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EFFECTIVENESS OF MODIFIED ARECA LEAF FIBER REINFORCING MATERIALS IN ECO-FRIENDLY COMPOSITES

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Abstract

This research work is mainly concerned with the production of composites from 5 % NaOH modified waste areca leaf fiber with recycled polyethylene as binder and the study of their characteristics. Composites were produced by mixing each modified waste areca leaf fiber (120 g) with various compositions (10 %, 20 %, 30 %, 40 %, 50 % and 60 %) of recycled polyethylene (PE) using hot compressing molding method at 120˚C and 2200 psi. The produced composites were characterized by physicochemical and physicomechanical parameters such as modulus of rupture, thickness, density, water absorption, swelling thickness and hardness. Based on the physicomechanical properties, MAFPE 4 composite was a quality grade composite among the produced composites. It has 2679.83 psi of modulus of rupture, 0.60 cm of thickness, 0.87 g cm^{-3} of density, 23.37 % of water absorption, 33.18 % of swelling thickness and 98 D of hardness. The surface morphology of MAFPE 4 composite was studied by SEM and heat characteristic of composite by TG-DTA analyses. MAFPE 4 composite can be used in furniture and building.

Keywords: Areca leaf fiber, polyethylene, composites, modulus of rupture

Introduction

Natural fiber composites are one such kind of material. The natural fibers are widely used in the composites due to inherited properties, such as lignocelluloses, renewable, and biodegradable. There are several other reasons that favor the use of natural fibers instead of any other artificial or synthetic fibers. There are several other advantages to using natural fibers over artificial or synthetic fibers. They are lightweight materials having superior strength, competitive specific mechanical properties, high specific modulus, and reduced energy consumption. Further, they are nontoxic and nonhazardous in nature, naturally recyclable, available in abundance, flexible in usage, less expensive and that allow clean energy recovery, etc. (Raghuveer *et al.*, 2016).

To develop a composite material made from natural fibers with significantly improved strength, stiffness, durability, and reliability, it is important to have better fiber-matrix interfacial bonding. This can be accomplished through surface treatment–and the manufacturing process technology used to create the composite. Recently, broad studies on natural fibers such as sisal, jute, pineapple, banana, and oil palm empty fruit bunch fibers with thermoplastic and thermosetting materials have been carried out (Srinivasa and Bharath, 2011).

The mechanical properties of composite like tensile and bending strengths increase because of surface modification. The chemical surface modifications such as alkali, acetic anhydride, stearic acid, permanganate, maleic anhydride, silane, and peroxides given to the fiber and matrix were found to be successful in improving the interfacial adhesion and compatibility between the fiber and matrix. A strong fiber-matrix interface bond is critical for the high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber, whereby maximum utilization of the fiber strength in the composite can be achieved. Most research reviewed indicated the effect of alkali treatment in improving fiber strength, fiber-matrix adhesion, and the performance of the natural fiber composites (Dhanalakshmi *et al*., 2016).

Amongst all-natural fiber reinforcing materials, areca appears to be a budding fiber because it is inexpensive, abundantly available and has a very high potential perennial crop. The botanical name of areca is *Areca Catechu* Linnaeus, and it belongs to the Arecaceae (palmae), palm family

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and Arecoideae subfamily. Arecas have superior properties such as light weight, strength, and a high strength to weight ratio. In addition, areca fibers are biodegradable, non-toxic, and eco-friendly and they have a low maintenance cost. Areca fiber is made from cellulose, lignin, and hemicellulose. Moreover, it contains minor constituents, for example, pectic, fatty and waxy matters. The main point that oversees the properties of short fiber dispersion, and fiber grid bonding. Blending the polar and hydrophilic strands with non-polar and hydrophobic matrix can bring about challenges related to the dispersion of fibers in the matrix. Additionally, the bonding between the fibers and matrix can be improved by improving the matrix with compatibilizers that adhere well to both fibers and matrix (Pavankalyan *et al*.,2018).

