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Properties of Bio-Composites Boards from *Gigantochloa Scortechinii* and *Themeda Arguens* (L.) Hack at Different Ratios and Resin Contents.

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ABSTRACT

Properties of composites boards from *Gigantochloa scortechinii* and *Themeda arguens* at different ratios and resin contents investigated. The two plants harvested at matured age and subsequently chipped into small sizes and mixed at five different ratios using 12% and 14% Urea formaldehyde (UF) resin into composite boards under a hot press machine. Hardener and wax with 3% and 1% respective weight added during the mixing process. The physical (basic density, thickness swelling and water absorption), mechanical (MOE, MOR, internal bonding and screw withdrawal), and thermal properties, were determined. All testing procedures were done by European Standards (EN). The result indicates that ratios and resin contents influence the properties of particleboard. Particleboard made from 100% *G. gigantochloa,* and 70% *T. arguens* show highest values in basic density, MOE, MOR, internal bonding and screw withdrawal. The value of final degradation point at the highest temperature of thermal properties for boards made from *G. Scortechinii* and *T. Arguens* were about 89.4% indicates that the presence of cellulose fibre from boards had a significant effect on thermal stability of the composites.

Keywords: Bio-composite boards, *Gigantochloa Scortechinii, Themeda Arguens,* physical properties, mechanical properties, thermal properties.

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INTRODUCTION

The demand for timber for human development has causes exploitation of virgin forests and clearing up of forest areas especially in the tropical region. Increased in consciousness particularly on recycling of traditional materials, unprecedented forest resource degeneration, and global warming has led to worldwide efforts to develop bio-composites from non-wood resources [1]. The wood composite industry has used forest plantation and mill residues in the past few decades as material for their production. Strict harvest regulation and pressure from environmental policy have resulted in a decline in the supply of high-quality timber and increases in costs. The non-wood and agricultural materials have received considerable attention as alternative raw materials for structural composite materials [2], [3]. Bio-composites made from lignocellulosic materials such are lighter, inexpensive and biodegradable, thus are considered eco-environmentally friendly [4]. These materials are readily available from the non-wood based resources and agricultural residues. This paper highlighted finding of the GT composite boards (short for composite boards from *Gigantochloa scortechinii* and *Themeda arguens*) made from a mixture of *G. scortechinii)* and *T. arguens* at a different ratio. The objectives of the study focussed on the physical, mechanical and thermal properties of the boards. The thermogravimetric analysis used in the thermal analysis of the boards.

MATERIALS AND METHODS

Two types of plants species used in this research were bamboo *Gigantochloa schortechinii* and a Chrismas grass *Themeda arguense (L.) Hack. Gigantochloa scortechinii* of age 3 to 4 years old and matured wild grass were used to produce the composite board. Materials from these species were cut, chipped into smaller pieces and bonded together using Urea Formaldehyde to produce GT composite boards. The composites produced by varying the ratio composition of the two materials.

Material Preparatio

Gigantochloa scortechinii and *Themeda arguense* harvested from FRIM Research Station in Batu Melintang, Jeli, Kelantan. The harvested bamboo culms *Gigantochloa scortechinii* were processed directly upon arrival at the wood workshop in UMK. Bamboo cut to the size of one meter, and then the inner and outer skins were peeled off manually using machetes. The stems of the Christmas grasses segregated from the leaves cut to a one-meter length for easy handling. The materials then undergo an air dried process to enhance their durability against fungi and insects attacks. The drying process was carried out for several days while waiting for transportation to FRIM, Kepong, for a subsequent process for composite boards manufacturing. Urea formaldehyde used in the research obtained from the company Dynea Malaysia Sdn. Bhd. in Seremban, Negeri Sembilan.

