Physical and mechanical properties of composite boards from the mixture of palm sugar fiber and cassava bagasse using mycelium of *Ganoderma lucidum* as a biological adhesive

W Agustina\textsuperscript{1, 2}, P Aditiawati\textsuperscript{2}, S S Kusumah\textsuperscript{3} and R Dungani\textsuperscript{2}

\textsuperscript{1} Research Center for Appropriate Technology, Indonesian Institute of Sciences, Subang-West Java 41213, Indonesia  
\textsuperscript{2} School of Life Sciences and Technology (SITH), Institut Teknologi Bandung, Jl. Ganesha No. 10, Bandung-West Java, Indonesia  
\textsuperscript{3} Research Center for Biomaterials, Indonesian Institute of Sciences, Cibinong Science Center, Cibinong-Bogor 16911, Indonesia

E-mail: wanwa03@gmail.com

**Abstract:** Composite board made from palm sugar fiber (PSF) and cassava bagasse fiber (CB) bonded with biological adhesive from mycelium of *Ganoderma lucidum* was prepared. The composite boards were divided by varying the composition ratios of the PSF and CB (A = 65: 35; B = 50: 50; and C = 35: 65\% w/w of composite board weight). The physical and mechanical properties of PSF/CB composite boards were carried out. The results showed that the moisture content, density, thickness swelling, and water absorption were 7.93 - 8.80\%; 0.32 - 0.61/cm\textsuperscript{3}; 13.5 - 18.00 \%; and 64.22 - 116.96\%, respectively. This study also revealed that the internal bond, modulus of rupture (MOR) and modulus of elasticity (MOE) were 0.03 - 0.76 MPa, 0.48 - 3.80 MPa, and 23.79 - 419.84 MPa, respectively. The Physical and mechanical properties of composite board fulfilled Japan Industrial Standard for particleboard. Hence, mycelium of *Ganoderma lucidum* could be used as a biological adhesive in composite board production.

1. **Introduction**

Starch and sugar industries made from cassava and palm respectively, have large amounts of solid waste. Cassava bagasse (CB) as a waste of starch industry and fibers (PSF) as a waste of palm sugar industry has been utilized optimally yet. Hence, the solid waste has become an environmental problem.

Basically, cassava skin and CB are a solid waste of starch industry. The utilization of cassava skin is for poultry feed ration [1] and animal feed [2]. Commonly, CB is used as animal feed [3]. Recently, there is study on utilizing CB to make bioethanol [4] and biodegradable plastic [5]. However, this utilization is not optimal.

The total amount of CB from tapioca starch production is about 2/3 of the raw material [5]. CB contains high carbohydrates and can be used as an energy source [3]. The components of CB are mostly carbohydrates in the form of cellulose and fiber [6]. The fiber of cassava bagasse consists of hemicellulose, pectin and cellulose [7]. The chemical composition based on the proximate test of the CB shows in table 1. The images of wet and dry cassava bagasse can be seen in figure 1.
Table 1. Chemical composition of cassava bagasse [8].

| Parameter      | Content (%) |
|----------------|-------------|
| Crude protein  | 2.2         |
| True protein   | 2.2         |
| Ash content    | 2.4         |
| Crude fiber    | 31.6        |
| Carbohydrate   | 51.8        |

Figure 1. (a) Wet cassava bagasse and (b) dry cassava bagasse (after drying) [9].

Solid wastes from the production of palm sugar starch include leaves, midrib, bark and palm sugar fiber. Until now, palm sugar residue has not been widely used. This solid waste is difficult to decompose naturally so that it accumulates and eventually pollutes the surrounding environment. The utilization of a small portion of palm sugar waste is carried out in the Ciamis region of West Java (Indonesia) including for animal feed [10] and for baglog mushroom [11].

PSF is a fibrous waste with high cellulose content [12]. The chemical composition of sugar palm waste is cellulose (60.61%), hemicellulose (15.74%), lignin (14.21%), water (7.87%), reducing sugar (0.5689%), and others (1%) [13]. Images of stems, bark and palm sugar can be seen in figure 2.

