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INSTITUTE OF TROPICAL FORESTRY AND FOREST PRODUCTS

Centre of R&D in Tropical Biocomposite and Bioresource Management

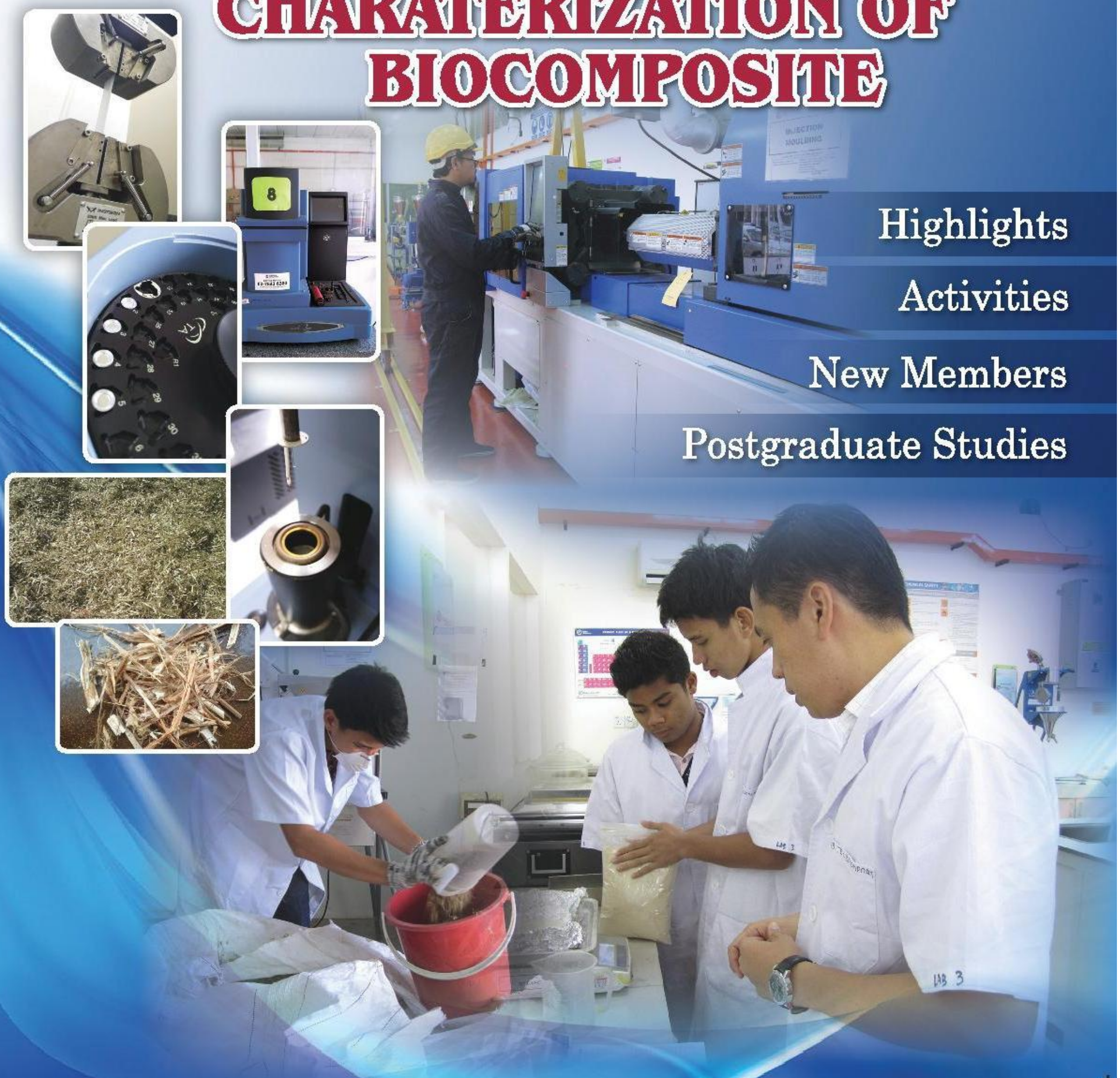
CHARATERIZATION OF BIOCOMPOSITE

Highlights

Activities

New Members

Postgraduate Studies



FROM THE EDITOR

السلام عليكم ورحمة الله وبركاته

During the last few decades, development of new materials is becoming increasingly difficult due to the increasing environmental concerns and shortages of the useful materials made from simple components. Among various environmentally friendly materials, renewable resources derived polymers (e.g., bio-based polymers) and biocomposites (e.g., natural fibers reinforced composites) are attracting a great deal of attention because of the inherent advantages of these polymers such as conservation of limited petroleum resources, biodegradability, low toxicity, easy availability, economy and the control of carbon dioxide emissions that lead to global warming.

One of the important aspects of biocomposites is that they can be designed and tailored to meet different desires. As the native biopolymers are not conventionally processable, research efforts have been focused on the processing and meeting the requirements of particular applications. The biobased materials are most frequently being used in the form of biocomposites. These biocomposites materials contain at least one component form the biorenewable resources that may either be the polymer matrix / reinforcement or may contain both.

From a characterization perspective, these materials can be treated as heterogeneous materials. While all characterization techniques can be used for homogeneous materials, the subject discussed in this volume emphasizes the unique features of biocomposite characterization. There are many techniques that can be used to characterize composite materials, and reviewing all of them is beyond the scope of this volume. Characterization techniques are divided into three categories: those which are considered extremely easy and routine, those which require special knowledge or advanced techniques but are available without extreme difficulties, and those which are quite unusual and of limited availability, to few laboratories. Historically, composite materials have been studied by evaluating mechanical properties, leading to a lack of molecular and chemical understanding. For this reason, it is our wish that this volume will provide more insight and views to this poorly exploited, yet important field of biocomposite research.

COMPOSITE PANELS FROM UNDER-UTILIZED WOOD AND AGRICULTURAL FIBER RESOURCES

By Salim Hiziroglu

Introduction

Production of wood composites such as particleboard, medium density fiberboard (MDF) and oriented strand board (OSB) continues to steadily increase in many countries. New wood-based composites are also progressively developed and successfully introduced as raw material for numerous structural and non-structural applications. Both particleboard and MDF are extensively used in furniture industry as substrate for thin overlays [6]. Using low quality small diameters trees which are not suitable for lumber manufacture is one of the main advantages of such panels. Within the scope of sustainable use of our forest resources underutilized wood species and agricultural fiber resources from various plants including rice straw, jute, coconut fiber, oil palm, bagasse, kenaf and bamboo are also getting popular to be used as raw material to produce different types of value-added composite panels [2,3,5,6]. As it is well known overall production process of such composite panels are quite similar to each other. In most cases, the chip or low quality logs are reduced into particles, fibers, or strand by using hammermill, disk refiner or flaker before the particles are dried to an approximate moisture content of 2-4%. Usually particles are classified as fine and coarse on different size of screens in a typical particleboard manufacture. Figure 1 illustrates various types of raw materials including particles, fibers and strands used for manufacture of experimental panels products. In the next step the material is blended with interior or exterior adhesive depending on the panel type. For example urea formaldehyde is the most widely used resin for manufacture of particleboard and MDF being interior panels while phenol formaldehyde is used for OSB having resistance under the outdoor conditions for building purposes. Wax and some other chemicals are also added into the resin to enhance overall properties of the final product. Blending is followed by the forming line where the raw material is configured into three layer loose mat having fine materials on the face and coarse material in the core layer of the panels. In the case of any type of fiberboard including MDF, thermally treated chips are converted into fibers using different techniques and equipment such as pressurized refiners. Multi opening presses are commonly used for most manufacturing processes of the composite panels. Heat and pressure are applied to the mat to cure the adhesive and give the desired strength properties to the final products. Figure 2 shows unpressed mats and finished panels. Last twenty years or so continuous press line is also getting more popular with respect its better efficiency and higher productivity. As mentioned above formaldehyde base adhesives are widely used in composite panel production. However these binders create significant health problems for both short and long-term exposure due to formaldehyde emission.

