

Tensile Strength of Some Natural-Fibre Composites

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ABSTRACT

The conversion of natural fibre into biocomposites is rapidly being exploited globally. Locally, there are some viable natural fibres that can be utilised for this. In this research project, several types of composites were produced, all of which were made from natural fibres. Four different natural cellulosic fibres were chosen, namely, kenaf, pineapple (pina), banana and coir. Hybrids of kenaf blended with each of these fibres were also woven. The samples were woven manually as weft yarn while the warp yarn used plied polyester thread. The samples were fabricated into composites using four types of matrices which were epoxy, polyester, polypropylene and polyethylene. The composites were fabricated using the manual compression method. These composites were then tested for their tensile strength in weft direction. All results were also analysed using Analysis of Variance (ANOVA) and ranked accordingly. It was found that woven samples made of 100% kenaf fibre exhibited the best tensile strength for all types of resin while coir was found to be the poorest. All kenaf hybrid composites mostly exhibited better results than the non-hybrid composites.

Keywords: Banana fibres, biocomposites, coir, kenaf, pina, pineapple fibres, tensile strength

Agriculture is an important sector contributing to economic growth in many countries around the world. Traditionally, the waste produced by this sector was just burnt away. One of the possible prospects is to

convert agricultural waste into a composite material for technical applications because fibre can be a source of reinforcement filler for composites (Salleh *et al.*, 2004). For example, after harvesting pineapples, the leaves of the plant were normally burnt. Producing fabric from pineapple leaves as done in the Philippines to create yarn and fabric involved laborious work. Producing fibres for composites, however, is a much simpler process.

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There are many types of fibre waste such as coir, banana fibre, paddy straw, pineapple leaf fibre, kenaf, sugarcane and many more. In recent years there have been studies to investigate the use of this waste as biocomposite materials (Rowell, 1992; Bledzki & Gassan, 1999; Summerscales *et al.*, 2010). The advantages offered here are the low cost of materials, renewable resources and low specific weight, which resulted in fairly good tensile properties (Mohanty, 2000; Badros, 2007). Nevertheless, composites made from these are only suitable for use in the low performance applications. (Shibata *et al.*, 2003; Burgueno *et al.*, 2004; O'Donnell *et al.*, 2004; Morye & Wool, 2005; Badros, 2007).

A bio-based composite can be defined as a material that includes some types of natural materials in its structure (Sanadi *et al.*, 2004). The biocomposites from cellulosic materials include those materials obtained from kenaf, pineapple, hemp, flax, bamboo, bast and core leaf plants (for instance, sisal and abaca), and agricultural fibres such as rice straw, corncobs, sugarcane baggase and coconut hair (coir). Many studies were also made on hybrids of natural fibre composites. It was said that hybridisation can be a cost-effective approach (Venkateshwaran, 2012).

Wan Ahmad *et al.* (2004) found that bio-based fibres could be used for composite production and kenaf was found to possess good properties for composites. A blend of kenaf and cotton was also found to possess good mechanical properties. Wambua *et al.* (2003) said that composites made from natural cellulosic fibres namely kenaf,

coir, sisal, hemp and jute (except for coir) yielded similar tensile strength with glass fibre. They concluded that natural-fibre composites had the potential of replacing glass fibre in several applications. Shibata *et al.* (2003) also found that kenaf fibre could be a good reinforcement candidate for high performance biodegradable polymer composites. Nevertheless, Akil *et al.* (2011) cautioned the setback of kenaf, which was the lack of good interfacial adhesion between the fibre and the polymer matrix. In solving this, Asumani *et al.* (2012) and Yousif *et al.* (2012) found that tensile and flexural properties of kenaf can be improved by treating the fibres with sodium hydroxide and silane.

In this research, natural fibre waste generated from agricultural practice was woven into fabric and then fabricated into biocomposite. The fibres used were kenaf, pineapple (pina), banana stem and coir. The fibres were then fabricated with two thermoset and two thermoplastic resins to produce biocomposites. The tensile properties of each were evaluated and compared.

MATERIALS AND METHODS

Materials

Kenaf, pineapple leaf, coir, banana stem and hybrids of 50/50% kenaf/pineapple and 50/50% kenaf/banana and 50/50% kenaf/coir fibres were used in this research project. Each material was first cut and the fibres were extracted through retting, crushing, combing and then dried. The fibres were then woven as weft yarns to form a fabric as

shown in Fig.1. This was to take advantage of the parallel weft, which was supposed to perform better than the randomly laid nonwoven. The warp used was polyester spun threads of 40/2's.