Figure 2. (a) Pieces of aren tree trunks [14], (b) Pieces of palm sugar after splitting, (c) solid waste of palm sugar [15].

One of the effective utilization from CB and PSF is composite development bonded with biological adhesive by fermentation. This fermentation technology will eliminate the use of chemicals (adhesives) in the manufacture of particle boards.

The fermentation process can be carried out using a biological agent in the form of fungi. One type of fungus that can be used is *Ganoderma sp.* Similar study has been done using *Ganoderma sp.* for the manufacture of packaging materials from cotton waste [16] *Ganoderma lucidum* can be grown in wood waste media to produce nutrient-rich mushrooms [17]. *Ganoderma applanatum* is also used as a popular mushroom for biomaterial art making [18]. Some sample products as a result of wood powder fermentation using fungi can be seen in figure 3.
Figure 3. Examples of commercial products using fungi-based fermentation technology: (a) Myco board™, (b) Myco foam™, (c) Myco make™ [19].

The objective of this study is to investigate the influence of different ratio of PSF and CB composition using fermentation techniques by *Ganoderma lucidum* on the physical and mechanical properties of composite board. The use of PSF and CB as reinforcement agents for mycelium fungi matrix adds value to these waste by-products.

2. Materials and methods

The cassava bagasse and palm sugar fiber used in this research were obtained from home industry in Subang Regency as solid waste. The chemical reagent used in this research was KH₂PO₄, K₂HPO₄, MgSO₄·7H₂O, yeast extract, and NH₄Cl obtained from local chemical vendor. Gypsum (CaSO₄) and lime (CaCO₃) used were obtained from building material shop. Rice bran was obtained from rice shop. The organism used was *Ganoderma lucidum*, which was obtained from the Mycological laboratory, Institut Teknologi Bandung (ITB).

2.1 Raw material characterization

The raw materials of FSP, CB and Rice bran were tested for chemical components including moisture content, ash content, protein, and ratio of C/N.

2.2 Microorganism and medium

*Ganoderma lucidum* stock was transferred onto potato dextrose agar (PDA). PDA plate was inoculated and incubated at room temperature (± 30 °C) for 10 days. Four mycelial agar square (± 5 mm x 5 mm) from a 10-day-old PDA medium were inoculated into 300 ml flask containing 100 mL of liquid medium and incubated at room temperature for eight days [20]. This material was used as inoculum for the production process. The composition of a liquid medium such as is used by Wan-Mohtar et al. [20].

2.3 Production medium preparation

Production medium is made from the main mixture of PSF and CB which is supplemented with other ingredients namely rice bran, CaCO₃, and gypsum. Production medium is made in three composition variations with the comparison of the main raw material PSF and CB A = 65: 35%; B = 50: 50%; and C = 35: 65%. Each variant was coded by PRA, PRB and PRC respectively. Composite board samples are made in two different sizes (2 types).

- Type-1: about 12 x 12 cm² in size with a thickness target of about 0.9 cm. Type 1 samples are used for testing Density (D), Internal Bonding (IB), Water absorption (WA) and Thickness swelling (TS).
- Type-2: around 30.5 x 10.5 cm² size in with a thickness target of about 0.9 cm. Type 2 samples are used for dry bending (DB) and moisture content (MC) testing.

2.3.1. Preparation of type -1 samples. About 200 grams of the total solid mixture (according to the composition) was added with distilled water until the final moisture content, then stirred as homogenously as possible. The mixture was then divided into two and put into a fermentation box with
a size of about 12.5 x 12.5 x 8 cm³. The sample was then sterilized by autoclave at 121 °C, 15 Psi for ±60 minutes, then removed and left for one night until inoculated.

2.3.2. Preparation of type -2 samples. About 231 g of total solid mixture (according to composition) was added with distilled water until the final moisture content, then stirred as homogeneously as possible. The mixture was then put into a fermented box a size of about 30.5 x 10.5 x 6 cm³. The sample was then sterilized by autoclave at 121 °C, 15 Psi for ± 60 minutes, then removed and left for one night until inoculated.

