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GREEN COMPOSITE
100% NATURAL MATERIALS

FROM CHIEF EDITOR

Fully biodegradable biopolymer composites are composites made from 100% biobased materials; the fibres are natural fibres and the matrices are biopolymers. The issues of petroleum resource depletion and environmental problems associated with plastic disposal had encouraged the use of the 100% biobased composites. However, to achieve this aim, there are various measures that have to be considered such as the use of these materials for structural and semi-structural components not simply on non-structural components and products. It is understood generally these composite materials are inferior in many respects particular in terms of strength and stiffness. Because of these, use of fullybiodegradable biopolymer composites is mainly centred in the packaging industry. However, it is not the excuse for us for not exploring beyond the norms. it should be borne in mind among the first car developed by Ford was made from fully biodegradable biopolymer composites; where the matrices were made from soya biopolymers and the fibre reinforcements were made from hemp fibres. The legacy of Ford should be continued and INTROP has the opportunity the venture into this. By the way, biopolymers generally used in such biocomposites can be obtained from i. plant and animal-based biomaterials like poly lactic acid (PLA) (e.g., from corn), and starch (e.g., arrowroot, soya), ii. from the mixture of petroleum and biomaterials (e.g., polybutylene succinate) (PBS) and iii. from petroleum such as bio-epoxy. At INTROP, natural fibres had been the main focus of the research since its inception. These fibres were often combined with either synthetic or biopolymers to form biocomposites. Natural fibres were used in different forms such as continuous fibres, woven fabrics, chopped fibres, particulates, and in the forms of micro and nanocelluloses. The innovation in material design has enabled the research on sandwich biocomposite structures, laminated biocomposites, biomimetics for biocomposite design concept generation, hybrid biocomposites, natural fibre metal composites and functionally graded biocomposite structures. The recent focus of INTROP is on the research and innovation principally in three main fibres i.e. kenaf, oil palm and bamboo. It is highlighted to be in line with the requirement of the HICoE in Tropical Wood and Fibres set by Ministry of Higher Education. However, research and exploration in other types of fibres such as sugar palm, arrowroot, cassava, corn, pineapple leaf, coconut, roselle, sugarcane, and are rice husk are considered to be the value addition.

With the aim of achieving practical exploration in fully biodegradable biopolymer composites, effort has been geared to develop these biocomposites beyond the packaging industry, biocomposite films and utilizing solution casting fabrication process. A recent work is directed toward the fabrication furniture from these biocomposites, using kenaf fibres and PLA biopolymers, which are understood to demonstrate sufficient properties compared to synthetic biopolymer counterpart for such component. In this connection, research on the optimum formulation of fibres and matrices and characterization of biocomposites, moulding and fabrication technology, life cycle assessment (LCA), hybridization, and computer aided design (CAD) and analysis are considered essential. Solving real industrial problems are the major focus of this kind of research.

The importance of product design, development and commercialization of biocomposite products cannot be underestimated. In the past, INTROP had successfully commercialized different products and one of them was Putra Frame. These frames were used for displaying certificates and photographs and we fabricated them in house using injection moulding and had attracted the attention of different customers. The frames were made of kenaf core fibres and high-density polyethylene (HDPE) composites. However, since HDPE is a synthetic polymer, and not a biodegradable material, it is hoped, future commercialization effort will be focussing on the use of natural fibres in biopolymer composites, i.e. fully biodegradable composites.

APPLICATION OF NATURAL FIBRE COMPOSITES

By
S.F.K. Sherwani[1] and S.M. Sapuan[1,2]
[1]Advanced Engineering Materials and Composites Research Centre (AEMC), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor
Laboratory of Biocomposite Technology
[1,2] Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor

Natural fibers are obtained from natural plants such as sugar palm, kenaf, flax, and bast which are extracted from their plants, stems, leaves or any part thereof which are classified as an eco-friendly material due its biodegradability and abundance. New natural fibers based composite are progressively developed and successfully introduced as body covering parts for motorcycle [1] [1]. The natural fibers Sisal *(Agave sisalana)*, Banana *(Musa sepientum)* and Roselle *(Hibiscus sabdariffa)* were used for fabricating a rear view mirror, visor in two wheeler, billion seat cover, indicator cover, cover L-side by hand layup method as shown in Fig. 1. [2]. G. S. Kumar [3] was focused on the used of sisal plant fibers as reinforced in epoxy resin for fabricating Motorcycle Mudguard. The wooden dies were used for making the pattern of this mudguard as shown in Fig. 2 (a) and (b). S-Sisal, R-Ramie and P-Pineapple Natural fibers were used in fabricating of Motorcycle mudguard again by hand lay-up method as shown in Fig. 3 [4]. Different laminates of these composites were tested and concludes that PSRS were the excellent laminate having the tensile strength of 24.43MPa and the compression load of 0.32KN. By simple hand lay-up technique, the carbon fiber reinforced epoxy composite was used to fabricate the side-part and mudguard of motorcycles shown in Fig. 2 (c) [5].

Fig. 1. Motorcycle covering part [2]

(a) (b) (c)

Fig. 2 (a) Wooden Mould and
(b) Composite Mudguard produced by Wooden mould [3]
(c) Carbon fiber composite finished Mudguard [5]

Fig. 3 Natural fiber fabricated Motorcycle Mudguard [4]

For manufacturing motorcycle brake pad, S. A. Bahari [6] uses Cocos nucifera husk particle (CHP) or Cocopeat as filler in polymer composite. The abrasive material used for making brake pad has the value of coefficient of friction in between 0.316 to 0.374 and also withstand at high temperature may be from 2000C to 8000C. Y. Sukrawan [7]replace asbestos material with bamboo fiber composite material. I. Rogacki [8] has developed a single frame of scooter which consists of steering system, seat, drive system and suspension in the structure as shown in Fig. 4 (a). The material used for making such a frame was epoxy carbon laminates (CFRP) material. The designing frame was established in such a manner that not only strength or durability improves but it functions properly. Fig. 4 (b) shows Motorcycle Apparel which was made from Kevlar® Fiber, This fabric was reinforced protective. This Apparel was comfortable, safer, protective as well as durable. DupontTM Kevlar® Fiber also makes other fittings, gloves, jackets, and pants [9].

4 (a) 4 (b)

Fig. 4 (a) Frame of Pneumatic Scooter [8]
Fig. 4 (b) Motorcycle Apparel which was made up of Kevlar® Fiber [9]

Natural fibers have used in the automotive industries for several decades, their application were not widespread due to some material property deficiencies. Natural fibers have inconsistent quality, a hydrophilic character, manufacturing temperature limitations and bonding issues with polymers. These problems diminish the desirability of natural fibers for use in automotive structural components. Numerous attempts have made to improve the mechanical properties of natural fibers. Modifying the reinforcement material, the resin material and the manufacturing process are the main methods to improve the deficiencies.

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Author:
Prof. Ir. Dr. Mohd Sapuan Salit
Head of Laboratory
Biocomposite Technology
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
Email: sapuan@upm.edu.my

THE IMPORTANCE OF INTERFACIAL ADHESION CONDITION AND VACUUM INFUSION PROCESSED (VIP) FOR PLANT FIBRE REINFORCED BIOPOLYMER COMPOSITES

LEE C.H., AISYAH H.A., KHALINA A., HAFIEZAL M.M.R & NORIHAN A.
Institute of Tropical Forestry and Forest Products (INTROP),
Department of Mechanical and Manufacturing Engineering, Faculty of Engineering,
Universiti Putra Malaysia
Faculty of Mechanical Engineering Technology, Universiti Malaysia Perlis.

Various composite fabrication methods such as hand lay-up technique, resin transfer moulding, hot press,vacuum-assisted resin transfer moulding, compression moulding, injection moulding, pultrusion and filament winding offers its own benefits. These methods were developed to meet specific design or manufacturing difficulties associated with fibre-reinforced polymer composites. Some of these methods allow for large quantities of production in a short period of time, while others have minimal start-up and materials costs. Selection of right method for a particular component, will depend on the materials, matrix, design and the final application [1]. Vacuum Infusion Processing (VIP) is a vacuum-assisted in closed-moulding process. The VIP is a well-known method for assembling the matrix and reinforcement, to offers excellent fibre volume ratio of up to 75% [2]. The use of VIP reduces voids and producing the composite with strong interfacial bonding between fibre/matrix boundary. The appearances of voids are undesirable as it was reported in deterioration of the composite properties and some even producing bad surface finish [3]. The general concept of VIP is shown in Figure 1. A vacuum pump is used to remove air from the inside of the bagging, resulting in a near vacuum. During the process, extra care must be taken where infusion time must be less than gelling time specified by the manufacturer [4]. Although VIP was commonly using thermoset such as epoxy resin, biobased thermoset polymers were also introduced in this VIP. The Biobased resin is a resin derived from biological sources for part or all of its component monomers and the main advantage is they decrease reliance on petrochemicals and promote greener products [5]. Much research worked on bio-epoxy derived from woods, biomass, and natural polymers [6,7]. One of the successfully developed bio-epoxy resin is jatropha oil blend with synthetic epoxy that was found to have good yield and performances [8]. Figure 2 illustrates various types of raw materials including woven fibres, carbon fibres, bio-epoxy resin and epoxy resin for manufacture of hybrid natural fibre polymer composites.

As mentioned above, interfacial bonding condition is one of the most crucial factors determining the performances of ended product. However, shortcomings of plant fibers especially on the hydrophilic nature of wood flour has always found deteriorated strength in hydrophobic-polymer composites. The structure of natural fibers (cellulose, hemicelluloses, and lignin) allows moisture absorption from the environment, resulting in weak fiber-polymer bonds. Thus, fiber treatments are often used to make them less hydrophilic for better interface adhesion. Nowadays, many treatments, coupling agents and compatibilizers have been applied when processing natural fibers purposely to strengthen the interfacial bonding between fiber/matrix [9]. The interface act as an intermediate layer between the fiber/matrix to create powerful linkages and allows for maximal stress transfer while minimizing disruption, resulting in excellent characteristics. There are four interface linkage mechanisms that facilitates a good interface state including physical adhesion, electrostatic adhesion, chemical adhesion, and mechanical interlocking. The mechanisms of the fiber/matrix interfacial bonding are shown in Figure 3. The poor interface in the composite may interface considerable degradation in mechanical, thermal and physical properties.