Synthetic polymers such as polystyrene, polyethylene, polypropylene, polyvinyl chloride etc. have higher mechanical properties, sustainability and durability compared to natural polymers. But they are not biodegradable, and they cause pollution of the environment. With this aim in mind, many researchers have developed different composites by combining natural and synthetic polymers and some of them have already been used as industrial products. Among synthetic polymers, polyethylene possesses outstanding properties like low density, low cost, good flex life, good surface hardness, scratch resistance and excellent electrical insulating properties (Miah *et al*., 2011).

It is thus the aim of the present work is to produce a polyethylene-areca leaf fiber composite using waste plastic material and modified areca leaf fiber under optimized conditions for a useful application.

Materials and Methods

All necessary research facilities were provided by the polymer department, Department of Research and Innovation, (DRI).

Collection of samples

In the experiments, waste areca leaf that is a by-product of the Nature Myanmar Company and recycled polyethylene (PE) were collected from Public waste at the Science Canteen, the Yangon University Campus, Yangon Region, and Myanmar.

Extraction of waste areca leaf fiber

Areca fibers are extracted from areca leaves after soaking them for 10-15 days. These drenched leaves are cleaned with the help of running water 5-10 times daily. The drenching process removes the dust particles. These leaves are dried in the sun for 3 days to remove the moisture content. The areca leaf fibers were cleaved into little pieces with the assistance of hand scissors. These leaves are dried in sun for 3 days to remove the moisture content. The areca leaf fibers were cleaved into little pieces with the assistance of hand scissors. After cutting, they were ground on an electric grinder obtaining a size of about 0.5-2.0 cm. The fibers were taken and dried in an oven at 70ºC. The dried samples were screened to pass through the sieve aperture of 25 meshes (0.5 mm) obtained. The sieved material was then stored in an airtight plastic bag for further experimentation.

Modification of waste areca leaf fiber

The fibers (ca. 400 g) were immersed in 6 L solution of (5 % w/v) NaOH (pH~ 13) at room temperature for 24 h, after which the fibers were washed thoroughly with plenty of water until drained water became neutral (pH~ 7). After treatment, they were dried in the sunlight and then in an oven at 70 ˚C for 3 h.

Preparation of recycled polyethylene

The collected empty drinking water bottles, made of recycled polyethylene were cut into pieces. The cut was washed thoroughly with distilled water, and then the cleaned samples were solar dried for a few days. The dried pieces were ground by a grinding machine. The particles were screened to pass through the 25 meshes (0.5 mm) of the sieve aperture. The sieved material was then stored in an airtight plastic bag for further experimentation.

Determination of physicochemical properties of modified areca leaf fiber and recycled polyethylene

The moisture content of samples was determined by oven drying method at (100 ± 5ºC), according to TAPPI-T210 om-6, 1992-1993, the solid contents of prepared samples were determined by procedure according to TAPPI-T210 om-6, 1992-1993, the ash content by ASTM test method, D 1102, 1986, the bulk density by tapping box method and the pH by using pH meter. The physicochemical properties (moisture content, ash content, solid content, bulk density, and pH) of the prepared samples were determined by conventional methods.

Characterization of areca leaf fiber, modified areca leaf fiber and recycled polyethylene

The scanning electron micrographs of areca leaf fiber, modified areca leaf fiber, and recycled polyethylene were obtained with the help of a Scanning Electron Microscope (JSM-5160, JEOL Ltd., Japan). Thermal analysis of modified areca leaf fiber and recycled polyethylene was determined by a DTA-60H (Hi-TGA 2950) thermal analyzer. TG-DTA thermogram and the description data are presented.

Production of modified areca leaf fiber-recycled polyethylene composites (MAFPE)

In this research, all the modified areca leaf fiber - recycled polyethylene composites were produced by the hot compressing molding method.

Effect of composition of recycled polyethylene (PE) on the production of modified areca leaf fiber - recycled polyethylene composites

Each modified areca leaf fiber (120 g) was mixed with (10, 20, 30, 40, 50 and 60%) recycled polyethylene before being mixed for 2 min in the Henschel mixer. The complete mixture was laid in mold. Later, this mat was carefully transferred to the hydraulic press machine for 15 min at 120 ˚C and 2200 psi. The composites from the hydraulic press were kept cool for at least 24 h and then went through a sanding process. The composites were kept at room temperature for 1 week and then the edges and both sides of the composite were trimmed and stood (15.24 cm x 15.24 cm).

