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REVIEW ARTICLE

COMPOSITE BOARDS FROM AGRO WASTE RESIDUE OF GRASS AND BAMBOO

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ABSTRACT

Properties of grass-bamboo bio-composite (GB bio-com) boards made from a mixture of grass *Themeda arguens* and bamboo *Gigantochloa scortechinii* studied. The GB bio-com boards produced at different mixture ratios of the grass and bamboo, as well as at various resin contents. The matured plants harvested, chipped into small pieces, mixed five ratios. Urea formaldehyde (UF) resin applied at 12% and 14% forming the bio-composite boards using a hot press machine. The physical, strength, and thermal properties of the boards determined by European Standards (EN) procedures. Statistical analysis showed the ratios and resin contents influence properties of grass-bamboo boards. Boards produced from 30% grass and 100% bamboo show overall best values in basic density, thickness swollen, MOE, MOR, internal bonding and screw withdrawal. The final degradation point at the highest temperature of thermal properties at 89.4% indicating the presence of cellulose fibre affecting the thermal stability.

INTRODUCTION

Efforts to develop an eco-friendly bio-composites boards from non-wood forest resources and agriculture waste has been on for quite some time now. The development has catalyzed from the consciousness on recycling of materials, unprecedented forest degradation, and the effect of global warming (Razak *et al*., 2015; Razak *et al*., 2013). The wood composites industry has used the timbers from the forest plantation and forest industry residues for the past few decades now. The supply of these resources, however, does not seem to be sufficient to meet the increasing demand for timber. The non-wood and agricultural resources have received considerable attention as alternative raw materials for light structural composite materials (Sukhairi *et al*., 2011). The bio-composites boards manufactured from lignocellulosic materials are lighter, cheaper and biodegradable and are considered eco-environmentally friendly. The materials from the non-wood forest resources as well as the agricultural sectors are readily available in the tropical regions of the world. This paper highlighted physical, strength and thermal properties of the GB bio-com boards (short for composite boards from grass *Themeda arguens* and bamboo *Gigantochloa scortechinii*) made at FIVE (5) ratio and TWO (2) resin contents.

MATERIALS AND METHODS

The Chrismas grass *T. arguense* (L.) Hack. and bamboo *G. schortechinii* used in this study. Matured wild grass stems and bamboo culms age 3 to 4-year-old used to produce the GB bio-com boards. Materials from these species were cut, chipped and glued together using Urea Formaldehyde to create GB composite boards. The composites produced at different ratios of the two materials.

Material Preparation: Both the grass and bamboo harvested from FRIM Research Station in Hulu Kelantan, Kelantan. For ease handling, the stems of the grass segregated from the leaves cut to a one-meter length. The harvested bamboo culms processed directly upon arrival at UMK. Bamboo cut to the size of one meter. The inner and outer skins peeled off manually using machetes. The materials then air-dried to increase their durability against attacks of fungi and insects. The drying process carried out for several days while waiting for transportation to FRIM, Kepong, for a subsequent process for composite boards manufacturing. The urea formaldehyde resin used in the research obtained from a private company.

Composite Board Process: Both species chipped using a chipper drum machine and inserted into the knife ring flakes. The flakes filtered using 0.5 mm, 0.8 mm, 4.0 mm, and <0.5

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mm sieve to 0.8 mm, placed on a tray and put in an oven. Both species dried in an oven at a temperature of 105 ± 2□C for 2 - 3 days. Samples size of 4.0 mm were run through the flaking process using the knife ring flakes and filtered to obtain the required size. Once dried, they were weighed and mixed with urea formaldehyde in mixer machine. Wax and hardener added according to the calculated ratio. The material fixed in a mold and compressed with a hot press machine set at 165□C with pressures of 70 N, 90 N and 120 N and duration of 1 min., 2 min., and 3 min., respectively to produce GB bio-com boards. Tests for physical and thermal properties carried out by using standard laboratory equipment. The mechanical testing performed using a Universal Testing Machine by methods employed by Sukhairi *et al.*, (2011) and Razak *et al.*, (2012)

Physical test

***Basic Density*:** Determined using water displacement method, the initial level of the volumetric cylinder recorded for green volume. The samples put in an oven set at 105□C for 48 hours before re-weighing for oven-dry weight. Determination of the basic density conducted by EN 323 (1993a).

