



SURFACE MORPHOLOGY AND INTERFACIAL BONDING BETWEEN PALM FIBER TREATED WITH SEA WATER AND SAGO MATRIX

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ABSTRACT

Surface morphology, roughness and bonding among palm fibers and sago matrix were observed. The sugar palm fiber was treated by sea water immersion with duration of 1, 2, 3 and 4 weeks, before naturally dried under the sun for 3 hours then continued by 6 hours oven at 80°C. SEM, XRD and roughness arithmetic tests are applied to see the surface morphology, roughness and bonding among fibers and the matrix. The result shows that fibers morphology and roughness changes with immersion duration. At longer immersion duration the roughness increases and the fiber-matrix quality is better. The best interlocking of matrix and fibers occurred after duration of 4 weeks fiber immersion, where no more gaps seen between the fiber and matrix.

Keywords: palm fiber, submersion, surface morphology, sago matrix, bonding.

INTRODUCTION

Cellulose-based natural fibers become a challenge for researchers to reveal their advantages compare to synthetic fibers, including the application possibilities to the global construction and engineering technology [1]. Natural palm fibers (*Arenga pinata*) have the prospect to be developed as reinforcement substance in composite material due to its flexural properties, salt water resistance, environmentally friendly and relatively high tensile strength [2]. Most of natural fibers are hydrophilic in nature, strongly opposite to the hydrophobic properties of polymer. Hence, soaking natural fiber in ocean water is intended to reduce the hydrophilic characteristic of natural fibers and presume to be more hydrophobic compatible to the polymer materials [2, 3].

Sea water immersion cleans the extractive media off the natural fibers such as lignin, pectin, wax and dirt (impurities) in order to obtain surface with relatively uniform topography. Topography of fiber surface affected by soaking treatment is reviewed qualitatively through observation by Scanning Electron Microscopy [4]. While quantitative characteristics of the fiber surface were observed by direct measurement of *Roughness Arithmetic Surface Area*, which provides information about porosity and roughness [5]. Change on the surface shapes were observed by comparing the differences of roughness patterns between the immersed fibers (treatment) and the untreated fibers (green fiber).

Fiber characteristics on morphology and surface roughness are crucial information for composite reinforcement applications [6]. With the increasing awareness of environmental protection, natural fibers should contribute to a cleaner environment while meet today's considerable demand of composites [7]. Natural fibers such as flax, hemp and jute are some of the most commonly used reinforcement material of fiber composite. Composites of polymers-reinforced natural fibers should be more eco-friendly as the reinforcement and matrix material (eg. *polylactide* - *PLA*) are degradable, as this bio-composites commonly named as "green composites" [8-9].

Although environmentally friendly, natural fibers have a major drawback associated with application for reinforcement of polymer matrix, such as problems associated with surface of natural fibers and polylactide. Several approaches have been made to the surface modification of cellulose (e.g. esterification of cellulose and cellulose substrate to graft copolymerization) and the use of multiple adjustments, i.e. maleated polylactide and isocyanate [7-9]. Several studies have been done to give more utilization of natural fibers focusing the issues of adhesion among natural fibers and the polymer matrix including opposite chemical properties of hydrophilic natural fibers and hydrophobic polymer matrix. Other factors include surface area, surface structures and porosity of the fiber relatively neglected in consideration of adhesion among surface fiber and the matrix [9].

The morphology and roughness of the surface of the natural fiber has been recognized as a significant factor for composite reinforcement. Its effects on the performance of composites have been investigated by the interfacial shear strength of fiber surface roughness through Scanning Electron Microscope [10]. Characteristics of natural fiber differed from commercial synthetic fibers in terms of geometry, morphology, and surface profiles. This study observe the effects of sea water on fiber surface morphology and roughness so that the interface of sugar palm fiber of sago matrix may be improved to be considered as bio-composite material. SEM and roughness arithmetic are utilized to analyze the surface morphology and roughness of the fiber surfaces.

Most of natural fibers consist of high cellulose with difference in particular micro structure. These particular microstructure have strong bonds of intra- and intermolecular hydrogen which are various in sizes. The larger the molecule size, the weaker the bond, and the smaller the molecular size, the stronger their bonds. Hence, microstructures affect the tensile strength of fibers. As microstructures of palm sugar fiber consist of 85% cellulose, and covering almost the whole fibers surface, the fibril bonds then become stronger.