Interface adhesion and characterization of the fibers mostly related to their chemical composition. Cellulose is one of the primary constituents in fibers and it provides strong interface with matrix forms due to the hydrogen bonding in the cellulose microfibrils. Therefore, good interface between fiber/matrix can achieve by reducing the cellulose contents in the fiber in order to create load absorbing capabilities and higher bonding capacity. One of the simplest and most cost-effective treatments that has been widely used to increase the adhesion between hydrophobic matrix and hydrophilic fibers is alkaline treatment. The crystallinity of cellulose in the fibers will improve when non-cellulosic components are reduced, thus improving the composite's mechanical characterization. On the other hand. the application of coupling agents or compatibilizers will create a new band in the FTIR spectrum while, the absence or reduction in absorbance bands indicate the loss of fiber surface components during fiber treatments [10]. The interfacial behavior of natural fiber reinforced polymer composites may be analyzed using a variety of approaches which one of them known as pull-out test. There is different fiber pull-out behavior occurred due to the various interfacial bonding strength levels. Higher interfacial bonding strength allows for higher tensile loading to prevent fiber debonding or sliding however, it resulted in reducing the loading transfer due to fiber breakage. Apart from that, interfacial adhesion between fibers and matrix is critical in defining the physical, mechanical, and thermal properties of composites. The natural fibres are abundant with cellulose and hemicelluloses which are hydroxyl and carbonyl groups that they are usually hydrophilic sources. This hydroxyl and carbonyl groups in fibre leads to accumulate a lot of moisture. The reduction of hydroxyl and carbonyl groups in the natural fiber can be achieved by mildly alkaline sodium bicarbonate treatment. However, it has reported that this treatment resulting in higher water absorption. Alkaline treatment can substantially enhance the mechanical interlocking and chemical bonding between fibres and matrix. There are several fibre treatments to enhance the interface adhesion, tensile and flexural strength for instance, the plasma treatment [11]. However, excessive treatment parameters were attributed to a deterioration in tensile strength due to damage on the crystallisation of cellulose structure, yet majority of biopolymer composites reported a positive improvement [12]. Besides, the interfacial adhesion has a significant effect in affecting the flexural strength compared to tensile strength. This is due to the flexural bending stresses on the specimens are a combination of compressive/tensile and interfacial shear stress. Besides, inadequate interfacial adhesion between fibres and matrix, will cause total fibre pull-out and debonding, resulting in inferior strength behaviour. The improved interfacialbonding also preventing the crack of full green biopolymer composite specimens as reported in previous [13]. Thermal degradation is the process of energy absorption to break the adhesiveness of the fibre/matrix interaction. Thermogravimetric analysis (TGA) can be used to evaluate the thermal stability of plant fibre composite. Treated plant fibre composites gives a higher thermal decomposition temperature due to good interfacial bonding mechanism. However, due to the fibre agglomeration, the fibre/matrix adhesion intensity is reduced well as the composite's thermal stability [14]. On the other hand, dynamic mechanical analysis (DMA) is to determine how much energy is dissipated during the relaxing and compressing phases over a wide temperature range.

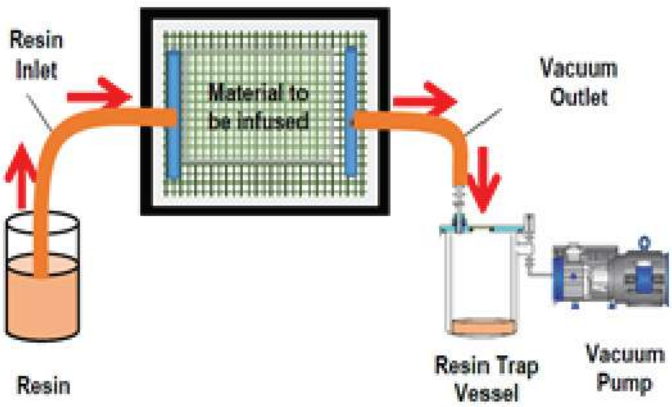

Figure 1. General concept on how VIP work

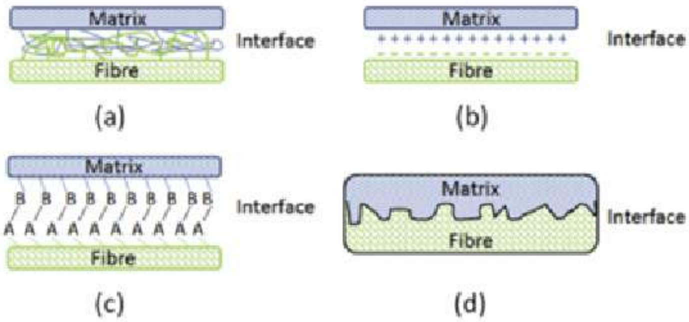

Figure 3. Illustration of the fiber/matrix interfacial bonding with the methods of (a) interdiffusion, (b) electrostatic adhesion, (c) chemical bonding, and (d) mechanical interlocking. [16]

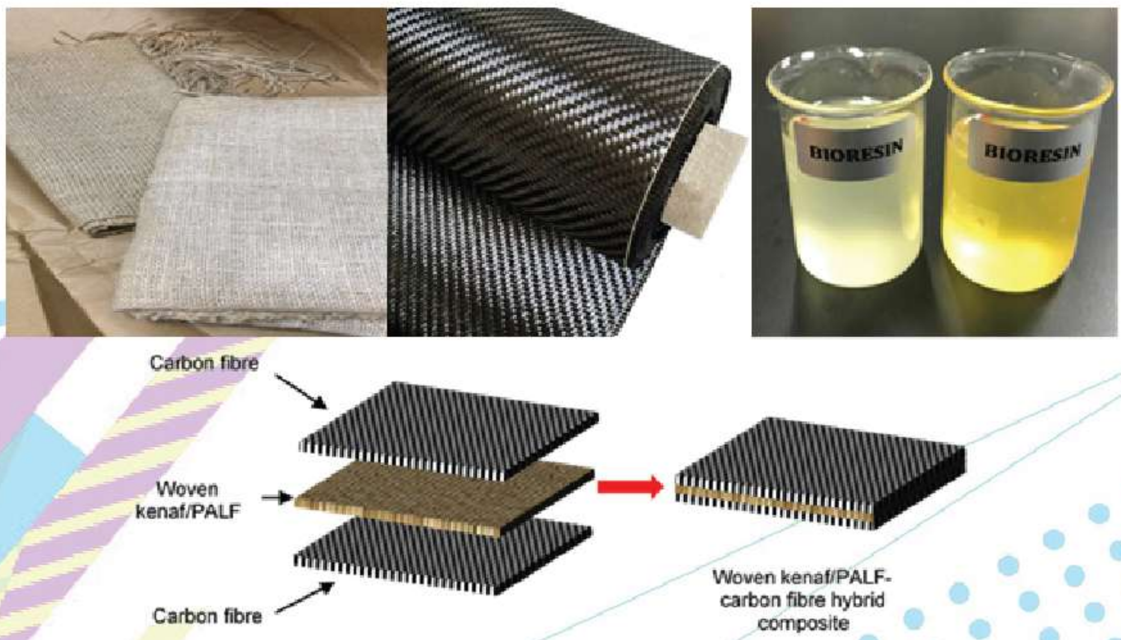

Figure 2. Unpressed mats and finished panel products [15]

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Author:
Dr. Lee Ching Hao
Post-Doctoral Researcher
Institute of Tropical Forestry and Forest Product
University Putra Malaysia, UPM
Serdang, Selangor, Malaysia
E-mail: leechinghao@upm.edu.my

JATROPHA OIL-BASED WATERBORNE POLYURETHANE - CELLULOSE NANOFIBRILS NANOCOMPOSITE FILM

Mohamad Ridzuan Amri[1], Chuah Teong Guan[1,2*], Syeed Saifulazry Osman Al-Edrus[2*], Faizah Md Yasin[2,3], and Siti Fatahiyah Mohamad[4]
[1]Institute of Tropical Forestry and Forest Product, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Department of Chemical Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3]Institute of Advance Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[4]Radiation Processing and Technology Division, Malaysia Nuclear Agency, 43000 Bangi Selangor Malaysia

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INTRODUCTION

In recent years, bio-based polyurethane has become a consumer preference and of interest to researchers. Two types of polyurethane (PU) are available, i.e., solvent and water-based polyurethane. Waterborne polyurethane is one of the environmentally friendly materials in the field of surface coatings, and water-based or waterborne pol-yurethane is not aqueous, but rather a well-dispersed mixture stabilized by electrostatic repulsive force [1]. The focus of PU in industry and academic research has shifted to-wards waterborne PU dispersion (WBPU) due to its replacement of volatile chemicals by water as a solvent in the production of PU. In addition, WBPU also offers several advantages, such as high flexibility at low temperatures, pollution-free, non-inflammable, good applicability, and non-toxic [2,3]. WBPU can be considered as a 'green' coating material compared to conventional PUs since it does not release any volatile organic compounds during the curing process. Jatropha oil consists of oleic acid (18:1), linoleic acid (18:2), palmitoleic acid (16:1), and linoleic acid (18:3) [4]. The presence of unsaturated fatty acids makes Jatropha oil a potential material for the production of polyols and the production of polyurethane. The extraction of polyols from Jatropha oil involves two consecutive steps: epoxidation and oxirane ring-opening. Epoxidation and oxirane ring-opening are extremely sensitive to any changes in temperature, therefore precautions are needed to avoid overheating of the reaction mixture [5]. Polyurethane is produced by the reaction between polyol and isocyanate, which refers to soft and hard segments, respectively. Jatropha oil-based polyol is then reacted with isophorone diisocyanate (IPDI). The addi-tion of dimethylol propionic acid (DMPA) was followed by dispersion at 1200 rpm with essential deionized water. DMPA acts as an internal emulsifier to build a hydrophilic group into the PU backbone. The resulting mixture is a waterborne polyurethane [6].There are a number of nanofillers that can be used to produce nanocomposites. These nanofillers are carbon nanotube, nano-silica, graphite and its derivatives, nanosilver, and nanoclay. However, these nanofillers are not preferred due to their tendency to sediment easily during the mixing and curing process of the nanocomposite. Nanocellulose, i.e., cellulose nanofibrils (CNF), is hydrophilic in nature, unlike the nanofillers mentioned above, and can be homogeneously mixed with any water solvent-based polymer. Nanocellulose reinforcement makes WBPU nano-composites ideal for 'green' coating materials. Most of the previous research has been done using CNF as a filler and it has been reported that it increases the strength of the composite film and shifts the temperature of degradation to a higher temperature [8–12]. However, the hydrophilicity characteristics of the cellulosic material may have an impact on the composite material as it may attract moisture/water to be absorbed [13]. Film performance may affect or deteriorate if the composite contains a large amount of moisture/water. Since the application of polyurethane is significant in the application of the coating, the water/moisture behavior must be minimal or non-existent.

As far as we concerned, there is no information or study involving CNF in waterborne Jatropha oil-based polyurethane. Hemce, in this work, a Jatropha oil-based waterborne polyu-rethane nanocomposite film containing CNF as a reinforcement was therefore prepared and characterized. The objective of this work was to study the influence of cellulose nanofibrils (CNF) on the physical, mechanical, and thermal properties of jatropha oil-based waterborne polyurethane (WBPU) nanocomposite films. The polyol to produce polyurethane was synthesised from crude jatropha oil through epoxidation and ring-opening method. The chain extender, 1,6-hexanediol, was used to improve film elasticity by 0.1, 0.25 and 0.5 wt.% of CNF loading was incorporated to enhance film performance. The chemical crosslinking and film morphology were studied using Fourier Transform Infrared (FTIR) and Field Emission Scanning Electron Microscopy (FESEM). Mechanical performance was studied using a universal test machine as specified in ASTM D638-03 Type V. Thermal Gravimetric Analysis (TGA) was performed to measure the thermal properties of film. Figure 1-4 shows properties of WBPU-CNF nanocomposite films.