***Thickness swelling*:** Determined by measuring increases in thickness of the samples after immersion in water. Test on thickness swelling carried out by EN 323 (1993b). The samples cut to the square shape of a length of 50±1 mm. Conditioned in a conditioning chamber set at a relative humidity (RH) 65±5 % and temp. 20 ±2□C to attain 12% moisture content. The samples immersed in distil water with their faces cleaned. This temperature maintained throughout the testing period. The samples separated from each other. The upper edges of the pieces covered with water throughout the test. The water changed after each test.

***Water Absorption*:** Determined by measuring the weight changes in the samples after complete immersion in water. The weight of the samples measured right before the thickness of each test sample recorded for thickness swelling.

Strength Study

***Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)*:** The study for MOE and MOR carried out concerning the European Standards EN310 (1993c).

***Internal Bonding*:** The tests conducted 24 hours after glue applied to the samples to avoid rupture occurring in the glue line. The fixed assembly stored under controlled conditions of (65±5) % relative humidity and a temperature of (20±2)□C before testing. The samples tested not more than 1 hour after removal from the conditioning environment.

***Screw Withdrawal*:** The force required to withdraw a wood screw from the samples measured. The test carried out by the British Standard. A small hole 1.5 mm in diameter drilled 6 mm in the center of one face and two adjacent edges of the samples. A screw inserted into each of the holes to a depth of 13 mm upright.

Thermogravimetric Analysis (TGA)

The thermal decomposition determined by measuring the weight loss with increasing temperature under a controlled atmosphere. The technique outlines by Razak *et al.*, (2014), adopted. Small pieces of the test samples taken from the boards. 20-30 mg of grounded samples placed in the ceramic pan securely using a small metal spoon to avoid contamination. The sample heated from 25□C-500□C with nitrogen gas flow of 100 ml/min. The decomposed samples analyzed using TA Instruments Q600 software which records the percentage weight loss at specific temperatures and time.

RESULTS AND DISCUSSIONS

Physical properties

Table 1 showed the results of the basic density, thickness swelling, and water absorption in the physical studies. These properties have a significant effect on the overall properties of the GB bio-com boards.

Basic density

The GB bio-com boards made from 100% bamboo at 0:100 ratios possess high values in basic density with 0.664 g/cm³ and 0.689 g/cm³ for both resin contents at 12% and 14% respectively. Follow boards at 70:30 ratios which were 0.522 g/cm³ and 0.633 g/cm³, boards made from 100% grass at 100:0 ratios which were 0.603 g/cm³ and 0.633 g/cm³, and boards at 50:50 ratios were 0.577 g/cm³ and 0.609 g/cm³ and for both 12% and 14% resin contents. Boards at 30:70 ratios have value at 0.609 g/cm³ and 0.638 g/cm³ for both 12% and 14% resin contents respectively. For resin contents, boards made of 14% resin content show higher values than boards with 12% resin contents. The basic density increases with increasing in resin content. The basic density significantly affected by moisture content.

Table 1. Basic density, thickness swelling and water absorption of GB bio-com boards

	Basic density		Thickness swelling (%)		Water absorption	
Ratios grass to bamboo	Resin Content		Resin Content		Resin Content	
	12 %	14 %	12 %	14 %	12 %	14 %
100:0	0.603	0.633	18.8	15.8	72.5	65.0
70:30	0.522	0.564	21.6	17.9	83.9	75.3
50:50	0.577	0.609	26.4	21.2	77.8	69.9
30:70	0.609	0.638	19.6	16.9	75.4	67.6
0:100	0.664	0.689	22.9	18.7	78.8	73.9