MATERIAL AND METHODS

Material

Green fibers are taken from a minimum 8 years old palm trunks which the composition shown in Table-1, and sea water as the immersion medium Table-2 is protected inside a 250 liters plastic containers to prevent contaminations during soaking period of 1, 2, 3 and 4 weeks in proper salinity.

Table-1. Palm fibers composition.

Element	Oxides	Unit (%)
Silicon	SiO ₂	30,45
Aluminum	Al ₂ O ₃	21,90
Sodium	Na ₂ O	18,44
Magnesium	MgO	9,00
Potassium	K ₂ O	0,71
Calcium	CaO	-
Phosphorus	P ₂ O ₅	5,06
Sulfur	SO ₃	4,74
Others		9,70
	Total	100

Table-2. Sea water composition.

Element	Amount (%)	Temperature
Natrium Chloride (NaCl)	88,7	20°C
Sulphur (SO ₃)	10,8	
Carbonate	0,3	
Others	0,2	
Total	100	

METHODS

Immersion process

The sugar palm fibers were immersed in sea water placed inside a 250 liters plastic container. Immersion durations are varied to 1, 2, 3 and 4 weeks with appropriate water salinity. Plastic containers are sealed to prevent open air contamination.

Specimen preparation

Both green and treated fibers are fully dried inside oven at 80° C for 6 hours, and then cut to approx. 4 mm long for testing on a TESCAN SEM VEGA 3 SB, XRD test applied on a Rigaku Mini Flex II Dekstop to identify contained elements of fibers. Surface roughness of fibers are determined by touch sensors attached on Mitutoyo SJ 301 by laying the fiber on the sample preparation glass where the sensors move along the 3 mm long fiber surface while recording their highest and lowest points.

Tensile strength test

Tensile test of single fiber applies ASTM 3379-75 by universal testing machine LR10K Plus twin columns with load capacity 10 kN. Fibers are glued on a cardboard which has been formed in accordance to the standard. At both ends of cardboard, clamps are pulled slowly loaded from zero to the fiber break point while set of computer records the actual stresses and strains.

RESULT AND DISCUSSIONS

Through SEM procedure as shown in Figure-1, surface morphology of fiber determined by the immersion duration in salt water. The surface of green fiber without treatment is covered by pectin and impurities, closing the gaps or holes on it Figure-1a. After a week of immersion, pectin starts to emerge on the fiber surface as water content increase Figure-1b. As the sea water immersion continued to 2 week Figure-1c pectin began to stand out and covers most of the surface at week 3 Figure-1d. At week 4, fibers surface become rough as impurities and pectin molecules which consist of group - OH attracted by Salt (Na) and Chloride (Cl) of the sea water, the polarity differences tend to bind one to another to form an ionic bond.

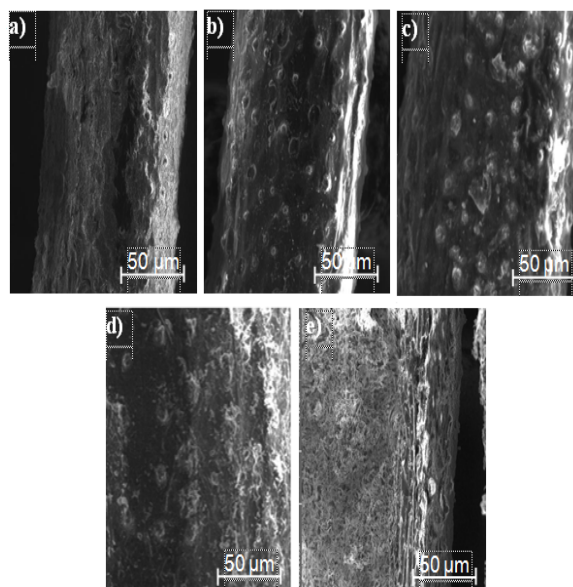


Figure-1. Surface Morphology (a) Green Fiber; (b) 1week immersion; (c) 2weeks immersion; (d) 3weeks immersion; (e) 4weeks immersion.

Roughness test

The surface roughness is generated by arithmetic average (Ra) deviations from the line profiles as seen in Figure-2, where ten highest and lowest peaks are divided into the earlier sample length, then again divided by 1000. The roughness of green fiber is 0.692 µm, 1.336 µm, 0.946 µm and 1.640 µm for 2, 3 and 4 weeks, respectively. The declining of roughness on the third week immersion occurred as pectin covers the fiber surface and begins to dissolve in the salt water. As the pectin, wax and other



impurities dissolved, coarseness of surface are exposed and increasing the roughness of fiber surface in week 4 Figure-3.

