoc. Prof. Dr. Hidayah Ariffin

STUDENTS GRADUATED IN 2018

MASTER

Name : Cindy Usun Sigau
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Thesis Title : Potential of Treated Sewage Sludge as an Organic Fertilizer and Assessing Phytoremediation Capablity of Jarak *(Ricinus communis)*
Supervisor : Prof. Dato' Dr. Nik Muhamad Nik Majid

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Supervisor : Dr. Mahnaz M. Abdi

Name : Naziratulasikin Abu Kassim
Matrix No : GS32671
Field of Study : Pulp and Paper Technology
Thesis Title : Effect of Maceration Time on the Characteristics of Acid-Hydrolyzed Cellulose from Pineapple Leaf
Supervisor : Assoc. Prof. Dr. Edi Syams Zainudin

1ST INTERNATIONAL CONFERENCE ON SAFE BIODEGRADABLE PACKAGING TECHNOLOGY (SAFEBIOPACK2018)

Date : 24 - 26 July 2018
Venue : MiGHT Partnership Hub, Cyberjaya, Selangor

The 1st International Conference of Safe Biodegradable Packaging (SafeBioPack2018) was successfully held in MiGHT Partnership Hub, Cyberjaya, Selangor. During the conference, two days were allocated for parallel oral session and the last day was spent for technical visit at Parkside Flexibles Ltd. Shah Alam, Selangor. It was co-organized with Malaysia Institute of Transport (MITRANS) Universiti Teknologi MARA (UiTM), Parkside Flexibles Ltd., TESCO, Bangor University, Polycomposites (M) Sdn. Bhd., Scitech Adhesives Coatings, Nextek Ltd. and Eco Premium Packaging (M) Sdn. Bhd. SafeBioPack2018 was supported by Malaysian Industry-Government Group for High Technology (MiGHT), Newton-Ungku Omar Fund, Research Councils UK and Innovate UK. The theme of this conference was 'Waste to Wealth' which firstly focused on the utilization of biomass residues such as agricultural waste in manufacturing various products dedicated on safe and biodegradable packaging.

The conference also aims to provide a platform to discuss and share information regarding food packaging technology. SafeBioPack2018 has gathered an amount of 80 experts from around the world such as United Kingdom, India, Australia, Morocco, Saudi Arabia, Chile, Tunisia and Malaysia in order to share ideas and experiences.

DECLARATION OF INTENT (DOI) SIGNING CEREMONY BETWEEN UPM AND HUG PROJECTS

Date : 20 August 2018
Venue : Putra Gallery, UPM

The signing of the DoI is going to be the first step in the cooperation to initiate the AMEES (Associating Media in Education for Environmental Sustainability) programme which serves as an educational and research programme by associating media in education to convey environmental sustainability awareness to its primary and secondary stakeholders. The DoI of cooperation between UPM and HUG projects was signed by Vice Chancellor of UPM, Prof. Datin Paduka Dato' Dr. Aini Ideris, and HUG Projects Founder, Mr. Mark Lee See Teck. The signing was witnessed by Director of INTROP, Prof. Dr. Ahmad Ainuddin Nuruddin and Ambassador of HUG Projects, Mr. Steve Yap Leong Chai.

UPM Vice Chancellor, Prof. Datin Paduka Dato' Dr. Aini Ideris said that developing countries in Asia are now setting up new role models and practices to promote research, education and cooperation in the area of environmental conservation and sustainability. According to Mark Lee See Teck, Founder of HUG Projects, Environmental Awareness Films able to paint pictures of everything that is wrong in the world, the problems that planet earth facing and how it is possible to make the world a better place to live in for future generations.