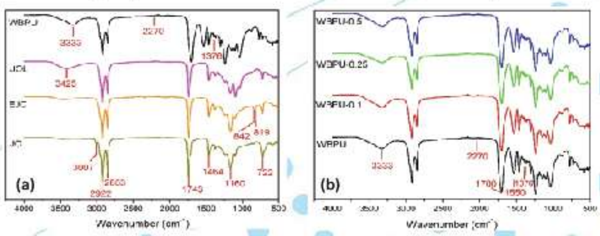

Figure 1: FTIR spectra of: (a) JO, EJO, JOL, WBPU; (b) WBPU-CNF nanocomposite films

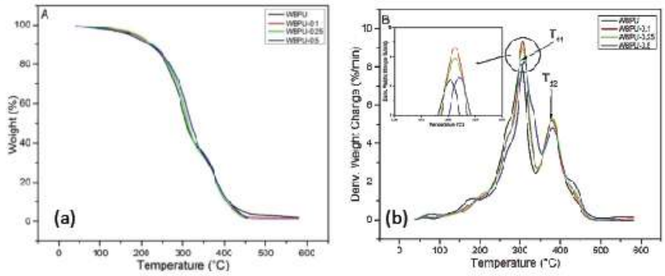

Figure 2: (a) TGA and (b) DTG curve for WBPU, WBPU-0.1, WBPU-0.25, and WBPU-0.5

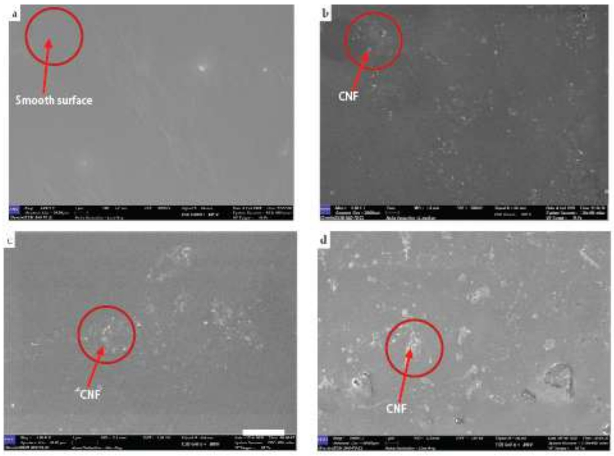

Figure 3: FESEM images of WBPU and WBPU-CNF films: (a) neat WBPU; (b) WBPU-0.1; (c) WBPU-CNF0.25; (d) WBPU-0.5

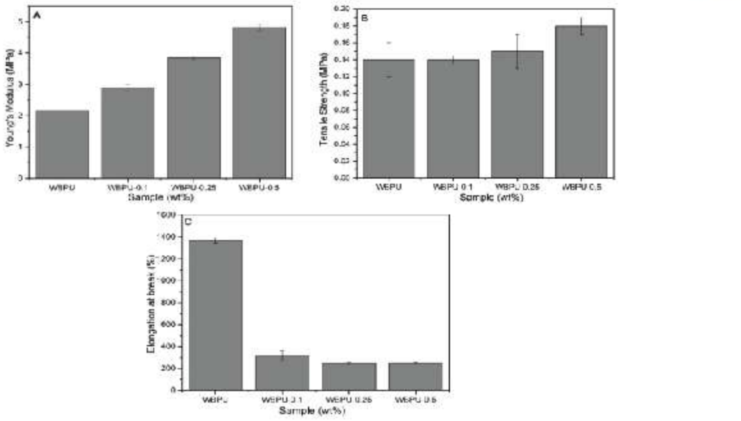

Figure 4: (a) Young's Modulus, (b) tensile strength, and (c) elongation at break of WBPU-CNF nanocomposite films

CONCLUSION

A significant effect on mechanical properties was observed over a range of 0.1 to 0.5 wt.% CNF loading. This could be attributed to the well dispersed CNF within the polymer matrix, as confirmed with FESEM images. Young's modulus and tensile strength of the composite films were increased by 55% and 22%, respectively, compared to the neat WBPU. Young's modulus and tensile strength were in-creased by 55% and 22%, respectively, after being incorporated into CNF. With the presence of a chain extender, the neat WBPU achieved 1370% elongation at break and reduced stretchability as the content of CNF increases. CNF loading strongly interacts with the hard segment of the WBPU matrix shifting the hard segment thermal degradation to higher temperature with increasing CNF loads.

CONCLUSION

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Author :
Dr. Syeed SaifulAzry Osman Al Edrus
Research Officer
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
Email : saifulazry@upm.edu.my

LIFE CYCLE ANALYSIS (LCA) OF FULLY DEGRADABLE BIOPOLYMER COMPOSITES

By
H.N. Salwa; S.M. Sapuan; R.A. Ilyas

INTRODUCTION

Plastic manufacturing consumes massive amounts of petroleum and emits hundreds of millions of tonnes of CO2 and other harmful gases into the atmosphere. Biobased materials will be considered in new innovative product design in the near future, and biopolymer materials have shown promising results in terms of environmental burdens. The development of a natural fiber-reinforced biopolymer composite, also known as a “green bio- composites,” with biodegradability and/or compostability attributes is perceived as one way to reduce municipal solid waste in landfills. Water and enzymes are produced by microorganisms to initiate biopolymer composites breakdown, which would then be taken up by microbial cells and converted into water, carbon dioxide, and biomass. Biopolymer composites aim to replicate the life cycle of biomass which includes preservation of fossil resources, and water and CO2 production. The fully bio-based materials do not leave the biological systems because they ultimately coming back to the environment after post-use cycles where landfilling does not occur as part of the systems. The measurement of a product's or system's "green" characteristics is highly dependent on its environmental impact and resource utilization. The Life Cycle Assessment (LCA) method is used to assess the environmental impacts of a service or product over the course of its life cycle. As such, LCA is used to "diagnose" a product and its environmental impact, thereby assisting manufacturing companies in redesigning their processes with the goal of reducing their environmental impact.

LIFE CYCLE ASSESSMENT (LCA)

Life cycle assessment (LCA) is a standardized method to learn the potential environmental impacts of a product over its entire life-cycle [1]. LCA could also be a supporting tool in the design process to understand and assess the technical solutions to be employed in the production process so that the impacts could be minimized, not only from the product itself but also from the phases of use and the end-of-life [2]. LCA can also be utilized for product development and improvement, strategizing plans, making public policies, marketing decisions, and a few different applications. The concept of LCA according to ISO 14040:2006 is as shown in Figure 1.

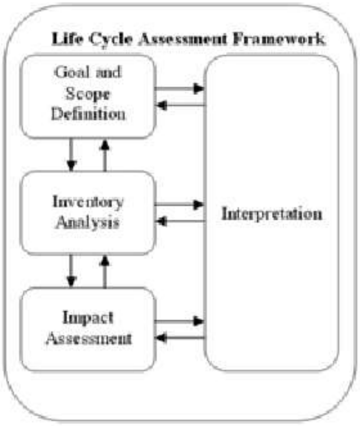

Figure 1: Concept of LCA outlined by ISO 14040:2006

Goal, Scope, and Functional Unit of the Study

LCA begins with a detailed definition of the reasons for the study. The goal of study and the scope of work are defined with respect to the functional unit, system boundaries, assumptions and limitations of the study. A functional unit (FU) is described as the functional requirements of a product system for a certain period which enables different systems to be regarded as functionally equivalent for direct comparison analysis [3]. System boundaries describe the LCA study of a complete analysis (cradle-to-grave) or a partial analysis (cradle-to-gate or gate-to-grave) [3,4] and must be defined clearly. Cradle-to-grave includes all life cycle phases beginning with production phase that comprises material and component productions, use phase and up to end-of-life (EOL) processing of the product. On the other hand, cradle-to-gate is a partial product life cycle involving resource extraction and production phase to the factory gate before it is sent to the manufacturer for application or consumers.

The life cycle of a sugar palm fiber-reinforced sago starch biopolymer composite takeout food container began with sago stem harvesting from sago tree felling, and SPF collected from sugar palm trees. These raw materials were sent to the mill for further processes, i.e., sago starch extraction, SPF washing, and grinding. Next was the compounding process to produce biocomposite resin. The composite resin was then extruded into sheets that underwent a thermoforming operation and converted into the designed containers [5]. After consumption, the containers reached the end-of-life stage and ended up in a landfill/composting facility. Figure 3 shows the system boundary of study which describe what is included and what is excluded from the analysis.

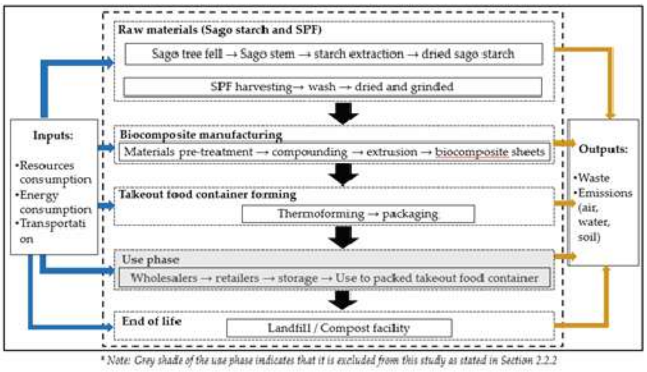

Figure 3: System boundary under investigation for the sugar palm fiber-reinforced sago starch biocomposite takeout food container.

Life Cycle Inventory (LCI)

Life Cycle Inventory (LCI) is the second phase of LCA where usage of resources and materials; and the consumption of fuels and energy need to be quantified. It is the crucial phase in LCA where data is collected to calculate material use, energy input, and pollutant emissions during the entire life cycle of a product or process. A set of LCI consists of inputs and outputs that represents the flow of material and energy used within the technical structure of the LCA; as well as emissions that are generated from the processes Compiled data on emissions and resources consumed attributed to a specific product shall be recorded. Other processes or activities outside the LCA boundary are ignored and thus environmental damages caused by them are not counted. All inputs and emissions of recorded data in LCI will to be translated into environmental impacts in the next phase.

Data for the production of biopolymer composite resin obtained from the software databases which include electricity and diesel consumed during the raw constituents' materials harvesting and their pre-treatment processes. Data for transportation of biopolymer and natural fiber from the mills to the product manufacturer's gate also included. The use stage of the biopolymer composite takeout food container was excluded in the study for the assumption of environmental impact during this stage is likely insignificant. Means of transportation of raw materials of the biopolymer composite which were located in different geographical locations were also recorded. Sago starch from Mukah is transported by trucks to Kuching port before being shipped to Port of Klang in Peninsular Malaysia and later delivered by trucks to composite manufacturing gate in Glenmarie Shah Alam, Selangor. End-of-life modelling in LCA has already been discussed in several studies. Composting would be an excellent option for waste management because the use of biopolymer composite products produced organic wastes in nature due to their fully biobased elements. Composting gives benefits to many agricultural activities such as farming productions, horticulture, and in some cases, for land restoration.

Life Cycle Impact Assessment (LCIA)

Third phase of the LCA framework is the life cycle impact assessment, which focuses on evaluating and understanding the environmental impacts established by the LCI analysis. The life cycle assessment (LCIA) phase was carried out based on a limited set of impact categories for all the output flows quantified in the LCI phase. They were grouped into damage categories, namely environmental compartments suffering the damage caused by the product in its life cycle. The end-point factors of characterization used in the ReCiPe method include: 1. Human health: stated as the number of years life lost and the number of years lived disabled and termed as disability adjusted life years (DALYs), an index used by the World Bank and World Health Organization (WHO). DALYs measure the difference between an ideal situation in which everyone lives to the standard life expectancy in perfect health and the actual situation. Generally, the DALY unit of "0" indicating indifference between the health state and full health and "1" indicating indifference between the health state and death [6]; 2. Ecosystems: expressed as the loss of species over a particular area during a specific time. It also includes altered pH, nutrient availability, and concentration in soil. The ecosystem damage potential (EDP)'s unit is species.year [7].

