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The loading effect of sugarcane powder on the tensile property of glass fibre/sugarcane powder/polymer hybrid composite

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The loading effect of sugarcane powder on the tensile property of glass fibre/sugarcane powder/polymer hybrid composite

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Abstract. The awareness of environment enhances the use of green and renewable materials. Glass fibre reinforced composite is a well known composite material. Utility of sugarcane fibre will decrease the use of synthetic fibre without losing the excellent of mechanical properties of glass fibre composite. In the experiment, the loading effect of sugarcane powder were 5,10 and 15 wt% and glass fibre were 5,10 and 15 wt%. The hybrid composite was simply prepared by hand lay-up method. The mechanical properties was characterized using tensile test. The result show that the tensile properties of composite increased with the addition of glass fibre and 1sugarcane powder. The rule of mixture was used to model the tensile property of composite.

1. Introduction

The dry pulpy residue left after the extraction of juice from sugarcane is called bagasse. A lot of amount of bagasse was produced as a waste from sugar industry. As other natural fibre, bagasse contained cellulose, hemicelluloses and lignin. Some research on natural fibre composite explored the use of bagasse fibre as reinforcement in composite. However, the strength relatively low. Hence, it is necessary to improve the strength of the composite through addition of synthetic fibre as hybrid composite. Hybrid composite can be consisted of two or more synthetic fibres/particles or combination between synthetic fibres/particles and natural fibres/particles.

The purpose of making hybrid natural/synthetic fibre composite were improving the mechanical properties of natural fibre composite and decreasing the negative effect of synthetic fibre composite on environment by using the lower cost and green fibre. The hybridization of natural PALF/sisal fibre with synthetic glass fibre in polymer matrix can enhance the durability and mechanical properties of composite [1] also glass/jute, glass/kenaf composites [2-3]. The preliminary research on natural fibre hybrid composite lamina was done by Clark and Ansell. It shown the toughness of glass/jute composite was increasing [4]. Based on the the properties of each kind of fibre. i.e. natural fibre is ductile and glass fibre is brittle.

The properties of composite were built by the fiber properties. In work on natural fibre composites, the elongation of hybrid composite increase with addition of oil palm fibre. In reverse, the dimensional stability was higher for a higher glass fibre addition [5]. The tensile properties of oil palm fibre hybrid composite increases up to 45% fibre loading. The tensile properties were enhanced by the addition of glass fibre addition. In reverse, the tensile strength decreases with increasing oil palm fibre addition. This due to the agglomeration of the fibre at high loading [6]. Porosity of sugarcane fibre or commonly know as bagasse fibre affected the mechanical properties of composite. Bagasse fibres have porous structure (75-80%) by volume. Bagasse contain hollow cavities called lumen. Porosity has negative effect on bagasse composite such as water absorption, fungus attack, and mechanical properties has positive effect such as acoustic and thermal insulation and decreasing the density of the composite [7-9].

The mechanical properties such as tensile, flexural, impact strength and elastic modulus of natural fibre composite was increased by addition of synthetic fibres. The enhancement of tensile strength was due to high modulus of glass fibre. The flexural strength was enhanced by addition of high shearing resistance of glass fibre. However, because of brittle behaviour of glass fibre, there was a decreasing of impact strength with further increase of glass fibre in hybrid composite [5].

This research investigated the tensile property of glass fibre/sugarcane powder/polymer hybrid composite. The loadings of sugarcane or bagasse particle and glass fibre were 5, 10 and 15 %wt. Composite was prepared using hand lay-up method. The morphology and failure mechanism of hybrid composite was observed using scanning electron microscope. The experiment result was compared to composite analytical model i.e. rule of mixture.

2. Materials and method

The matrix material was polyester BTQN-157 with density of 1.215 gr/cm^3. The catalyst was the metyl-etyl-keton peroksida (MEXPO). The natural fibre particle was extracted from sugarcane fibre from Lampung Province, Indonesia. The sugarcane fibre was crushed to powder of 200 mesh in size. The density was 0.78 gr/cm^3. The glass fibre was randomly chooped glass fibre. The density of glass fibre was 2.5 gr/cm^3.

