

Mechanical Improvement of Ramie Woven Reinforced-Starch Based Biocomposite Using Biosizing Method

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1. Introduction

Biocomposite materials have been developed that offer certain mechanical and environmental advantages and also renewable-abundant resources. Biocomposite are defined as composite materials that build up by natural cellulose fibers as reinforcement fibers and starch or biopolymer as natural matrix. Biocomposites also called as green composites.

Based on previous paper (Marsyahyo *et al*, 2008), the density of ramie fibers is much less than that of synthetic fibers such as E-glass fibers but ramie fibers has surface characteristic to be applied as superior reinforcement in composite material. The specific strength and specific modulus of natural fibres are comparable or even superior to E-glass fibres. Hence, there is an opportunity for using the natural fibres such as ramie) to replace the E-glass fibre for a composite reinforcement (Drzal *et al*. 2004). Drzal *et al* (2004) suggested that in order to develop biocomposites with better mechanical properties, it is necessary to solve the problems by suitable treatments to enhance the compatibility between fibers and the matrix. Natural fibers are inexpensive, abundant and renewable, lightweight, degradable and abrasive to processing equipments (Alvarez, Vazquez, & Bernal, 2006).

According to Kalambur and Rizvi (2006), starch as biodegradable polymer to replace synthetic polymer has still needed to improve because of complex disadvantages including brittleness in the absence of suitable plasticizers, hydrophilic nature of starch and poor water resistance, deterioration of mechanical properties upon exposure to environmental conditions like humidity, and soft and weak nature of starch in the presence of plasticizers. Starch as an inexpensive material and renewable source is biodegradable and biocompatible. Its small granule size makes it as good particulate filler in many polymer blending systems (Ning *et al* , 2010). Also starch has its stiffness, tensile strength, and gas permeability are comparable to those of synthetic polymers from fossil fuels as a matrix in composite. Torres *et al* (2007) reported that starch processing method was not so complicated compare to synthetic polymers and can be produced from a wide variety natural resources and also compatible to plasticizer to improve their properties. Because of their mechanical performances, natural fiber and natural starch, as a composite system, were used intensively for components substitution in automotive and engineering structures

(Chen *et al*, 2005; Muller and Krobjilowski, 2003). Moreover, Rochardjo *et al* (2009) also utilised ramie fiber for high impact resistant panel for body armours. Figure 1 shows theoretical background on how the composite laminated to be made including stacking sequence, the number of ply and also fiber volume fraction embedded in matrix as a composite system.

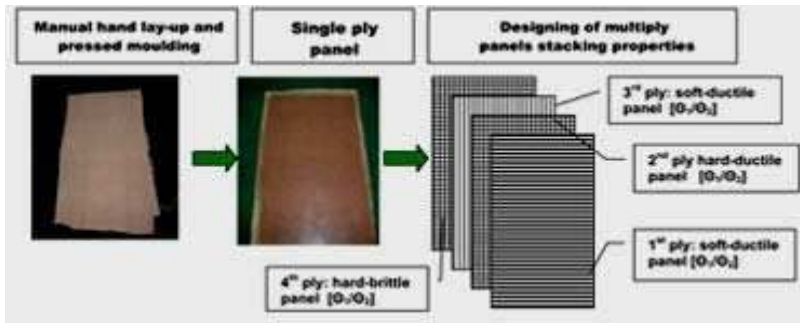


Fig. 1. Laminated composite system (Rochardjo *et al*, 2009)



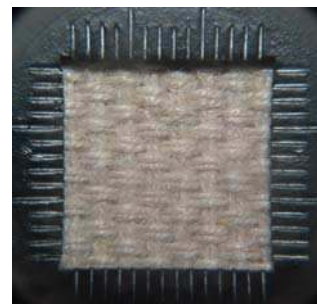
(a) Ramie yarns in cones



(b) Rami woven



(c) Ramie yarns 12s/3 (mag. 25x)



(d) Plain weave ramie woven (mag.10x)

Fig. 2. Ramie woven structure

2. Materials and methods

Ramie (*Boehmeria nivea*) woven in plain weave structures with double warp and weft orientation was treated by biosizing materials. Dextrin was prepared and used as biosizing materials and matrix to build-up for biocomposites were made from starch based materials obtained from gelatinized garut (*Maranta arundinacea*) and tapioka (*Manihot esculenta*). **Appendix 1** shows FTIR group function identification of dextrin, garut and tapioka starches. All biosizing material was processed in boiling water with mixing in one part starch and 3 parts water in kilograms/liters. Ramie woven was hot-dipped into the mixtures of dextrin and boiled water for 30 minutes and drained in room temperature for 6 hours before used as reinforcement material in biocomposite system. All biosized ramie woven was tested to obtain mechanical strength in laminate forms or multi layer ramie woven biocomposite. The ramie woven structure as a reinforcement material was design in plain weaving with double warp and weft of ramie yarn structure as seen on Figure 2.