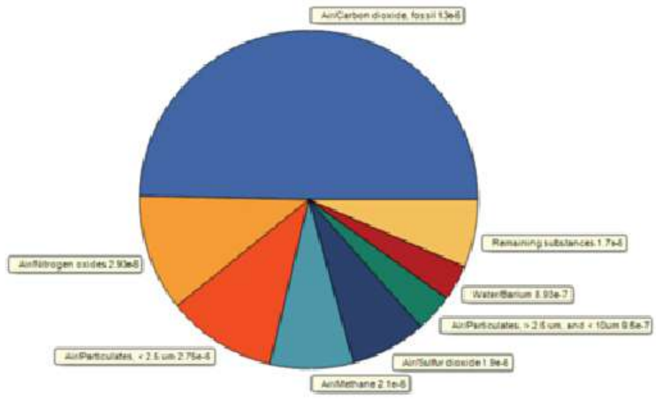

Figure 4: Human health damage assessment of 1kg of SPF-reinforced sago starch composite takeout food container analyzed (Damage assessment/ Excluding long-term emissions)

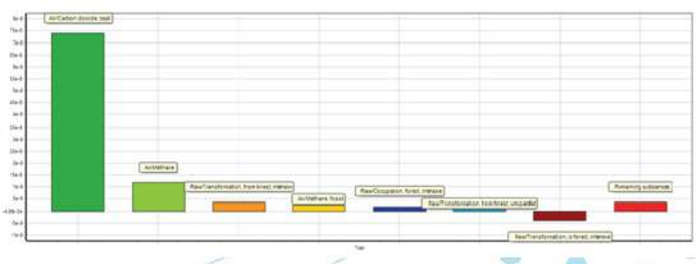

Figure 5: Ecosystem damage assessment of 1kg of SPF-reinforced sago starch composite takeout food container analyzed (Damage assessment/ Excluding long-term emissions/ cut off 1%)

CONCLUSION

From the analysis, the LCA of the cradle-to-grave approach of SPF-reinforced sago starch biocomposite for the concept design of takeout food containers is safe, with extremely minimal emission. The total damages for the cradle-to-grave of 1 kg of the takeout food containers realized from SPF-reinforced sago starch composite were 2.63 x 10-5 DALY and 9.46 x 10-8 species.year for the categories of human health and the ecosystem, respectively. Thus, it causes insignificant harm to human health and the ecosystem. Additionally, it also proves that utilizing locally sourced sago starch and sugar palm fiber as the constituents' materials in green biocomposite to design a takeout food container and the whole product system is environmentally friendly and safe for the human and ecosystem.

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Author :
Dr. Nor Salwa Hamdan
Senior Assistant Director
Department Skills Development, Ministry of Human Resources
Salwa.hamdan@mohr.gov.my

ARROWROOT FIBRE REINFORCED ARROWROOT STARCH COMPOSITES: A REVIEW

By
S.F.K. Sherwani[1] and S.M. Sapuan[1,2]
J. Tarique1 and S.M. Sapuan[1,2]
[1]Advanced Engineering Materials and Composites Research Centre (AEMC), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor
[1,2] Laboratory of Biocomposite Technology
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor

Raising environmental awareness had forced researchers to explore the potential and implementation of environmentally friendly materials as alternatives for conventional materials. The environmentally friendly materials are those natural materials that are biodegradable. These materials are safer, non-toxic, lightweight, cheap, and readily available. Arrowroot plant has outstanding mechanical properties owing to its high content of cellulose. Arrowroot (Maranta arundinacea) has a pivotal role in the development of biodegradable products such as biocomposites. This paper highlights the properties of arrowroot fibre and starch as well as their applications. The rhizome of arrowroot is the main origin of starch and fibre, and arrowroot plant is mainly found in the West Indies (Jamaica), Indonesia, Philippines, India, and Sri Lanka [1]. It can be blended with biopolymers like polylactic acid (PLA), polyvinyl alcohol (PVA), polyhydroxyalkanoate (PHA), and polyethylene glycol (PEG) to create more usable biocomposites and biomaterials, as well as to boost the versatility of arrowroot starch [8]. The biodegradability of arrowroot fiber can be prolonged by blending the fibre with PLA [9]. The arrowroot rhizome product can also be used for packaging materials, biomedical materials, and agricultural purposes [10]. Arrowroot starch plays a significant role in the development of a biopolymer. In this context, the combination of arrowroot starch and natural rubber can enhance the elastic nature as well as decomposability. Table.3 displayed that arrowroot starch registered superior amylose content (40.86%) when compared to other starches such as Tapioca (17%), Sago (24-27%), Potato (20-25%), wheat (26-27%) and Maize (26-28%) [2]. As for amylopectin, it is a highly branched polysaccharide component of starch that consists of hundreds of shorts chains formed of α-D- glucopyranosyl residues with (1→4) linkages. AS have low protein and fat contents of 0.40% and 0.12% (w/w), respectively [3].

Table 3: Chemical composition of Arrowroot starch and other commercial starches.

Starch	Moisture content (%)	Density (g/cm3)	Amylose (%)	Ash (%)	Reference
Arrowroot	13.2	-	40.86	0.31	[4]
Tapioca	13	1.446-1.461	17	0.2	[5,6]
Sago	10-20	-	24-27	0.2	[7,8]
Potato	18-19	1.54-1.55	20-25	0.4	[6,9]
Wheat	13	1.44	26-27	0.2	[2,6,9]
Maize	12-13	1.5	26-28	0.1	[2,6,9]
Sugar Palm	15	1.54	37.60	0.2	[10]

Fig. 1 Arrowroot fiber obtained from starch extraction mill [11].

Fig.2 Novelty Items from waste rhizomes or “sapal” [12].

According to a study conducted by Branco et al. [11], the arrowroot fiber is coarser and longer compared to cassava. Fig.1 displays the residue that was obtained from the starch extraction mill. A review of the literature revealed that approximately 38.1% of bagasse residue fiber was found in arrowroot [13]. Massive amount of arrowroot waste is produced during the processing of arrowroot starch, which were developed into different novelty items and products as presented in Fig. 2, [12]. The fiber is short in length and small in diameter. It can be deduced that the fiber can be used to make the tear-resistant paper such as bags and wrapping paper [13]. Franco et al. [14] reported that the incorporation of bio-fibers with polymers plays a vital role to control the destruction of eco-environment as well as delivers high mechanical properties of composite materials. Recently, nanoparticles such as carbon nanotubes and cellulose nano whiskers obtained from arrowroot fibers are being used as strengthening materials in nanocomposites [15]. In this review, it can be concluded that the arrowroot starch or fibers obtained from arrowroot plants are useful for various applications. It can be used for food packaging products due to its biodegradability, antioxidant property, and antimicrob al nature. The arrowroot starch becomes more stable if it is blended by polylactic acid (PLA), polyvinyl alcohol (PVA) and polyhydroxyalkanoate (PHA). From the perspective of nano-composites application, stable nanoparticles such as carbon nanotubes and cellulose nanowhiskers extracted from arrowroot fibers can be used as a source of strengthening agent. Overall, this paper provides a platform for the application of arrowroot starch and fiber for food packaging, food products, medicines, and much more.

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Author :
Prof. Ir. Dr. Mohd Sapuan Salit
Head of Laboratory
Biocomposite Technology
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
Email : sapuan@upm.edu.my

BINDERLESS COMPOSITE: A SOLUTION FOR 100% NATURAL MATERIALS!

By
Juliana Abdul Halip

INTRODUCTION

The demand for green composites has been increasing in recent years as the next generation of sustainable composite materials. Green composites defines as various definitions; (i) Green or fully biodegradable composite where the composite is made of natural fibres and biodegradable resin/polymer matrix, (ii) Partially green/biodegradable composite composed of natural fibres (biofibres) and traditional petroleum-based non-biodegradable resin/polymer matrix, and (iii) Hybrid green/biodegradable composite that consisted of two or more different natural fibres in combination with biodegradable or petroleum-based resin/polymer [1,2]. Most of the reported studies on green composites are categorized as partially green composite or hybrid green composites, thus leading to environmental and health concerns namely formaldehyde emission. Due to this issue, manufacturing of fully green composite such as binderless composite is one of the environmental friendly solutions. Binderless composites drew interest from many researchers due to the environmental friendly properties, simple manufacturing process and low cost [3]. Apart from wood, there are many studies using non-wood materials as binderless composite including bamboo, kenaf, oil palm residues, bagasse, coconut husk, banana residues, durian peels, wheat straw, rice straw, and cotton stalk. Figure 1 shows a binderless composite made from rice straw particles and rice straw powder done by Kurakochi and Sato [4].

Figure 1: (a) Binderless composite made from rice straw whole particles (b) Binderless composite made from rice straw whole powder [4]

Binderless composite can be applied in the fibreboard, particleboard and plywood manufacturing. As it is well known, the overall manufacturing process of binderless composite is quite similar to the conventional process. Manufacturing process of fibreboard basically occurs in wet or dry processes, while particleboard and plywood occur in the dry process. In most cases, the raw materials namely fibres, particles and veneers are produced using refiner, hammermill/flaker, and rotary lathe machines, respectively. In the next step, the raw materials are dried and placed in a mould/die/forming box without addition of resin. They use lignin present in the lignocellulosic material as a substitution of synthetic adhesive to bind the materials. Lignin plays an important role in binderless or self-bonding composites which act as a natural binder for fibres with glass transition values in a dry state at 200˚C [5, 6]. Then, step followed by removal of the mould/die/forming box, pre-pressed, and press using the hot-press machine. Hot-press machine or known as heat treatment applied heat and pressure to the mat and identified it as the simplest and most common method in binderless manufacturing. When heat is applied, heat activates the chemical components of the raw materials and the combination of both heat and pressure allow the melting of lignin through the entire board and provide good distribution of lignin between the fibres [7, 8]. Cellulose and hemicellulose are partially hydrolyzed to simple soluble sugars that contribute to self-bonding [9].

In the manufacturing of binderless composites, the pressing temperatures are generally higher compared to conventional composites. Fibreboard and particleboard have the pressing temperature, pressure and time ranging from 160 to 220˚C, 1.4 to 5.3 MPa, and 10 min, respectively. While in plywood, the pressing time was significantly longer and up to 20 to 30 min [10]. Basically, increasing the pressing time and temperature reduces the water absorption and improves the dimension stability of binderless composite. In a prior study, three pressing temperatures used in a binderless particleboard are 160˚C, 180˚C and 200˚C [5]. Their findings reported that the water absorption (WA) and thickness swelling (TS) of the boards decreased with increasing press temperature. The board pressed at 200˚C has the highest modulus of rupture (MOR) compared to others with the values of 5.73 MPa. However, conventional heat treatment binderless composite has poor dimensional stability. Therefore, pretreatment processes such as steam pretreatment, chemical pretreatments, enzyme pretreatments, preheating, grinding and extrusion processes are required to enhance the properties of binderless composites. These pretreatments mostly increase the mechanical and physical properties of the binderless composite.