Thickness Swelling

The GB bio-com boards made 100% grass has low values in thickness swelling at 18.8% and 15.8% respectively for both 12% and 14% resin contents. Boards at 70:30 ratios have values at 21.6% and 17.9%, boards at 50:50 ratios have values at 26.4% and 21.2%, and boards at 100% bamboo at 22.9% and 18.7% for resin contents of 12% and 14%. The boards of grass-bamboo at 30:70 ratios showed uptakes of moisture in thickness swelling at 19.6% and 16.9% at 12% and 14% resin contents. The boards with 14% resin show lower values than boards of 12% resin. The thickness swelling decreased with increases of resin contents. Boards made from 100% grass at 14% resin contents is the only boards that met the optimum requirement of thickness swelling (16.0%) for general uses (EN Standard 317, 1993b). Thickness and swelling of the boards are proportional to the water absorbed. When the water absorption increased, the thickness and swelling also increase due to the swelling of the fibres present inside the boards. When the composite boards exposed to moisture, the hydrophilic of the grass and bamboo swells makes the thickness and swelling increase. The highly porous structure of the GB bio-com boards allows absorption of more water that causes the boards to swell and rise in thickness swelling.

Water Absorption

The GB bio-com boards from 100% grass absorbed less amount of water at 72.5% and 65.0% respectively for 12% and 14% resin content. Followed by boards of 70:30 ratios (grass to bamboo) at 83.9% and 75.3%, boards at 50:50 ratios at 77.8% and 69.9%, and finally boards of 100% bamboo at 78.8% and 73.9% for both 12% and 14% resin. The boards at 30:70 ratios absorbed an amount of water at 75.4% and 67.6% respectively for 12% and 14% resin contents. The boards with 14% resin content absorbed less water compared to the boards of 12%. The absorption attributed to the penetrability of water and capillary action, which becomes active as water penetrates in the interface via void-induced by swelling of fibres (Mazuki *et al*., 2011; Mohd Tamizi *et al*., 2011). Water absorption is a condition when the fibre swells due to the absorption of moisture and water. The water absorption characteristic is dependent on the fibre content, fibre orientation, temperature, area of the exposed surface, the permeability of fibre, and void content (Dhakal *et al*., 2007). The parenchyma present in bamboo behaves like a sponge and can quickly absorb moisture (Paridah and Anis, 2008). The larger the fibres size, the higher the water absorption. The effect of fibres length on water uptake is dependent on the fibre content. The bast fibre present in grass composites absorbs water in the fibres and matrix. It causes water to exist in the voids of the composite. The present of grass reduces water absorption.

Strength properties

Strength properties are essential characteristics of the material to counter externally applied forces (Razak *et al*., 2012; Winandy, 1994). The strength properties reflect the force and resistance to deforming of the material. The most common strength properties reported, are the MOE and MOR. MOE measures the stiffness or rigidity of material while the MOR measures the resistance of the material to breakage. Table 2 shows the modulus of Elasticity (MOE), modulus of rupture and internal bonding of the tested GB bio-composite boards.

Modulus of Elasticity (MOE)

Boards of 100% bamboo possess high values of MOE at 2857.4 N/mm^2 and 2873.5 N/mm^2 for both 12% and 14% resin contents respectively. Follow by, boards at 30:70 ratios (grass to bamboo) which were 2777.0 N/mm^2 and 2803.3 N/mm^2, boards of 100% grass possess 2738.0 N/mm^2 and 2783.4 N/mm^2, and boards at 50:50 ratios were 2691.5 N/mm^2 and 2726.7 N/mm^2 for both 12% and 14% resin contents respectively. Boards made at 70:30 ratios show lowest values at 2596.4 N/mm^{2}and 2630.9 N/mm^2 for both 12% and 14% resin contents respectively. For resin contents, boards made with 14% resin content show higher values than boards made of 12% resin contents. The MOE increases with the increases in resin content. Boards made from both 12% and 14% resin contents met the minimum requirement of MOE for general application type of boards according to European Standard EN 310 (1993c), and all the values were higher than the rubberwood MOE (Sukhairi *et al*., 2011). MOE is the quantity material's elasticity that is recoverable resistance to deformation under load. MOE is a material property, and stiffness depending on both the material and the size of the beam. Large and small beams of similar material would have similar MOE's but different stiffness. The MOE calculated from the stress-strain curve of the change in stress causing a corresponding change in strain. The addition of resin into the board increases the MOE but makes the board more brittle (James *et al*., 1999; Razak *et al*., 2012).