Figure 2(a) and (c) are pure ramie yarn. The yarns to be designed in woven form with double warp and weft as shown in Figure 2(b) and (d). Specification of the woven structure is showed in Table 1.

Specifications ramie woven#	
a. Tensile strength (cN/tex)	45 - 75
b. Elongation (%)	7 - 12
c. Bursting strength (MPa)	8,5 - 16
d. Tearing strength (N)	300 - 550

Yarn dimension is 12/3s and containing 100% ramie fiber. The woven structure is plain weave double warp/weft.

Table 1. Ramie woven specifications

Ramie woven material for tensile testing showed in Figure 3(a) and bending Figure 3(b). All specimen was prepared and cut into standard size for mechanical testing before laminated to build up biocomposite system.



(a) Ramie woven for tensile testing

(b) ramie woven for bending test

Fig. 3. Ramie woven as fiber reinforcement material

The number of each group of the specimens to be tested is 15 samples. Testing was conducted according to ASTM standards. The standards used in this test were D 638 for tensile testing, D790 for bending testing and D 256 for impact test.

Figure 4 shows the biosizing method to process ramie woven. Both garut (*Maranta arundinacea*) and tapioka (*Manihot esculenta*) boiled in 3 parts of water until reached gelatinised starch for biosizing and applied to ramie woven surfaces.

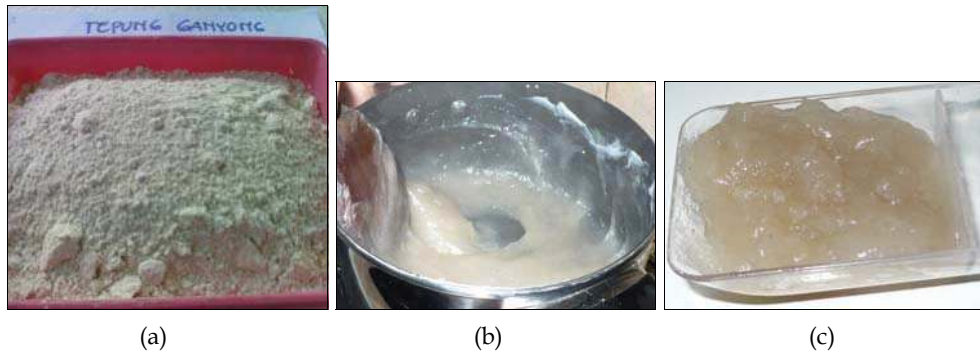


Fig. 4. Making biosizing for matrix in biocomposite system. (a) starch based material for sizing; (b) Gelatinised starch; (c) biosizing ready to use

Figure 4(a) is starch based from garut (*Maranta arundinacea*) and tapioka (*Manihot esculenta*) to be processed into gelatinised starch becoming biosizing material which had a capability to bond the ramie woven in laminated composite and to fill the gap between ramie yarn in double warp and weft as woven plain weave structure.

3. Results and discussions

3.1 Tensile strength

Tensile strength of biocomposite ramie without treatment showed has a lower strength about 14.45 MPa for ramie-garut biocomposite and 12.81 for ramie-tapioka biocomposite. In certain volume fraction, the optimum tensile strength was 19.47 MPa for 60% containing fiber embedded in garut as composite matrix but for tapioka matrix showed 70% fiber content has optimum tensile strength 16.84 MPa in average. Figure 5 shows ramie-garut biocomposite relatively has higher tensile strength than ramie-tapioka.

