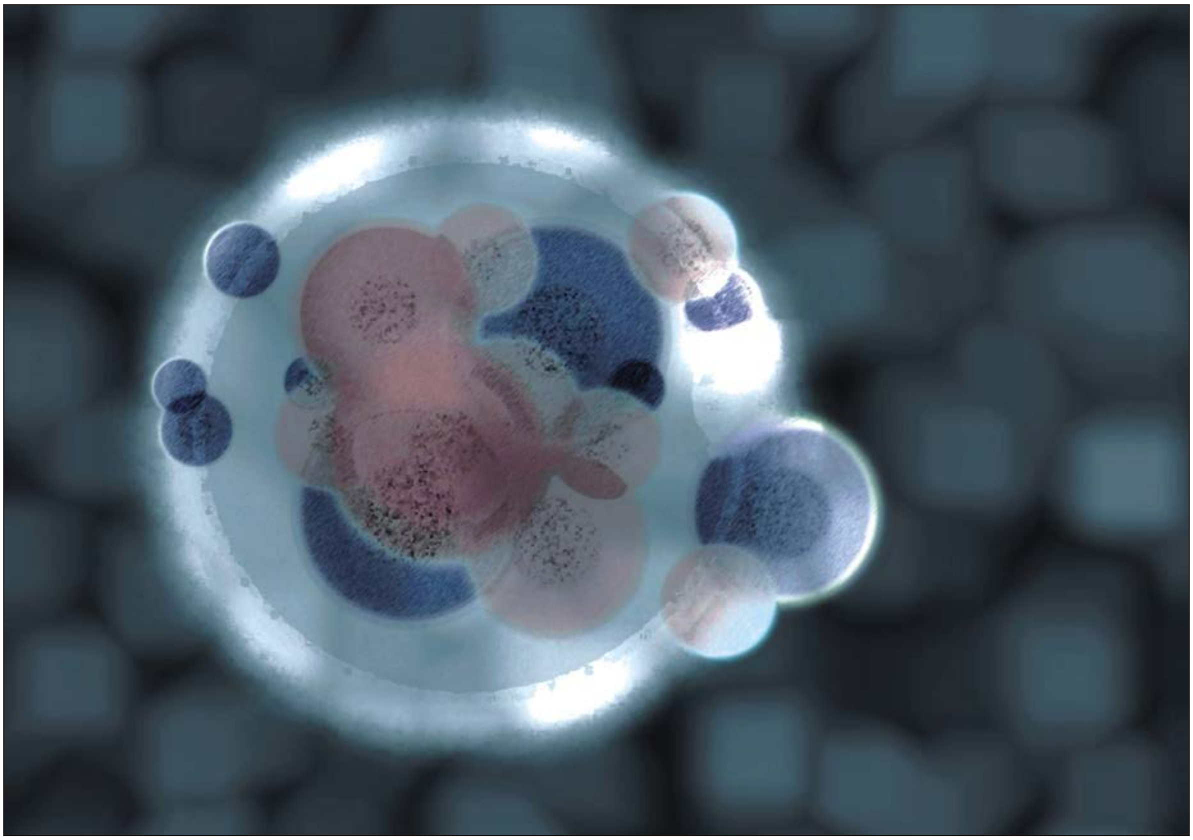

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Physical and Mechanical Properties of Natural Fibers Filled Polypropylene Composites and Its Recycle

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Abstract: This study discusses the influence of natural fiber type on the performance of polypropylene and its recycle. Composites consisting of polypropylene (PP) and natural fiber from wood (*Acacia mangium*), water hyacinth (*Eichornia crassipes*), kenaf (*Hibiscus cannabinus*), banana (*Musa paradisiaca*) and empty fruit bunch of oil palm (*Elaeis guineensis*) were prepared by extrusion and compression process based on the ratio of 50:50% (w/w) with the addition of 2.5% polypropylene modified with maleic anhydride (MAPP). The effect of fiber type on the composites was evaluated. Physical and mechanical properties were studied. The composite showed significantly different properties based on the fiber type. Kenaf filled composite showed high tensile strength, break strain and modulus of elasticity properties but least absorbed water. Banana fiber filled propylene composite is comparable with that of kenaf. In general, recycle polypropylene can replace virgin polypropylene since their natural fibers filled composites showed similar mechanical and physical properties.