Therefore, formaldehyde emission has been the major concern associated with urea and phenol formaldehyde bonded wood composite panels [1,6]. From the perspective of green approach starch and soy based adhesives are getting attention in the industry. Starch from various plant materials such as corn, cassava, potato, and rice were studied to be used in wood composite panels as binders in past studies [2,5]. In one of these attempts modified starch combined with very small amount of formaldehyde based adhesive was used to produce experimental particleboard panels having an underutilized species, Eastern redcedar as raw material. The samples made in this work had modulus of elasticity values of 2,241.92 MPa, 2,344.32 MPa, modulus of rupture values of 11.17 MPa, 12.14 MPa and internal bond strength values of 0.57 MPa, 0.62 MPa for the panels with 0.70 g/cm3 and 0.80 g/cm3 density levels, respectively [5]. It was found that these panels satisfied properties stated in the American National Standard Institute [4]. However the dimensional stability of the samples need to be enhanced.

Figure 1. Various types of raw materials used for experimental composite panel manufacture [5,6].

Figure 2. Unpressed mats and finished panel products [5,6].

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SUGAR PALM FIBER: FROM TRADITIONAL TO ADVANCE APPLICATIONS

by Muhammed Lamin Sanyang

Introduction

Renewable and biodegradable materials are the hope of the near future. The devastating environmental issues generated by petroleum-based materials can be eliminated or at least minimized with the corporation of natural fibers and biopolymers in composite materials. The development of such green composites can yield significant environmental improvements, address plastic waste disposal and the reduction of carbon footprint of petroleum-based materials. For better sustainable future, bio-resources are increasing being utilized as potential alternatives for non-biodegradable synthetic materials. Abundant availability and low cost of these green materials grant them much attention for the past few decades.

Sugar palm *(Arenga pinnata)* is a multipurpose tree with several traditional uses. Different components of the tree have been extensively used for making numerous local products. Due to their outstanding mechanical properties, sugar palm fibers can compete with most natural fibers in the market such as coir, oil palm fiber, kenaf, cotton, jute and many more fibers.

Traditional uses of sugar palm fiber

The durability and resistance of sugar palm fiber to sea water resulted to their widespread usage in rural areas for manufacturing many traditional products (Figure 1). Martini et al. (2012) reported that different ethnic groups in Indonesia utilized sugar palm fiber for different purposes depending on their socio-economic activities, market opportunities and availability of other natural resources. Overall, the fiber immensely contributes to human livelihood in Indonesia, Thailand, Cambodia, Philippines etc. The fiber can be manually spun unidirectional to make ropes, or woven into mats. Traditionally, it is proven to be a suitable material for making ship ropes, brushes and brooms. It is also identified by the villages as one of the best options for traditional roofing and bridge construction which can withstand tropical climate for many years (Ticualo et al., 2013).

Figure 1: Traditional uses of sugar palm fiber

Applications of Green biocomposites from sugar palm fibers

Automotive Application

On the basis of sustainability, renewability, and affordability, biocomposite is a highly promising material for the automotive industry. Hence, there is an on-going research on the fabrication of glass/sugar palm fibre reinforced polyurethane hybrid composites as an anti-roll bar for sedan vehicles (Figure 2). This investigation is an innovation towards a greener future. The use of biobased anti-roll bar in vehicles will promote sustainability, reduce the car's consumption of fuel and emission of CO2 as well as addresses the negative impact of non-biodegradable plastics and fibers on the environment (Muscat et al., 2012). Thus, glass/sugar palm fibre reinforced polyurethane hybrid composites anti-roll bar is a potential alternative to conventional anti-roll bars. In one word, this research has presented a new perspective to sustainability research related to the automotive industry.

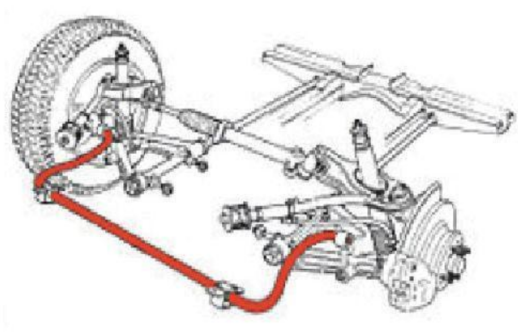

Figure 2: Antiroll bar to be fabricated from glass/sugar palm fibre reinforced polyurethane hybrid composites

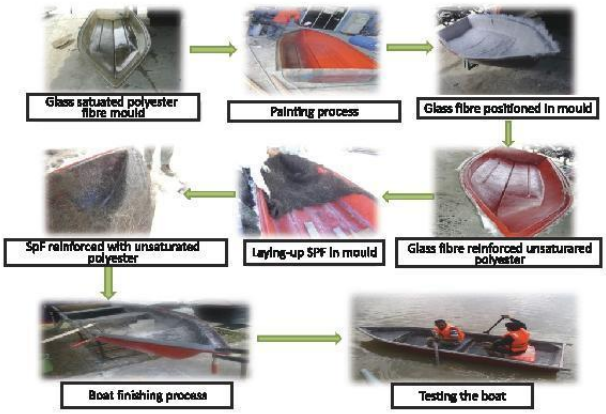

Figure 3: Fabrication of sugar palm/glass fiber hybrid boat (Sanyang et al., 2016a)

Marine Application

Sugar palm fiber is long since known for its resistance to seawater, as such, the rural fisher men often use it as a rope to tie small boats. In support of this custom, Leman et al. (2008) treated sugar palm fiber with seawater. They reported that the mechanical properties of the treated fiber employed to reinforce epoxy composites increased by soaking it in seawater for 30 days. Subsequently, Misri et al. (2010) fabricated a 12 feet (length) hybrid composite boat from the combination of sugar palm and glass fiber with unsaturated polyester as the matrix (Figure 3).

Packaging Application

Biopolymers (bio-based polymers) are considered biodegradable but not all biodegradable polymers are biopolymers. Reinforcement of the biodegradable materials with natural fibers yield improved material properties desired in various applications without compromising their biodegradability. When both the fiber and matrix are from renewable resources, the resulting composite material can be referred to as "100% bio-based biocomposites" or "fully biodegradable green composite" (Vilaplana et al., 2010). The use of such biocomposites should be encourage for less environmental impact.

In the case of sugar palm, starch can be obtained from the inner core of the trunk. Number of studies has been reported on the suitability of sugar palm starch for preparing shopping bags and food packaging films (Sanyang et al., 2016a; 2016b; 2016c) (see Figure 4). Starch based films are renewable and 100% biodegradable material and are potential replacement of non-renewable packaging films. However, the main water, which can be attributed their hydrophilic and hygroscopic nature as well as the high plasticizing effect of water (Olsson et al., 2013). In general, these films are considered to have moderate oxygen barrier properties but poor moisture barrier and mechanical properties, which limit their wide applications for food packaging. Therefore, the development of packaging materials with good barrier against water and acceptable mechanical strength is a primary concern in the food packaging industry. On these bases, a recent study was conducted by Sanyang et al. (2016c) in which sugar palm-derived cellulose (SPC) composites were prepared and utilized as reinforcement material to improve the mechanical and water vapor barrier properties of sugar palm starch (SPS)-based films. The incorporation of 1 wt. % SPC loading significantly improved the water vapor permeability (WVP) of the composite film by 63.53%, thus, enhance their suitability for food packaging applications.