CONCLUSION

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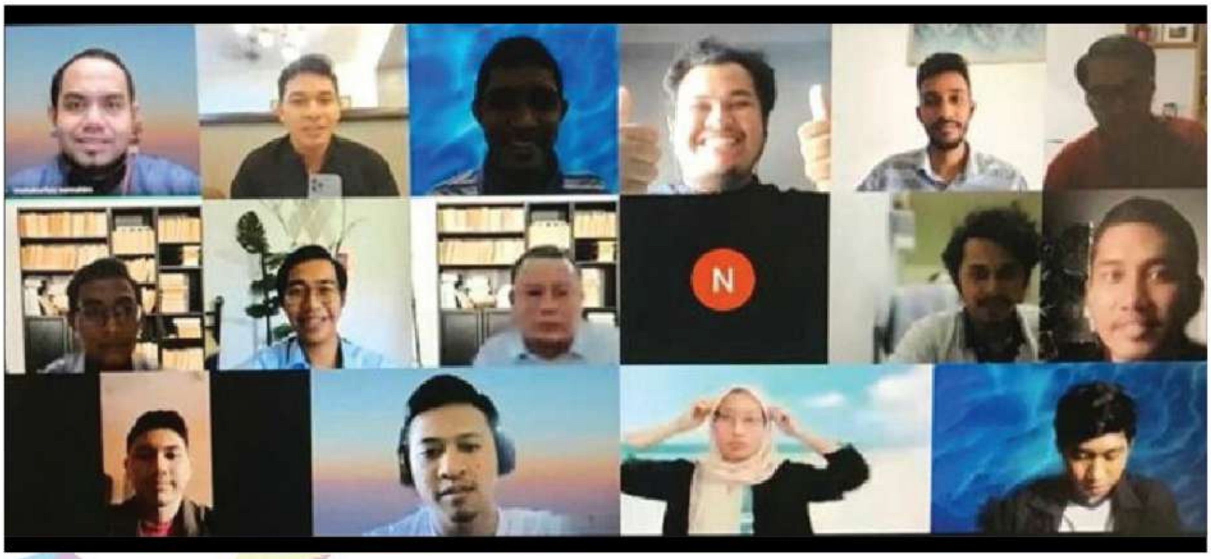
Author:
Dr. Juliana Abdul Halip
Senior Lecturer
Department of Production and Operation Management
Universiti Tun Hussein Onn Malaysia
Batu Pahat, Johor, Malaysia
https://ftmb.uthm.edu.my/
E-mail: julianaah@uthm.edu.my

SEMINAR ON ADVANCED BIO- AND MINERAL BASEDNATURAL FIBRE COMPOSITES (SBMC2021)

25th January 2021- Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia and Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia conducted Seminar on Advanced Bio- and Mineral based Natural Fibre Composites (SBMC2021). This year, 19 Universiti Putra Malaysia (UPM) Mechanical Engineering students were given a unique task to write on topic of bio- and mineral based natural fibre composites as well as to conduct the internal seminar. This seminar served as a platform for undergraduate students to communicate their research through oral presentation and publication and to share and exchange information and knowledge among the students and academic staff. This seminar also is a step towardsachieving UPM vision in becoming a world-class academic and research institution in order to produce human capital with first class mentality. The final presentation was held on 25th January 2021 where students were evaluated by Panels from Universiti Pertahanan Nasional Malaysia, Universitas Jember, Indonesia, and Universiti Putra Malaysia. Opening ceremony and Keynote speakers were given by Prof. Ir. Dr. Mohd Sapuan bin Salit, FASc (Universiti Putra Malaysia) and Dr. Ahmad Ilyas bin Rushdan (Universiti Teknologi Malaysia). The Top 3 Best Presenter are awarded to Tahrim Hossain Rafin, Nur Afiqah Binti Adnan, and Muhammad Danial Syazani Bin Muhammed Syamsulbahrin. The Top 3 Best Manuscript are awarded to Muhammad Hariz Bin Hassim, Abdul Kadir Bin Jailani, and Muhammad Zahfiq Bin Mohamad Zaihan Pang.



Written by:

S.M. Sapuan
Composite Materials Advanced and Engineering Materials and Composites Research Centre (AEMC) Department of Mechanical and Manufacturing Engineering Universiti Putra Malaysia 43400 UPM Serdang, Selangor
[2]Head, Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP) Universiti Putra Malaysia 43400 UPM Serdang, Selangor

R.A. Ilyas
Sustainable Waste Management Research Group (SWAM), School of Chemical and Energy Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
Centre for Advanced Composite Materials (CACM), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.

INTERNATIONAL WEBINAR SERIES ON BIOPOLYMER COMPOSITES

Organized By: Laboratory of Biocomposite Technology (BIOCOMPOSITE)

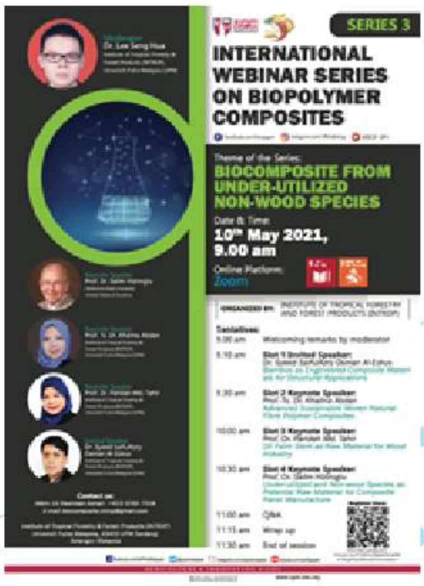
Laboratory of Biocomposite Technology (BIOCOMPOSITE), INTROP has organized three series (3) of international seminars in the field of composite biopolymers held through Zoom meeting application on 2 April 2021 for the first series, for the second series held on 27 April 2021 while for the third series it was held on 10 May 2021 with each different themes. The program has invited international speakers as keynote speakers who mentor research officers from the Biocomposite Laboratory to provide relevant sharing of their research.

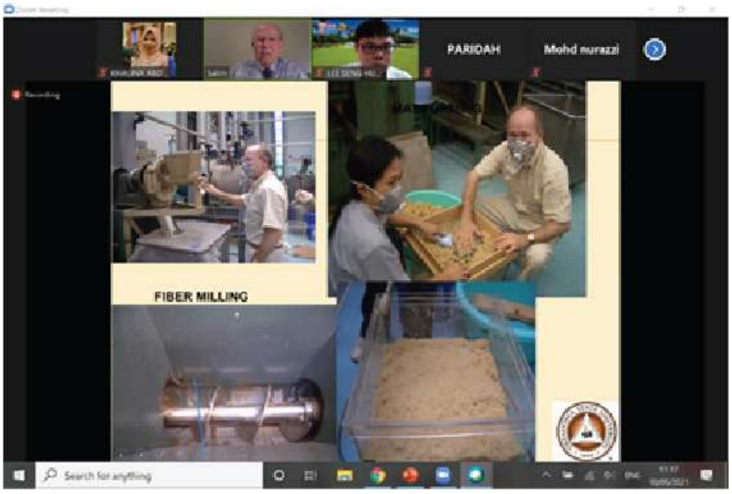
The 1st webinar series with the theme of green composites has invited Prof. Dr. Tatsuo from Japan Advanced Institute of Science and Technology (JAIST), Japan and Prof. Ir. Dr Mohd Sapuan Salit, Head of Laboratory Biocomposite (INTROP) as keynote speaker. Prof Tatsuo's and Prof Ir. Dr Mohd Sapuan's presentation tittles were New molecular design concept of high-performance bioplastics and Materials selection and conceptual design in natural composites, respectively. While Dr. Ahmad Adlie Shamsuri of Introp as the guest speaker presented on Polybutylene Succinate (PBS) /natural fiber green composites: Preparation and properties.

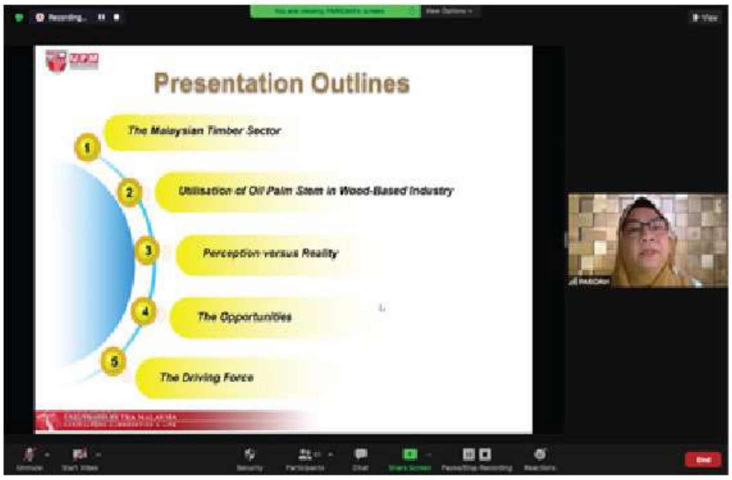
For the 2nd series of this webinar, the theme was Modifications and treatment in biocomposites has invited Prof. Dr. Ir. Yusuf Sudo Hadi, from Bogor Agricultural Institute, Indonesia, and Dr. Mohammad Jawaid as the keynote speakers. The title of Prof. Dr. Ir Yusof Hadi presentation is Enhancement of wood composites quality through acetylation, binderless, lamina grading and smoked while Dr. Jawaid gave a presentation on Kenaf (Hibiscuss cannabinus): Versatile materials for diverse applications. The guest speaker for this 2nd series is Dr. Muhammad Aizat Abd Ghani of Introp with title of his presentation is Wood quality enhancement via phenolic treatment.

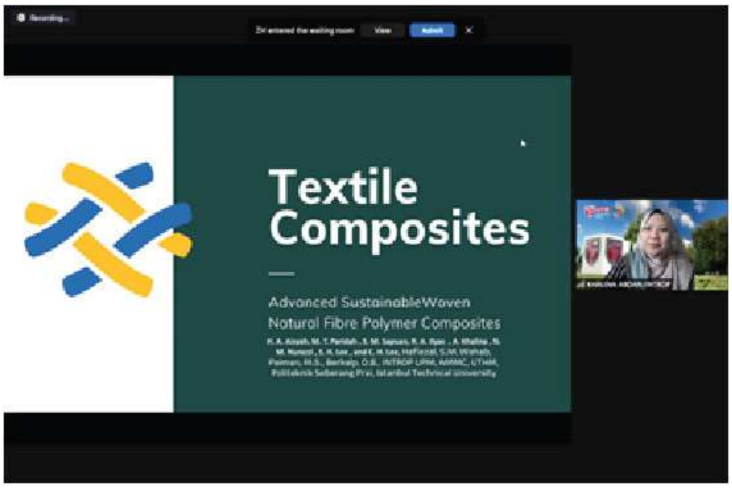
With the theme of Biocomposites from under-utilized non-wood species, this 3rd webinar series has invited Prof. Dr. Salim Hirizoglu, Prof. Ts. Dr. Khalina Abdan and Prof. Dr. Paridah Md. Tahir as the keynote speakers. Each of panel presented on Under-utilized and non-wood species as potential raw material for composite panel manufacture, Advanced sustainable woven natural fiber polymer composites and Oil palm stem as raw material for wood industry, respectively and the research officer from Biocomposite Laboratory, Dr. Syeed SaifulAzry Osman Al-Edrus as the invited speaker and his presentation entitled Bamboo as Engineered composites materials for structural applications.