Determination of the physicochemical and physicomechanical properties of modified areca leaf fiber - recycled polyethylene composites

Modulus of rupture of composites was determined according to B.S 1811:1916, thickness by Micrometer or Screw gauge, veneer clipper according to IS: 3087:1965, density by B.S 1811: 1961, water absorption by IS: 3087:1965, and swelling thickness by IS: 3087-1965. Durometer hardness by Wallance Micro Hardness Tester readings were performed according to ASTM D 2240.

Characterization of the Selected Composite (MAFPE 4)

The morphology of composite MAFPE 4 was studied by using scanning electron micrograph for analysing micro and macro pores present on the surface of samples. Thermal analysis of composite MAFPE 4 was determined by a DTA-60H (Hi-TGA 2950) thermal analyzer.

Determination of Heat Resistance of MAFPE 4 Composite

Composites were cut into 2.54 cm × 2.54 cm pieces and weighed. These pieces of composites were heated at different temperatures (100, 200, 300, 400, 500, 600 ˚C) for 5 h. Weight loss percentages were determined after.

Results and Discussion

Table 1 shows the physicochemical properties (moisture content, ash content, bulk density, and pH) of the modified areca fiber and recycled polyethylene.

Table 1. Physicochemical Properties of Modified Areca Leaf Fiber and Recycled Polyethylene

No.	Physicochemical properties	Modified areca leaf fiber	Recycled polyethylene
1.	Moisture content (%)	12.45	0.70
2.	Ash content (%)	6.78	1.30
3.	Solid content (%)	87.55	99.30
4.	Bulk density (g mL^{-1})	28.40	2.50
5.	pH	6.70	6.80

Characterization of Modified Areca Leaf Fiber and Recycled Polyethylene
SEM analysis

In Figure 1, the SEM photographs show the areca leaf fiber surface morphology before and after treatment. The micrograph of untreated fibers showed a clear network structure in which the fibrils are bound together by hemicelluloses and lignin (Figure 1 (a)). But in Figure 1 (b), when the fibers are treated with alkali, the fiber structure is formed of several bundles of filaments aligned to the plant's length. When the morphology of the treated sample is compared with the original fiber surface topography, it can be seen as a partially cleaned surface, and its roughness is formed by the partial pulling of the fibrous structure of sample. The recycled polyethylene (Figure 2), in this image has a flake like nature and is not similar in size.

Figure 1(a). SEM micrograph of areca leaf fiber

Figure 1(b) SEM micrograph of modified areca leaf fiber

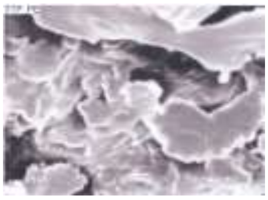

Figure 2. SEM micrograph of recycled polyethylene

TG-DTA analysis

Thermal stability of modified areca leaf fiber (Figure 3) and the interpretation (Table 2) are given. Data showed three distinct weight losses: the first one corresponded to dehydration, the second to the decomposition of small segments from cellulose and lignin and the third to the combustion.

Thermal stability of recycled polyethylene was investigated by TG-DTA analysis and the nature of the thermo gravimetric scan is shown in Figure 4 and the descriptions are shown in Table 3. Data showed two distinct weight losses: the first one attributed to the removal of moisture and the second to the combustion.