Modulus of Rupture (MOR)

MOR of GB bio-com boards of 100% bamboo possesses high values at 16.9 N/mm^2 and 17.5 N/mm^2 for both 12% and 14% resin contents respectively. Follow by boards at 30:70 ratios which are 16.3 N/mm^2 and 16.9 N/mm^2, boards of 100% grass were 16.3 N/mm^2 and 16.5 N/mm^2, and the boards at 50:50 ratios at 15.6 N/mm^2 and 15.7 N/mm^2 respectively for the 12% and 14% resin contents. Boards at 70:30 ratios possess low values at 13.9 N/mm^2 and 14.8 N/mm^2 for both 12% and 14% resin contents. The boards made of 14% resin content show higher MOR values than the boards of 12% resin. The MOR increases with the increases in resin content. Boards at all ratios manufactured from both 12% and 14% resin contents meet the minimum requirement of MOR (14.0 N/mm^2) according to European Standard EN 310 (1993c). The MOR values of boards with resin contents of 12% and 14% were lower than MOR value of rubberwood (22.8 N/mm^2). The MOR is the ability of a specimen to withstand a transverse (bending) force perpendicular to its longitudinal axis, MOR results of the composite boards at higher resin contents can withstand such force. The quantity of adhesive used plays a major role in improving the MOR value of the composites board. Adhesive can effectively transfer and distribute stresses, thereby increasing the strength and stiffness of the composite board. Urea formaldehyde has higher solids content. Thus, it found that the penetration of high viscosity urea formaldehyde resin probably would break the cell walls of the compressed composite boards (Razak *et al*., 2005; Abdullah, 2010). This action makes it difficult for the fibre and matrix to withstand greater loads. It can assume that the urea-formaldehyde resin enhanced the strength of MOR of the composites board.

Internal Bonding

Internal bonding of GB bio-com boards made from 100% bamboo shows highest values at 0.623 N/mm^2 and 0.688 N/mm^2 for both 12% and 14% resin contents respectively. Follow by, boards made from grass and bamboo at 30:70 ratios which are 0.501 N/mm^2 and 0.534 N/mm^2, boards made from 100% grass 0.474 N/mm^2 and 0.526 N/mm^2, and boards at 50:50 ratios at 0.437 N/mm^2 and 0.478 N/mm^2 for both 12% and 14% resin contents respectively. Boards at 70:30 ratios show lowest values at 0.391 N/mm^{2}and 0.434 N/mm^2 for both 12% and 14% resin contents respectively. Boards made of

14% resin content show higher values than boards made of 12% resin contents. The internal bonding increased with the increased of resin content. Boards at all ratios with 12% and 14% resin contents met the minimum requirement of internal bonding for general according to European Standard EN 310 (1993c) except the GB bio-com boards at 70:30 ratios which were 0.391 N/mm2 at 12% resin. The internal bonding strength of the GB bio-com boards with both 12% and 14% resin contents are lower than internal bonding value of rubberwood (1.300 N/mm^2). Internal Bonding (IB) test conducted to determine the interfacial bonding strength between fibres in the boards.