Composite Board Process

Both species were chipped using a chipper drum machine. After the samples have become a chip, the samples were inserted into the knife ring flakes. The flakes were filtered using 4.00mm, 0.8mm, 0.5mm and <0.5mm sieve to 0.8mm. Once filtered, the samples placed on a tray and inserted into an oven. Both species were dried in an oven at a temperature of 105 ± 2^{o}C for 2 to 3 days. Samples size of 4.0mm were run through the flaking process again using the knife ring flakes and were filtered again to obtain the required size of samples. After the drying process, the two species were weighed and mixed in mixer machine with urea formaldehyde, wax and hardener according to the calculated ratio which has been pre-calculated. The mixing material fixed in the mold and compress with a cold press machine. The compressing process occurred for a few minutes at a strain of 20kg/m^3. The halfway boards put in hot press machine at 165^{o}C with pressures of 120, 90 and 70 MPa and timing of 3 minutes, 2 minutes and 1 minute respectively to produce GT composite boards. Tests for physical and thermal properties were carried out by using laboratory equipment standard, while, testing of mechanical characteristics were performed using Instron Universal Testing Machine. All testing conducted at FRIM, Kepong using methods employed by Rasat *et al*., [3] and Wahab *et al*., [5].

Physical test

Basic Density

Determination of the basic density was done in accordance EN 323: 1993 [6]. By using water displacement method, the initial level of the volumetric cylinder recorded for green volume. The samples then placed in an oven set at 105^{o}C for 48hrs. before re-weighing for oven-dry weight.

Thickness swelling

The swelling in thickness determined by measuring the increased in thickness of the test samples after complete immersion in water. Test of thickness swelling was carried out concerning the European Norm (EN 317: 1993 [7]. The test pieces were cut to the square of the length 50 ± 1 mm. The test piece then conditioned at a relative humidity of (65±5)% and a temperature of (20±2)^{o}C to attain 12% moisture content. The thickness of each test piece measured to an accuracy of ±0.1 mm at the intersection of the diagonals in accordance to EN 317-1993 [7]. The test pieces immersed with their faces vertical in clean, still water, having a pH of 7±1 and a temperature of (20±1)^{o}C. This temperature maintained throughout the test period. The test pieces separated from each other and the bottom and the side of the water bath. The upper edges of the pieces were covered by (25±5) mm of water throughout the test. The water changed after each test.

Water Absorption

Water absorption determined by measuring the increase in weight of the test piece after complete immersion in water. This test is conducted for the collection of the data to observe how much water is absorbed by the composite boards produced. The weight of each test piece measured right before the thickness of each test piece measured for thickness swelling data. This test was carried out together with the test of water absorption.

Mechanical Test

Modulus of elasticity (MOE) and Modulus Of Rupture (MOR)

The modulus of elasticity in bending determined by applying a load to the centre of the test samples supported at two points. The modulus of elasticity calculated using the slope of the linear region of the load-deflection curve; the value calculated is the apparent modulus, not the right modulus because the test method includes shear as well as bending. The bending strength of test piece calculated by determining the ratio of the bending moment M, at the maximum load F max, to the time of its full cross section. Test of MOE and MOR was carried out concerning the European Norm (EN 310 [8]).

Internal Bonding

The trial start when the glue has had sufficient time to cure so that the rupture does not occur in the glue line, and until the test pieces have regained an equal distribution of moisture. By experience, approximately 24 hours are sufficient if hot-melt or epoxy glues used, and almost 72 hrs., if other adhesives used. During this time, the glued assembly was stored under controlled conditions of (65 ± 5) % relative humidity and a temperature of (20 ± 2) ^{o}C. The test pieces were tested not more than 1 hour after removal from the conditioning environment. Conditioning is not applicable to test parts or glued assemblies subjected to a cyclic test in humid conditions or an immersion-in-water test and tested in the wet stage.

Screw Withdrawal

The force required to withdraw a wood screw from the test specimen is measured. Test of screw withdrawal was carried out concerning the British Standard [9]. The test pieces were square with a side length of (50 ± 1) mm.A 1.5 mm diameter hole drilled to a depth of 6 mm in the center of one face and two adjacent edges of the test samples. A screw was inserted into each of the holes to a depth of 13 mm, ensuring that it is upright.