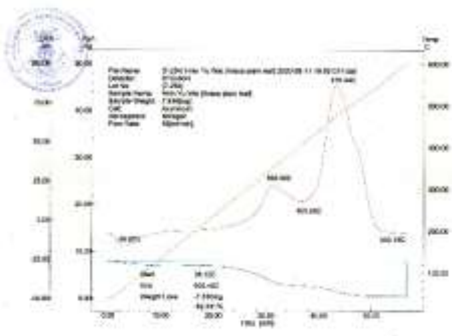

Figure 3. TG-DTA thermogram of modified areca leaf fiber

Table 2. Thermal Analysis Data of Modified Areca Leaf Fiber

TG		DTA		Remarks
Temperature range (ºC)	**Weight loss (%)**	**Peak temperature (ºC)**	**Nature of peak**	
38-100	9.29	59.87	endothermic	Dehydration due to surface water
100-380	68.33	350.99	exothermic	Decomposition of small segments from cellulose and lignin
380-500	14.68	476.34	exothermic	Combustion

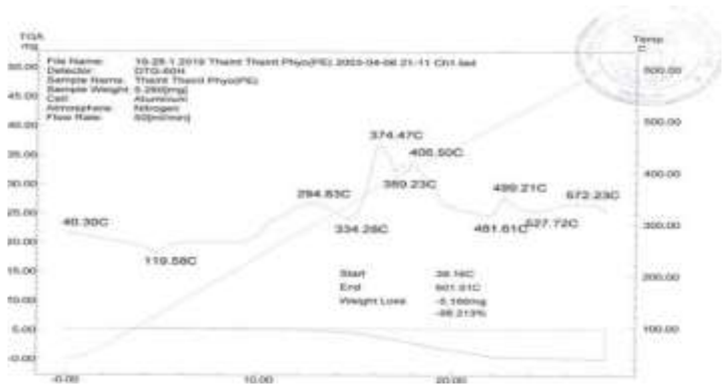

Figure 4. TG-DTA thermogram of recycled polyethylene

Table 3. Thermal Analysis Data of Recycled Polyethylene

TG		DTA		Remarks
Temperature range (ºC)	Weight loss (%)	Peak temperature (ºC)	Nature of peak	
40-360	17.68	119.58	endothermic	Removal of moisture and volatile materials
360-600	76.05	499.21	exothermic	Combustion

On the Aspect of the Production of Modified Areca Leaf Fiber - Recycled Polyethylene Composites

The composites were fabricated by hand lay-up technique. The inner cavity dimension of the mold is 15.4 cm x 15.4 cm. Each 5 % sodium hydroxide modified areca leaf fiber and various compositions of polyethylene (10, 20, 30, 40, 50 and 60 %) of recycled polyethylene were mixed by Henschel mixer for 2 min. The complete mixture of fiber and binder was laid in a mold. It was necessary to get a uniform surface of the mixture in cold section and later it was slowly transferred to the hydraulic press machine under the pressure 2200 psi and applied temperature at 120˚C. Composites of various compositions with constant fiber loading are made. The composites from the cold press were kept at room temperature for 24 h. The composites prepared for testing were cut to the conform to the dimensions of the specimen.

Effect of Composition of Recycled Polyethylene on the production of Composites

MAFPE 1, MAFPE 2, MAFPE 3, MAFPE 4, MAFPE 5 and MAFPE 6 composites were produced by mixing each modified areca fiber (120 g) with various compositions of polyethylene (10, 20, 30, 40, 50 and 60 %) at 2200 psi of pressure and applied temperature at 120 ˚C. The results of the physicochemical and physicomechanical properties of produced composites are presented (Table 4 and Figures 5, 6 and 7). It was found that the composite MAFPE 4 made with modified areca fiber (120 g) and 40 % of recycled polyethylene has the highest modulus of rupture among them. Therefore, composite MAFPE 4 was chosen to make the most suitable composite.

Table 4. Physicochemical and Physicomechanical Properties of Composites with Various Compositions of Recycled Polyethylene (PE)

Types of composite	PE (%)	Modulus of rupture (psi)	Thickness (cm)	Density (gcm^{-3})	*Water absorption (%)	*Swelling thickness (%)	Hardness shore (D)
MAFPE 1	10	1860.37	0.52	0.78	13.80	17.57	89
MAFPE 2	20	2198.12	0.54	0.82	20.36	27.89	92
MAFPE 3	30	2368.45	0.57	0.84	24.52	34.43	94
MAFPE 4	40	2679.83	0.60	0.87	23.37	33.18	98
MAFPE 5	50	2463.69	0.62	0.89	23.52	33.34	98
MAFPE 6	60	2254.23	0.63	1.14	23.98	33.76	97