The composite was prepared with hand lay-up technique [10]. The preparation of composite component was as follow: firstly, the fibre treatment; the sugarcane fibre was washed with distilled water, then the fibre was dried naturally under the sunlight for 12 hours. Next, sugarcane powder was alkali treated with 5% NaOH for 3 hours. It was followed by drying the fibre for 12 hours under the sunlight. Then the powder was milled using commercial mixer into powder of 200 mesh in size. Secondly, the preparation of matrix; the polyester matrix was mixed with 1% of catalyst for 2 minutes. Thirdly, the sugarcane powder was mixed with polyester.

Then, the preparation of hybrid composite; firstly, the glass fibre was hand lay up in the mould. Then, mixed polyester and sugarcane powder was poured into the mould. Repeat the same proses to the desire layer. In this preparation, the layering and pouring processes were done for 5 times. The mould then was closed. Then, the sample was cure in the oven for 70 °C for 3 hours. The cured sample was taken out from the oven and was left in room temperature for 12 hours.

The tensile test according to ASTM D638 was conducted to investigate the mechanical properties of the hybrid composite. The observation of the morphology of composite was investigated using SEM micrograph.

3. Result and discussion

The composition of hybrid composite is shown in Table 1. The specimen of hybrid composite is shown in Figure 1. As shown in Figures 2-4, the stress-strain curve shown at the first stage, the matrix and the fibres behave linearly. At the second stage, the stress-strain curve deviated from linearity. It is because the matrix is deformed and the matrix micro cracking occurred. Randomly oriented fibre acted as obstacle of crack propagation. After microcracking, debonding between fibre and matrix occured and it was followed by fibre pull-out. As the fibre loading increases, the slope of stress-strain curve increases.

In elastic range, the stress-strain curves of each specimen show a similar gradient. When the load increased beyond the elastic range, the shape of the curve of all specimens deviated from each other. The stress increased a bit before fracture of composite. This behaviour was not seen in non hybrid glass fibre reinforced composite. Increasing of stress before final failure was higher for composite with high percentage of bagasse particle. The different in damage mechanism and fibre-matrix interaction in each specimen might cause this.

Table 1. The composition of sugarcane/glass/polyester hybrid composite

No	Sample name	Sugarcane powder (wt%)	Glass fibre (wt%)	Polyester (wt%)
1	SGP5	5	5	90
2	SGP10	10	10	80
3	SGP15	15	15	70