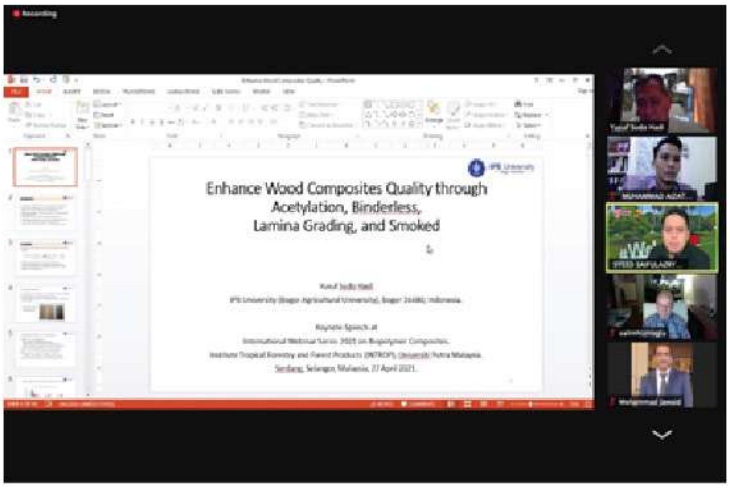
In total, the webinar was attended by more than 100 participants consisting of lecturers, research officers, graduate and undergraduate students, industry workers from various local and foreign agencies. All papers presented in this Webinar Series will be published in an edited book by an international publisher. It is hoped in the future, INTROP can organized this kind of webinar and can invite more leading international researchers as keynote speakers and can attract more participants.

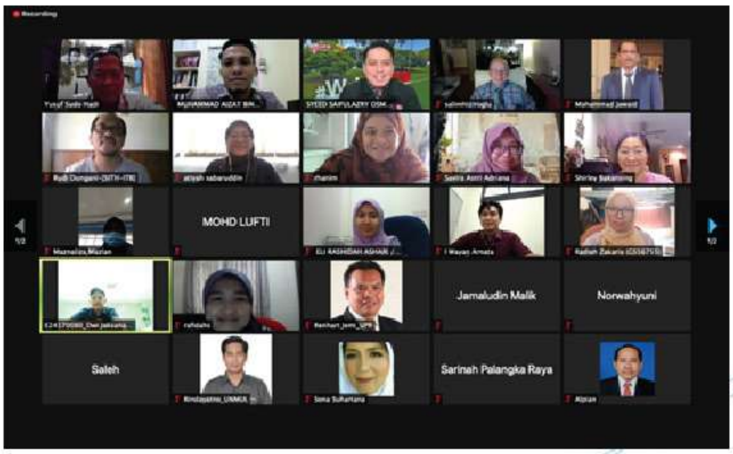



PARIDAH
Mohd nurazzi
FIBER MILLING


Presentation Outlines
1 The Malaysian Timber Sector
2 Utilisation of Oil Palm Stem in Wood-Based Industry
3 Perception versus Reality
4 The Opportunities
5 The Driving Force


Textile Composites
Advanced SustainableWoven
Natural Fibre Polymer Composites


Enhance Wood Composites Quality through
Acetylation, Binderless,
Lamina Grading, and Smoked


MOHD LUFTI
Jamaludin Malik
Norwahyuni
Saleh
Sarinah Palangka Raya

Webinar on Tropical Wood and Fiber: Development, Potential and Challenges in Research and Application

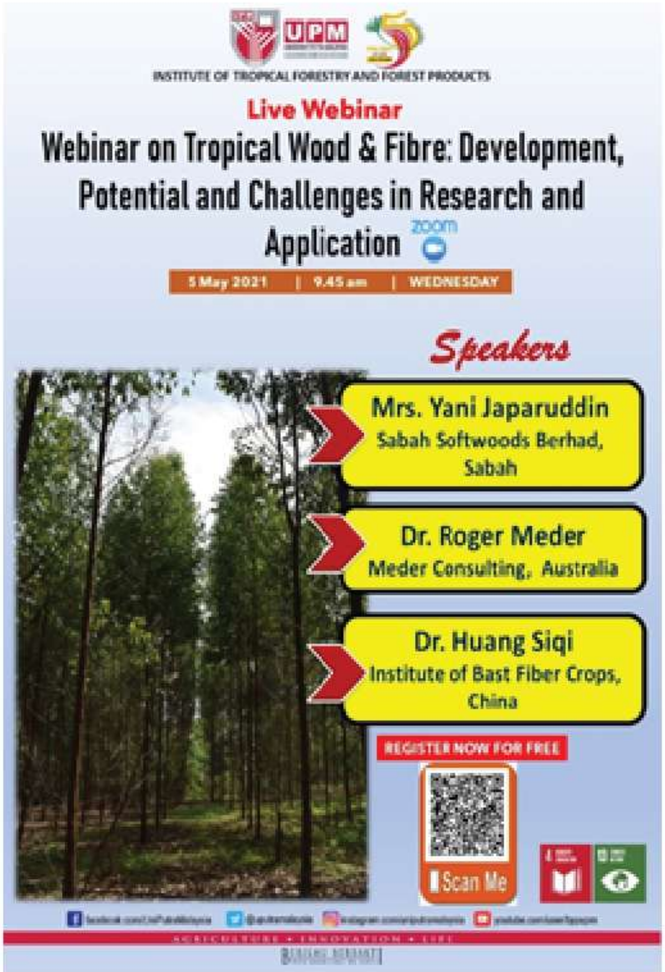
5 May 2021

Organized by: Bioresource Management (BIOREM)

Laboratory of Sustainable Bioresource Management (BIOREM), INTROP has organized a seminar entitled 'Webinar on Tropical Wood and Fiber: Development, Potential and Challenges in Research and Application' on 5th May 2021 which was held through the Zoom Meeting application. The program was also attended by the Director of INTROP, Prof. Ts. Dr. Khalina Abdan who gave a welcoming speech at the opening of the program.

The talk session was started by Pn. Yani Japaruddin from Sabah Softwoods Berhad with the presentation title 'Issues and Challenges in Forest Plantation Management: SSB's Experience'. The next session was continued by Dr. Roger Meder of Meder Consulting Australia who is also a consultant for Borneo Forest Cooperative (BFC). The title he presented was 'Towards Precision Forestry: The Role of Non-Destructive Evaluation in Managing Forests and Characterizing Wood Products'. The last speaker of the webinar was delivered by Dr. Huang Siqi, a lecturer at the Institute of Bast Fiber Crops, China with the title 'Hybrid Kenaf Breeding and Utilization in China'.

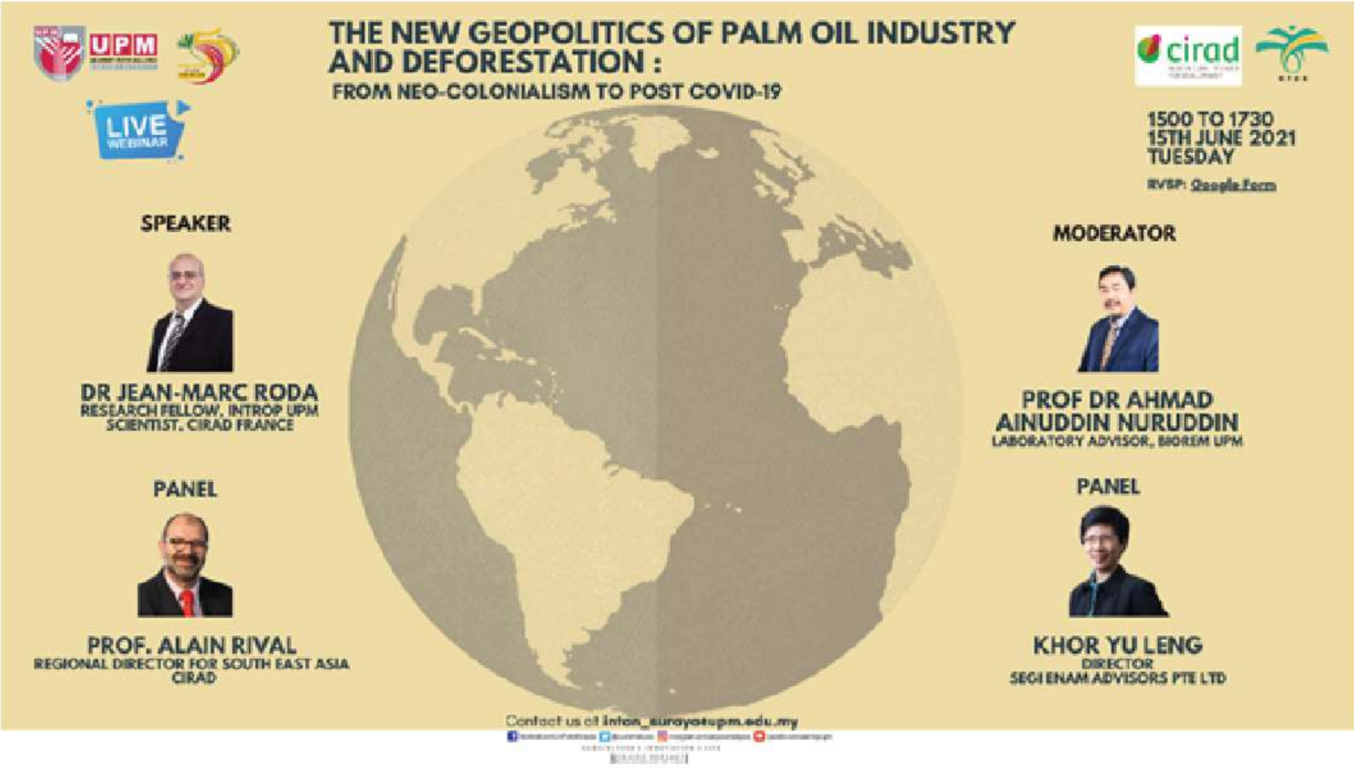
The webinar was attended by 40 participants from various government agencies, private and students who have inspired learning about the potential and challenges in empowering forest plantations and the fibre industry. We hope this collaboration can lead to more competitive research collaborations in the future to ensure sustainable management of fiber and timber bioresources.



UPM-CIRAD-MPOB Webinar Series: The New Geopolitics of Palm Oil: From neo-colonialism to post COVID-19

15 June 2021

Organized by: Bioresource Management (BIOREM)



The Laboratory of Sustainable Biosource Management (BIOREM), INTROP has organized a series of webinars entitled 'The New Geopolitics of Palm Oil: From Neo-colonialism to Post COVID-19' on 15 June 2021 held through the Zoom Meeting app and INTROP's Facebook Page. The webinar series was also organized in collaboration with the Malaysian Palm Oil Board (MPOB) and the French Agricultural Research Center for International Development (CIRAD), France. The program was also attended by the Deputy Vice Chancellor (Industry and Community Relations), Prof. Ir. B. T. Hang Tuah Baharudin who gave a welcoming speech as soon as the program began.