*After 24 h
Applied pressure -2200 psi, Applied temperature -120 ˚C
MAFPE 1 = (120) g modified areca leaf fiber with 10 % PE
MAFPE 2 = (120) g modified areca leaf fiber with 20 % PE
MAFPE 3 = (120) g modified areca leaf fiber with 30 % PE
MAFPE 4 = (120) g modified areca leaf fiber with 40 % PE
MAFPE 5 = (120) g modified areca leaf fiber with 50 % PE
MAFPE 6 = (120) g modified areca leaf fiber with 60 % PE

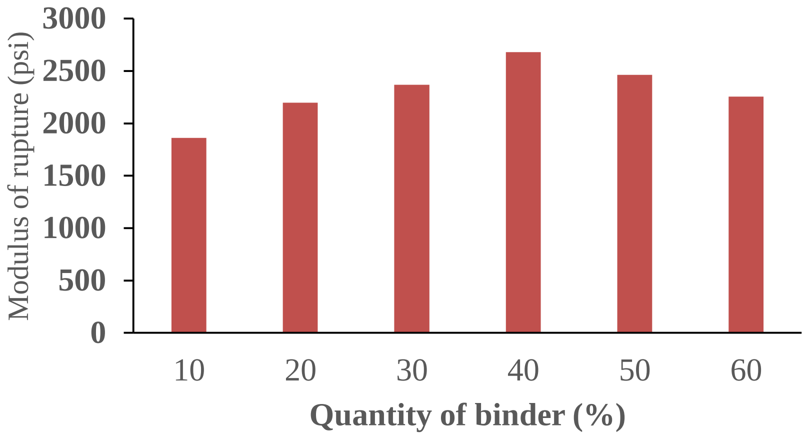

Figure 5. Modulus of rupture of MAFPE composites as a function of quantity of binder

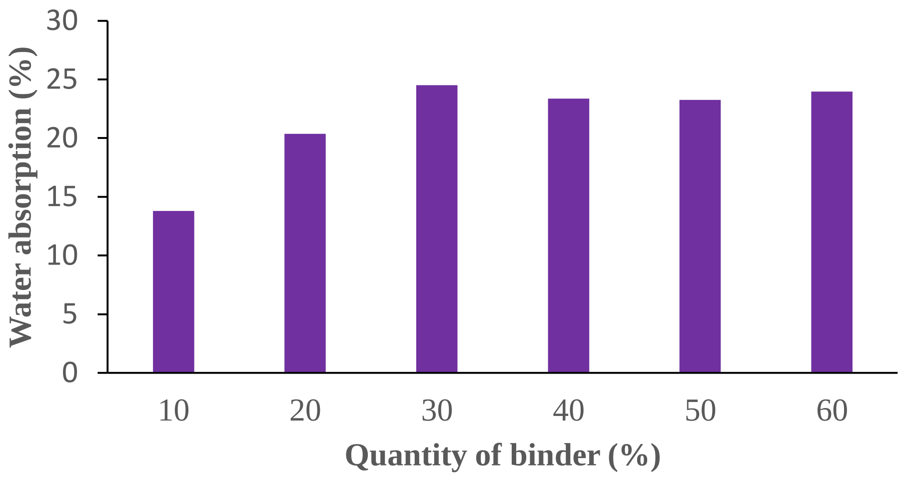

Figure 6. Water absorption of MAFPE composites as a function of quantity of binder