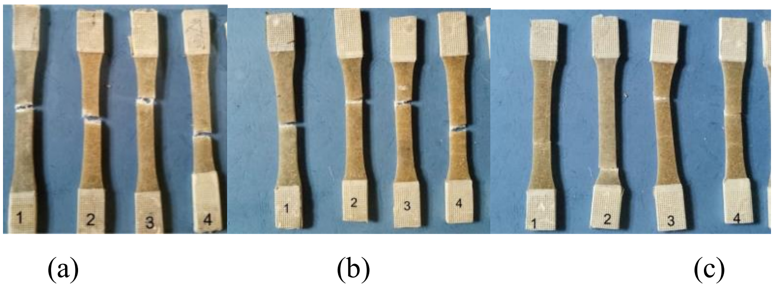


Figure 1. The specimen of hybrid composites (a) 70:15:15 (b) 80:10:10 (c) 90:5:5

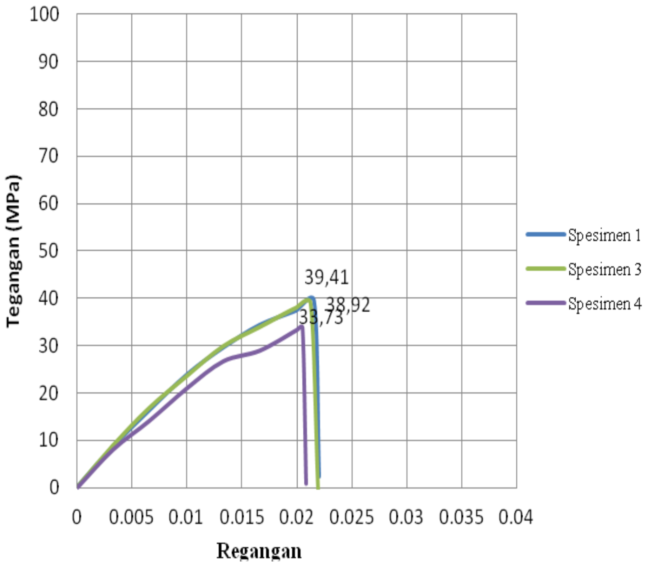


Figure 2. Stress-strain curve of 70:5:5 hybrid composite

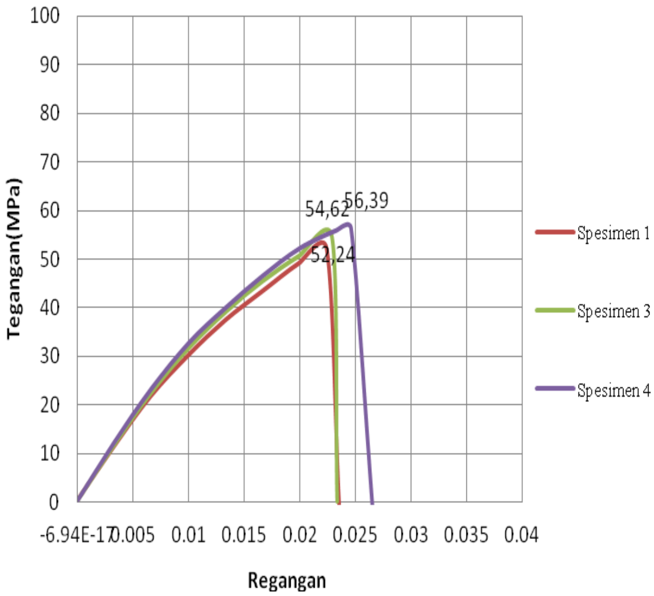


Figure 3. Stress-strain curve of 80:10:10 hybrid composite

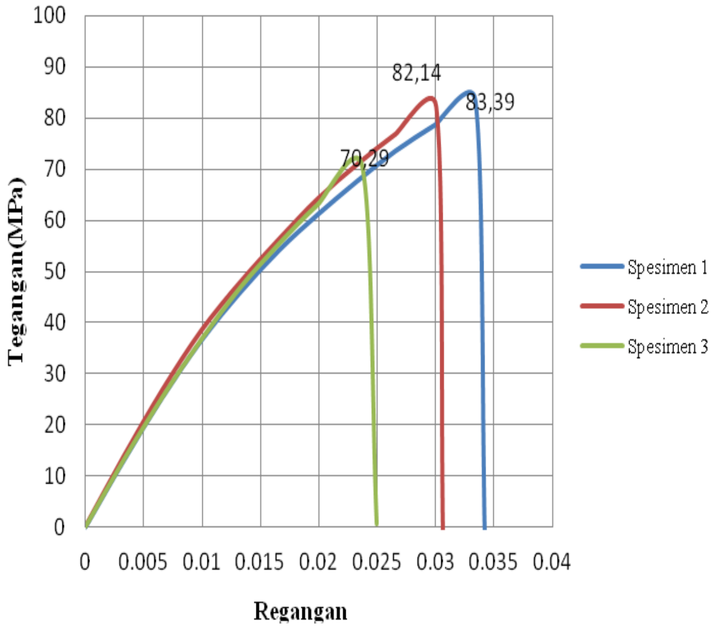


Figure 4. Stress-strain curve of 90:15:15 hybrid composite

The tensile strength, strain at failure and tensile modulus of composite are shown in Figures 5-7. the tensile strength of hybrid composite was higher than the pure polyester. The tensile strength of hybrid composite was increased with the increasing of weight of glass fibre and bagasse particle. The strain at failure did not change very much with the fibre and particle loadings. The elastic modulus of fibre was higher for hybrid composite than pure polyester. As the weight of glass fibre and bagasse particle increase in polyester matrix, the elastic modulus of hybrid composite also increased.

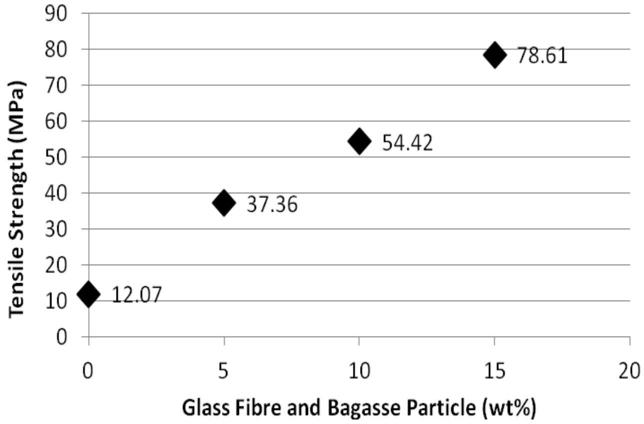


Figure 5. Tensile strength of hybrid composite as a function of weight fraction of fibre and particle in composite