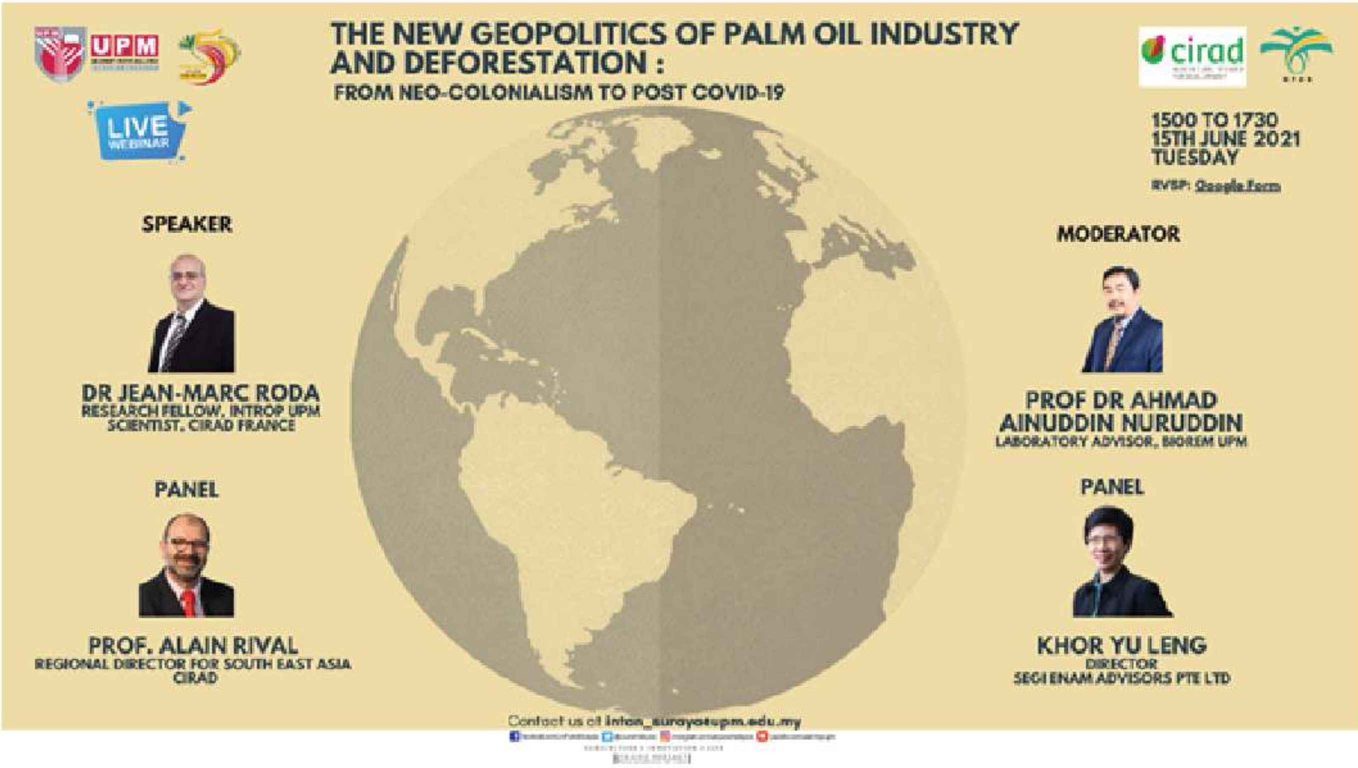
The talk session was started by Dr. Jean-Marc Roda, BIOREM's Research Fellow to discuss global geopolitical perspectives on oil palm and the palm oil industry as well as ssues related to deforestation and the implications involved during the COVID-19 pandemic. The next session continued with a forum to discuss the above issues led by the moderator, Prof. Dr. Ahmad Ainuddin Nuruddin, BIOREM's Laboratory Advisor. Among the panel members involved are Prof. Dr. Alain Rival, CIRAD Southeast Asia Regional Director and Mrs. Khor Yu Leng, Director of Segi Enam Advisors Pte. Ltd.

The webinar was attended by 167 participants from various private government agencies and stakeholders who have inspired learning on trade and diplomatic relations related to palm oil between Malaysia and Western countries. We hope this collaboration can lead to further research collaborations in the future to ensure the sustainable management of oil palm bioresources and forest landscapes.

UPM-CIRAD-MPOB Webinar Series: The New Geopolitics of Palm Oil: From neo-colonialism to post COVID-19

15 June 2021

Organized by: Bioresource Management (BIOREM)



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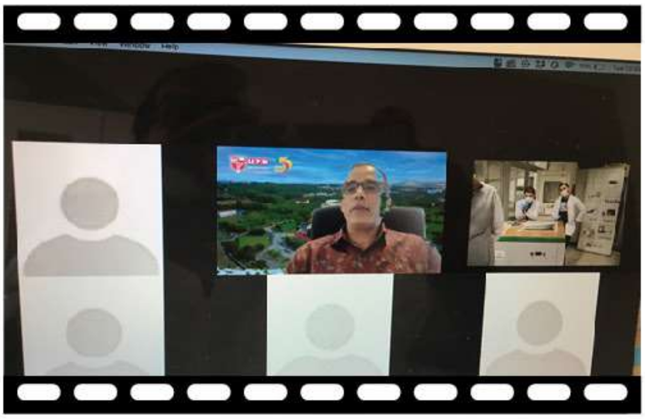
International Workshop between INTROP, UPM and TEMAG Lab, Istanbul Technical University, Turkey

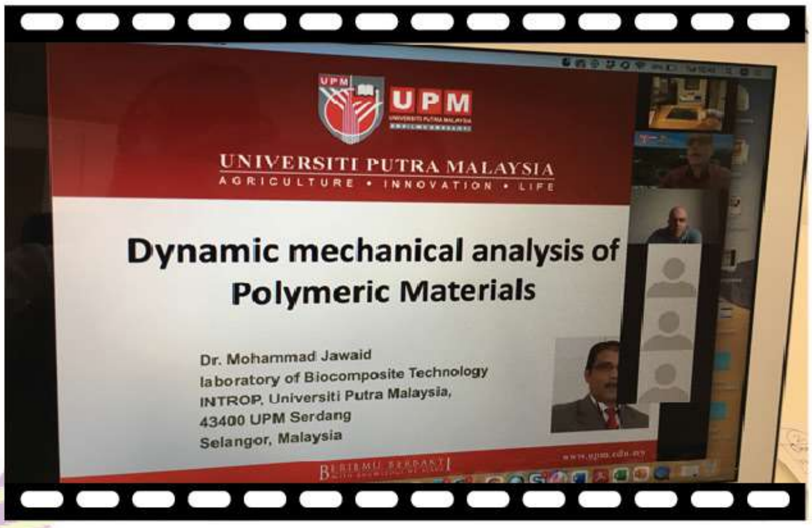
8 April 2021

Laboratory of Biocomposite Technology, INTROP and TEMAG Lab, Istanbul Technical University (ITU), Turkey doing collaborative research work from long time! We Conducted joint workshop to share expertise of researchers from both Laboratory. In this workshop, ITU researchers share their expertise on "Use of Vacuum Assisted Resin Transfer Moulding (VARTM) system. Associate Prof Dr. Ali Kilic and Dr. Yusof Polat conducted live demonstration of Fabrication of Natural fibre composites by VARTM Technique. Dr. Mohammad Jawaid, Senior Fellow at Laboratory of biocomposite Technology, INTROP conducted workshop on "Application of Dynamic Mechanical Analysis (DMA)" to Participants. More than 100 participants attended this workshop from Malaysia, Turkey, India, Iraq, Australia, Tunisia, Morocco, Eqypt, Saudi Arabia, Libya and Indonesia. Prof Sapuan mohd Salit from INTROP, UPM and Prof Ali Demir from TEMAG Lab, ITU Co-ordinated this workshop with support of Staff of Laboratory Biocomposite Technology.



Dr.Mohammad Jawaid-Chair Workshop

Live Demonstration of VARTM from ITU, Turkey



Application of Dynamic Mechanical Analysis workshop by Dr. Mohammad Jawaid

INSTITUTE OF TROPICAL FORESTRY AND FOREST PRODUCTS (INTROP) INNOVATION OPEN DAY 2021

Innovation Open Day (IOD) has been held by Institute of Tropical Forestry and Forest Products (INTROP), UPM on 9 April 2021. The program was in conjunction with the INTROP site visit which was attended by the Chairman of the UPM's Board of Directors, YAM Tengku Syarif Laksamana Perlis Dato 'Seri DiRaja Syed Razlan Syed Putra Jamalullail and the University's Top Management. The purpose of the program was to share and deliver the latest information on research, products, and innovations produced by INTROP researchers.

The agenda of the programme includes presentation on the HICoE's impacts on the field of plantation crops, video screenings on marine grade equivalent oil palm trunk plywood, laminated structural bamboo boards, kenaf pulp, and climate monitoring stations for Eucalyptus research plots. In addition, exhibition booth tours include enau starch and PPE biocomposites, SafeBiopack sets and food equipment, high-velocity and anti-puncture impact clothing, as well as nanocellulose has conducted. A demonstration workshops to share the processing of the products and innovations has been done. Finally, the planting of the iconic INTROP tree (Eucalyptus) was also held near the badminton square of the INTROP building.

A presentation on the impact of HICoE on plantation crops was presented by Prof. Ts. Dr. Khalina Abdan, the Director of INTROP. The presentation was on the impact of the recognition of INTROP as a HICoE (Higher Education Center of Excellence) on plantation crops in Malaysia. Among the crops studied by INTROP researchers are Eucalyptus, bamboo, oil palm, kenaf, and enau. This opens up space to potential commodities such as biodegradable materials that can be applied in aviation cabins, automotive, medicine, agriculture, buildings, packaging, and pulp.

INTROP IOD 2021 was also witnessed live by more than 60 UPM staff and graduate students through the Zoom platform. Not only were they able to watch HICoE impact presentations and INTROP research videos, they were also able to watch research posters as well as virtual visits to exhibition tables and demonstration workshops to see the products and innovations produced by INTROP researchers. Since the establishment of INTROP in 2006, this is the 3rd Innovation Open Day successfully organized by INTROP.

At the end of the program, the iconic INTROP tree planting ceremony was also held which was officiated by YAM Tengku Syarif Laksamana Perlis Dato 'Seri DiRaja Syed Razlan Syed Putra Jamalullail, Chairman of the UPM's Board of Directors and YBhg. Dato' Sri Ir. Dr. Judin Abdul Karim, Executive Vice President of MRCB (Malaysian Resources Corporation Berhad). This initiative was inspired by the 100 Million Tree Planting Campaign by the Ministry of Energy and Natural Resources. The iconic INTROP tree planted is the Eucalyptus pellita tree which has great potential to be a source of fiber for pulp production as well as wood and veneer production.

Script prepared by : Dr. Ahmad Adlie Shamsuri (BM Version)
Translated by : Dr. Lee Seng Hua (BI Version)

Exhibition booth tours

Lab visit for products fabrication process

Tree planting ceremony officiated by YAM Tengku Syarif Laksamana Perlis Dato' Seri DiRaja Syed Razlan Syed Putra Jamalullail, Chairman of the UPM's Board of Directors

Group photo with YAM Tengku Syarif Laksamana Perlis Dato' Seri DiRaja Syed Razlan Syed Putra Jamalullail, University's Top Management and Organisers of INTROP IOD 2019

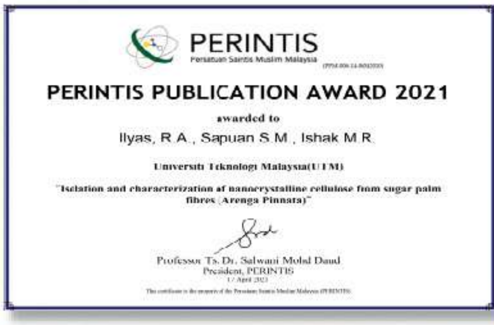
CONCEPTUAL DESIGN AND LIFE CYCLE ASSESSMENT OF NATURAL FIBRE-REINFORCED BIOPOLYMER COMPOSITES TAKEOUT FOOD CONTAINER USING CONCURRENT ENGINEERING

Name: NOR SALWA BINTI HAMDAN
Programme: Doctor of Philosophy
Field of study: Biocomposite Technology and Design

Almost all municipal solid waste (MSW) collected go to landfills instead of being recycled where packaging has a big portion and mostly are contributed by food packaging. With the concept of design for sustainability (DFS), a product design and development process of a fully biodegradable and biobased takeout food container was carried out utilizing natural fibre reinforced biopolymer composite. Using Concurrent Engineering (CE), the materials selection of natural fibre and biopolymer matrix, concept design generation and selection of final design, and Life Cycle Assessment (LCA) of the new takeout food container design were performed. Seven elements of product design specification (PDS) were considered based on market investigation. The evaluation and selection of natural fibre as reinforcement in the biopolymer composite was carried out by applying Analytic Hierarchy Process (AHP). The results indicated that ijuk or sugar palm fibre obtained the highest priority of the nine (9) natural fibre alternatives. Concurrently, the selection of the biopolymer matrix was performed, limited only to starch biopolymers, employing Shannon's entropy integrated with AHP and Experts Choice software. From the six starch alternatives, Sago starch was at the top rank. Simultaneously, the design concept development and selection of the final takeout food container concept design were completed using combination of the Kano model, Quality Function Deployment for Environment (QFDE), and AHP. Nineteen concept design ideas were generated, and the final design was selected using AHP. The final design selected was a rectangular clamshell type with I-rib on wall and bottom of container base and locking structure of latching (male-female) at four corners. Lastly, the new design was assessed by attributional LCA using SimaPro software. The results showed that the new concept of takeout food container produced a total impact of $2.63 \times 10{-}5$ DALY for the Human Heath Damage, $9.46 \times 10{-}8$ species.yr for the Ecosystem damage and $0.491 for the Resources Scarcity.