Table 2. Modulus of elasticity, modulus of rupture and internal bonding of GB bio-com boards

	Modulus of Elasticity (MOE) (N/mm^2)		Modulus of Rupture (MOR) (N/mm^2)		Internal Bonding (N/mm^2)	
Ratios grass to bamboo	Resin Content		Resin Content		Resin Content	
	12 %	14 %	12 %	14 %	12 %	14 %
100:0	2738.0	2783.4	16.3	16.5	0.474	0.526
70:30	2596.4	2630.9	13.9	14.8	0.391	0.434
50:50	2691.5	2726.7	15.6	15.7	0.437	0.478
30:70	2777.0	2803.3	16.3	16.9	0.501	0.534
0:100	2857.4	2873.5	16.9	17.5	0.623	0.688

The result indicates that high amount of resin used produced stronger interfacial bonding between fibres in the boards hence prolong the ability for boards to withstand pulling force created. The lower value of internal bonding expected due to the surface chemical properties of fibrillar in extractives and lignin that influences the absorption, adhesion and strength properties and interrupt the bonding properties of the sample (Kangas and Kleen, 2004; Zaidon *et al*., 2004; Razak *et al*., 2010). Weak bonding occurred when the fibre cut into small particles cannot be splitted further and maintain a tubular shape, which prevents resin from reaching internal surfaces of the fibres (Hammer *et al*., 2001). Most of the failures came from the boards which have grass fibre located.

Screw withdrawal

A screw inserted into each of the holes at the center of one face and two adjacent edges of the test samples to a depth of 13 mm. The test is designed to evaluate the screw holding strength of the board. Higher particle loading strengthens of the boards as well as increases their densities helps the board to hold screw better. Table 3 showed the results for both edge Screw withdrawal (tangential direction), edge screw withdrawal (radial direction) and face screw withdrawal.

Edge Screw Withdrawal (Tangential direction)

The edge screw withdrawal in the tangential direction of boards made from 100% bamboo shows highest values at 570.7 N/mm^2 and 609.8 N/mm^2 for both 12% and 14% resin contents respectively. Follow by, boards made from 100% grass at 460.6 N/mm^2 and 518.4 N/mm^2, boards at 70:30 ratios which are 417.9 N/mm^2 and 486.2 N/mm^2, and boards at 50:50 ratio which were 358.0 N/mm^2 and 406.4 N/mm^2 for both 12% and 14% resin contents respectively. Boards at 30:70 ratios show lowest values which were 345.6 N/mm^2 and 376.5 N/mm^2 for both 12% and 14% resin contents respectively. At all ratios of boards with 14% resin content show high values than boards with 12% resin. The result of the edge screw withdrawal at tangential direction increases with the increases of resin. Boards at 50:50 ratios possess values at 358.0 N/mm^2 and boards at 30:70 ratios at 345.6 N/mm^2. Both boards at 12% resin contents did not meet the minimum requirement of edge screw withdrawal according to British Standard 5669 (1989), while the others exceed the minimum requirement.

Edge Screw Withdrawal (Radial direction)

Edge screw withdrawal of boards in radial direction made from 100% bamboo shows highest values at 561.8 N/mm^2 and 628.6 N/mm^2 for both 12% and 14% resin contents. Boards of 100% grass have values at 471.9N/mm^2 and 551.1 N/mm^2, boards at 70:30 ratios 449.6 N/mm^2 and 532.8 N/mm^2, and boards made at 30:70 ratios which were 366.0 N/mm2 and 403.0 N/mm2 for both 12% and 14% resin contents respectively. Boards at 50:50 ratios show lowest values at 337.2 N/mm^2 and 384.6 N/mm2 for both 12% and 14% resin contents respectively. At all ratios of the boards with 14% resin content show high values than boards with 12% resin. The result indicates that the edge screw withdrawal at radial direction increases with the increases of resin content. All boards at 12% and 14% resin contents excluding boards made at 50:50 ratios at 337.2 N/mm^2 at 12% resin contents surpass the minimum requirement of edge screw withdrawal (360.0 N/mm^2) for general uses type of boards according to British Standard BS 5669 (1989).