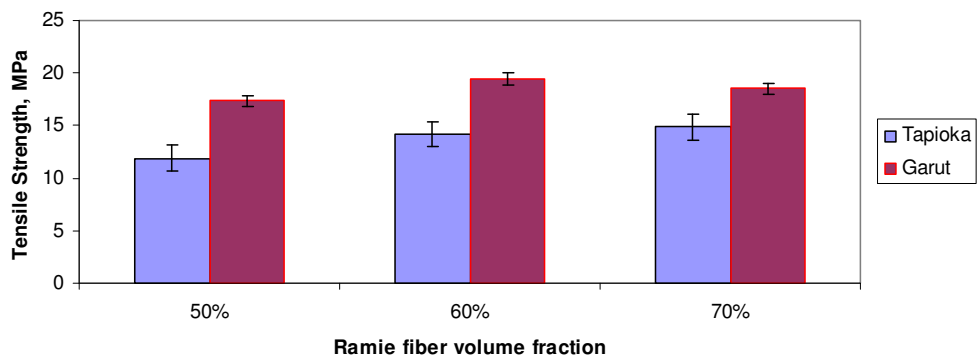


Fig. 5. Tensile strength ramie-garut and ramie -tapioka biocomposite

From figure 6 it can be showed that without biosizing, spesimen damage after tensile testing mostly dominated by debonding interlayer because low bonding mechanism between the woven and the matrix and affected to debonding failure easily.



Fig. 6. Failure in biocomposite with different fiber volume fraction

Figure 6 also shows that fiber broken dominate biocomposte failure especially for 60% and 70% ramie content embedded in the matrix both tapioka and garut.

3.2 Bending strength

The result of bending test showed that ramie woven treated by dextrin biosizing had bending strength higher than without treatment. Biocomposite 60% fiber volume frcation embedded in garut matrix showed bending strength 18.2 MPa and relatively higher than other combinations (Figure 7). The function of the 60% ramie woven fiber in garut matrix indicated effective load transfer during flexuring or deflection.

Deformation after bending test in Figure 8 showed that ramie woven composite in stacking still bonding together. There was no debonding between each plies of the stacking woven both fiber volume fraction 70/30 and 50/50. It was indicate that ramie woven biosized using garut and tapioca had capability to resist debonding during deflection in bending load test.

3.3 Impact strength

Untreated ramie or without sizing using dextrine media shows that the value of their impact strength did not differ sharply. Ramie-garut biocomposite had 4-6 % higher than ramie-tapioka biocomposite as seen in figure 9. Varied in fiber volume fraction both for ramie-tapioka and ramie-garut biocomposite also shows a little difference and it can be understood that the fibers function more effectively absorbed impact energy than the matrix.

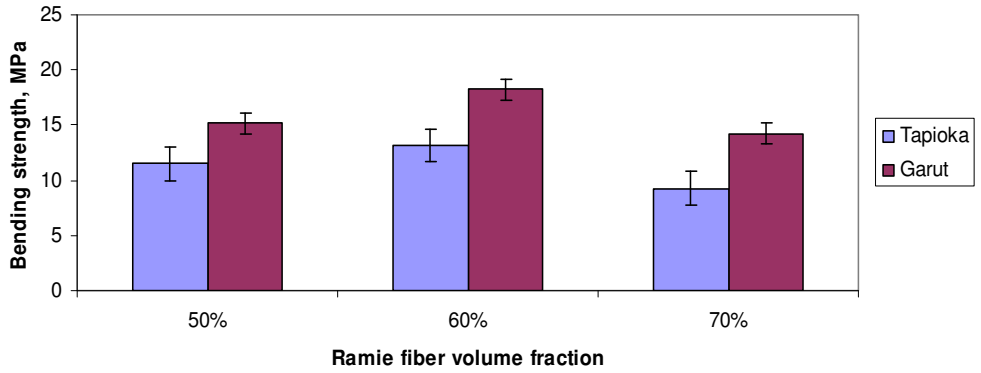


Fig. 7. Bending strength comparison between ramie-tapioka and ramie-garut biocomposite