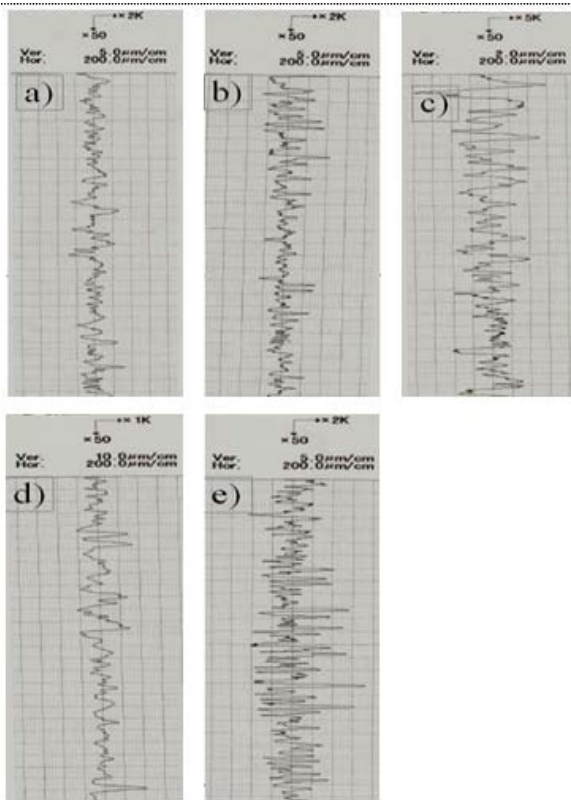


Figure-2. Profile of roughness arithmetic (a) Green fiber; (b) 1week immersion; (c) 2weeks immersion; (d) 3weeks immersion; (e) 4weeks immersion.

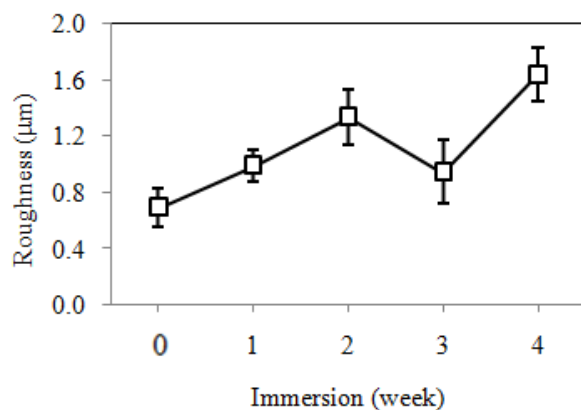


Figure-3. Roughness arithmetic (Ra).

Interfacial bonding

Interfaces among matrix of sago starch and sugar palm fibers are shown in Figure-3. Large surface tension occurred among untreated green fiber and the matrix Figure-3a where the matrix refuses to fuse due to the

overlaid pectin film on fiber surfaces. In contrast, immersion treatments for the next 1, 2 and 3 weeks shows improvement of matrix-fiber bonding as the slits among them became closer while the surface tension slowly reduced Figure-3b-d. A strong fiber-matrix bond occurs after 4 weeks immersion, characterized by slit disappearance and invisible loopholes of interfaces.

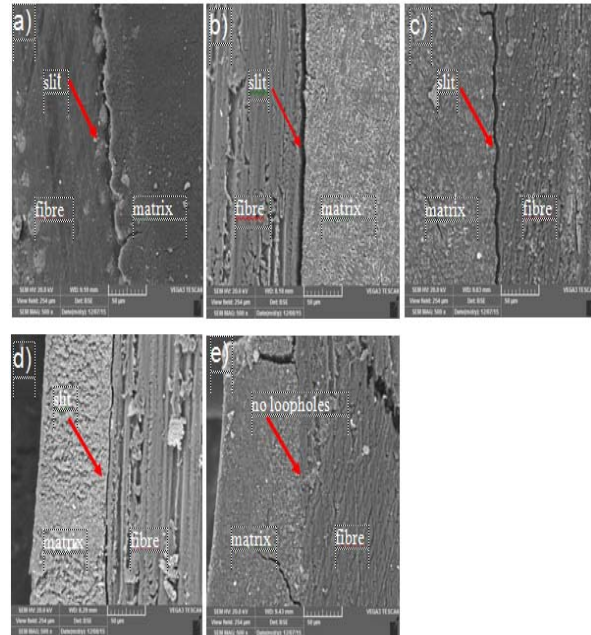


Figure-4. SEM image of matrix-fiber interface (a) Green Fiber; (b) 1week immersion; (c) 2weeks immersion; (d) 3weeks immersion; (e) 4weeks immersion.