Thermogravimetric Analysis (TGA) Test

Thermal decomposition determined by measuring the weight loss with increasing temperature under a controlled atmosphere. Test of TGA was carried out using TA Instruments DSC SDT Q600 V20.9 Build 20 - Thermogravimetric Analyzer (TGA), and Differential Scanning Calorimeter (DSC). Technique outlines by Wahab *et al*.,[10] was adopted. Small pieces of the samples taken from the boards. The pieces were grinded using a Wiley mill. Approximately 20-30 mg of ground samples were placed in the ceramic pan securely using a small metal spoon to avoid contamination. The sample heated from 25ºC to 500ºC with nitrogen gas flow of 100 ml/min. The heating rate controlled at 10ºC/min. The decomposition of the samples analyzed by using TA Instruments Q600 software. The continuous records of percentage weight loss at specific temperatures and time obtained. The result shown in a form of graft from TA Instrument computer.

RESULT AND DISCUSSION

Physical properties of GT composite boards

Several physical properties of boards made from *Gigantochloa scortechinii* (bamboo) and *Themeda arguens* (L.) Hack (Christmas grass) investigated in this study. The properties were basic density, thickness swelling, and water absorption. The results of the basic density, thickness swelling, and water absorption shown in Table 1.

Basic density

The basic density of GT composite boards made from 100% *G. scortechinii* at 0:100 ratios show highest values which were 0.689 g/cm³ and 0.664 g/cm³ for both 14% and 12% resin contents respectively. Follow by GT composite boards at 30:70 ratios which were 0.638 g/cm³ and 0.609 g/cm³, GT composite boards made from 100% *T. arguens* at 100:0 ratios which were 0.633 g/cm³ and 0.603 g/cm³, and boards at 50:50 ratios were 0.609 g/cm³ and 0.577 g/cm³ for both 14% and 12% resin contents respectively. Boards at 70:30 ratios show lowest values which were 0.564 g/cm³ and 0.522 g/cm³ for both 14% and 12% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show higher values than boards with 12% resin contents. The basic density increases with the increasing of the resin contents. Basic density is important as it affects every aspect of the quality and quantity of the test samples [11], [12]. The wood density value is significantly affected by moisture content. The oven-dry density of test samples, with its uniqueness of determination, is used to compare results because of the influential. This value expresses the amount of wood mass in a volume of wood with certain moisture [13]. Basic density is important in estimating the variability in the strength of a wood product [14], [15].

Thickness Swelling

Thickness swelling of boards made from 100% *T.arguens* at 100:0 ratios show lowest values which are 18.8% and 15.8% for both 12% and 14% resin contents respectively. Boards at 70:30 ratios have values of19.6% and 16.9%, boards at 50:50 ratios having values at 21.6% and 17.9%, and boards at 0:100 ratios 22.9% and 18.7% for both 12% and 14% resin contents respectively. The boards at 30:70 ratios show the highest values of thickness swelling which were 26.4% and 21.2% for both 12% and 14% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show lower values than particleboard made of 12% resin contents. The thickness swelling decreased with the increasing of the resin contents. Boards made from 100% *T. arguens* at 100:0 ratios which are 15.8% at 14% resin contents is the only boards that meet the minimum requirement of thickness swelling (16.0%) for general uses type of board according to EN Standard 317 [7]. The thickness swelling measured by calculating the difference between the thicknesses of the sample before and after soaked in the water for 24 hrs. Thickness and swelling of the particleboard are proportional to water absorption. When the water absorption is high, the thickness and swelling will also occur greater due to the swelling of the fibre inside the particleboard manufactured. Thickness swelling generally will occur due to the swelling of the fibres itself when soaking in the water for 24 hours. When the composite exposed to the moisture, the hydrophilic of *G. scortechinii* and *T. arguens* swells makes the thickness and swelling increase. The highly porous structure of the GT composite boards allows high water absorption which causes the board to swell and subsequently causes the rise in thickness swelling.