Key words: Natural fibers, recycle polypropylene, composites, properties

INTRODUCTION

Natural fibers are lignocellulosic in nature and the most abundant renewable biomaterial of photosynthesis on earth. Underutilized natural fiber residues are a readily available rich resources of lignocellulosic materials. Since last decade, there is considerable worldwide interest in the potential in substituting natural fibers (agrofibers) for either wood or man made fiber (e.g., fiber glass) in composite materials. Composites consisting lignocellulosic fibers and synthetic thermoplastics have received substantial attention in scientific literature as well as industry primarily due to improvements in process technology and economic factor (Sanadi, 1992; Yam, 1990). The use of lignocellulosic fibers in plastic composites is of particular interest because such fibers can serve as a good reinforce and/or filler for synthetic polymers to enhance certain properties while reducing material cost (Kazayawoko, 1998). These fibers have many advantages, such as low density, high specific strength and modulus, relative non-abrasiveness, ease of fiber surface modification and wide availability (Gauthier, 1998). In addition, the use of fibre-reinforced plastic composite arises due to the increasing environmental consciousness such as the problem of convenient removal after the end of life time which is relatively stable and difficult to separate and recycle. The bast fiber of flax (*Linum usitatissimum*) and hemp (*Cannabis sativa*) are commonly quoted as being among the strongest and the stiffest of the available natural fibers (Kessler and Kohler, 1996; Robson and Hague, 1996). Fibers from bamboo also appear to compare favorably. Kenaf fiber is a potentially an outstanding reinforcing filler in thermoplastic composites (Rowell *et al.*, 1999).

Due to the difficulties of its biodegradability, polymer brings about a serious environmental pollution. As an illustration, the total amount of polymer produced in Indonesia is 183,000 ton and will increase gradually (ISC, 1999). Consequently, the total amount of waste from the production increases significantly as the production increasing. Therefore, utilization of polymer waste as a matrix resin for composites is of indispensable in order to alleviate waste disposal problem and reduce the amount of polymer used.

Studies on the polypropylene composites filled with natural fibers have been reported and most of the study reported with jute, ramie and flax (Vun *et al.*, 2004; Gurram *et al.*, 2002; Ververis *et al.*, 2004). In this study, virgin and first recycle of polypropylene are used as matrices resin for natural fibers filled composites. The effect of natural fibers type namely from wood (*Acacia mangium*), water hyacinth (*Eichornia crassipes*), kenaf (*Hibiscus cannabinus*), empty fruit bunch (EFB) of oil palm (*Elaeis guineensis*) and banana trunk fiber

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(*Musa paradisiaca*) on mechanical (tensile, break strain, modulus elasticity) and physical (water absorption and thickness swelling) properties of composites was evaluated.

MATERIALS AND METHODS

Materials: The matrices used in this experiment were polypropylene (PP J 150 G EB 267) and recycle polypropylene (RPP). Recycle polypropylene was obtained from post consume recycling polypropylene. These were collected from local industry in Bandung, province of West Java. Natural fibers used in this study were wood (*Acacia mangium*) obtained from Sindur Mountain, Serpong, West Java, water hyacinth (*Eichornia crassipes*) and banana trunk fiber (*Musa paradisiaca*) were collected from local farmer in Subang district, West Java, kenaf (*Hibiscus cannabinus*) was from PT Global Agrotek Nusantara and empty fruit bunches (EFB) of oil palm (*Elaeis guineensis*) from PT Condong Garut Estate Crop. Prior to compounding, all natural fibers were run through a ball mill (100 mesh screen), dried in an oven at 100°C for 24 h and its moisture content was controlled within 2-3% and used as filler. A Maleic Anhydride Grafted Polypropylene (MAPP) Toyotac M-300 with a melt flow rate of 13 g/10 min and melting point of 160°C was donated by Toyoseiki Kogyo and used as a modifier for natural fibers/polypropylene composites and its recycle. Modifier is generally used to modify the fiber-matrix interface and thereby enhance the fiber-matrix adhesion. The concentration level of MAPP was 2,5% with respect to the weight of polypropylene/its recycle. Composites were made from 50% (weight) of fiber and 50% (weight) of polypropylene/its recycle. This work was conducted in Polymer Test Laboratory, Division of New Material, Research Center for Physics, Indonesian Institute of Sciences, Bandung, Indonesia from July 2005 to February 2006.