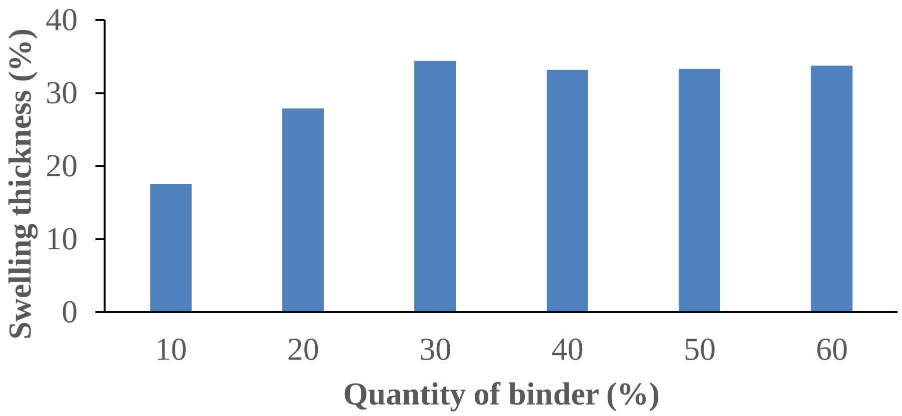

Figure 7. Swelling thickness of MAFPE composites as a function of quantity of binder

Characterization of Selected Composite (MAFPE 4)

SEM analysis

The SEM micrograph of MAFPE 4 composite showed that a longitudinal filament of fiber has been embedded in the whole surface, layer by layer presence of white sheets of matrix having different sizes on the composite (Figure 8).

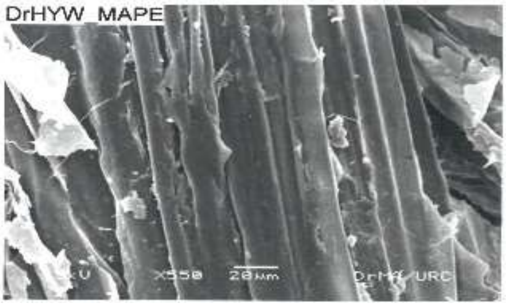

Figure 8. SEM micrograph of MAFPE 4 composite

TG-DTA analysis

Thermal stability of composite (MAFPE 4) (Figure 9) and the interpretation (Table 5) are given. Data showed three distinct weight losses: the first one corresponded to dehydration, the second to the decomposition of cellulose and lignin, and the third to the combustion.

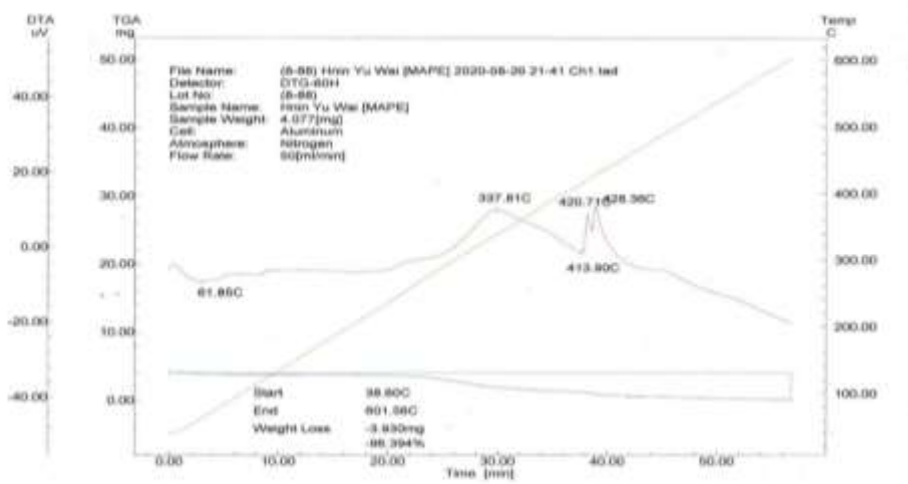

Figure 9. TG-DTA thermogram of MAFPE 4 composite

Table 5. Thermal Analysis Data of MAFPE 4 Composite

TG		DTA		Remarks
Temperature range (°C)	**Weight loss (%)**	**Peak temperature (°C)**	**Nature of peak**	
38-100	14.15	61.85	endothermic	Dehydration due to surface water
100-360	65.71	337.81	exothermic	Decomposition of cellulose and lignin
360-460	16.50	413.90	endothermic	Combustion
		420.71	exothermic	
		428.36	exothermic	

Heat Resistance of MAFPE 4 Composite

Table 6 and Figure 10 show the heat resistance property of the composite. When each MAFPE 4 composite was heated in the furnace at different temperatures (100. 200, 300, 400, 500, 600 ºC) changes in the colour of composites occurred. From the experimental results, the heat resistance of MAFPE 4 composite is with stand able up to 400 ºC. At 600 ºC, the composite became ash. This is due to burning at high temperature.