For the hybrids, the weft picks were arranged alternately during weft insertion. Each of the weft was measured in terms of its linear density (0.3 gm each) before alternately inserted as weft. The average thread densities for warps and wefts of the fabric were 6 ends and 12 picks per 2.5 cm.



Fig.1: Woven materials.

Fabrication Methods

Two thermoset and two thermoplastic resins were used in the experiments, namely polyester and epoxy for the thermoset, and high density polyethylene (HDPE) and polypropylene for the thermoplastic. The thermoplastic resins were in pallet form, and these were melted to form sheets before the lay-up process.

For composite fabrication, two layers of fabrics were laid on an aluminium plate and the resin with the hardener (where needed)

was applied evenly on the fabric using a roller. Once completed, another aluminium plate was placed on top of the resinated fabric. Force was applied using a G-clamp to the aluminium plates as shown in Fig.2 so that the resin would be distributed evenly among the fibres. Spacers of 2-mm thickness were placed in between the aluminium plates to ensure even thickness of the composites.

The polyester resin samples were left to cure at room temperature for 24 hours and the epoxy samples were put under a hot press for 8 hours at 120°C. The thermoplastic samples were cured under hot press at 190°C for 5 minutes. The samples were left to cool down for another 24 hours before the assembly was dismantled. Four composites for each resin treatment with dimensions of 26 cm x 26 cm were made.

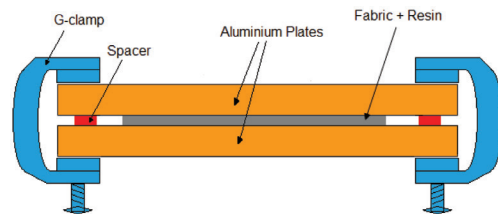


Fig.2: Fabrication arrangement.

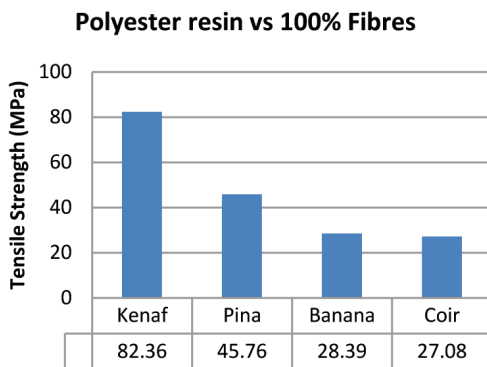
Testing

Tensile testing was done in accordance to Composites Research Advisory Group 302 (CRAG 302). Since the fibres used were all in the weft direction, testing was conducted with the weft direction only. Five samples for each resin treatment were cut using a rotary cutter with size 20 mm x 150 mm. Nevertheless, the sample where tensile breakage occurred at the tab was discarded and replaced with another sample. The

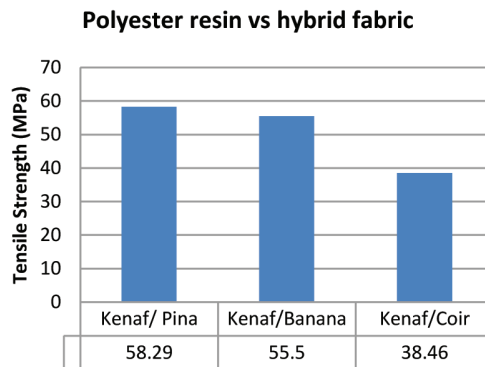
gauge length was 100 mm and the crosshead speed was 5 mm/min. Analysis of variance (ANOVA) was conducted to rank the result of tensile strength of those composites.

RESULTS AND DISCUSSIONS

The results for the composites made from 100% natural fibres are presented separately from those obtained using the blended or hybrid fabrics. Fig.3a and 3b show the results of these composites using polyester resin. From Fig.3a and 3b it can be seen that composites made from 100% kenaf exhibited the highest tensile strength at 83 MPa compared to other 100% fibre composites. For the hybrids, kenaf/pina showed the highest tensile strength at 58 MPa. It is interesting to note that the kenaf/pina hybrid recorded tensile properties higher than the 100% pina fibres. All the hybrid composites showed that kenaf fibres had a strong influence on the strength of these composites. Composites from coir displayed the weakest tensile results, and this included its hybrid with kenaf.