2.4. Composite board production
The production medium was then inoculated with amount of liquid inoculum. The sample was then incubated at room temperature for ± 12 days. After being covered by the mycelium, the samples were then pressed using a hydraulic press (cool press) to the target thickness and held for 10 minutes. The compressed sample was then dried in a tray dryer with a temperature of 55 - 60 °C for about ± 20 hours.

2.5. Determination of physical and mechanical properties
The physical and mechanical properties analysis were done according to the Indonesian Standard (SNI: 03-2105-2006) [21].

3. Result and discussion

3.1. Raw material characteristic
The chemical characteristics of FSP, CB and rice bran raw materials can be seen in table 2.

| Raw Material             | Moisture content (%) | Ash content (%) | Organic-C | Total-N | Ratio of C/N | Protein (%) |
|--------------------------|----------------------|-----------------|-----------|---------|--------------|-------------|
| FSP (Falm Sugar Fiber)   | 7.17                 | 1.16            | 50.01     | 0.21    | 238.09       | 1.33        |
| CB (Cassava Bagasse)     | 8.85                 | 0.57            | 50.99     | 0.27    | 188.85       | 1.67        |
| Rice bran                | 5.76                 | 3.67            | 47.95     | 1.13    | 42.43        | 7.09        |

3.2. Physical properties
Some parameters of physical characteristics observed and measured include physical appearance, density, moisture content, thickness swelling and water absorption.

3.2.1. Physical appearance of the product. The visual observation of the physical appearance of composite board products is described in table 3.

| Visual of product samples | Description                                                                 |
|--------------------------|-----------------------------------------------------------------------------|
| PRA, PRB, and PRC        | sample of composite board from formula A, B, and C                          |
| Surface appearance of    | three samples, PRA, PRB and PRC, did not clearly differences.               |
| three samples, PRA, PRB  |                                                                             |
| and PRC                  |                                                                             |
Table 3. Visual observations of composite board product sample.

| Visual of product samples | Description |
|---------------------------|-------------|
| ![Sample of Composite board (PRB)](image1) | • FSP is still visible on the surface of the sample and on the sidelines of the FSP is a white matrix which is the mycelium of the fungus G. lucidum. |
| ![Sample of Composite board (PRC)](image2) | • Based on its thickness, PRA, PRB and PRC samples tend to be thinner. |

• Ratio of FSP: CB
PRA = 65:35, PRB = 50:50 and PRC = 35:60%

Samples of PRA, PRB and PRC are stacked (from top to bottom)

3.2.2. Density. The density of the composite board on various types (PRA, PRB and PRC) ranged between 0.32 - 0.61 g/cm³. PRB and PRC are in accordance with the Indonesian National Standard [21]. While the PRA sample does not meet the standard. The density of each formula can be seen in figure 4.

Figure 4 shows the change in density of composite board with the increasing number of cassava bagasse. The highest density value of PRC formula is 0.61 g/cm³. This value is higher than Myco-Board™ (particle board which made of wood powder and produced by a similar method) which is 30 lbs/ft³ or equal to 0.48 g/cm³. It is almost the same as the density of Myco Board™ lamination which is 37 lbs/ft³ or equal to 0.59 g/cm³, and lower than the medium density fibreboard (MDF) which is 50 lbs/ft³ or equal to 0.8 g/cm³ [22]. According to Muruganandam [23], The Density of Commercial standard particles board should be 37-50 lbs/ft³ or equal to 0.5 - 0.8 g/cm³. While according to Indonesian National Standard (SNI: 03-2105-2006) [21], the density of particle board should be between 0.40 - 0.90 g/cm³.

![Figure 4. The density of composite board.](image3)
It is possible that the increase in density is influenced by the increasing number of small particles derived from cassava pulp. According to Cosereanu [24], the particle board made from a combination of particles size showed that the density decreased with the increasing particle size. The fine particles were easier to be pressed at a high temperature, resulting in higher density panels [25]. In addition, it is assumed that the composite board density is influenced by the number of mycelium formed which acts as a binder. The density of particle board partly depends on glue [26].