Figure 4: Potential applications of sugar palm based biocomposites for shopping bags and food packaging materials

Conclusions

Most interestingly, 'one-source' green composite can be fabricated by 'marrying' natural fiber with biopolymer from a single sugar palm tree. In general, use of sugar palm fiber and starch in green composites can help in: (1) reducing the negative environmental impact of synthetic polymers and fibers; (2) decreasing the pressure for the dependence on petroleum products; and (3) developing sugar palm as new industrial crop in the future, most especially in tropical countries. Consequently, this can lead to better socio-economic empowerment of the rural people by increasing revenues and creating more job opportunities. However, the gigantic opportunity of utilizing sugar palm fiber and biopolymer in the composite industry for various potential industrial applications has not been widely exploited.

Future perspectives

So far, substantial works were done on sugar palm based composite but there is no reported investigation on sugar palm based nanocomposites. Venturing into sugar palm nanocomposites can enhance the reputation of sugar palm biocomposite industry and open new markets such as pharmaceutical and electronic packaging. This is a virgin research and innovation area to address some concerns hindering potential industrial applications of sugar palm fibers, biopolymer and their composites.

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CHARACTERIZATION OF WOOD AND NON-WOOD PARTICLES PROPERTIES

by Juliana Abdul Halip, Lee Seng Hua, and Paridah Md Tahir

Introduction

There are many lignocellulosic resources in Malaysia and this resources can be classified as wood and non-wood. Commonly, the term "wood" is based on tree, and "non-wood" is based on non-tree plant (including shrub, palm, grass, etc). In order to use these lignocellulosic resources in particle-based composite manufacturing, the characterization of the particles is crucial. Characterization can defined as a description of the distinctive nature or features of something. In this article, the characterizations of particles are including the size (length, width and thickness), aspect ratio and geometry of wood and non-wood particles. These characteristics are substantially affecting the performance of the manufactured composites.

Commonly, particles are used in particleboard and wood plastic composite manufacturer. The term "particle" is a generic term applied to all lignocellulosic elements, either wood or non-wood, from which composites are made. The terminology can be referred to various types of particles depending on their applications. For example, the major types of particles used in particleboard manufacturing include wood shavings, flakes, wafers, chips, sawdust, strands, slivers, and wood wool (Moslemi 1974). Meanwhile the major types of particles used in wood plastic composite are commonly called fibre, particle, wood flour and sometime sawdust. Wood flour and sawdust are the same product, but in different size where the sawdust is normally having smaller size as compared to the wood flour. Figure 1 illustrates the types of particles that commonly used in composites.

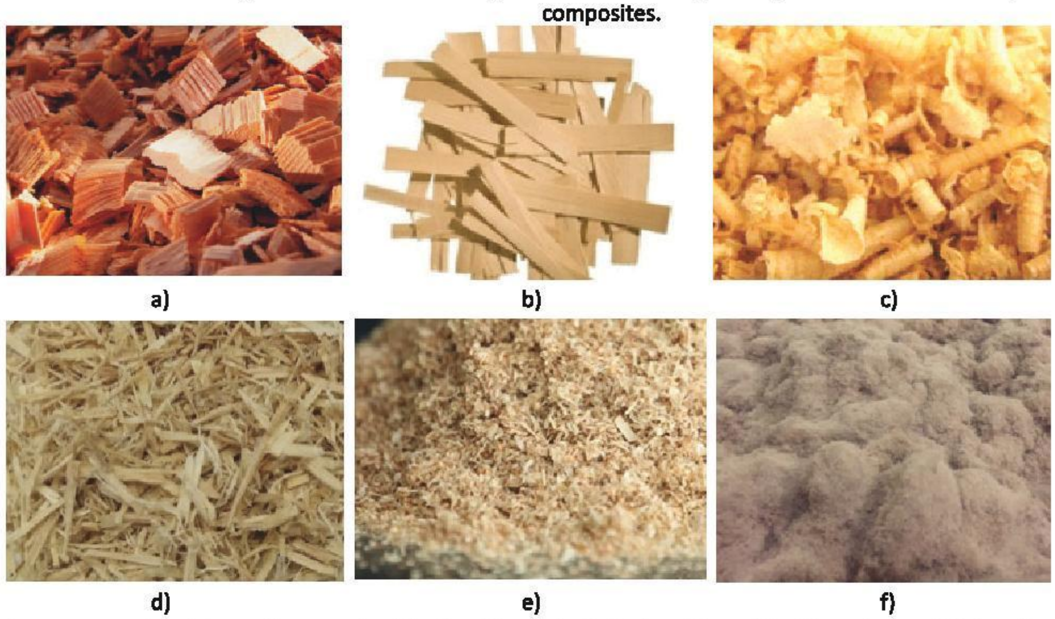

Figure 1: Types of particles used in composites (a) chips, (b) strands, (c) shavings, (d) particles, (e) sawdust, and (f) short fibres

One of the most main characters of particle is the size (including length, width and thickness). Afterwards, this size will indicate the slenderness ratio (length to thickness) and aspect ratio (length to width) of the particles. In a comparative study done by Juliana et al (2017), typical wood and non-wood particles sizes for particleboard production is 9.90 to 15.60 mm and 1.89 to 48.60 mm, respectively. Longer particle produced by non-wood might be due to the particles are in the presence of vascular bundles. Hashim et al (2009) reported that the length of vascular bundles of oil palm tree are ranging from 30 to 50 mm. Meanwhile, in wood plastic composite, short and tiny fibres (average particle size 0.24–0.35 mm) should be preferred for wood plastic composite (Ashori, 2008). Other studies stated that typical particles sizes for wood plastic composite production is 10 to 80 mesh or 0.18 to 2.0 mm, and the smaller particles were said to yield better performance (Takatani et al. 2000; Clemons 2002). The differentiation on the length and width of particles was due to the different specific gravity of the materials. As mentioned by Maloney (1993), during flaking, the ability of a knife blade to penetrate the wood and slice it depends, to a great extent, on the specific gravity and hardness of the wood.

Particle size is one of the main parameters that have been reported to affect the properties of the end product, namely particleboard and wood plastic composite (Moslemi, 1974; Ashori, 2008). For instance, particleboard comprises of larger and longer sized particles were found significantly stronger in bending and bonding strength as compared to the board made from smaller sized particles (Ong 1981; Jamaludin et al. 2001; Migneault et al 2008; Juliana et al. 2012). Increasing the length of particles and the slenderness ratio (length/thickness) also increases both modulus of rupture (MOR) and modulus of elasticity (MOE), but decreases the bonding strength (Miyamoto et al. 2002). In a comparative study done by Juliana et al (2017), they stated that the mechanical properties of wood plastic composites are significantly increased with increasing particle length from 0.18 mm to approximately 0.50mm, but the properties are adversely affected when the particle length increased to 0.68 mm and above.

Another character influencing the properties of composite is particle geometry, which indicates the shape and the size. Majority of wood particles appeared in form of rectangular and nearly rectangular form (Kruse et al., 2000). Meanwhile, kenaf with lower density were present in a semi-circular-end shape but most of them still retained the rectangular shapes (Juliana et al., 2012). A study reported that semi-circular end-shaped particles gave low strength, rectangular-shaped particles gave superior strength, and that flat, end-tapered and pointed, end-tapered shapes gave moderate strengths (Schneider and Conway, 1969). Overall, wood particles are more consistent in term of length and geometry. Meanwhile, non-wood particles have fluctuate length and geometry. However, some of non-wood particles has comparable characters as wood, and some other such as bamboo exhibits superior properties compared to wood.

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INFLUENCE OF CHITOSAN ON PROCESSING CHARACTERISTICS OF POLYETHYLENE/KENAF BIOCOMPOSITES

Ahmad Adlie Shamsuri and Muhammad Izzuddin Syariff Tan

Introduction

Kenaf core fibre (KCF) was utilized as primary filler and chitosan was used as secondary filler, whereas low-density polyethylene (LDPE) was applied as polymer matrix for preparation of hybridized natural fibres polymer biocomposites. The use of dual natural fillers is very promising due to they can mutually assist between each other in the reinforcement of the biocomposites (Shamsuri et al. 2015). The main purpose of this research is to identify the influence of chitosan addition on the processing characteristics of the LDPE/KCF biocomposites. The main difference between chitosan and KCF is that chitosan has anti-microbial character, easy to acquire (derived from shrimp shell), and biocompatible as well (Nazarudin et al. 2011).