INTERNATIONAL TROPICAL ARBORICULTURE CONFERENCE 2018 (INTACKL2018)

Date : 25 - 27 September 2018
Venue : Sunway Hotel Kuala Lumpur

International Tropical Arboriculture Conference (INTACKL2018) has been organized by Persatuan Arborist Malaysia (PArM) while Institute of Tropical Forestry and Forest Products (INTROP) was the co-organizer for this international conference. INTACKL2018 has been officiated by YBM Senator Dato' Raja Kamarul Bahrin Shah Ibni Raja Ahmad Baharuddin Shah, Deputy Minister at Ministry of Housing and Local Government. INTAC KL 2018 with the theme of Urban Trees: Safety, Resiliency & Sustainability serve as a forum for like-minded stakeholders to discuss, deliberate and share knowledge on the issues of managing tropical trees in urban areas within the context of their sustenance and the benefits while keeping them safe and healthy. The objectives of this conference were to provide opportunities for networking and collaboration among stakeholders in tropical arboriculture, to provide an avenue for a better understanding of functions and benefits of urban trees towards ensuring and to propose resolution(s) for formulation of national policy related to the improvement of arboriculture industry in Malaysia.

TRAINING ON FLAMMABILITY TESTING

Date : 10 October 2019 (Wednesday)
Venue : INTROP, UPM

Laboratory of Biocomposite Technology, INTROP, UPM has organized a training on flammability testing. The equipment involved is this workshop were Limiting Oxygen Index and UL94 Chamber. The training was conducted by GT Instruments Sdn. Bhd.

INTROP HOODING CEREMONY

Date : 26 Octpber 2018
Venue : INTROP, UPM

INTROP Hooding Ceremony is a special recognition for graduates who receiving a master's degree and a Ph.D. All candidates are individually recognized at the Hooding Ceremony. They received their hood from their main supervisor. As for 2018, 11 students were graduated (6 Ph.Ds and 5 Masters) and 2 of them have attained GOT (Graduate on Time) title.



MOU SIGNING CEREMONY BETWEEN UNIVERSITI PUTRA MALAYSIA AND BORNEO FORESTRY COOPERATIVE

Date : 3 December 2018
Venue : Putra Gallery, UPM

MoU signing ceremony between Universiti Putra Malaysia (UPM) and Borneo Forestry Cooperative (BFC) was officiated by Deputy Vice Chancellor Research and Innovation, Prof. Dr. Zulkifli Idrus and the MoU were signed by the Chairman of BFC, Mr. David Boden in the presence of Director of BFC Research and Development Sdn. Bhd., Mr. Hattah Jaafar. Meanwhile, on behalf of UPM, the MoU were signed by Vice Chancellor of UPM, Prof. Datin Paduka Dato' Aini Ideris, in the presence of Director of INTROP, Prof. Dr. Ahmad Ainuddin Nuruddin. The areas of cooperation between both parties includes joint research project in tropical forestry plantation; development of academic status among UPM and BFC staffs and students; jointly organize of workshop, lecture, seminar and conference and other cooperation to be mutually agreed upon by the parties.


EQUIPMENT/SERVICES AVAILABLE AT INTROP (LABORATORY OF BIORESOURCE MANAGEMENT)

No	Equipment/Services	Function	Person In charge	Contact No
1	Portable Soil Moisture	To measure soil moisture and soil temperature	Mr. Mohd Hambali Mohd Jailani	03-9769 1898
2	Gel Documentation System	To record and measure labeled nucleic acid and protein in various types of media such as agarose, acrylamide or cellulose	Mdm. Intan Suraya Ibrahim	03-9769 8424
3	Autoclave	To sterilize materials/samples	Mdm. Intan Suraya Ibrahim	03-9769 8424
4	PCR	To amplify, or copy, a specific DNA target from a mixture of DNA molecules	Mdm. Intan Suraya Ibrahim	03-9769 8424
5	Plant Nursery (900 sq ft)	For plant propagation and growth of seedlings at early stage	Mr. Mohd Hambali Mohd Jailani	03-9769 1898
6	Control Environment System (1200 sq ft)	To control and shield crops from extreme weather, mostly for research purposes	Mr. Mohd Hambali Mohd Jailani	03-9769 1898


Portable Soil Moisture


Gel Documentation System


Autoclave


PCR

Control Environment System (1200 sq ft)


Plant Nursery (900 sq ft)