3.2.3. Moisture content. The moisture content of composite board product made from combination formulas of PSF and CB range from 7.9 - 8.8%. The lowest water content is 7.9% in the PRA formula, while the highest is in the PRC formula which is 8.8%. The moisture content between samples with different material compositions is not significant. The moisture content of the three can be seen in figure 5.

Based on these results, all of them meet the requirements of Indonesian National Standard (SNI: 03-2105-2006) [21] that the content of composite board should be less than 14%. According to Muruganandam [23], the equilibrium of moisture content of the particleboard was 8% and the average for all board was 9%. For information, drying of composite board samples was carried out at temperatures around 55 - 65 °C, for ± 20 hours. The moisture content of the sample may be lower if the drying process is optimal.

Oliveira [27] reported that particleboard made from sugarcane bagasse has a moisture content of 9%. Particle board made from mixture of bagasse and industrial wood particles using urea formaldehyde as resin has a moisture content of 12% and 8% [28]. Moisture content of binderless boards made from sugarcane bagasse ranges from 6 - 9% [29].

![Figure 5. Moisture content of composite board.](image)

### 3.2.4. Thickness swelling and water absorption.

The thickness swelling of three samples PRA, PRB and PRC ranges between 13.65 to 18.00 %. The lowest thickness swelling is sample PRB was 13.65%. The PRC sample has the highest, which is 18%. All of the samples meet the requirement of the Indonesian National Standard [21]. Thickness swelling of binderless particles board made from sugarcane bagasse with a density of 0.45g/cm³ with a 3-min pressing time is 125%, and decreases after pressing time addition (for 6-min and 10-min) to 21% and 7%, respectively [29]. Thickness swelling of particle board made in China from sugarcane bagasse is about 11.6% [27]. Thickness swelling value of composite board samples can be seen in figure 6.

Thickness swelling can be affected by the particle size of the material. The greater the particle size used, the Thickness swelling value also tends to be higher [30]. According to [31], thickness swelling can also be affected by other factors such as particle geometry, particle structure and also the number of voids that allow the board to swelling.

Water absorption value of composite board samples (PRA, PRB, and PRC) ranges from 64.22% to 116.96%. The sample with the highest water absorption is PRA which is 116.96% and the lowest is the
PRB sample which is 64.22% while the PRC sample is 67.47% (figure 6). Water absorption of particle board made from sugarcane bagasse is about 43.8% \[27\]. Water absorption of particle board made from sago particles with particle sizes of 0.6 mm, 1 mm, and 2 mm was around of 80%, 65%, and 70%, respectively, at 24-hour immersion times \[30\].

PRB and PRC board were not significantly different, but those boards were significantly different with PRA board. This water absorption is influenced by two significant factors, namely the size and shape of the particles. The speed of water absorption will increase in thicker particles \[30\]. An indicator of the ability of composites to absorb water is porosity \[32\]. Based on the study results, \[30\] revealed that the best sago particles that produce the lowest porosity with the smallest water absorption were 1 mm in size and the results are better than two other sizes namely 0.6 mm and 2 mm.

3.3. Mechanical properties

3.3.1. Internal bond strength. The effects of different composition of palm sugar fiber and cassava bagasse on the IB strength of composite boards are shown in figure 7. The IB value of samples ranges from 0.03 to 0.76 MPa. The highest IB value is a PRC sample and the lowest is PRA sample. The values of IB strength are positively correlated with the increase of cassava bagasse composition in the formula mixture and also the density of composite board. The more cassava bagasse, the higher the density and the higher the IB strength. According to Indonesian National standard \[20\], minimum value of particle board ranges from 0.15 to 3.0 MPa for all type. It means that the samples of PRB and PRC meet the requirement of Indonesian standard. It means that PRB and PRC samples are in accordance with the Indonesian national standards, but not for PRA samples.
Tudryn [21] reported that particle board produced by a similar method, myco board™, Myco board™ laminate and MDF had IB strength values equal to 0.38, 0.38 and 0.30 MPa. Particle board made from sorghum bagasse with the addition of 20% Citric acid (CA), 12% phenol formaldehyde and 8% polymeric 4,4’-methylene diphenyl isocyanate (pMDI) with certain temperature and heating time has an IB value of 0.89, 0.78 and 1.33 MPa respectively [33]. The binderless particles board made from pith sugarcane at density of 0.45g/cm³ has IB value of 0.1 MPa, and at the density of 0.75 g/cm³ it is 0.2 MPa [29].