Materials and Method

LDPE (coating grade) was purchased from the Lotte Chemical Titan (M) Sdn. Bhd., Malaysia. KCF (420 µm) was obtained from the National Kenaf and Tobacco Board, Malaysia. Chitosan was procured from the Sigma-Aldrich (M) Sdn. Bhd., Malaysia. All materials were consumed as attained without further refinement (Shamsuri et al. 2014). Brabender internal mixer machine was used to prepare the biocomposites. The machine was equipped with a real-time processing recorder. The compositing was done at a temperature of 150°C, and the rotor speed was fixed at 60 rpm. First of all, 24 g of LDPE was inserted into the mixing chamber, and allowed to melt for 3 minutes. After that, 16 g of KCF was added into the chamber, and permitted to composite for 6 minutes. Finally, chitosan was incorporated into the composite, and allowed to blend for 6 minutes. The period of the whole process was 15 minutes (Shamsuri et al. 2015). The contents of the chitosan were varied from 3 to 18 wt.%. The biocomposite containing only LDPE and KCF was also processed for comparison purposes.

Results and Discussion

Processing torque is one of the processing characteristics, it has been recorded during the processing of the materials. Figure 1 showed the processing torque-time curves of the LDPE/KCF biocomposites with different contents of chitosan. The increased torque curves at around the first minute for all samples are due to the unmelted LDPE that increased the resistance on the internal mixer rotors. The curves then decreased at around the second minute because the melting of LDPE took place. The torque curves started to increase again at around the fourth minute after KCF added to all samples. This is due to it required more force for distributing the KCF filler in the molten LDPE. Then, the torques obviously started to decrease again when the KCF thoroughly dispresed in the LDPE matrix.

The processing torque for the sample with 0 wt.% of chitosan was decreased and persisted almost unchanged at a certain level until the end of mixing time. For the sample with 3 wt.% of chitosan, there was a slight increase of the processing torque at around the tenth minute compared to the previous sample. It showed that a small amount of friction from the chitosan acting on the molten biocomposites. On the other hand, for the samples with 6 to 18 wt.% of chitosan, there were significant increases in the processing torques due to large amounts of friction exerted on the molten biocomposites. Nevertheless, the torques was slowly decreased once the chitosan is completely dispersed in the molten biocomposites (Shamsuri et al. 2014). Then, the torques of all samples started to maintain stable at around the thirteen minute until the end of processing. This is due to the LDPE, KCF and chitosan have been mixed well during the processing (Sudari et al. 2015).

Figure 2 demonstrated the influence of chitosan on the stabilization torque of the LDPE/KCF biocomposites. The torque values specifically at the fifteenth minute were regarded as the stabilization torque values (Shamsuri et al. 2015). The diverse values of stabilization torque were based on the fact that the contents of chitosan added into mixing chamber are varied with one another.

In figure 2, the graphs showed that the stabilization torques increased for the samples added with chitosan from 3 to 18 wt.%. Moreover, for the biocomposites with more chitosan they tend to have higher stabilization torques compared to the samples with less chitosan although at similar loading of LDPE/KCF. This is due to the more addition of secondary filler to the biocomposites, the higher viscosity of the molten biocomposites attained (Shamsuri et al. 2015).

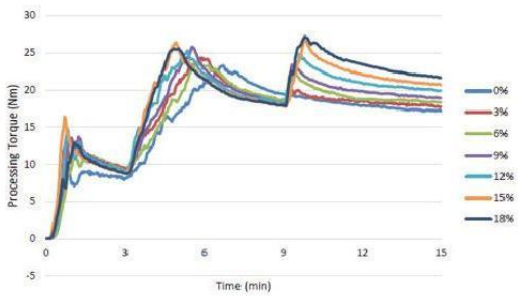

Figure 1. Processing torque-time curves of the LDPE/KCF biocomposites

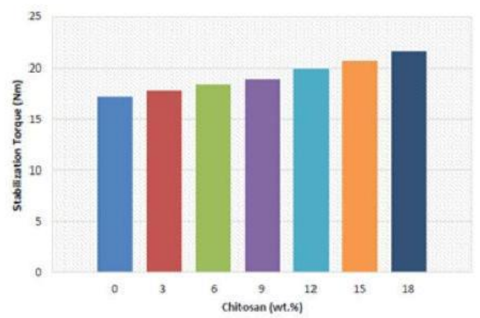

Figure 2. Stabilization torque-chitosan graphs of the LDPE/KCF biocomposites

Conclusion

From this research, the LDPE/KCF biocomposites added with chitosan as secondary filler were successfully processed. It can be seen that the processing torque and stabilization torque have increased after chitosan added to the biocomposites. This is due to the fact that the addition of chitosan has exerted some amounts of friction on the molten biocomposites. Therefore, with the addition of chitosan, it enhanced the melt viscosity of the biocomposites. This concluded that the LDPE/KCF biocomposites with chitosan added as secondary filler can potentially develop stiffer products as compared to the one without chitosan.

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DEVELOPMENT OF PRODUCTS FROM SUGAR PALM TREES (ARENGA PINNNATA WURB. MERR): A COMMUNITY PROJECT

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Abstract

This project is concerned with the development of products from sugar palm tree *(pokok enau)* under the UCTC-NBOS program and was funded by the Ministry of Education Malaysia under the 8th National Blue Ocean Strategy (NBOS). This community project was carried out in collaboration with the *Jawatan Kuasa Kemajuan dan Keselamatan Kampung (JKKK)*, Kampung Kuala Jempol, Bahau, Negeri Sembilan. Twelve products including sugar palm syrup, sugar palm sugar block, sugar palm fine sugar, sugar palm fruits, sugar palm vinegar, broom, general cleaning brush, bottle cleaning brush, rope, sugar palm fibres, sugar palm starch, and roof have been developed in this community project. The main objective of this project was to help villagers to develop and commercialize the sugar palm products, which, in turn improved their socio-economic level. Villagers from Kampung Kuala Jempol were excited with this project as 'wastes' in their village had been converted into 'wealth'. Knowledge transfers of various methods and technologies had been conducted through a series of demonstration. The major advantages resulting from this project were achieved in all aspects including cost and quality of product produced, as well as transferring university expertise to the community.


Figure 1: A series of demonstration to the community on how to obtain sugar palm starch and sugar palm fibres

Introduction

Sugar palm (Arenga pinnata wurb. merr) trees had been around for making variety of by-products for hundreds of years (Tomlinson, 1962). In Malaysia, it is popular activity among villagers to tap palm sap for making traditional sugar blocks locally known as gula enau or kabung (Ishak et al. 2011a). There are three main objectives in this project; i.e. to transfer the knowledge for the development of products based on sugar palm fibres, to transfer the knowledge based on sugar palm tree (other than fibres), and to help the local community in commercializing and marketing the products. From this project, the village community was exposed to the potentials of sugar palm tree that was usually known for only making food items and beverages. At the end of this project, the community continued the process of collecting and making products based on sugar palm trees and marketing them throughout Malaysia.

UCTC-NBOS project was successfully completed within one year and three months with total cost of RM 156,100.00. The entire fund was spent to transfer the expertise to generate skill and knowledge about sugar palm tree and it products to the community and to ensure it sustainability. Through this project, the funds were not only allocated for holding talks, exhibition and demonstration to the community (Figure 1), but also providing equipment including a building in the form a shed for the purpose of producing sugar palm products.