Plant Nursery (900 sq ft)

We are selling forest trees, landscape trees and fruit trees. The lists as per below:

	Forest Trees
1	Meranti tembaga *(Shorea leprosula)*
2	Meranti langgong *(Shorea lepidota)*
3	Balau laut *(Shorea glauca)*
4	Chengal *(Neobalanocarpus heimii)*
5	Resak laru *(Valica pauciflora)*
6	*Kapur (Dryobalanops aromatica)*
7	Merawan siput jantan *(Hopea odorata)*
8	Belian *(Eusideroxylon zwageri)*

	Landscape Trees
1	Pogamia (Pogamia pinnata)
2	Kelat paya (Syzygium myrtifolium)
3	Tulang Daing (Calerya artopurpurea)
4	Ashoka (Polyalthia longifolia)
5	Doa (Terminalia mantaly)
6	Manggis jepun (Garcinia elliptica)
7	Bunga tanjung (Mimusops elengi)

	Forest Trees
1	Mulberi *(Morus australis)*
2	Mentega *(Diospyros discolor)*
3	Lemon *(Citrus limon)*
4	Kuning telur *(Pouteria campechiana)*
5	Asam gelugor *(Garcinia atroviridis)*
6	Binjai *(Mangifera caesia)*
7	Terap Borneo *(Artocarpus odoratissimus)*
8	Nangka *(Artocarpus heterophyllus)*
9	Nona *(Annona reticulata)*

	Fig Trees
1	Barjousotte noire
2	Purple jordan
3	BK 2
4	Super Jumbo Long
5	Masui Dauphine

EQUIPMENT/SERVICES AVAILABLE AT INTROP (LABORATORY OF BIOCOMPOSITE)

No	Equipment	Application	Person In charge	Contact No
1	BRABENDER Internal Mixer	To melt-mix polymer samples with natural/synthetic fillers at low volume.	Ms. Ana Salleza Md. Salleh	03-9769 1885
2	Thermoplastic Compression Moulding (40 tonne)	To melt compress plastic/composite samples at low pressure.	Ms. Ana Salleza Md. Salleh	03-9769 1885
3	Hot Press (100 tonne)	To compress wood/composite samples at high pressure.	Ms. Ana Salleza Md. Salleh	03-9769 1885
4	Twin Screw Extruder	To melt-mix polymer samples with natural/synthetic fillers at high volume.	Ms. Ana Salleza Md. Salleh	03-9769 1885
5	Various chipper and milling machines	To chip and grind wood and fiber sample	Ms. Ana Salleza Md. Salleh	03-9769 1885
6	Injection Moulding	To inject polymer/composite samples into a mould cavity.	Ms. Ana Salleza Md. Salleh	03-9769 1885
7	Universal Testing Machine (UTM) (30 kN)	To determine tensile/flexural properties of polymer/composite samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
8	Thermal Gravimetric Analyzer (TGA)	To determine thermal decomposition of samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
9	Differential Scanning Calorimeter (DSC)	To determine thermal behaviours of samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
10	Dynamic Mechanical Analyzer (DMA)	To determine mechanical-thermal properties of samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
11	Thermal Mechanical Analyzer (TMA)	To determine thermal-mechanical behaviours of samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
12	Dynamic Mechanical Analyzer (DMA)	To determine impact properties of polymer/composite samples.	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
13	Digital Image Analyzer	To visualize fibre/composite sample at low magnification (40x).	Mr. Mohd Lutfi Mohd Tawil	03-9769 9615
14	Freezer Mill / Cryocrusher (excluding liquid nitrogen)	To crush leaf/fibre samples via cryogenic process.	Ms. Ana Salleza Md. Salleh	03-9769 1885

Universal Testing Machine

OSB Resin Mixer

Injection Moulding Machine

Optical Microscope

Compression Moulding Machine

EQUIPMENT/SERVICES AVAILABLE AT INTROP (LABORATORY OF BIOPOLYMER AND DEVIVATIVES)