(a) bending specimens biosized 70:30

(b) biosized 50:50

Fig. 8. Bending failure of the specimens

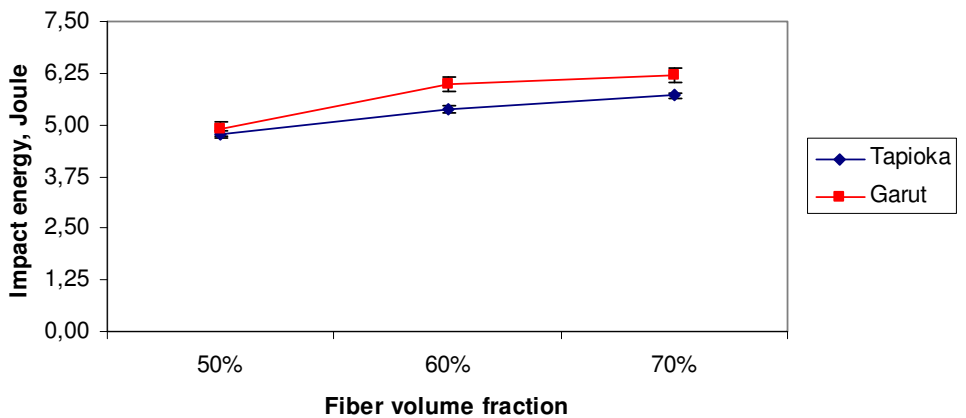


Fig. 9. Impact strength untreated ramie-tapioka and ramie-garut biocomposite

Increasing the impact strength of treated ramie by dextrin showed in figure 10. Ramie-garut biocomposite had impact strength higher than ramie-tapioka. Impact strength between 60% and 70% ramie fiber volume fraction embedded in both for garut and tapioka matrix showed little difference due to rigidity of the fiber remain uniform and did not affected by the matrix very much.

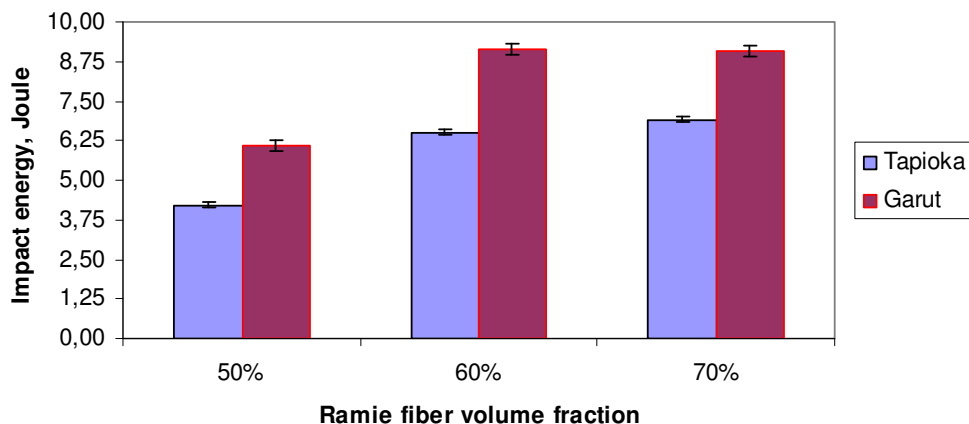


Fig. 10. Impact strength treated ramie-garut and ramie-tapioka biocomposite

For further development of some extent of application for low impact resistant biocomposite product, ramie-garut biocomposite system was also tested for especially safety helmets as shown in figure 11. This preliminary safety helmets were designed for low compressive load.



Fig. 11. Preliminary design safety helmet ramie-garut biocomposite

The helmets were designed in laminated biocomposite with 4 plies or layers of ramie woven. Fiber volume fraction of the ramie woven was about 60%. Garut as material for matrix was blended with antibacterial (see Appendix 1) media to protect from environment such as moisture and tropical fungus. The helmets were tested in 2 direction (figure 12) of compressive load. The test speed was set-up about 10 mm/sec.