Traditionally, sugar palm sap was processed for making traditional sugar blocks and was processed in the forms of crystal and brown sugars as alternatives to the commercialized sugarcane granular sugar. It was also fermented to produce bioethanol for production of varieties of products (chemical products, solvents, pharmaceutical, medicines, beverages, etc. and would also be used for production of biofuel. The next important part after palm sap is its fruit. It can be processed for making pickles, juices, desserts, for canned foods, and also being cooked for making traditional sugary syrup. There were other commercial purposes of sugar palm such as production of sago and its hard wood (Ishak et al., 2011b).

However, the most important part after its palm sugar and it fruit is its fibre. Its black fibre or locally known as ijuk fibre was used for making ropes, brooms, brushes, paint brush, septic tank base filter, roofing, fishing tools and for handicrafts (Sastra et al. 2006, Bachtiar, et al. 2008 and Leman, et al. 2008).The project team had successfully developed 12 products based on sugar palm trees namely sugar palm fibre, starch, roof, rope brooms, brushes (berus sabut), brushes for cleaning bottles, vinegar, fruit, liquid sugar, fine sugar, and sugar block (Figure 2). In the project, all products were realized along with packaging.

Fig. 2: Twelve products produced from sugar palm tree

A lot of efforts had been put into the project, including a visit to a company involving in commercializing sugar palm fibre products in Indonesia; this visit had greatly benefited to the development of the project. The visit was organized by the project research team to obtain more practical information about sugar palm fibre industry in CV. Mulya Perkasa, Tasikmalaya, Indonesia, which had a wide and long experience in producing sugar palm fibre products. From the visit, practical knowledge on how to produce brushes, brooms, roof and the rope was brought back to Malaysia. In addition, the team also visited Kampung Naga, Tasikmalaya, Indonesia, to study the use of sugar palm fibres as the roofing materials, which was very important to be highlighted in Malaysia. The quest for traditional touch in decoration of buildings in Malaysia is increasing as the existence of holiday resorts, which choose traditional materials to build gazebos, cottages and chalets. After returning to Malaysia, the team shared the information and products to the villagers in Kampung Kuala Jempol and this made them more eager to run the project by themselves. It was quite a challenge to convince the communities at first, especially the younger generation that this project has a great potential and it was really the villagers who is supposed to make it to happen.

From the first launch of the project until handing over the technology, machinery (Figure 3) and a building to the community, it was observed that a lot of people were getting involved and more participation from the community in this project because it can help them to generate extra income. The increase in participation was more significant when a building in the form of shed with traditional features was built. The building (Figure 4) was built with traditional features with the purpose of attracting more visitors to come and they can experience the process of preparing sugar palm products first hand. Besides that, the visitors also can buy the product directly.

Figure 3: Among the machines used to make sugar palm products

Figure 4: A building for the purpose of collecting, processing and commercializing of sugar palm products

The villagers were impressed with this project after seeing the seriousness of the UPM team and the project will be registered with the state's tourism department to promote Kampung Kuala Jempol as a tourist attraction as well as to respond to the government's call for *"One District One Industry"*. The project also promoted the name of Kampung Kuala Jempol as a new attraction for tourists in Negeri Sembilan.

Conclusion

The potential of sugar palm tree were successfully explored under UCTC-NBOS project. Twelve product were developed in this community project; i.e. sugar palm syrup, sugar palm sugar block, sugar palm fine sugar, sugar palm fruits, sugar palm vinegar, broom, general cleaning brush, bottle cleaning brush, rope, sugar palm fibers, sugar palm starch, and roof. With total cost of RM156 100.00, this project succeed in providing the knowledge, skill, equipment including a building for the benefit of the community. This project also become one of the tourist attraction in Kampung Kuala Jempol, Negeri Sembilan.

Acknowledgement

The authors wish to thank Ministry of Education Malaysia for the research grant under the UCTC-NBOS (grant vote no: 6234004). We also appreciate the assistance and contribution of the collaborating communities; i.e. team project and JKKK Kampung Kuala Jempol, Negeri Sembilan. We also thank to CV. Mulya Perkasa, Tasikmalaya, Indonesia for sharing the knowledge on product development of ijuk and to Universiti Putra Malaysia for providing the research facilities.

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CHARACTERIZATION OF BIOCOMPOSITES

By Rasha M Sheltami

Introduction

Biocomposites are composite materials consist of one or more phase(s) derived from a renewable resource, commonly matrix material and natural reinforcements, to combine the different features and benefits of the components to produce a useful product having the requisite cost and performance properties for applications with eco-friendly features. Matrices might be natural or synthetic polymers such as starches, polylactic acid, polyethylene, polypropylene, polystyrene, polyvinyl chloride and unsaturated polyesters. The reinforcement could include plant fibers such as wood, kenaf, cotton, flax, hemp, sisal, and rice husk. Fibers from recycled waste papers and regenerated cellulose fibers are also included in this statement. The use of fiber-reinforced polymer composites began in early of the 1900s and the demand of the composites based on natural fibers rises with the increase of environmental concern as well as the increasing oil prices. The biocomposites are exploited in several applications such as automotive sectors, packaging, furniture and building components. Natural fibers are in general suitable to reinforce polymers owing to their relatively high strength and stiffness with low density. Moreover, the natural fibers possess excellent sound-absorbing efficiency and have excellent energy management characteristics (Bledzki and Gassan, 1999; Mohanty et al., 2005).To finalize the manufactured biocomposites for applications, the mechanical properties should be analyzed. The mechanical properties of a material are affected the mechanical strength and ability of material to be molded in suitable shape. In addition, other properties should be analyzed and investigated. In this article, the important characterizations of the biocomposites will be highlighted.

Characterization

Different characterizations can be applied to the biocomposites to evaluate their properties, including the mechanical, thermal and morphological properties as well as water uptake, acoustic emission, and the biodegradability studies. Figure 1 shows some of the instruments in the Institute of Tropical Forestry and Forest Products (INTROP) for investigation the biocomposites properties.

Figure 1: Some instruments in the Institute of Tropical Forestry and Forest Products (INTROP) for analyzing and testing the thermal

Mechanical properties are the properties in which the samples subject to forces (loads), the properties help to understand and measure how the biocomposites behave under the load. The common mechanical properties considered are strength, ductility, hardness, fracture toughness and impact resistance measured using tensile test and impact tests. The tests are carried out according to standard methods depends on the matrix type and size, e.g. the method used for tensile properties of plastics is ISO 527-1 (or ASTM D638) and a thin plastic sheet is ISO 527-3 (or ASTM D882).

Figure 2 shows the mechanical properties of several polymer composites, it displays the effect of different types of natural fibres on the mechanical properties of the polymer matrices. Generally, the use of natural fibres as reinforcement for polymeric composites improves the mechanical behaviour of polymers and usually the natural fibres reinforced polymer composites exhibit better mechanical properties than the polymer matrix. In previous studies, jute fibres improved the tensile strength of poly(lactic acid) (PLA) and the enhancement was about 75.8%.

In addition, the fibres enhanced all the mechanical properties of polyester composites. But, the tensile strength of PLA was decreased with the addition of flax fibres. Furthermore, kenaf, hemp, and cotton improved the tensile strength of polypropylene (PP) composite. The tensile strength of epoxy improved with the addition of jute fibres, meanwhile, the compressive strength was deteriorated (Shalwan and Yousif 2013, Plackett et al. 2003, Kim et al. 2008).