No	Equipment	Application	Person In charge	Contact No
1	Gas Chromatography Mass Spectrometry (GCMS)	Characterization of sample in components in samples (e.g: fatty acids, organic acids, biodiesel (FAME)	Mdm. Nor Azizah Haron	03-9769 1887
2	Pulp Digester	To convert wood/non-wood into pulp	Mdm. Nazlia Girun	03-9769 7009
3	Papermaking instruments (handsheet former)	To convert pulp into paper/board	Mdm. Nazlia Girun	03-9769 7009
4	Beater (PFI mill)	To beat pulp	Mdm. Nazlia Girun	03-9769 7009
5	Pulp Viscometer	To find the viscosity of pulp	Mdm. Nazlia Girun	03-9769 7009
6	Paper/board tensile machine	To find the strength of paper/paperboard	Mdm. Nazlia Girun	03-9769 7009
7	Chemical compositional analysis	To measure the composition of cellulose, hemicellulose and lignin	Mdm. Nazlia Girun	03-9769 7009
8	Scanning Electron Microscope (SEM)	To get an image which describe the surface of material	Mdm. Nazlia Girun	03-9769 7009


Beater (PFI Mill)


Canadian Standard Feeness


Disintegrator

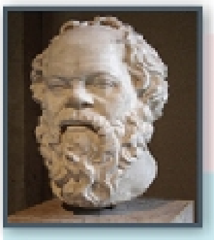

Pulp Viscometer


Handsheet Former

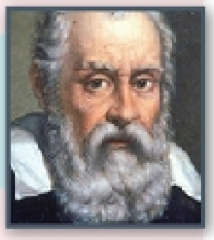

Gas Chromatography Mass Spectrometry (GCMS)

Scanning Electron Microscope (SEM)

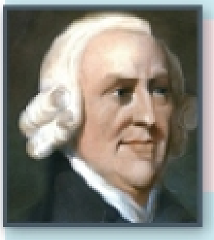
BRILLIANT SCIENTIST QUOTES



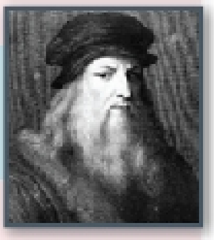
True knowledge exists in knowing that you know nothing.
Socrates, 470 – 399 BC
Philosopher



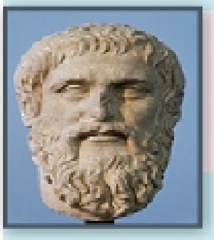
You cannot teach a man anything; you can only help him discover it in himself.
Galileo Galilei, 1564-1642
Astronomer



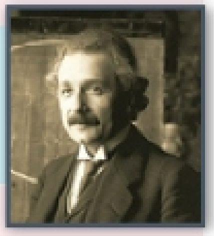
Science is the great antidote to the poison of enthusiasm and superstition.
Adam Smith, 1723-1790
Economist



Learning never exhausts the mind.
Leonardo da Vinci, 1452-1519
Polymath

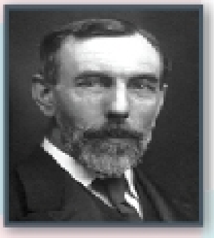


True courage is knowing what not to fear.
Plato, 424 – 348 BC
Philosopher

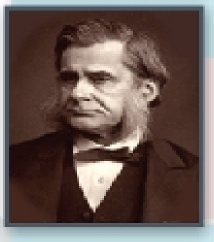


The important thing is not to stop questioning. Curiosity has its own reason for existing.
Albert Einstein, 1879-1955
Theoretical physicist

Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less.
Marie Curie, 1867-1934
Physicist and chemist



Progress is made by trial and failure; the failures are generally a hundred times more numerous than the successes; yet they are usually left unchronicled.
William Ramsay, 1852-1916
Chemist



The great tragedy of science - the slaying of a beautiful hypothesis by an ugly fact.
Thomas Huxley, 1825-1895
Biologiest

The good thing about science is that it's true whether or not you believe in it.
Neil deGrasse Tyson, 1958
Astrophysicist

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