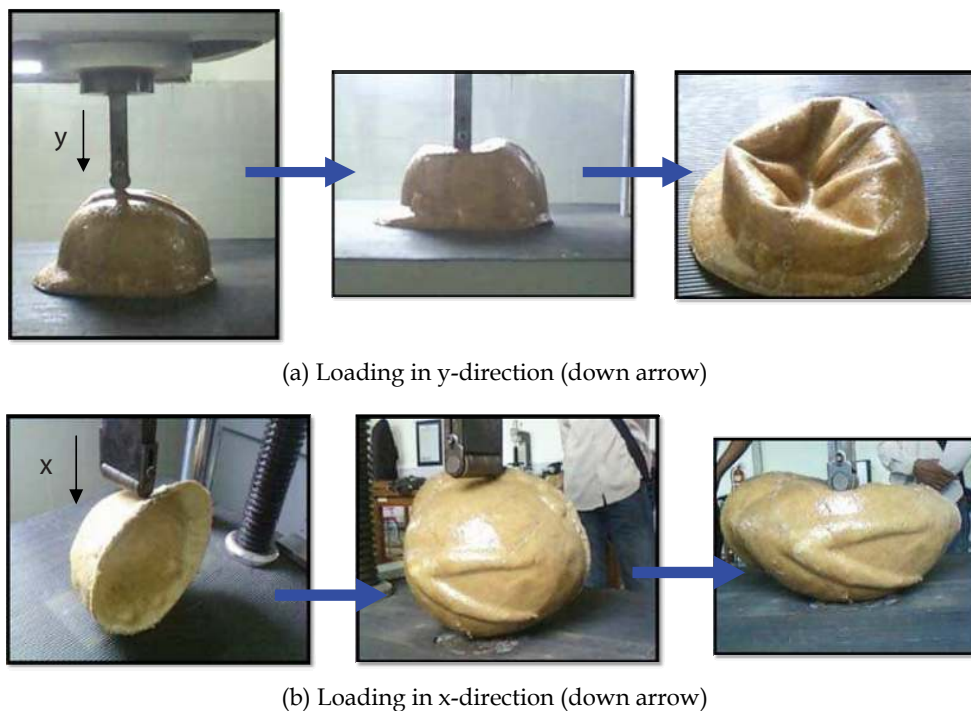


Fig. 12. Compressive testing of the helmets

The load application of the compressive testing resulting a compressive strength in y-direction was 1026 N in average and in x-direction was 483 N. From the point of view, abundant supply and low cost of ramie woven will further promote in engineering applications and also market worldwide.

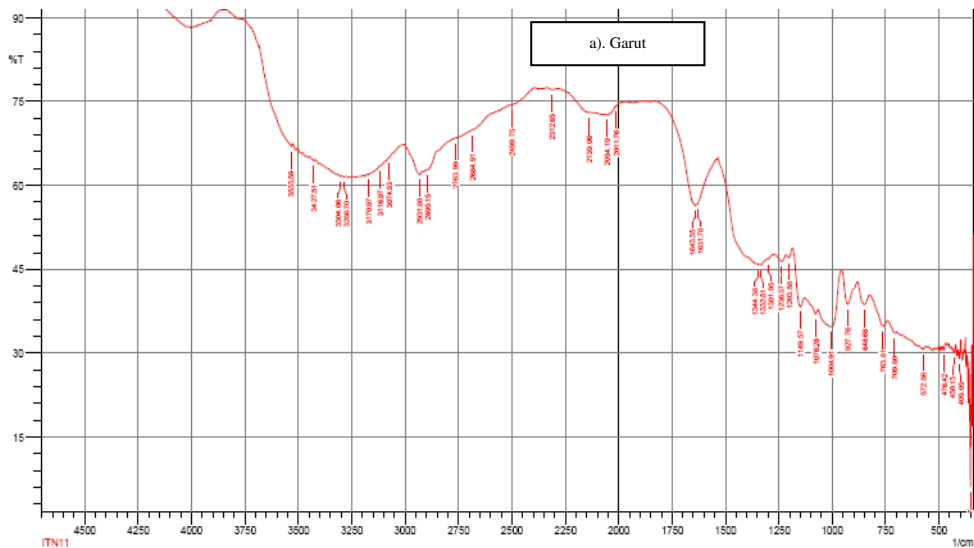
4. Conclusions

Improving mechanical properties of the ramie woven by sizing method using dextrin media showed the enhancement 40 % to 50 % of tensile strength, flexural strength and impact strength of the ramie-garut and ramie-tapioka biocomposite system. Ramie-garut biocomposite had more optimum mechanical strength than ramie-tapioka due to effective adhesive bonding mechanism between fiber and matrix. Ramie fiber volume fraction 60% potentially the best choice for reinforcement in garut as a matrix to build up biocomposite system to meet mechanical and fully biodegradable criteria for further engineering applications.