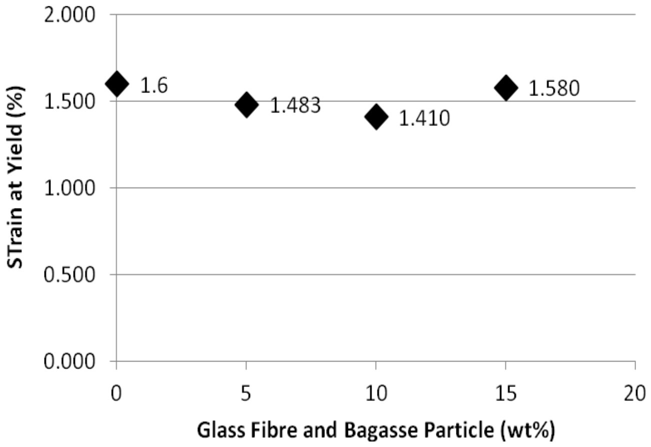


Figure 6. Strain at failure of hybrid composite as a function of weight fraction of fibre and particle

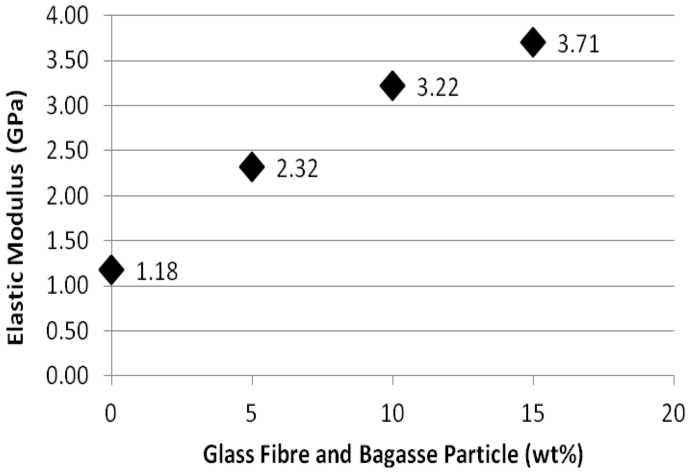


Figure 7. Elastic modulus of hybrid composite as a function of weight fraction of fibre and particle

Theoretically, elastic modulus can be calculated using the rule of mixture (ROM) [11]. The elastic modulus of unidirectional composite that was loaded paralel to the fibre direction, is as follow:

$$E_1 = E_{//} = E_{f1}V_{f1} + E_mV_m \ (1) \quad (1)$$

The elastic modulus for the unidirectional composite that was loaded in perpendicular to the fibre direction, is as follow:

$$1/E_2= 1/E_{\perp} = V_{f1}/E_{f1}+V_m/E_m \quad (2)$$

Where, E_1 and E_2 are the elastic modulus of composite of upper and lower bound, respectively. Ef and Em are the elastic modulus of fibre and matrix, respectively. Vf and Vm are the elastic modulus of fibre and matrix, respectively.

The ROM equation for hybrid composite loaded parallel to the fibre direction was as follow:

$$E_1 = E_{//} = E_{f1}V_{f1}+E_{f2}V_{f2}+E_mV_m \quad (3)$$

The ROM equation for the unidirectional composite loaded perpendicular to the fibre direction was as follow:

$$1/E_2 = 1/E_{\perp} = V_{f1}/E_{f1} + V_{f2}/E_{f2} + V_m/E_m \quad (4)$$

Where, E_1 and E_2 are the elastic modulus of hybrid composite of upper and lower bound, respectively. E_{f1} and E_{f2} were the elastic modulus of fibre 1 and fibre 2, respectively. Table 2 depicted the list of elastic modulus of matrix and fiber, The experiment result was compared to the theoretical one as shown in Figure 8.