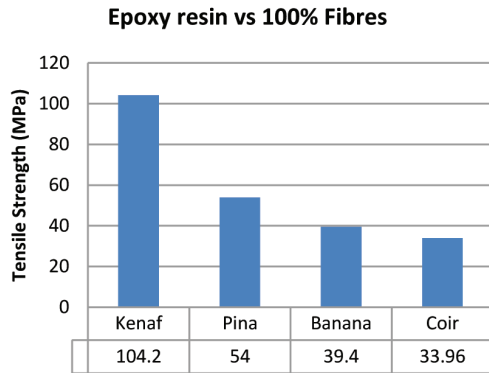
(a)



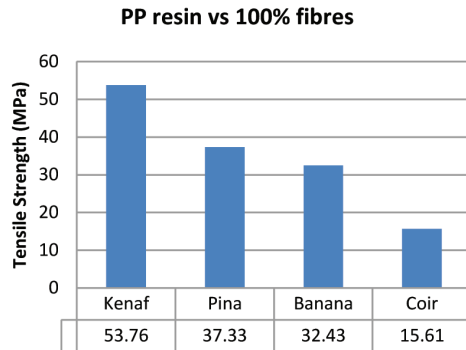
(b)

Fig.3: Tensile strength using polyester resin

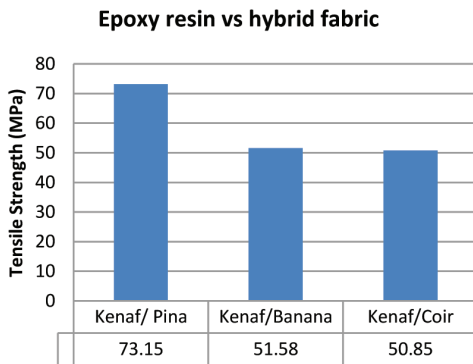
Fig.4a and 4b show the results of tensile test using epoxy resin. Again, it can be seen that 100% kenaf exhibited the highest tensile strength at 104 MPa followed by pina, banana and coir again the lowest. With the hybrids, kenaf/pina showed the highest properties and, similar to composites with polyester resin, the strength of kenaf/pina was higher than that of 100% pina, which were 73 MPa and 54 Mpa, respectively. In fact, kenaf/coir hybrid strength was almost reaching the strength of 100% pina composites. Therefore, with epoxy resin, kenaf also played an important role in strengthening the hybrid composites.



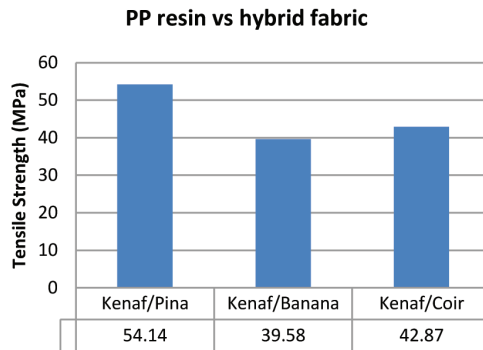
(a)



(a)



(b)



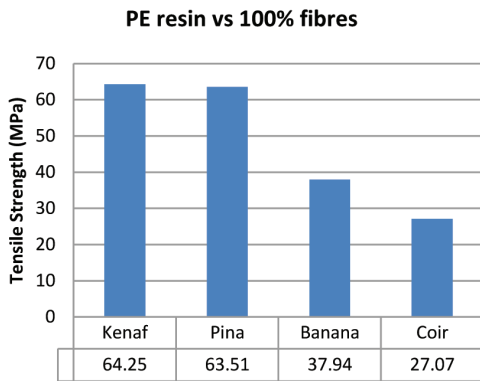
(b)

Fig.4: Tensile strength using epoxy resin.

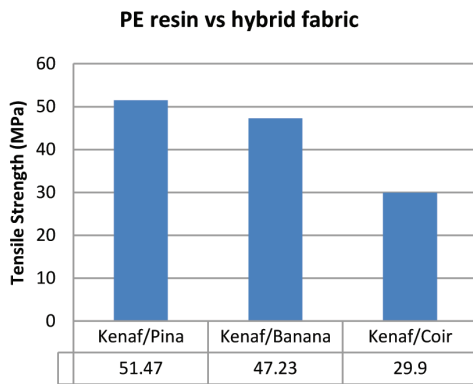
Fig.5: Tensile strength using polypropylene resin.