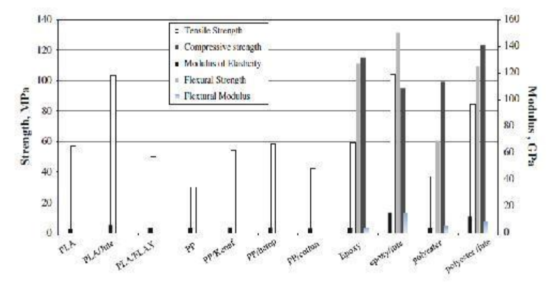

Figure 2: Some of the mechancial properties of natural fibre/polymer composites (Source: Shalwan and Yousif, 2013)

Thermal analysis is used to investigate the thermal parameters and properties of the biocomposites. Several instruments are applied, including differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical thermal analysis (DMTA) and thermomechanical analysis (TMA) for the thermal study. The thermal stability of the biocomposites is one of the important considerations; other parameters are important to be measured and understand inclusive thermal transitions and thermal expansion. That would be important for both the process of fabrication and the applications of the biocomposites which subject to heat. In general, the addition of natural fibres to polymer matrices leads to increase the thermal transitions, reduce the thermal expansion and might show different effect on the thermal stability. Figure 3 shows thermal degradation curves of kenaf fibers (KF) reinforced poly(vinyl chloride) (PVC)/thermoplastic polyurethane (TPU) poly-blend composites, it was studied by El-Shekeil et al. (2014). The degradation occurred in three stages and the effect of the fiber content was different during the degradation. The composites and the matrix had the similar stability at the first stage, the matrix showed a slightly better stability than the composites at the second stage. At the third stage, composites showed a better stability than the matrix.

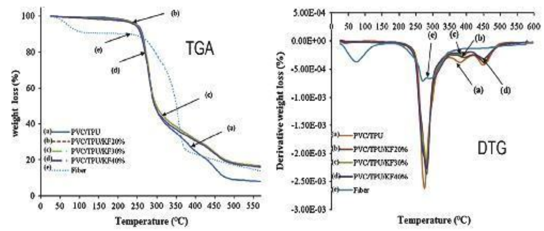

Figure 3: Effect of fiber content on thermal degradation of PVC/TPU/KF (Source: El-Shekeil et al., 2014)

The scanning electron microscope (SEM) is used to study the morphology of the biocomposite surfaces and to investigate the fibre-matrix interface. Figure 4 shows the SEM micrographs of fractured surfaces of low density polyethylene (LDPE)-based composites reinforced with cellulosic fibers for different magnifications to compare between the fibre-matrix interface before (Figure 4a) and after silane treatment with Methacryloxypropyltrimethoxysilane (MPS) (Figure 4b). It is clear that the interfacial adhesion between the fibre and matrix was improved after silane treatment as can be seen from the micrographs. For bio-nanocompostes, field emission scanning electron microscope (FESEM) and atomic force microscopy (AFM) are used to investigate the surface morphology. Furthermore, transmission electron microscopy (TEM) is used for the nanocomposites after preparing a thin film (~70 nm thickness) using cryo-ultramicrotomy. Figure 5 shows TEM images of unsaturated polyester (UPR) nanocomposites, they displays the distribution of cellulose nanocrystals (CNC) and silane treated nanocrystals (STCNC) into the UPR matrix.

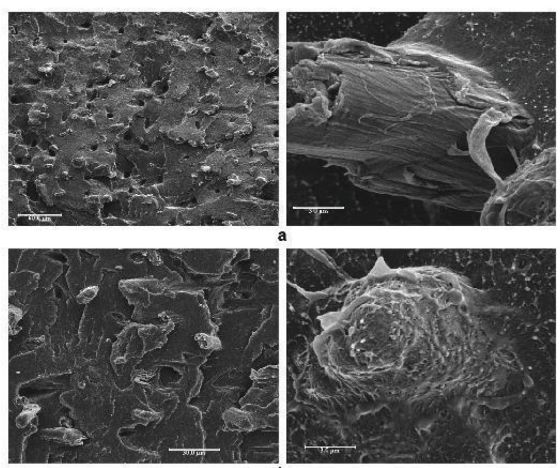

Figure 4: SEM micrographs of fractured surfaces of LDPE-based composites reinforced with cellulosic fibers (a) untreated and (b) MPS-treated fibers
(Source: Abdelmouleh et al., 2007)

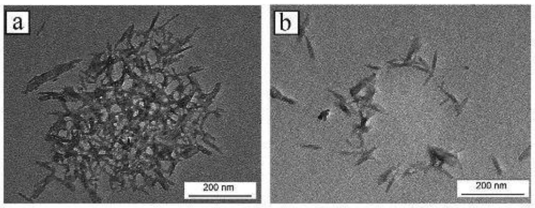

Figure 5: TEM images of (a) CNC-UPR nanocomposite, and (b) STCNC-UPR nanocomposite
(Source: Kargarzadeh et al., 2015)

Several standard test methods are used to study the behaviour of the biocomposites and the influence of moisture/weathering/environment on the properties of biocomposites, e.g. ISO 18249 (or ASTM E2076) is for acoustic emission test., ISO 62 (or ASTM D570) is used to measure the water absorption, ISO 15512 (or ASTM D789) is used to obtain moisture content, and ISO 14855 is a standard biodegradation test method to determine ultimate aerobic biodegradability. The importance of evaluation the biocomposite properties is to accomplish the manufactured biocomposites and reach the required properties for the applications. The characterization and testing should be chosen based on the fabrication and applications demands.

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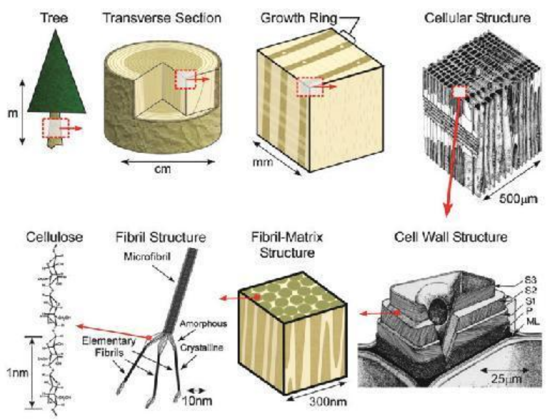
CELLULOSE CHARACTERISTICS : FROM MICRO TO NANO

by Syeed SaifulAzry, Luqman Chuah Abdullah and Paridah Md Tahir

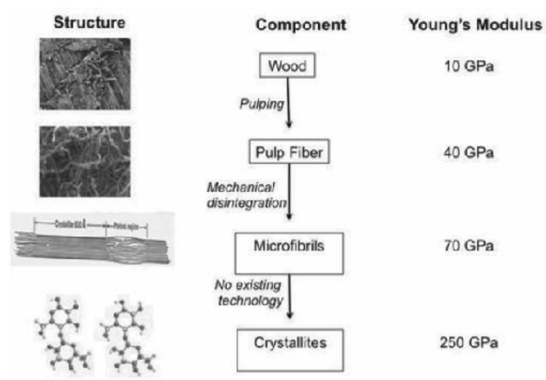
Introduction

Cellulose characteristics very much depending on hierarchical structure design that spans nanoscale to macroscopic dimensions as illustrated in Figure 1. It possesses several attributes such as a fine cross section, the ability to absorb moisture, high strength and durability, high thermal stability, good biocompatibility, relatively low cost and low density yet good mechanical properties (Roy et al., 2009). However, cellulose fibres properties are strongly influenced by many factors, which differ from different parts of a plant as well as from different plants (Siquera, Bras, & Dufresne, 2010). Due to this inuniformity and some of cellulose natural characteristics (i.e high hydrophilicity, poor dimensional stability, easily attack by insects and fungi), its promotes endless efforts esspecially by scientist to improve and modify drawbacks that associate with cellulose in original form. The improvement and modification of cellulose can be done physically and/or chemically depending on properties that desired to be improved.