Water Absorption

Water absorption of GT composite boards made from 100% grass at 100:0 ratios shows the lowest values which were 72.5% and 65.0% for both 12% and 14% resin contents respectively. Follow by boards at 70:30 ratios which were 75.4% and 67.6%, boards at 50:50 ratios 77.8% and 69.9%, and finally boards at 0:100 ratios 78.8% and 73.9% for both 12% and 14% resin contents respectively. Boards at 30:70 ratios show the highest values which were 83.9% and 75.3% for both 12% and 14% resin contents respectively. For resin contents, all ratios of particleboard made of 14% resin content show lower values than particleboard made of 12% resin contents. The result shows that the water absorption decreased with the increasing of resin content. This occured because of the chemical components in the resin that is capable of cross-linking with the hydroxyl group of *T. arguens* and *G. scortechinii* fibres. Hence, reducing the hygroscopic expansion affected by various factors such as the monomer, the polymerization rates, the cross-linking and pore sizes of the fibres and bond strength.

Water absorption in composite boards is a serious concern, especially for their potential indoor and outdoor applications. Composite boards at 30:70 ratios absorb more water in the short run than 100% *T. arguens*. The increasing of water absorption in the composite of 30:70 ratios showed the rapid moisture penetration into the composite materials. The pattern 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 [16]. Water absorption is a condition when the fibre swells due to the absorption of moisture and water. Water absorption experiments conducted because cause changes in the shape, debonding, or loss of strength in products regularly exposed to moisture [17]. For a given boards, the water absorption characteristic depends on the content of the fibre, fibre orientation, temperature, area of the exposed surface, and permeability of fibre, void content, and the hydrophilicity of the individual components [18]. Paridah and Anis [19] reported that parenchyma behaves like a sponge and can quickly absorb moisture. The larger the particles or fibres size, the higher the water absorption, thus, the effect of fibres length on water uptake is dependent on fibre content. An increasing in moisture makes the ability fibre for absorbing or desorbed moisture should consider when evaluating the suitability of fibre for various applications [20]. Bast fibre composites absorb water in the fibres and matrix. It makes water exists in the voids of the composite.

Mechanical properties of boards

Mechanical properties are the characteristics of a material in response to externally applied forces [21], [22]. Mechanical properties reflect the strength and resistance of deformation of the material. The most common mechanical properties reported, are the modulus of elasticity (MOE) and modulus of rupture (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 GT composite boards.

Modulus of Elasticity (MOE)

Modulus of Elasticity (MOE) of boards made from 100% bamboo at 0:100 ratios show highest values which are 2873.5 N/mm^2 and 2857.4 N/mm^2 for both 14% and 12% resin contents respectively. Follow by, boards at 30:70 ratios (*T. arguens* and *G. scortechinii*) which were 2803.3 N/mm^2 and 2777.0 N/mm^2, boards at 100:0 ratios (100% *T. arguens*) 2783.4 N/mm^2 and 2738.0 N/mm^2, and boards at 50:50 ratios were 2726.7 N/mm^2 and 2691.5 N/mm^2 for both 14% and 12% resin contents respectively. Boards made from *T. arguens* and *G. scortechinii* at 70:30 ratios show lowest values which are 2630.9 N/mm^{2}and 2596.4 N/mm^2 for both 14% and 12% resin contents respectively.

For resin contents, all ratios of boards made of 14% resin content show higher values than boards made of 12% resin contents. The result shows that the modulus of elasticity (MOE) increases with the increases of resin content. Boards made from both 12% and 14% resin contents meet the minimum requirement of MOE for general uses type of boards according to EN Standard 312-3, and all the values were higher that MOE value of rubberwood [3]. The modulus of elasticity is the quantify material's elastic that is recoverable resistance to deformation under load. MOE is solely a material property, and stiffness depends both on 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 as the change in stress causing a corresponding change in strain. This show that the addition of resin into the board has increased MOE or makes the board more brittle [23].