Face Screw Withdrawal

Face screw withdrawal of particleboard made from 100% bamboo shows highest values which are 596.0 N/mm^2 and 683.9 N/mm^2 for both 12% and 14% resin contents respectively. Boards made from 100% grass have values of 582.8 N/mm^2 and 643.4 N/mm^2, GB bio-com boards at 70:30 ratios 510.5 N/mm^{2}and 589.2 N/mm^2, and particleboard made from grass and bamboo at 30:70 ratios which are 462.3 N/mm^2 and 531.2 N/mm^2 for both 12% and 14% resin contents respectively. Bio-boards made from grass and bamboo at 50:50 ratios show lowest values which are 442.0 N/mm^2 and 499.9 N/mm^2 for both 12% and 14% resin contents. The boards made of 14% resin content show higher values than boards made of 12% resin contents. The result indicates that the face screw withdrawal increased with the increasing of resin content.

Statistical Analysis

Table 4 showed the ANOVA of the physical and strength properties at different ratios between grass and bamboo. All physical properties showed significant differences with ratios where basic density and thickness swelling have high significant differences at p-value ≤ 0.01 and water absorption at p-value ≤ 0.05. In the mechanical properties, MOE has the significant differences at p-value ≤ 0.05, MOR, and internal bonding have the highly significant differences at p-value ≤0.01, and screw withdrawal has no significant differences. It means that the differences of ratios were affected and influenced the result of physical and strength properties value of this composite excluding screw withdrawal properties.

Table 3. Edge screw and face screw withdrawal of the GB bio-com boards

	Edge screw withdrawal (tangential direction)		Edge screw withdrawal (radial direction)		Face screw withdrawal (N/mm^2)	
Ratios grass to bamboo	Resin Content		Resin Content		Resin Content	
	12 %	14 %	12 %	14 %	12 %	14 %
100:0	460.6	518.4	471.9	551.1	582.8	643.4
70:30	417.9	486.2	449.6	532.8	510.5	589.2
50:50	358.0	406.4	337.2	384.6	442.0	499.9
30:70	345.6	376.5	366.0	403.0	462.3	531.2
0:100	570.7	609.8	561.8	628.6	596.0	683.9

Table 4. ANOVA of physical and mechanical properties of GB bio-com boards

Source of Variance	Dependent	df	Sum of square	Mean square	Pr (F)
Ratio	BD	1	0.051	0.051	0.0000**
	TS	1	158.875	158.875	0.0000**
	WA	1	142.662	142.662	0.0141*
	MOE	1	178834.000	178834.300	0.0271*
	MOR	1	18.615	18.615	0.0091**
	IB	1	0.207	0.207	0.0001**
	SWA	1	235.100	235.060	0.8707ns
	SWB	1	3113.000	3113.050	0.5790ns
	SWC	1	625.600	625.630	0.7811ns
Resin Content	BD	1	0.010	0.010	0.0621ns
	TS	1	174.268	174.268	0.0000**
	WA	1	527.589	527.589	0.0000**
	MOE	1	14910.000	14909.800	0.5149ns
	MOR	1	3.388	3.388	0.2540ns
	IB	1	0.033	0.033	0.0972ns
	SWA	1	92327.800	92327.810	0.0020**
	SWB	1	77918.500	77918.480	0.0072**
	SWC	1	68945.800	68945.820	0.0049**

Table 5. Correlation Coefficient on Physical, Mechanical Properties of GB bio-com boards

	RC	RTO	BD	TS	WA	MOE	MOR	IB	SWA	SWB	SWC
RC	1.0000	0.0000**	0.2138ns	-0.4995**	-0.5194**	0.0831ns	0.1424ns	0.1923ns	0.3940ns	0.3475ns	0.3640ns
RTO		1.0000	0.4889ns	0.4770ns	0.2701ns	0.2878ns	0.3338ns	0.4846ns	-0.0199**	-0.0695**	-0.0347**
BD			1.0000	0.1218ns	-0.0109**	0.3163ns	0.5421ns	0.5355ns	0.2701ns	0.3106ns	0.2825ns
TS				1.0000	0.6691ns	0.1028ns	0.0969ns	-0.0288**	-0.4870**	-0.5616**	-.04870**
WA					1.0000	0.1509ns	0.0767ns	-0.0399**	-0.5524**	-0.5716**	-0.6033**
MOE						1.0000	0.5902ns	0.4418ns	0.2250ns	0.123ns	0.0911ns
MOR							1.0000	0.5659ns	0.3196ns	0.1979ns	0.1484ns
IB								1.0000	0.2997ns	0.2984ns	0.2913ns
SWA									1.0000	0.7930ns	0.7500ns
SWB										1.0000	0.7438ns
SWC											1.0000