Source : Dufresne, 2013

Figure 1 : Illustration of cellulose hierachical structure



Source : Silva et al., 2015

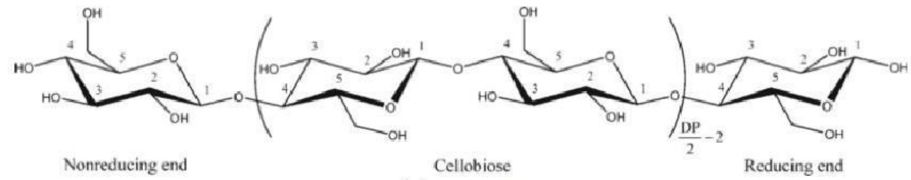
Figure 2 : Correlation between structure, process, component and modulus

The hierarchical structure design of cellulose fibres exhibit uniqueness to it properties. The mechanical performance of cellulose fibre increase tremendously as it is downscaled from macro to nano level. As illustrated in Figure 2, the modulus of wood in original form is about 10Gpa. It increase to 40GPa after separated and downsize into pulps and further to 70 GPa at microfibrill form and 250 Gpa as in crystalite (nano) form (Silva et al, 2015). In fact, at the nanoscale level, some material properties are affected by the laws of atomic physics rather than behaving as traditional bulk materials do. Their extremely small features size is of the same scale as the critical size for some physical phenomena, such as light (Brinchi, et al., 2013). This makes cellulose fibre at nanoscle open a wide range of possible properties to be discovered. Generally, the size of nanocellulose fibres are in the range from 2 to 20 nm in diameter, and a length of more than a few micrometers.

Cellulose structure and arrangement

Cellulose molecular structure

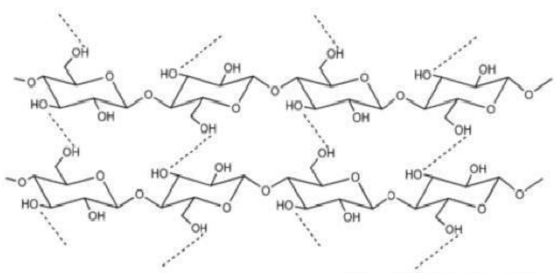
The cellulose molecule is a linear homopolysacchride that composed of D-anhydroglucopyranose units linked together by β-1,4-glycoside bonds. The molecular structure of cellulose shown in Figure 3.



Source : Habibi, Lucia, & Rojas, 2010

Figure 3 : Structure of cellulose with carbon atom numbering with hemiacetal at the reducing end and free hydroxyl group at C4 as non-reducing end

As illustrated in Figure 3, cellulose is 1,4-linked glucans that has one reducing end containing an unsubstituted hemiacetal, and one non-reducing end containing an additional hydroxyl group at C4. Each monomer attached with three hydroxyl groups where C6-OH act as primary group and C1-OH and C2-OH as secondary group (Wertz, Bédué, & Mercier, 2010). These hydroxyl groups will determine the cellulose reactivity. Generally, the reactivity of these hydroxyl groups can be expressed as OH–C6 >> OH–C2 > OH–C3 (Roy et al., 2009). Besides, these groups are resposible for the formation of strong hydrogen bonding inter- and intra-cellulose molecule chain (Figure 4). The hydrogen bonding will attributes to cellulose important properties esspecially its (i) multi-scale microfibrillated structure, (ii) hierarchical organization (crystalline vs. amorphous regions), and (iii) highly cohesive nature (with a glass transition temperature higher than its degradation temperature (Lavoine et al., 2012).

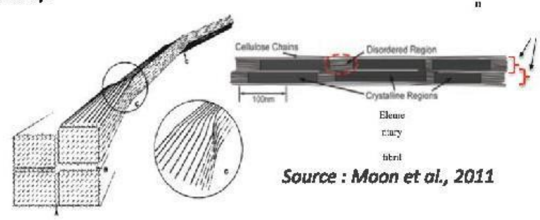


Source : Roy et al., 2009

Figure 4 : Hydrogen bonding in cellulose molecules (a) intramolecular; (b) intermolecular

Cellulose polymerization and packing assemblies

The degree of polymerization of native cellulose from various sources is ranging from 1000 to 30,000, which corresponds to chain lengths from 500 to 15000 nm (Ioelovich, 2008). As mentioned earlier, cellulose is a hierichal structure. It has a complex, multi-level from macro to nano-scale architecture. It assemble from packing bundles of elementary fibrils that have size 3-15 nm in diameter and length about 1µm. These packing assemblies of elementary fibrils consist of 60-80% of ordered domain and remaining as disordered domain. Ordered domains also called as crystalline region contains highly ordered and very minimal defect crystallite chains having length in range of 50-150 nm. Meanwhile, disordered domain which commonly known as armophous region is 25-50 nm (Ioelovich, 2008).



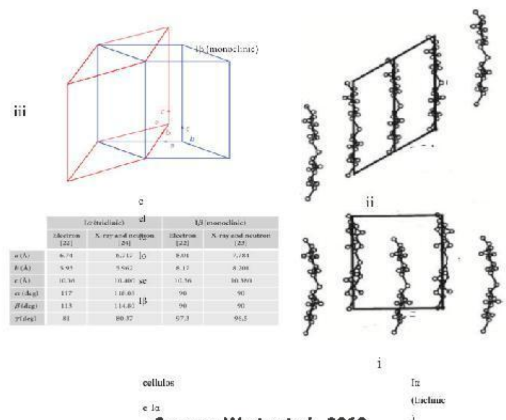
Source : Moon et al., 2011

Figure 5: Illustration on the microstructure of the microfibril a) cross-section view of microfibril that comprise elementary fibrils bundle b) single elementary fibril c) amorphous region/defects due to distorted by internal strain in the fibre and proceed to tilt and twist d) side-view of microfibrils and elementary fibril bundles

The amorphous regions are scattered along the microfibrils. One of well accepted theory of how amorphous region occurs was due to microfibrils are distorted by internal strain in the fibre and proceed to tilt and twist and producing chain dislocations/defects on segments along the elementary fibril packings as illustrated in Figure 5 (Habibi et al., 2010).

Cellulose polymorph and packing arrangement

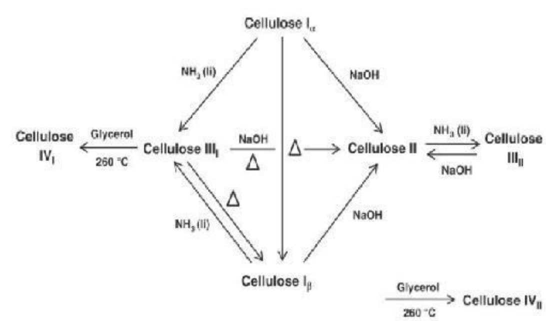
There are six crystalline polymorphs of pure cellulose with different packing arrangements ; cellulose I, II, III_I, III_{II} IV_I and IV_{II} (O'sullivan, 1997). Cellulose I also called as native cellulose because its the most cellulose polymorphs that found in nature. Naturally, within the same microfibril, cellulose I coexists in two crystal phase suballomorphs, cellulose Iα and cellulose Iβ. Cellulose Iα is richly found in algae and bacterial cellulose, whilst cellulose Iβ dominantly in higher plant and tunicate (Wertz et al., 2010). Phase Iα has a triclinic unit cell containing one chain, whereas cellulose Iβ is represented by a monoclinic unit cell containing two parallel chains (Nishiyama et al., 2002). These were by measured it vectors (a, b and c) and vectors angle. Thus, its attributes to displacement of adjacent chains of cellulose molecular unit arrangement whether it diagonally shifted for cellulose Iα or a staggered for cellulose Iβ. (Wertz et al., 2010). Figure 6 shows schematic drawing and measurement of the cellulose unit coordinate systems for cellulose Iα and Iβ.



Source : Wertz et al., 2010

Figure 6 : Cellulose Iα (triclinic) and Iβ (monoclinic) coordinate systems (i) Cellulose unit orientation; (ii). Measurement of vectors and angle; (iii) View of five cellulose chains viewed orientation and arrangement.