Congratulation 2021 International Award

PROF. IR. DR. MOHD. SAPUAN SALIT


PERINTIS
Persatuan Saintis Muslim Malaysia

PERINTIS PUBLICATION AWARD 2021

awarded to

Ilyas, R.A., Sapuan S.M., Ishak M.R.

Universiti Teknologi Malaysia(UTM)

"Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata)"

Professor Ts. Dr. Salwani Mohd Daud
President, PERINTIS

- Perintis Publication Award 2021
  "Isolation and characterization of nanocrystalline cellulose from sugar palm fibres (Arenga Pinnata)" organized by Persatuan Saintis Muslim Malaysia (PERINTIS), Malaysia
- Felo - Akademi Sains Malaysia

Anugerah Perkhidmatan Cemerlang 2020

DR. NORFARYANTI KAMARUDDIN
Promotion: gred Q52

NURUL JANNAH MAT SALLEH

CONDOLENCES

In a memory of Dr Harmaen Ahmad Saffian, Research officer of INTROP

It is with greatest sadness that we inform you of the passing of Dr. Harmaen Ahmad Saffian passed away on 11 June 2021. He has been an important and vibrant member of our team since [starting year] and will be **dearly missed**. He is very dedicated person and very hardworking person. His warm spirit and generosity was a joy to all who knew him.

"Once again we wish to extend our condolences to his family and pray that they find strength during this difficult time.

NEW MEMBERS

Ms. Amirah Nur Amallina binti Osman
Administrative Assistant
1 July 2021

Ms. Zakiah Binti Sobri
Executive officer
11 Januari 2021

Ms. Che Nordiana Binti Che Nordin
Deputy Director's Secretary
1 April 2021

Mrs. Siti Nurulhuda Binti Ahmad Tarmizi
Science officer
3 May 2021

Mrs. Siti Aisyah Binti Shahadan
Assistant Office Secretary
17 May 2021

Mr. Mohd Muhaizi Bin Mat Daud
Research Officer
1 June 2021

Mr. Mohd Ashadie Bin Kusno
Research Officer
1 June 2021

Mrs. Suryani Binti Ahmad
Senior Assistant Registrar
15 June 2021

THANK YOU FOR **YOUR HARD WORK** AND **DEDICATION!**

Ms. Aidawati Binti Ramali
Senior Assistant Registrar
From: 22 April 2013 until 15 November 2020
New Atatchment : Centre For Quality Assurance (CQA)

Mrs. Nurul Jannah Binti Mat Salleh
Assistant Office Secretary
From: 15 September 2915 until 30 November 2020
New Atatchment : Faculty of Design and Architecture

Mrs. Nor Azizah Binti Haron
Science officer
From : 3 November 2007 until 30 April 2021
New Attachment: Faculty of Science

Mrs. Nazlia Binti Girun
Science officer
From : 1 Oktober 2007 – 30 April 2021
New Attachment: Institute of Plantation Studies (IKP)

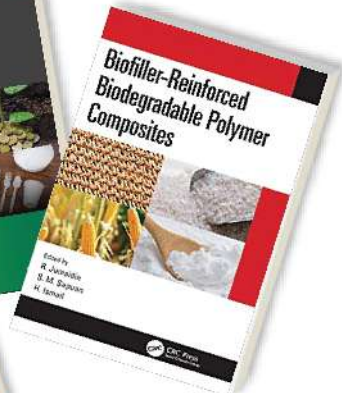
Mrs. Nur Fazrina Binti Ismail
Senior Assistant Registrar
From : 16 November 2020 until 14 June 2021
New Attachment: Sultan Alaeddin Suleiman Shah College

Mrs. Aiedah Binti Abdullah
Office Secretary
From : 1 June 2016 until 15 May 2021
New Attachment: Student Affairs Division

BOOK SHELF

- Bio-Based Packaging
  Material, Environmental and Economic Aspects
  Editor : Salit Mohd Sapuan , Rushdan Ahmad Ilyas , Christian V. Stevens
  Year : 8th June 2021
  ISBN No : 9781119381075

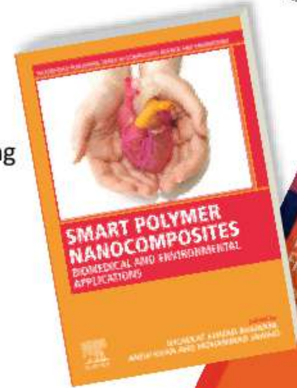
- Biofiller-Reinforced Biodegradable Polymer Composites
  1st Edition
  Editor : R. Jumaidin , S. M. Sapuan , H. Ismail
  Year : 2021
  ISBN No : 978-0-367-27264-74 (hbk)
  978-0-367-55569-6 (pbk)
  978-0-429-32211-2 (ebk)



- Design for Sustainability
  1st Edition
  Green Materials and Processes
  Editors : S.M. Sapuan, Muhd Mansor
  Paperback ISBN: 9780128194829
  eBook ISBN: 9780128194423
  Published Date: 13th March 2021

- Biocomposite and Synthetic Composites for Automotive Applications
  Editor : S. M. Sapuan , Edited by R. A. Ilyas
  Year : 2021
  ISBN No : 978-0-12-820559-4 (print)
  978-0-12-820923-3 (online)

- Smart Polymer Nanocomposites
  Biomedical and Environmental Applications
  A volume in Woodhead Publishig Series in composites science and engineering
  Editor : Showkat Ahmad Bhawani, Anish Khan and Mohammad Jawaid
  Year : 2021
  ISBN : 978 – 0- 12-819961 - 9



- Eco-Friendly Adhesives for Wood and Natural Fiber Composites
  Characterization, Fabrication and Applications
  Editors : Jawaid, M., Khan, T.A., Nasir, M., Asim, M. (Eds.)
  Year : 2021
  ISBN : 978-981-334-748-9 ; 978-981-334-749-6 (e-ISBN)

- Bamboo Fiber Composites
  Processing, Properties and Applications
  Editors : Jawaid, Mohammad, M.R, Sanjay, Siengchin, Suchart (Eds.)
  Year : 2021
  ISBN : 978-981-15-8488-6

- Hybrid Natural Fiber Composites
  1st Edition
  Material Formulations, Processing, Characterization, Properties, and Engineering Applications
  Editor : Anish Khan Sanjay M.R. Suchart Siengchin,
  Mohammad Jawaid Abdullah Asiri
  Year : 2021
  ISBN : 978-0-12-819900-8

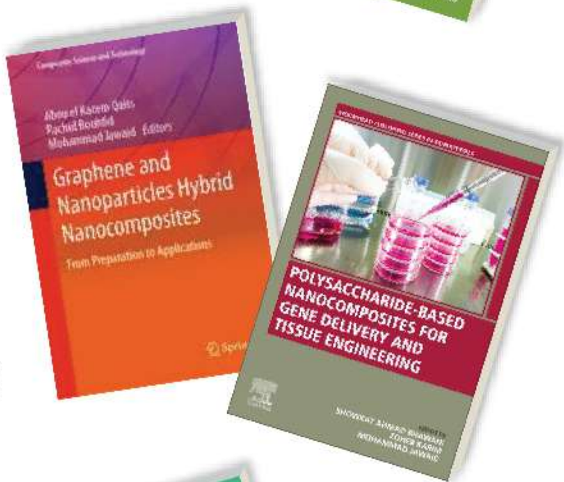
BOOK SHELF

- Phenolic Polymers Based Composite Materials
  Editors : Jawaid, Mohammad, Asim, Mohammad (Eds.)
  Year : 2021
  ISBN : 978-981-15-8931-7

- Advanced Technology for the Conversion of Waste into Fuels and Chemicals
  1st Edition
  Volume 1: Biological Processes
  Editors : Anish Khan, Mohammad Jawaid, Antonio Pizzi Naved, Azum Abdullah Asiri Illyas Isa
  Year : 2021
  ISBN : 9780128231395

- Green Biocomposites for Biomedical Engineering
  1st Edition
  Design, Properties, and Applications
  Editors : Md Enamul Hoque Ahmed Sharif Mohammad Jawaid
  Year : 2021
  eBook ISBN: 9780128215548
  Paperback ISBN: 9780128215531

- Vegetable Fiber Composites and their Technological Applications
  Editors : Jawaid, Mohammad, Khan, Anish (Eds.)
  Year : 2021
  ISBN : 978-981-16-1853-6



- Polysaccharide-Based Nanocomposites for Gene Delivery and Tissue Engineering
  1st Edition
  Editors : Showkat Ahmad Bhawani Zoheb Karim Mohammad Jawaid
  Year : 2nd June 2021
  eBook ISBN: 9780128232187
  Paperback ISBN: 9780128212301

- Graphene and Nanoparticles Hybrid Nanocomposites
  From Preparation to Applications
  Editors: Qaiss, Abouelkacem, Bouhfid, Rachid, Jawaid, Mohammad (Eds.)
  Year : 2021
  ISBN : 978-981-334-987-2 ; 978-981-334-988-9 (e-ISBN)

- Environmental Remediation Through Carbon Based Nano Composites
  Editors : Jawaid, M., Ahmad, A., Ismail, N., Rafatullah, M. (Eds.)
  YEAR : 2021
  ISBN : 978-981-15-6698-1 ; 978-981-15-6699-8 (e-book)

- Advanced Technology for the Conversion of Waste into Fuels and Chemicals
  1st Edition
  Volume 2: Chemical Processes
  Editors : Anish Khan Mohammad Jawaid A. Pizzi Naved Azum Abdullah Asiri Illyas Isa
  Year : 2021
  eBook ISBN: 9780323901512
  Paperback ISBN: 9780323901505

INTROPica

FORESTS: HUMAN HEALTH AND WELLBEING

Institute of Tropical Forestry and Forest Products (INTROP)
Universiti Putra Malaysia (UPM)
43400 UPM Serdang, Selangor, Malaysia.
Phone : +603 8947 1880 / 1881 / 1895
Fax : +603 8947 1896
www.introp.upm.edu.my