Methods

Composites compounding: Polypropylene/its recycle was blended with natural fibers in a Laboplastomill extruder (Toyoseiki, 30R-150) single screw in which the temperature was at 175°C. The blending was accomplished at 10 rpm. The mixed blends were then granulated.

Composites sheet preparation: Granulated samples were molded into sheet by hot pressing. Around 10 g of blended sample was placed between a pair of glossing plate with 3 mm thick spacer. Hot press temperature was set at 175°C. The samples were pressed at 75 kgf cm^{-2} for 30 min followed by cold pressing at the same pressure for 10 min.

Specimen for mechanical properties test: Prior to tensile test, samples were shaped to dumbbell according to ISO 527 type 5 then conditioned at 23°C, RH 50% for a minimum 40 h before testing. Tensile test was performed according to ISO 527 on a Universal Testing Machine (Orientec UCT-5T) using 5 specimens at room temperature (23°C, 50%).

Water absorption and thickness swelling: Specimens of 50×25×3 mm of size were prepared from composites. Water absorption test were conducted by submerging the specimens in water for 24 h and measuring the increase in weight and thickness as compared to the original oven dry weight of the specimens. Five specimens of each type were tested in a adjusted room (23°C and 50% relative humidity) and the results averaged. Water absorption and thickness swelling were calculated as indicated previously (Febrianto *et al*., 2006).

RESULTS AND DISCUSSION

The mechanical and physical of polypropylene composites and its recycle (RPP) with various type of fiber.

Mechanical properties obtained for 50% natural fibers filled polypropylene and its recycles are shown in Table 1. The addition of natural fibers into the polymer, decreases tensile strength and break strain but increases modulus of elasticity of composites. This is the common observation with almost all filled polymer system. Table 1 shows tensile strength of composites. The decreasing in tensile properties of composites causes by the poor fiber dispersion in matrix. Micro-fibril in fiber was strongly linked due to the fiber hydrogen bonding that makes fiber hardly dispersed each other easily. From the same table it shows that the tensile strength of fiber filler composites was not affected by the polymer origins. Both

Table 1: Mechanical properties of natural fibers-composites

	Tensile strength (MPa)		Break strain [%]		Modulus of elasticity (MPa)	
Composites	PP	RPP	PP	RPP	PP	RPP
Kenaf	16.85	14.87	2.09	1.99	1156	971.9
Acacia	13.03	15.36	1.56	1.93	972	1018.0
Water hyacinth	14.72	13.69	1.75	1.99	1106	999.7
Banana	16.18	16.39	1.85	2.25	1115	1075.2
EFB	13.61	14.36	1.79	2.11	959	958.3
Polymer	30.71	28.86	11.00	12.00	791	866.91

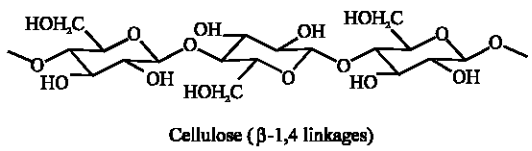

Fig. 1: Structure of cellulose

polypropylene and its recycle show the similar results. However, it is remarkable that the type of fiber filler affects tensile strength. Cellulose content of fiber plays an important role in the tensile strength. Cellulose is a homopolysaccharide composed of β-D-glucopyranose unit which are linked together by (1→4)-glycosidic bonds (Fig. 1). Cellulose molecules are completely linear and have a strong tendency to form intra and intermolecular hydrogen bonds. Bundles of cellulose molecules are thus aggregated together in the form micro-fibrils, in which crystalline regions alternate with amorphous region. Micro-fibrils build up fibrils and finally cellulose fibers. As consequence of its fibrous structure and strong hydrogen bonds, cellulose has a high tensile strength. Consequently, the higher the cellulose content, the higher the tensile strength. Kenaf and banana fiber filled polypropylene composites showed the high tensile properties due to the high cellulose content 45-60% and 45-50%, respectively, compared with acacia and empty fruit bunch (Table 3). Similar results has been reported when kenaf used as filler in the polypropylene composites (Mohanty *et al*., 2000; Rowell *et al*., 1999).