Cellulose polymorphs are intertransform as shown in Figure 7. Some of polymorph are irreversible once been transformed into different polymorph i.e cellulose II. The transformation of cellulose II from cellulose I can be done by two distinct routes: mercerization (alkali treatment) and regeneration (solubilization and subsequent recrystallization). Celluloses III_I and III_{II} can be formed from celluloses I and II, respectively, by treatment with liquid ammonia, and the reaction is reversible. Celluloses IV_I and IV_{II} can be obtained by heating celluloses III_I and III_{II}, respectively. (Klemm et al., 2005; O'Sullivan, 1997; Abdul Khalil et al., 2012;



Source : Wustenberg, 2015

Figure 7 : Transformation of cellulose into its various polymorphs

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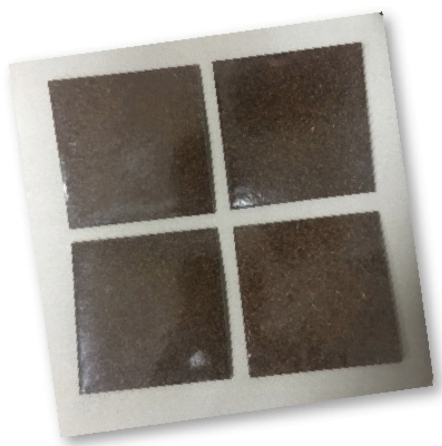
DEVELOPMENT AND CHARACTERIZATION OF KENAF/PINEAPPLE LEAF FIBRE REINFORCED PHENOLIC HYBRID COMPOSITES

Name : Mohammad Asim
Programme : Doctor of Philosophy
Field of study : Biocomposite Technology

The attention on natural fibre-reinforced polymer composite materials is swiftly rising in terms of their manufacturing applications and elementary research. The advantages of natural fibres are its availability, easy and safe handling, mechanical, thermal and biodegradable properties. Pineapple leaf fibre (PALF), kenaf fibre (KF) and phenolic reisn (PF) have been used to make effective hybrid composite in various applications. In this study, PALF and KF fibres are treated and categorized; the best treatment was further used for hybrid composite characterizations. The treatment was carried out by soaking fibres in chemicals and the composites were made by using hand lay-up technique. The effects of alkali, silane and combined alkali and silane treatment on the mechanical, morphological, and chemical properties of pineapple leaf fibre (PALF) and kenaf fibre were carried out with the aim to improve their compatibility with polymer matrices. The mechanical, physical, thermal and flammability test of PALF phenolic composites (PF) were investigated on different fibre loadings and compared with KF/PF composites. Treated PALF/phenolic composites at 50% PALF composite exhibited tensile strength Untreated and treated PALF/KF/PF hybrid composites were compared and analyzed the physical, mechanical, thermal and flammability properties. Untreated 30% PALF and 70% KF (3P7K) hybrid composite showed improved tensile strength and modulus, flexural strength and modulus and impact strengths. Hybrid composites showed excellent effects of silane treatments such as physical, mechanical, thermal and flammability properties over untreated hybrid composites. Treated 30%PALF and 70KF hybrid composite showed excellent overall properties among the all hybrid composites and it is very suitable for required light density, good mechanical strength fire sensitive areas such as aircraft, automobile and other industrial components.



ACTIVITY
INTROP INNOVATION OPEN DAY 2016

Date: 15th December 2016
Venue: INTROP, UPM

The Institute of Tropical Forestry and Forest Products (INTROP) has successfully organized the second Innovation Open Day on 15th December 2016. The open day was officiated by former director of INTROP, Y.Bhg. Dato' Dr. Jalaluddin Harun, he is also the Director General of Malaysian Timber Industry Board. The main objective of this open day is to present research and development activities to the university staffs, students and the press as well as representatives from the industry. The open day also celebrated a decade of INTROP and launched a book entitled 'Reflections of a Journey'. There were 19 products have been exhibited whereby 8 products are commercial potential product, 10 products are emerging product and 1 community product. The commercial potential products were presented by Ms. Rajeswari Murugayah an Executive Officer from Putra Science Park. The open day has attracted a total of 30 guests from the industry and 50 guests from inside and outside of UPM which most of them are researchers. The memorandum of understanding (MOU) signing ceremony between the INTROP and Kuala Lumpur and Selangor Furniture Industry Association (KLSFIA) was also held during the open day. In addition, Assoc. Prof. Dr. Edi Suhaimi was interviewed by the press for his invention entitled 'A Method of Producing *'Compreg' Oil Palm Wood'*. This open day was chaired by Prof. Ir. Dr. Mohd Sapuan Salit and Dr.Ahmad Adlie Shamsuri was assigned as secretary.















Muhammed Lamin Sanyang
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Field of Specialization
Green Engineering

Achievements in International Level: *Recently*
- Published over 13 peer review journals, 2 edited books, 10 book chapters and 10 conference papers.
- Serve as a reviewer for many citation index journals
- Resource person for environmental research and engineering for Jula Consultancy Ltd, Sharjah, the United Arab Emirates.

Recent Project
Extraction of nanocellulose and development of nanocomposites from sugar palm fibers

What is your feeling when joining INTROP?
INTROP is like a big family with members from diverse backgrounds but working towards a common goal and destination. Indeed! I feel deeply honoured and excited to be part and parcel of such an auspicious family. This is an Institution where everyone receives you with smiles and open arms.

What is your strategy for the future as Post-Doc in INTROP?
I intend to further boost the reputation of INTROP at both national and international level by:
- Conducting high impact researches
- Publishing high impact factor journals
- Collaborating with renown researchers, academicians and industry players
- Obtaining attractive national and international grants

What is your opinion of INTROP's Working environment?
INTROP's working environment is quite conducive.

How do you see INTROP 5 years onwards?
5 years from now, I envision INTROP as a global leading centre for Tropical wood and fibre research
(In Shaa Allah).

Ferial Ghaemi
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Field of Specialization
Nanotechnology; Polymer Science; Chemistry

Achievements in International Level: *Recently*
I have published 18 papers in peer reviewed journals and my googlescholar h-index is 6.

Recent Project
Synthesis of nanocellulose-nanosilver hybrid for drug delivery applications

What is your feeling when joining INTROP?
Here, I would like to appreciate and thank all my colleagues in INTROP for the cooperation and making the process of my career started extremely smooth. I really felt the friendly and close bond between the co-workers that makes the environment comfortable and enhances the work performance.

What is your strategy for the future as Post-Doc in INTROP?
I intend to broaden my knowledge and experience of research skills and publications. Working in a research group as a teamwork is the most important point to reach the goal. Moreover, building a strong research network with researchers in INTROP will give me an opportunity to continue a high level of research and collaborations with INTROP researchers when I go back to my country.

What is your opinion of INTROP's Working environment?
It is really a friendly and comfortable environment what makes the institute an ideal place to work.

How do you see INTROP 5 years onwards?
The activities of the institute and its progress in the research, collaborations, and achievements would make INTROP reaches its goals and grows globally. From my perspective, INTROP would be one of the international referral centres of research and development in the natural fibres management and biocomposites.

Rasha Mohamed Sheltami
rashasheltami@upm.edu.my /
rashasheltami@yahoo.com

Field of Specialization
Chemistry; Polymer Science; Bio-nanocomposites

Achievements in International Level: *Recently*
I have published 6 papers in peer reviewed journals and my Scopus h-index is 3.

Recent Project
Development and Evaluation of a Conductive Cellulose Nanocomposite.

What is your feeling when joining INTROP?
Here, I would like to appreciate and thank all my colleagues in INTROP for the cooperation and making the process of my career started extremely smooth. I really felt the friendly and close bond between the co-workers that makes the environment comfortable and enhances the work performance.

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