The internal bond strength (IB) of composite board increased with increasing CB in the mixture. The density of composite board improved since the CB content increased. The increasing number of small particles originating from CB can increase the density of composite boards. According to [34] internal bonding strength correlates with particle board density values. In the same production conditions the particle board density can increase IB strength. In addition, the strength of IB is influenced by the increasing amount of starch originating from CB and the amount of mycelium in the sample which can act as an adhesive. According to [35], naturally, mushroom mycelium acts as a natural adhesive and can actually unite various constituents.

3.3.2. Dry bending strength. The effects of different composition of palm sugar fiber and cassava bagasse on the bending strength (modulus of rupture, MOR and modulus of elasticity, MOE) of composite board are shown in figure 8. The value of MOR of PRA, PRB and PRC is 0.48, 0.79 and 3.08 MPa respectively. MOR value of myco board™, Myco board™ laminate and MDF is 820, 1,700 and 1,595 Psi or equal to 5.65, 11.72 and 10.99 MPa respectively [22]. Particle board made from sorghum bagasse with the addition of 20% Citric acid (CA), 12% phenol formaldehyde and 8% polymeric 4,4’-methylene diphenyl isocyanate (pMDI) with certain temperature and heating time has an MOR value of 21.8, 32.9 and 34.1 MPa respectively [33]. The binderless particles board made from pith sugarcane at density of 0.45g/cm³ has IB value of 2.2 MPa, and at the density of 0.75 g/cm³ it is 9.9 MPa [29].

The MOE value of PRA, PRB and PRC is 23.79, 68.52 and 419.84 MPa respectively. While the MOE value of myco board™, Myco board™ laminate and MDF is 120,400, 336.100 and 217,500 Psi or equal to 830, 2,317 and 1,499 MPa respectively [22]. Particle board made from sorghum bagasse with the addition of 20% Citric acid (CA), 12% phenol formaldehyde and 8% polymeric 4,4’-methylene diphenyl isocyanate (pMDI) with certain temperature and heating time has an MOE value of 5.2, 4.5 and 4.6 MPa respectively [33]. The average values of modulus of elasticity (MOE) to compression in MPa of particle board made from sugarcane bagasse is 754.1 MPa [27].

![Figure 8. MOR and MOE value of composite board samples.](image_url)

As same as with internal bonding strength, dry bending strength also correlates with density values. The MOE or MOR value increased with increasing of board density. This is in line with the statement of [36] namely that increasing the density value significantly increases the MOR and MOE value.
4. Conclusion
Differences in the composition of the main raw materials of FSP and CB did not significantly affect the water content of composite board samples, but significantly affected the density, swelling thickness, water absorption, internal bond strength, and dry bending strength (MOE and MOR) value. The more CB is added to the material mixture, the higher the density, internal bond strength, and dry flexural strength (MOE and MOR). The best quality product sample is PRC with a composition ratio of FSP and CB 35:65. The selected composite board samples of the highest quality have met the quality requirements in accordance with SNI 03-2105-2006 regarding particle boards except for MOR.

Acknowledgement
I would like to express my deep gratitude to the Indonesian Institute of Sciences for the study opportunities provided. The Ministry of Research, Technology and Higher Education of the Republic of Indonesia for the Scholarship. I would also like to thank Institut Teknologi Bandung; Research Center for Appropriate Technology-LIPI; Research Center for Biomaterials-LIPI and all its staff and employees for their support and contribution.