We found that substantial decreasing of the break strain of composites after the fiber addition. This is due to the hydrophilic property of natural fibers that may have taken up moisture and interfered with the adsorption effect by reducing the effect of physical bonding between the fiber surface and polypropylene and its recycle (Febrianto *et al*., 2006). The fact that the addition of natural fiber decreased break strain property indicated that natural fibers more rigid than polypropylene and its recycle. Table 1 reveals that kenaf is the most ductile compared with other natural fibers followed with banana fiber. Table 1 clear indicates kenaf filled polyproplene composite has similar break strain property with that of its recycle. Thus, recycle propylene can replace its virgin.

Table 1 shows that the addition of natural fibers increased modulus of elasticity significantly. This is due to the fact that natural fibers are more rigid than that of polymers. Among the different fibers, kenaf contributes the most increasing modulus of elasticity followed by banana. Composites containing EFB have the lowest values over the modulus investigated. The modulus elasticity between EFB and acacia composites is comparable. These results showed that kenaf is the most rigid fiber followed by banana. This leads banana comparable with that of kenaf for composites. Table 1 shows that EFB filled polypropylene has similar modulus property with that of its recycle. Therefore, recycle polypropylene can be utilized in order to replace its virgin. In general, improvement the higher modulus elasticity was achieved by incorporating kenaf and banana fiber in polypropylene and its recycle composites and these suggests the possibility of having high modulus specimen by using cheap, low weight and eco-friendly filler.

Table 2: Water absorption and thickness swelling of natural fibers-composites

	Water absorption (%)		Thickness swelling (%)	
Composites	PP	RPP	PP	RPP
Kenaf	1.30	1.04	0.97	2.05
Acacia	1.58	1.09	2.21	1.67
Water hyacinth	3.18	3.91	5.02	10.34
Banana	1.64	1.39	3.29	2.66
EFB	2.07	2.22	3.05	4.18
Polymer	0.04	0.08	0.08	0.09

Table 3: Cellulose content of fibers

Type of fiber	Cellulose (%)
Kenaf [a)]	45-60
Banana [b)]	45-50
Acacia [c)]	15-30
EFB [d)]	14-20

[a)]Lilholt and Lawther (2000), [b)]Onggo and Tri Astuti (2003a), [c)]Yunianti and Priyatno (2003) and [d)]Ramli *et al.* (2002)

Table 4: Thickness of cell wall

Type of fiber	Thickness of cell wall (μm)
Water hyacinth [a)]	1.6
EFB [b)]	3.3
Banana [c)]	4.5

[a)]Onggo and Tri Astuti (1998), [b)] Erwinsyah *et al.* (1998) and [c)] Onggo and Tri Astuti (2003b)

Table 2 showed water absorption and thickness swelling values of fibers filled polypropylene and its recycle. The values of water absorption and thickness swelling of polypropylene and its recycle which is hydrophobic in nature was negligible since did not absorb water during 24 h of immersion time. Therefore, it can be assumed that all the water absorption and thickness swelling of the composites was caused by the hydrophilic fiber and not by the hydrophobic polypropylene and its recycle. This natural water uptake ability makes it easier to reduce the physical bonding with matrices. The value of water absorption of kenaf and is 1.3%, smallest than other fibers. Therefore, kenaf and banana keep physical bonding stronger than others. On the other hand, the value of water absorption of water hyacinth filled polypropylene is 3.7%, higher than that of other composites. The water uptake ability relates with the cell wall thickness. The thinner the cell wall, the easier the fiber to absorb water. Table 4 clearly indicated that the cell wall thickness of water hyacinth is 1.6 μm, much thinner than that of EFB and banana fiber. In consequent, water hyacinth easily absorbs water than other fibers.

CONCLUSIONS

Physical and mechanical properties of natural fibers filled polypropylene composites and its recycle were studied. Physical and mechanical properties of composites were affected of the type of natural fibers. The addition of natural fiber decreases tensile strength and break strain of the composites. However, it increases modulus of elasticity of composites. Compared with other natural fibers, kenaf filled composites showed highest tensile strength, break strain and modulus of elasticity but absorbed least water. Banana filled composite showed similar mechanical and physical properties with kenaf. In general, first recycle polypropylene can replace its virgin application since its filled natural fibers composite has similar mechanical and physical property with its polypropylene.

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