The elastic modulus of the hybrid composite from the experiment was laid in between the lower and upper bound of hybrid composite calculated from ROM and it was laid in between the lower and upper bound of glass fibre reinforced polyester composite. In this study, the glass fibre was randomly oriented and the bagasse in form of particle. As we known, the rule of mixture was basicly differentiate from unidirectional fibre reinforced metal matrix composite with the load parallel with the fibre. Theoritically, the elastic modulus of randomly oriented fibre composite will have lower elastic modulus than unidirectional composite loaded paralel to the fibre direction. Figure 9 shows the distribution of glass fibre and bagasse particle in polyester matrix in fracture section of hybrid composite after tensile test. Glass fibres were pulled out from the matrix. Bagasse fibre mixed with the polyester matrix.

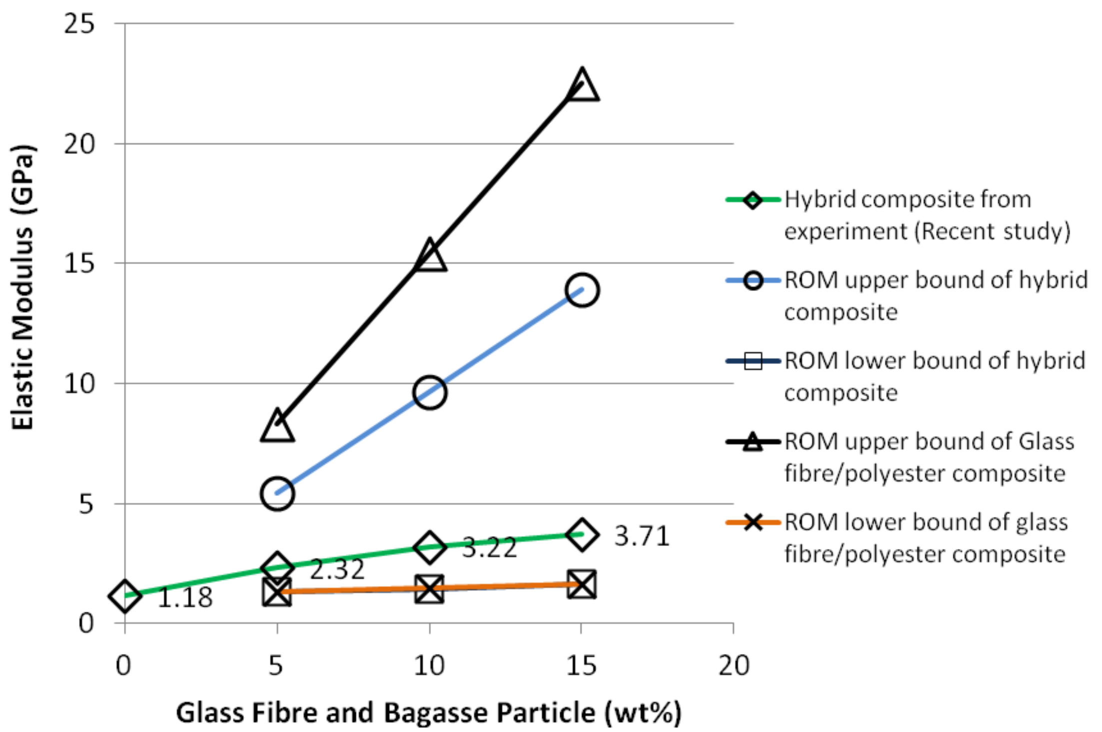
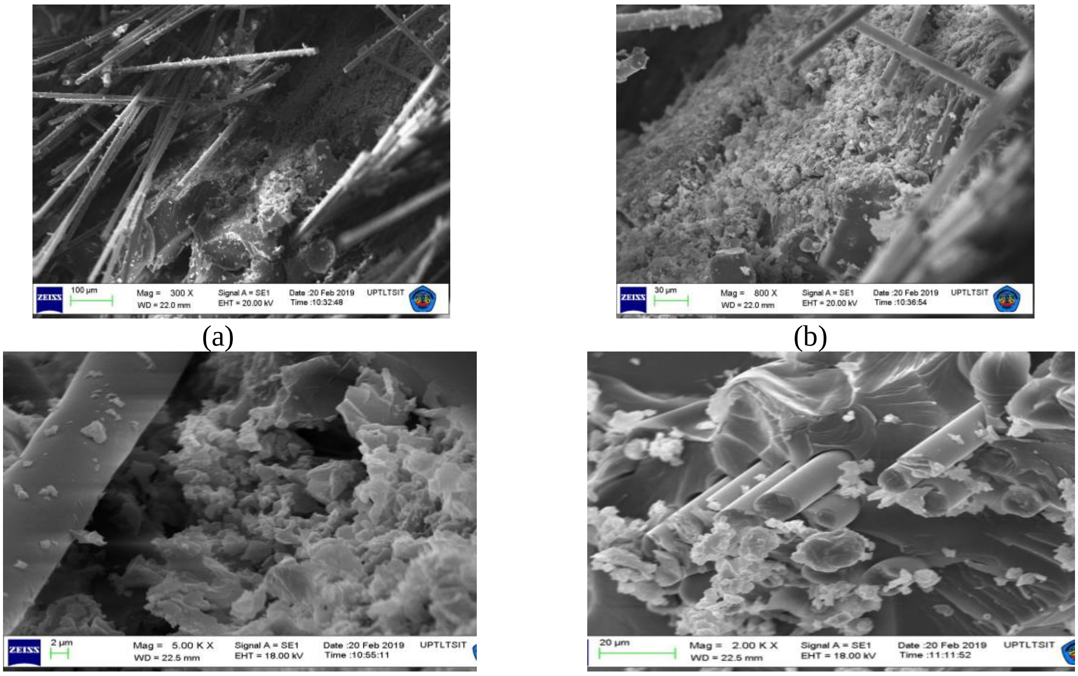