Modulus of Rupture (MOR)

Modulus of Rupture (MOR) of GT composite boards of 100% bamboo at 0:100 ratios show highest values at 17.5 N/mm^2 and 16.9 N/mm^2 for both 14% and 12% resin contents respectively. Follow by boards at 30:70 ratios which are 16.9 N/mm^2 and 16.3 N/mm^2, boards of 100% grass at 100:0 ratios were 16.5 N/mm^2 and 16.3 N/mm^2, and boards at 50:50 ratios were 15.7 N/mm^2 and 15.6 N/mm^2 for both 14% and 12% resin contents respectively. Boards at 70:30 ratios show lowest values which are 14.8 N/mm^{2}and 13.9 N/mm^2 for both 14% and 12% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show higher values than boards made of 12% resin contents. The Modulus of Rupture (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 EN Standard 310 [8]. 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 indicates 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 amount of adhesive 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. By the fact that urea formaldehyde has higher solids content, thus, it was found that the penetration of high viscosity urea formaldehyde resin probably would break the cell walls of the compressed composite boards Abdullah [24]. This action would make it impossible for the fibre and matrix to withstand greater loads. It is can assume that the urea-formaldehyde resin enhanced the strength of MOR of the composites board.

Internal Bonding

Internal bonding of GT composite boards made from 100% bamboo at 0:100 ratios show highest values which are 0.688 N/mm^2 and 0.623 N/mm^2 for both 14% and 12% resin contents respectively. Follow by, boards made from *T. arguens* and *G. scortechinii* at 30:70 ratios which are 0.534 N/mm^2 and 0.501 N/mm^2, boards made from 100% grass at 100:0 ratios which were 0.526 N/mm^2 and 0.474 N/mm^2, and boards at 50:50 ratios which are 0.478 N/mm^2 and 0.437 N/mm^2 for both 14% and 12% resin contents respectively. Boards at 70:30 ratios show lowest values which were 0.434 N/mm^{2}and 0.391 N/mm^2 for both 14% and 12% resin contents respectively. For resin contents, all ratios of 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 EN Standard 310 [8] except the GT composite boards at 70:30 ratios which were 0.391 N/mm^2 at 12% resin contents. However, internal bonding values of boards made from both 12% and 14% resin contents are lower than internal bonding value of rubberwood (1.300 N/mm^2). Internal Bonding (IB) test was conducted to determine the interfacial bonding strength between fibres in the boards.

The result indicates that high amount of resin influences stronger interfacial bonding between fibres in the boards hence prolong the ability for boards to withstand pulling force created. The lower mean value of internal bonding expected due to the Kangas and Kleen [25] stated that the surface chemical properties of fibrillar in extractives and lignin that influences the absorption, adhesion and strength properties and finally interrupt the bonding properties of the sample. Weak bonding between occur 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 [26]. Most of the failures originated from the boards which have *T. arguens* fibre located.

Screw withdrawal

A screw inserted into each of the holes at the centre of one face and two adjacent edges of the test specimen to a depth of 13 mm. The purpose of screw withdrawal test was to evaluate the screw holding strength of the board. Higher particle loading strengthens the boards as well as increases their densities which helps the board to hold screw better. Screw withdrawal resistance associated highly with the board density and the geometry of the particles [27]. Table 3 showed the screw withdrawal tests 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 (tangential direction) (N/mm^2) of boards made from 100% bamboo at 0:100 ratios show highest values which were 609.8 N/mm^2 and 570.7 N/mm^2 for both 14% and 12% resin contents respectively. Follow by, boards made from 100% *T. arguens* at 100:0 ratios which were 518.4 N/mm^2 and 460.6 N/mm^2, boards at 70:30 ratios which are 486.2 $N/mm^2$and 417.9 N/mm^2, and boards at 50:50 ratios which were 406.4 N/mm^2 and 358.0 N/mm^2 for both 14% and 12% resin contents respectively. Boards at 30:70 ratios show lowest values which were 376.5 N/mm^2 and 345.6 N/mm^2 for both 14% and 12% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show higher values than boards made of 12% resin contents. The result shows that the edge screw withdrawal at tangential direction increases with the increases of resin content. GT boards made at 50:50 ratios haves values at 358.0 N/mm^2 and boards at 30:70 ratios 345.6 N/mm^2 both at 12% resin contents are not meet the minimum requirement of edge screw withdrawal (360.0 N/mm^2) for general uses type of boards according to BS Standard, BS 5669 [9], while the others exceed the minimum requirement.