Table 6. **Heat Resistance of (MAFPE 4) Composites at Different Temperatures**

Temperature (°C)	Before heating weight (g)	After heating weight (g)	Weight loss (%)	Observation
100	3.4380	3.2540	5.30	No colour change
200	3.4324	3.0500	11.14	No colour change
300	3.4280	2.5470	31.56	Pale brown colour is formed
400	3.3950	1.9400	42.85	Brown colour is formed
500	3.3870	0.5640	83.34	Black colour is formed
600	3.3680	0.2178	92.214	Ash pale brown colour is formed

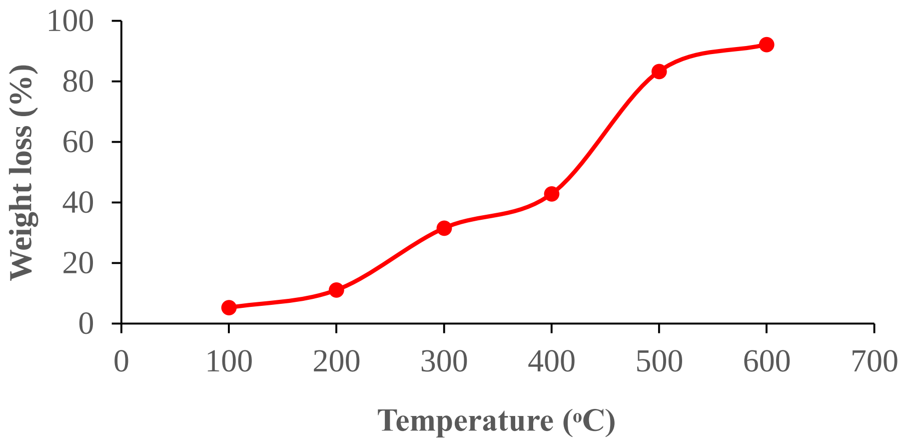

Figure 10. Weight losses (%) of (MAFPE 4) composite as a function of different temperatures

Some Possible Applications of Produced Composites

The produced composites can be used for domestic purpose like furniture, window, door, matting, civil construction etc. The photographs of produced MAFPE composites are presented (Figure 11).

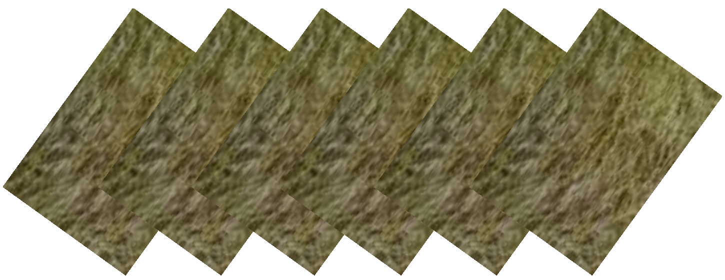

Figure 11. Photographs of MAFPE composites

Conclusion

This study reveals the use of fiber in the development of polymer composites. Improved composites were produced from 5 % (w/v) NaOH used as surface modifiers of fibers to form modified areca leaf fiber. Composites, namely MAFPE, were produced by mixing each 120 g of modified areca leaf fiber with various compositions of recycled polyethylene (PE) by using the hot-pressing method at 2200 psi and 120 ˚C. The optimal condition influencing the production of composites is based on the composition of the binder (40 %) in PE. It was found that the optimized MAFPE 4 composite possesses 2679.83 psi of modulus of rupture, 0.60 cm of thickness, 0.87 g cm^{-3} of density, 23.37 % of water absorption, 33.18 % of swelling thickness, and 98 D of hardness. Composites produced from modified areca leaf fiber are more environmentally friendly, and are used in the building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc.

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