Note : Total number of samples for each testing = 60, **= significant at $p \leq 0.01$,
WA= Water Absorption,= significant at $p \leq 0.05$, MOE= Modulus of Elasticity, ns= not significant, MOR= Modulus of Rupture, RC= Resin Content, IB= Internal bonding, RTO= ratio, SWA= Edge screw withdrawal (tangential direction), BD = Basic Density, SWB= Edge screw withdrawal (radial direction), TS= Thickness and Swelling, SWC= Face screw withdrawal.*

The correlation among physical and strength properties of particleboard made from grass and bamboo showed in Table 5. The physical properties show a positive correlation with difference ratios. Negative correlations observed between resin contents with both thickness swelling and water absorption. These negative correlations supported by significant differences in the analysis of variance (ANOVA) displayed in Table 4. It can suggest that resin contents had the inverse effect on thickness swelling and water absorptions. Basic density shows a positive correlation with difference resin contents. For strength properties of boards made from grass and bamboo, there was a correlation with different ratios and difference resin content. All mechanical properties show a positive correlation with difference ratios except screw withdrawal. Negative correlations occur between difference ratios with screw withdrawal which are SWA, SWB, and SWC respectively. All strength properties show a positive correlation with difference resin contents.

Thermo-gravimetric Analysis (TGA)

Table 6 show the weight loss with a temperature experienced by the GB bio-com boards, and UF resin sample of the bio-com boards at ratio 30:70 (grass to bamboo). Figure 1 shows TGA graph of particleboard made from grass and bamboo. The decomposition of the GB bio-com boards begun at 100°C (first peak). The decomposition continued to the second peak at 210°C and completed at the third peak (402°C). The degradation of UF resin initiated at 100ºC (first peak), continues at 168°C (second peak) and completed at third peak (389°C). Both boards and UF resin loss most of their weight at the third peak which is 66.18 % and 58.48 % respectively.

Table 6. Weight loss in TGA with a temperature of GB bio-com boards and UF resin

		1st peak	2nd peak	3rd peak
Boards from	Temperature	99.93°C	210.08°C	401.91°C
grass and bamboo	Weight loss	8.182%	10.63%	66.18%
with UF Resins	Temperature	99.93°C	168.45°C	389.26°C
	Weight loss	8.433%	9.389%	58.48%