Edge Screw Withdrawal (Radial direction)

Edge screw withdrawal (radial direction) (N/mm^2) of boards made from 100% *G. scortechinii* at 0:100 ratios show highest values which are 628.6 N/mm^2 and 561.8 N/mm^2 for both 14% and 12% resin contents respectively. Boards of 100% grass have values at 551.1 N/mm^2 and 471.9 N/mm^2, boards at 70:30 ratios 532.8 $N/mm^2$and 449.6 N/mm^2, and boards made at 30:70 ratios which were 403.0 N/mm^2 and 366.0 N/mm^2 for both 14% and 12% resin contents respectively. Boards made at 50:50 ratios show lowest values which were 384.6 N/mm^2 and 337.2 N/mm^2 for both 14% and 12% resin contents respectively. For resin contents, all ratios of particleboard made of 14% resin content show higher values than boards made of 12% resin contents. The result indicates that the edge screw withdrawal at radial direction increases with the increases of resin content. All boards at 14% and 12% resin contents excluding boards made at 50:50 ratios which were 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 BS Standard, BS 5669 [9].

Face Screw Withdrawal

Face screw withdrawal (N/mm^2) of particleboard made from 100% bamboo at 0:100 ratios show highest values which are 683.9 N/mm^2 and 596.0 N/mm^2 for both 14% and 12% resin contents respectively. Boards made from 100% *T. arguens* have values of 643.4 N/mm^2 and 582.8 N/mm^2, GT boards at 70:30 ratios 589.2 $N/mm^2$and 510.5 N/mm^2, and particleboard made from *T. arguens* and *G. scortechinii* at 30:70 ratios which are 531.2 N/mm^2 and 462.3 N/mm^2 for both 14% and 12% resin contents respectively. Boards made from *T. arguens* and *G. scortechinii* at 50:50 ratios show lowest values which are 499.9 N/mm^2 and 442.0 N/mm^2 for both 14% and 12% resin contents respectively. For resin contents, all ratios of 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.

Analysis Of Variance (ANOVA)

Table 4 showed significant differences between physical and mechanical properties with the ratios of varying *T. arguens* and *G. scortechinii* except for screw withdrawal of mechanical properties. 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 mechanical and physical properties value of this composite excluding screw withdrawal properties. For resin contents, the results showed the mixed significant difference. In physical properties, basic density has no significant difference while thickness swelling and water absorption have the significant differences at p-value ≤0.05. The MOE, MOR, and internal bonding have no significant difference while screw withdrawal has the significant differences at p-value ≤0.05. The resin contents have no effect on the basic density, MOE, MOR and internal bonding but influence the result of thickness swelling, water absorption, and screw withdrawal.

The correlation among physical and mechanical properties of particleboard made from grass *T. arguens* and bamboo *G. scortechinii* are 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 mechanical properties of boards made from *T. arguens* and *G. scortechinii*, 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 mechanical properties show a positive correlation with difference resin contents.

Thermogravimetric Analysis (TGA)

Table 6 show percentage weight loss with a temperature of GT composite boards, and UF resin sample. Figure 1 shows TGA graph of particleboard made from *T. arguens* and *G. scortechinii*. The decomposition of the GT composite boards begun at 100ºC (first peak). The decomposition continued to the second peak at 210ºC and completed at the third peak (402ºC). The degradation of UF resin was initiated at 100ºC (first peak), continues at 168ºC (second peak) and completed at third peak (389ºC). Both boards and UF resin loss most of their weight at the third peak which is 66.18% and 58.48% respectively. 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 began to occur at a temperature of 210°C. The value of degradation point for the boards took place at 89.37%. This probably due to dehydration of the samples and degradation of hemicelluloses [28]. The first stage of mass loss was due to the evaporation of water and depolymerisation of molecules structure from the samples [29], [30]. The process continued by cleaves of linkage that occurred in the composite and UF resin. Kim *et al.* [31] reported the lignocellulosic material decomposed thermochemically between 150°C and 500°C, which hemicelluloses mainly between 150°C and 350°C, cellulose between 275°C and 350°C and lignin between 250°C and 500°C. Thermal degradation of polymer blocks of biomass occurred at the second peak. Hemicellulose and Lignin degraded earlier [32], [33]. This might be due to their molecular structure that less rigid (amorphous that cellulose) compared to cellulose. Finally, upon introduction of oxygen at the third peak, combustion occurred, and the final weight loss infers the amount of carbon in the composites. The carbon contents of the composites and UF resin are 66.18% and 58.48% respectively. Changes of 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 [33].