5. References
[1] Akhadiarto, S 2010 J. Tek. Ling. 11 127-138
[2] Hanifah V W, Yulistiani D, and Asmarasari, S A A 2010 Optimization utilization of cassava skin waste to empower entrepreneurs of Enye-Enye (in Indonesian). Proceeding of “Prosiding Seminar Nasional Teknologi Peternakan dan Veteriner” 550-556
[3] Antari R, and Umiyasih U 2009 Optimizing the use of cassava plant and its by product as ruminant feed (in Indonesian). Wartazoa : Indonesian Bulletin of Animal and Veterinary Sciences 19 4 191-200
[4] Siswanti M E S 2009 Minithesis: Bioethanol level of ground solid dry tapioca waste (flour) by addition of yeast and various fermentation time (in Indonesian). Faculty of Teaching and Science Education. UMS Surakarta
[5] Normiyanti A 2011 Minithesis: Utilization of Tapioca Solid Waste as raw material for easy-decomposed Plastic (Biodegradable) (in Indonesian). Program Studi Teknik Sipil & Perencanaan. Universitas Pembangunan Nasional “Veteran”. Jawa Timur
[6] Muryani, Sri Suharni, Sulastri, and Windi Sugesti 2012 Utilization of Solid Waste Tapioca as Rural Household Industry. Jurnal kelitbangan 01 63-72
[7] Yusrin and Mukaromah A H 2010 Hydrolysis process of Onggok with variation of acid in ethanol production (in Indonesian). Proceeding of “Seminar Nasional UNIMUS, ISBN 978.979.704.883.9. 20-25
[8] Supriyati 2003 Fermented cassava waste and its utilization in broiler chickens rations. Indonesian Journal of Animal and Veterinary Science 8(3) 146-150
[9] Mesintepungindustri.com 2011 Industrial flour machine http://www.mesintepungindustri.com/2011/07/membuat-tepung-onggok-ampas-tapioka.html. Accessed January 11, 2016
[10] Wartapiangan.com 2015 After reaped problem, now Kertahaja sugar palm flour becomes blessing (in Indonesian). http://www.wartapiangan.com/setelah-menuai-masalah-kini-limbah-tepung-aren-kertaharja-menjadi-berkah/10180/. Accessed December 1, 2016
[11] Harapanrakyat.com. 2015. In polemic, someone utilize sugar palm waste for fungi in Ciamis. http://www.harapanrakyat.com/2015/04/di-saat-polemik-di-ciamis-ada-orang-manfaatkan-limbah-aren-buat-jamur/. Accesssed December 11, 2016
[12] Herawati A and Wijayanti L 2015 Production of glucose from industrial solid waste of starch sugar palm using Trichoderma sp. (in Indonesian). Proceedings of “Seminar Nasional Teknologi Kimia, Industri dan Informasi. 119-133
[13] Purnavita S dan Herman Y S 2011 Production of bioethanol from Sugar Palm Starch Waste enzymatically using cellulosytic microbe from termite extract (in Indonesian). Jurnal Teknologi Pangan dan Hasil Pertanian 8 (2) 54 – 60
[14] Disbun.jabarprov.go.id 2015 The philosophy of sugar palm (Arenga pinnata) in meaningful life. http://disbun.jabarprov.go.id/index.php/artikel/detailartikel/77, Accessed December 5, 2016

[15] Sulaiman and Darmanto S 2013 Processing and treatment of sugar palm stem dregs fiber (in Indonesian). Seminar Nasional ke-8: Rekayasa Teknologi Industri dan Informasi. Sekolah Tinggi Teknologi nasional. 75-78

[16] Holt G A, McIntyre G, Flagg D, Bayer, Wanjura J D and Pelletier M G 2012 Fungal Mycelium and Cotton Plant Materials in the Manufacture of Biodegradable Molded Packaging Material: Evaluation Study of Select Blends of Cotton Byproducts. Journal of Biobased Materials and Bioenergy 6, 431–439