The results for tensile test using polypropylene resin for the composites made from 100% natural fibres and the hybrids fabrics are shown in Fig.5a and 5b, respectively. Using the polypropylene also, composites made from 100% kenaf showed the highest tensile strength followed by pina, banana and coir. Similar to the thermosets, the hybrids also behaved in the same way. However, it was noticed that the kenaf/coir hybrid exhibited higher tensile properties than the 100% pina composites.

Fig.6a and 6b exhibit tensile test results from using polyethylene resin. With this resin also, 100% kenaf composites demonstrated the highest in tensile strength. Nevertheless, 100% pina fibres also showed quite a remarkable tensile strength compared to kenaf. Analysis of this result showed that there was no significant difference between the two. As for the hybrids, the results were similar to the other resins.



(a)



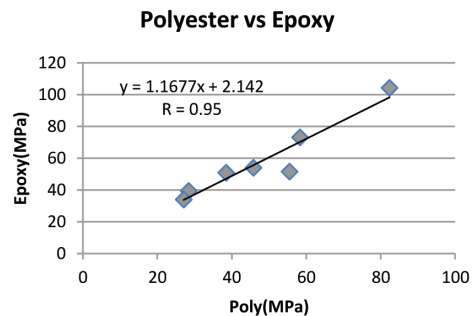
(b)

Fig.6: Tensile strength using polyethylene resin.

Analysis of variance conducted to rank the tensile strength confirmed that the highest tensile strength was exhibited by 100% kenaf followed by pina, banana and coir. With the exception of polyethylene resin, 100% kenaf was significantly higher in tensile properties when it was compared to other natural-fibre composites in this project. This was in agreement with the result of Wan Ahmad *et al.* (2004). With the hybrids, kenaf/pina hybrid was significantly

higher in tensile strength to other hybrids, but the ranking between kenaf/ banana and kenaf/coir was a little inconsistent with the epoxy and polypropylene resins.

Correlation analyses were also conducted between the tensile results of the thermoset and the thermoplastic resins for all the composites fabricated and shown in Fig.7a and 7b, respectively. This was done to examine the effect of composite fabrication for each fabric and resin. It can be seen that the tensile test results using the two thermoset resins correlated very well with $R = 0.95$. This showed that the fabrication and the fibres had been consistent for all the composites. However, the correlation for the composites using the thermoplastic resin was moderate with $R = 0.63$. The result for 100% pina with polyethylene resin and the result for kenaf/coir for polypropylene resin could have caused this irregularity. It was probably because the thermoplastic resins were applied using sheets and not liquid. The thickness of the polypropylene sheets was not that consistent. It also could be due to lack of interfacial adhesion as mentioned by Akil *et al.* (2011).



(a)

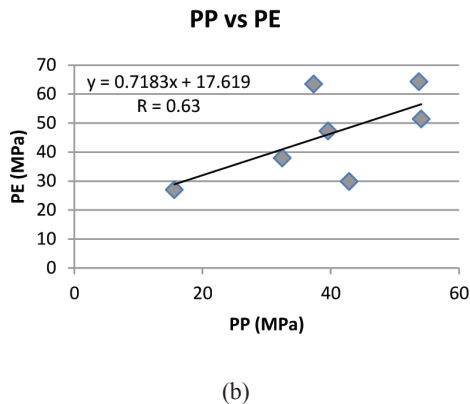


Fig.7: Correlation analysis between the resins.

CONCLUSION

The results of this research project demonstrated that functional composites can be developed using local cellulosic fibres as reinforcing materials for biocomposites. Kenaf was found to be the best reinforcing fibre compared to pineapple fibres, banana and coir in terms of tensile strength. Its tensile properties were consistent with all types of resin used in this project. Next to kenaf was pina which has good potential as reinforcing material for composites.

It is possible to produce a good hybrid composite by weaving these fibres to form fabric. Blending of kenaf with other fibres shows that kenaf fibres has very strong influence on the strength of these composites. Kenaf/pina is consistently higher in tensile properties compared to other hybrids. Almost all kenaf hybrid composites exhibit tensile results higher than the non-hybrid composites.

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