This phenomenon is closely related to the decreasing hydrophobic properties of fibers and promotes reactions of polymerization of the two materials components. In addition, fiber compound of positive ions and negative ions from NaCl accentuate the bond strength where the matrix envelops the fibers thoroughly while in the same time, reduction of hemicelluloses and pectin can also improve their mechanical interlocking.

X-Ray Diffractometry

The number of fiber cellulose determines the nature of structure and crystal resulted by X-ray diffractometer as shown in Figure-5. Spectrum of untreated sugar palm fiber shows two peaks at $2\theta = 16.25^\circ$ and 22.35° with profile curve of small size crystals. In comparison, the spectrum of immersed fibers also shown typical crystal index. The consistent emergence phenomenon of crystal peak diffraction as the reaction of sea water occurred throughout all duration of immersed fibers, 1 to 4 weeks, where the typical small size crystals had no effect on the tensile strength.

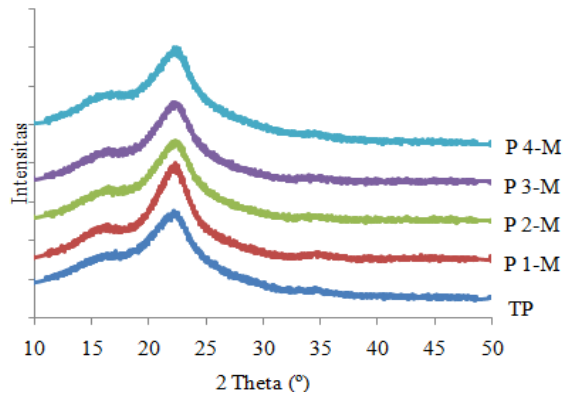


Figure-5. X-ray Diffractometry.

Tensile Strength

Figure-6 shows the results of tensile stress for 2 weeks immersion decrease to $\sigma = 195.768 \text{ N / mm}^2$, possibly due to the increasing Silicon (Si) element from 30.45% to 44.33%. As the silicon element rises, fibers become more brittle (brittle) and decline the tensile stress result. Further immersion of 3 weeks improves tensile strength to $\sigma = 298.646 \text{ N / mm}^2$ and keep the increasing trend to week 4 by tensile stress $\sigma = 420.004 \text{ N / mm}^2$. Increase in tensile strength made by infiltration of some elements into fibers body (Table-3), causing the cellulose element increased, and developing compound with more interfacial energy which strengthen the immersed fibers.

Table-3. Composition of immersed fibers.

Element	Oxide	Green (%)	1 w (%)	2 w (%)	3 w (%)	4 w (%)
Silicon	SiO ₂	30,45	35,95	44,33	33,25	40,67
Aluminium	Al ₂ O ₃	21,9	9,49	10,38	16,76	14,23
Sodium	Na ₂ O	18,44	14,78	16,87	15,25	12,17
Magnesium	MgO	9,0	12,06	11,23	14,14	12,52
Potassium	K ₂ O	0,77	0,71	0,3	1,23	1,07
Calcium	CaO	-	4,04	0,98	2,42	0,35
Phosphorus	P ₂ O ₅	5,06	7,72	7,49	7,33	8,93
Sulfur	SO ₃	4,74	11,54	6,82	7,74	8,32

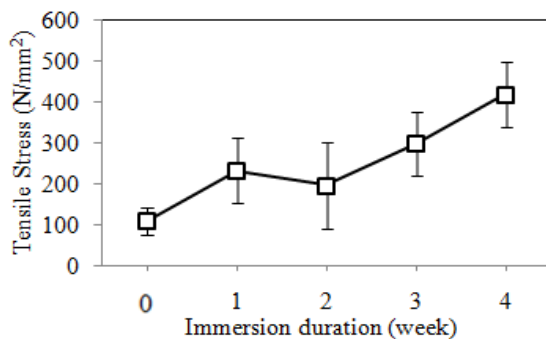


Figure-6. Tensile stress of sugar palm fiber.

CONCLUSIONS

Sea water demonstrated the ability to effectively remove the unwanted components on the fiber surfaces such as pectin, wax and impurities, while reducing the hydrophobic characteristics of sugar palm fibers. Increasing of small pores on the fiber surface indicates effective morphology may occur over 4 weeks, associated with increasing values of surface roughness. The surface morphology of fiber due to sea water treatment has significantly improved the mechanical bonding effect with the sugar palm matrix.

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