Figure 8. The comparison of elastic modulus from experiment and calculated using Rule of Mixture (ROM)

Table 2. Elastic modulus of polyester matrix and reinforcing fibres.

	Polyester (GPa)	Glass fibre (GPa)	Bagasse fibre (GPa)
E (GPa)	1.18	72.4	15



(a) (b) (c) (d)

Figure 9. Glass fibre, sugarcane particle distribution in polyester matrix and failure mechanism of sugarcane/glass/polyester hybrid composite on composite cross section after tensile: (a) fibre pull out (b) particle distribution (c) adherence of particle on fibre (d) fibre full out and particle

4. Conclusions

Glass fibre/sugarcane powder/polymer hybrid composite was made using hand lay up method. The stress strain curve shows the curve deviate between specimens outside the elastic range. It was because the damage mechanism was different between each composite. The tensile property of glass fibre/sugarcane powder/polymer hybrid composite such as tensile strength and elastic modulus increased with the addition of glass fibre and sugarcane powder. The calculation using Rule of Mixture (ROM) shows the elastic modulus of the hybrid composite in this experiment laid between lower bound and upper bound of glass fibre/ sugarcane fibre/polymer hybrid composite. The scanning electron microscope observation shows the pull-out of glass fibre as fracture mechanism and the bagasse fibre bond with the polyester matrix.

References

[1] Mishra S, Mohanty A K, Drzal LT, M Misra, S Parija, S K Nayak, S STripathy 2003 Compos. Sci. and Tech. 63 p 1377
[2] K Sabeel Ahmed and S Vijayarangan 2008 J. Mat. Process. Technol. 207 p 330
[3] Davoodi M M, Sapuan S M, Ahmad D, Ali A, Khalina A and Jonoobi M 2010 Mater. Des. 31 p 4927
[4] Kong K, Hejda M, Young R J, Eichhorn S J 2009 Compos. Sci. Technol. 69 p 2218
[5] Nunna S, Ravi C P, Shrivastava S and Jalan A K 2012 J of Reinf. Plast. Compos. 31 p 756
[6] Abdul Khalil HPS, Kang CW, Khairul A, Ramli R, Adawi T O 2009 J Reinf. Plast. Compos. 28 p 1123
[7] Wei Xiong 2017 J Thermoplast. Compos. Mat. p 1–35
[8] Vilay V, Mariatti M, Taib RM and Todo M 2008 Compos. Sci. Technol. 68 p 631
[9] Shibata S, Bozlur RM and Fukumoto I, Kanda Y 2010 Bioresources. 5 p 2097
[10] Zin M H, Razzi M F, Othman S, Liew K, Abdan K, Mazlan N 2016 Mater. Sci. Eng. 152
[11] Chen Y, Sun L, Negulescu I, Wu Q and Henderson G 2007 J Ind Cemp 12 p 27