[17] Djarwanto dan Suprapti S 2010 Growth of Ganoderma lucidum cultivated on medium of mangium wastes and its nutritious values (in Indonesian). Jurnal Penelitian Hasil Hutan 28(1) 9-17

[18] Zeller, P dan Zocher D. 2012. Ecovative’s Breakthrough Biomaterials. FUNGI 5(1) 51-56

[19] Ecovativedesign.com. 2016. We Grow Materials. http://www.ecovativedesign.com/myco-board. Accessed December 5, 2016

[20] W A A Q I Wan-Mohtar, Safuan A K, and Nazamid S 2016 Biotechnology Reports 11 2-11

[21] Indonesian National Standard 2006 SNI: 03-2105-2006 National Standardization Body Indonesia

[22] Tudryn G J 2014 A Formaldehyde-Free: Sustainable Alternatif for the Engineered Wood Industry. Radiotech report issue 2 40-45

[23] Muruganandam L, J Ranjitha and A Harshavardhan 2016 A Review Report on Physical and Mechanical Properties of Partition Boards from Organic Waste. International Journal of Chemtech Research 9(1) 64-72 ISSN : 0974-4290

[24] Camelia Cosereanu, Luminita-Maria Brenci, Octavia Zeleniuc, and Adriana Fotin 2015 Seed particle size, BioResources 10(1) 1127-36

[25] Cai, Wu Q, Lee J N, Hiziroglu S 2004 Influence of board density, mat construction, and chip type on performance of particleboard made from eastern redcedar. Forest Products Journal 54(12) 226-232

[26] Rishell C A 1956 Particle Board : Their Manufacture and Uses, 5th Annual Meeting Technical Sessions on Building Product, Building Research Institute, Division of Engineering and Industrial Research, National Academy of Sciences-National Research Council, Washington D.C.

[27] Stefania Lima Oliveira, Rafael F M, Lourival M M, and Ticyane P 2016 Particleboard Panels Made from Sugarcane Bagasse: Characterization for Use in the Furniture Industry. Materials Research 19(4) 914-922

[28] Dahmardehghalehno M and Bayatkashkoli A 2013 Experimental particleboard from bagasse and industrial wood particles. Int. J. Agric. Crop Sci. 5(15) 1626–31

[29] Ragil W, Jianying Xu, Kenji U, and Shuichi K 2005 Manufacture and properties of binderless particleboard from bagasse I: effects of raw material type, storage methods, and manufacturing process. Journal of Wood Science 51 648–654

[30] Tay C Chiang, Mohd S O, and Sinin H 2012 Water Absorption and Thickness Swelling Behavior of Sago Particles Urea Formaldehyde Particleboard. International Journal of Science and Research (IJSR). 3(12): 1375-79

[31] Olufemi A S, Abiodun O O, Omaojorogedoh, Paul F A 2012 Evaluation of cement-bonded particle board produced from afzelia Africana wood residues. Journal of engineering science and technology. 7(6): 732-743

[32] Svetlana B, Ossi M, and Timo K 2011 Properties of wood fibre-polypropylene composites: effect of wood fibre source. Appl comp mater 18:101-111

[33] Sukma S K, Kenji U, Ikhsan G, Tsuyoshi Y, and Kozo K 2017 Utilization of sweet sorghum bagasse and citric acid for manufacturing of particleboard II: influences of pressing temperature and time on particleboard properties. Journal of Wood Science. 63 (2)161–172

[34] Sedano-Mendoza, M P Navarrete, and A Pizzi 2010 Effect of layers relative moisture content on the IB strength of pine tannin bonded particleboard. Eur.J.Wood Prod. 68: 355-357
[35]  Kalita G, S Chakravarty, S Baruah, S Sen, and P J Hazarika (2018) Using Mycelium as a Building Material in India. Conference: RECYCLE: International Conference on Waste Management.

[36]  Abdullah İstek1, and Hüseyin Siradağ. 2013. The Effect of Density on Particleboard Properties. International Caucasian Forestry Symposium 24-26 October 2013. Artvin: Turkey