Table 1: Basic density, thickness swelling and water absorption of ComBoGiTe.

Ratios grass to bamboo	Basic density		Thickness swelling (%)		Water absorption	
	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	19.6	16.9	75.4	67.6
50:50	0.577	0.609	21.6	17.9	77.8	69.9
30:70	0.609	0.638	26.4	21.2	83.9	75.3
0:100	0.664	0.689	22.9	18.7	78.8	73.9

Table 2: Modulus of elasticity (MOE), modulus of rupture and internal bonding of ComBoGiTe.

Ratios grass to bamboo	Modulus of Elasticity (MOE) (N/mm^2)		Modulus of Rupture (MOR) (N/mm^2)		Internal bonding (N/mm^2)	
	Resin Content		Resin Content		Resin Content	
	12%	14%	12%	14%	12%	14%
100:0	0.603	0.633	18.8	15.8	0.474	0.526
70:30	0.522	0.564	19.6	16.9	0.391	0.434
50:50	0.577	0.609	21.6	17.9	0.437	0.478
30:70	0.609	0.638	26.4	21.2	0.501	0.534
0:100	0.664	0.689	22.9	18.7	0.623	0.688

Table 3: Edge screw and face screw withdrawal at radial direction of the board.

Ratios of grass: bamboo	Edge screw withdrawal (tangential direction)		Edge screw withdrawal (radial direction)		Face Screw Withdrawal	
	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 ComBoGiTe.

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

Note: Total number of samples for each testing = 60, **= significant at p≤ 0.01,
*= significant at p≤ 0.05, ns= not significant, BD=Basic density, TS=Thickness and swelling,
WA= Water absorption, MOE= Modulus of elasticity, MOR= Modulus of rupture,
IB= Internal bonding, SWA= Edge screw withdrawal (tangential direction),
SWB= Edge screw withdrawal (radial direction), SWC= Face screw withdrawal.

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Table 5: Correlation Coefficient on Physical and Mechanical Properties of ComBoGiTe.

	RC	RTO	BD	TS	WA	MOE	MOR	IB	SWA	SWB	SWC
RC	-	0.0000**	0.2138ns	- 0.4995**	- 0.5194**	0.0831ns	0.1424ns	0.1923ns	0.3940ns	0.3475ns	0.3640ns
RTO		-	0.4889ns	0.4770ns	0.2701ns	0.2878ns	0.3338ns	0.4846ns	- 0.0199**	- 0.0695**	- 0.0347**
BD			-	0.1218ns	-0.0109**	0.3163ns	0.5421ns	0.5355ns	0.2701ns	0.3106ns	0.2825ns
TS				-	0.6691ns	0.1028ns	0.0969ns	- 0.0288**	- 0.4870**	- 0.5690**	- 0.4870**
WA					-	0.1509ns	0.0767ns	- 0.0399**	- 0.5524**	- 0.5716**	- 0.6033**
MOE						-	0.5902ns	0.4418ns	0.2250ns	0.1230ns	0.0911ns
MOR							-	0.5659ns	0.3196ns	0.1979ns	0.1484ns
IB								-	0.2997ns	0.2984ns	0.2913ns
SWA									-	0.7930ns	0.7500ns
SWB										-	0.7438ns
SWC											-

Note : Total number of samples for each testing = 60
**= significant at p ≤ 0.01,WA= Water Absorption,*= significant at p ≤ 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.

Table 6: Weight loss in TGA with a temperature of ComBoGiTe and UF resin.