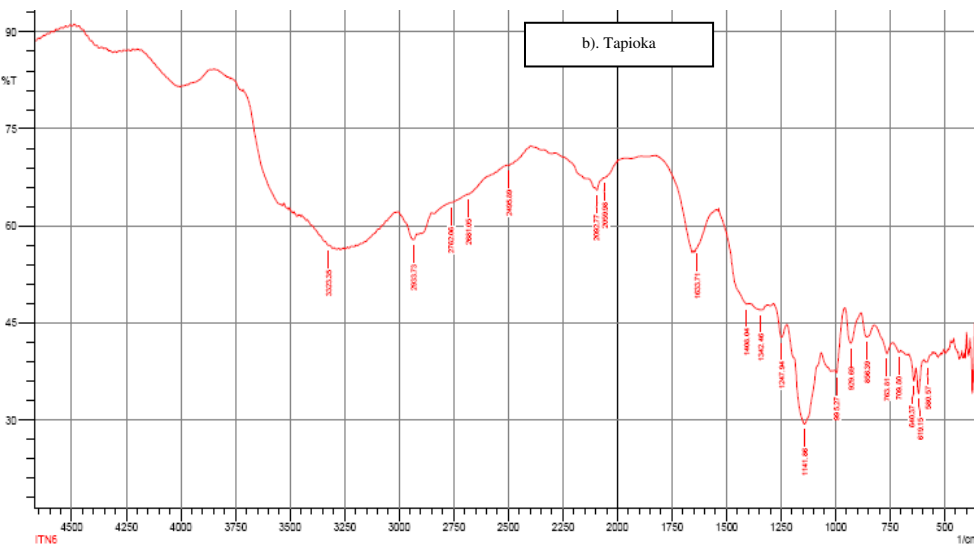
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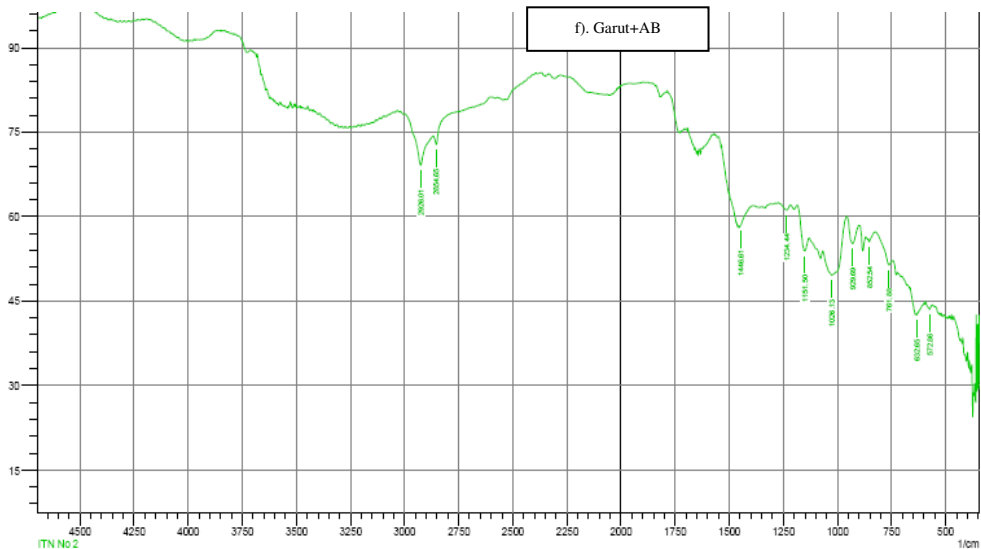
Appendix 1. FTIR group function of garut (*Maranta arundinacea*) and tapioka (*Manihot esculenta*) biosizing starches



(a) FTIR group function of Garut (*Maranta arundinacea*)



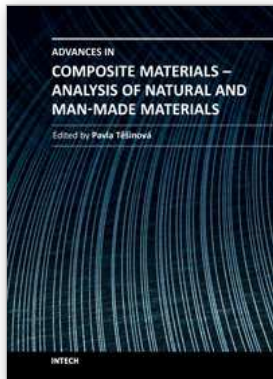
(b) FTIR group function of tapioka (*Manihot esculenta*)



(c) FTIR group function of garut blended antibacterial agent (AB)

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Composites are made up of constituent materials with high engineering potential. This potential is wide as wide is the variation of materials and structure constructions when new updates are invented every day. Technological advances in composite field are included in the equipment surrounding us daily; our lives are becoming safer, hand in hand with economical and ecological advantages. This book collects original studies concerning composite materials, their properties and testing from various points of view. Chapters are divided into groups according to their main aim. Material properties are described in innovative way either for standard components as glass, epoxy, carbon, etc. or biomaterials and natural sources materials as ramie, bone, wood, etc. Manufacturing processes are represented by moulding methods; lamination process includes monitoring during process. Innovative testing procedures are described in electrochemistry, pulse velocity, fracture toughness in macro-micro mechanical behaviour and more.

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