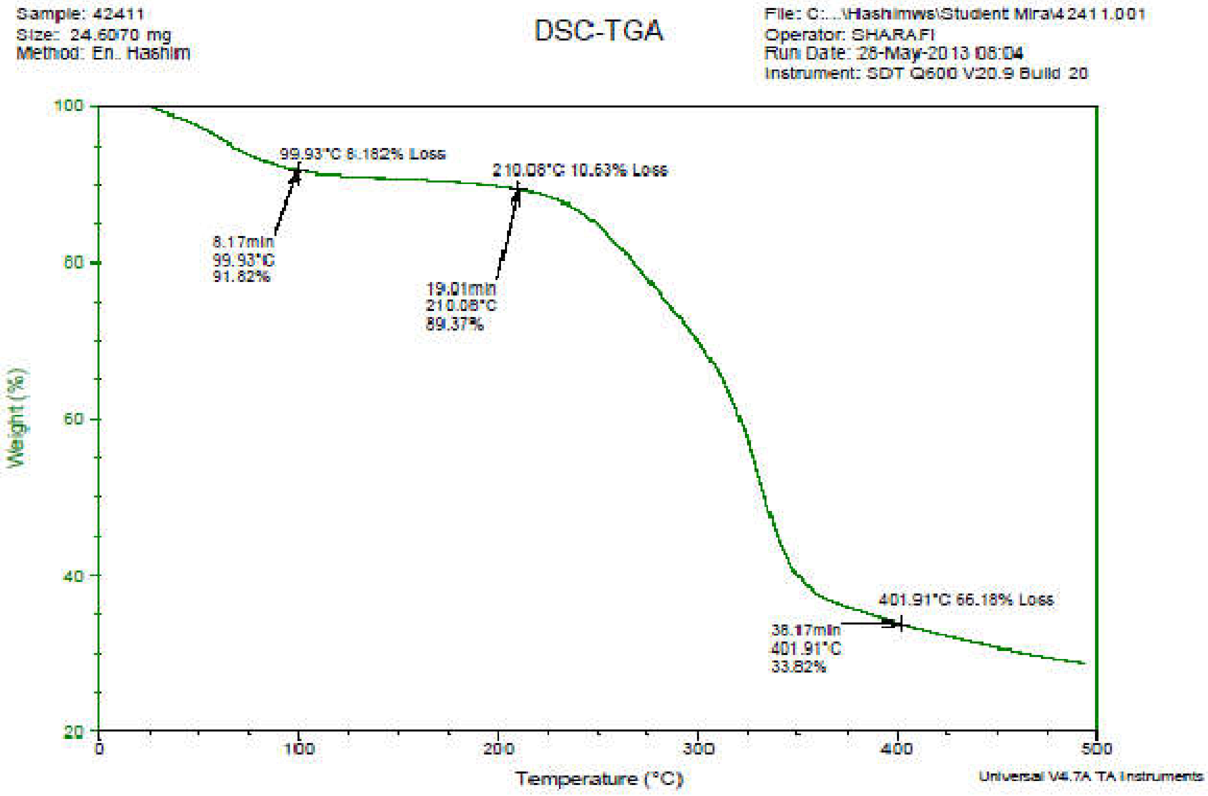

Figure 1. TGA graph of GB bio-com boards at ratio 30:70 *T. Arguens* and *G. scortechinii*

The final decomposition of boards is higher that the UF resin which indicates that the presence of cellulose fibre from particleboard had a significant effect on thermal stability of the composites. The weight loss occurs at a temperature 210°C. The degradation occurred at 89.37%. This probably due to dehydration of the samples mainly the hemicelluloses (Ndazi *et al.*, 2007). The first stage of degradation caused the evaporation of water and depolymerisation of molecules structure from the samples (Xiao *et al.*, 2001; Zorba *et al.*, 2008). The process continued by cleaves of linkage that occurred in the boards and UF resin. The lignocellulosic material decomposed thermochemically between 150°C and 500°C, hemicellulose between 150°C and 350°C, cellulose between 275°C, and 350°C and lignin between 250°C and 500°C (Kim *et al.*, 2004). Thermal degradation of samples occurred at the second peak. The hemicellulose and Lignin degraded earlier due to their molecular structure that less rigid (amorphous that cellulose) compared to cellulose (Rosnah *et al.*, 2006; Abdullah & Bridgewater, 2006). Finally, upon introduction of oxygen at the third peak, combustion occurred, and the final weight loss infers the amount of carbon in the boards. The carbon contents of the bio-com boards and UF resin are 66.18% and 58.48% respectively. Changes in mass usually occur during sublimation evaporation, decomposition and chemical reaction, and magnetic or electrical transformation of the material, which is directly related to thermal stability (Abdullah & Bridgewater, 2006).

Conclusions

In conclusion, the grass bamboo at 30:70 ratio possesses an overall desired properties in term of the physical, strength and thermal properties for bio-composites boards manufacturing. This composites could utilize as an alternative to wood in the furniture and light construction works.

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