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

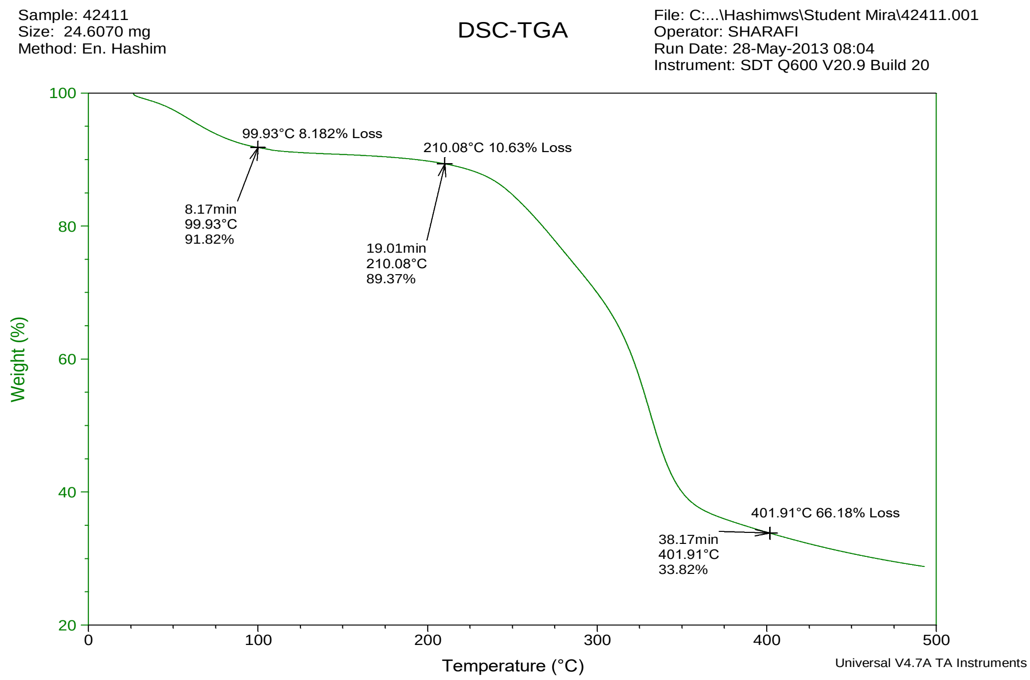

Figure 1: TGA graph of ComBoGiTe from *G. scortechinii* and *T. Arguens*.

CONCLUSION

The basic density of boards made from 100% bamboo and 75% *G. scortechinii* ratios show highest values for both 14% and 12% resin contents respectively. All boards at 14% possess higher values of basic density than boards having 12%. Boards of GT composite boards at 30:70 ratios of *G. scortechinii* and *T. arguens* show highest values for both 12% and 14% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show lower values than boards made of 12% resin contents.

Modulus of Elasticity (MOE) (N/mm^2) of boards made from 100% bamboo shows highest for both 14% and 12% resin contents respectively. Boards with 14% resin content show higher values than boards made of 12% resin contents. Modulus of Rupture of boards made from 100% bamboo shows high values for both 14% and 12% resin contents respectively. Internal bonding of boards made from 100% bamboo shows higher values for both 14% and 12% resin contents respectively. Edge screw withdrawal (tangential direction) of boards made from 100% bamboo show excellent values for both 14% and 12% resin contents respectively. Edge screw withdrawal (radial direction) of boards made from 100% bamboo at 0:100 ratios show for both 14% and 12% resin contents respectively. Face screw withdrawal of boards made from 100% bamboo at 0:100 ratios show for both 14% and 12% resin contents respectively. For resin contents, all ratios of boards made of 14% resin content show higher values than boards made of 12% resin contents in all mechanical tests.

The decomposition of the boards began at 100ºC (first peak). The decomposition continued to the second peak at 210ºC and completed at third peak (402ºC). The high temperature at the final decomposition of boards indicates that the presence of cellulose fibre from boards had a significant effect on thermal stability of the composites.

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