
Characterization of *Africa Fan Palm Petioles* fibre for Particleboard Production as Wood Substitute for various Applications

By

**Salihu, A. A., Gimba, C. E. and Mamza, P. A. P.*

Department of Chemistry,
Ahmadu Bello University, Zaria

*E-Mail salihuaudu4u@gmail.com

ABSTRACT

This research work is based on the characterization of Africa fan palm petioles (AFPP) fibre and saw dust (SD) fibre where chemical, ash and moisture composition were analysed. Composites of particleboard were formulated with varying weight fraction of reinforcements: 90%, 80%, 70%, 60% and 50% to 10%, 20%, 30%, 40% and 50% urea formaldehyde. The physical properties (water absorption, thickness swelling) of the particleboards were tested and compared. The results indicated that the AFPP particleboards had better properties compared to that of SD particleboards, thus AFPP can serve as a better substitute for wood in various structural applications.

Keywords: *Africa fan palm petioles, Fibre characterization, Mechanical properties, Particleboards, Physical properties, Saw dust.*

INTRODUCTION

Urea formaldehyde resins are the most common thermosetting resins usually referred to as amino resins. It is commonly used as adhesive by the forest product industries due to number of advantages, including low cost, ease to use under wide variety of curing condition, low cure temperature, water solubility, resistance to micro organisms and to abrasion hardness, excellent thermal properties, fire resistant etc (Sharma *et al.*, 2015; Birol and Cagri, 2017). They have disadvantages such as low resistance to water and moisture which brings about the reversibility of the aminomethylene link mostly at high temperature and consequently persistent formaldehyde release from the UF-bonded wood panels (Pizzi, 2003). Over the last few years, different types of waste materials (natural fibres and plastic waste) have been utilized in composite production; which offers an opportunity for waste materials re-utilization and thereby reduce environmental pollution (Eze *et al.*, 2013). Many papers have reported work on natural fibres based composites; examples are bagasse (Naguib *et al.*, 2015), Jute (Gupta 2018), bamboo (Abdulkareem *et al.*, 2017) Palmyra palm petiole (Srinivasababu *et al.*, 2014) among others. Much research work has not been done to develop the particle Board from Africa Fan Palm Petioles in Nigeria and abroad. Ghosh and Nayak (2006) have done successful research work in the laboratory scale to produce the date-palm leaf (DPL) boards and its application for the false ceiling. In the world, Iraq has been producing thermal insulating Boards for covering electrical wires.

Wood resources are continuously depleted as the demand keep on increasing with increase in population and various area of applications consequently causing shortage of wood in the forest reserve (Ghosh and Nayak 2006). Recently, natural fibre plastic composites gained increasing interest among scientists due to the desirable properties of natural fibres

and their broader application (Alireza *et al.*, 2010). This has made it necessary for scientists to find alternative raw materials which will play an important role in the wood fibre supply/demand map of the future (Ibrahim *et al.*, 2005).

Africa fan palm is a woody plant with numerous petioles, an annually renewable agro-waste, could be used as a good replacement for wood products development. The tree has many uses: It is used globally for both medicinal (Sarkodie *et al.*, 2015) and non-medicinal purposes. The fruit are edible; the fruit is made into soft drinks (Ogbuagu *et al.*, 2013). Fibres can be obtained from the leaves; and the wood (which is reputed to be termite-proof) can be used in construction (Bailey *et al.*, 1976).

Physical properties like water absorption, thickness swelling of wood are of great importance, especially in the structural application. However, wood undergoes changes in its moisture content all the time and the water absorption properties significantly affect the mechanical properties of a product (Khazaei, 2007). The rate of these changes could be as a result of the presence of some oxides constituents in the fibre. The water absorption rate of a composite is influenced by the factors such as; type of fibre and matrix, atmosphere environment like temperature and humidity, water distribution within the composite and reaction between water and matrix, porosity and volume fraction of fibres (Svetlana *et al.*, 2011).

The size of the individual particles is a significant factor that influences the properties of particle board. Small particle size has better mechanical and physical properties than large ones (Tay *et al.*, 2013). This is due to the low diffusion rate in a particleboard as a result of high interfacial bonding between matrix and fibre which reduced its porosity and thus improves the mechanical and physical properties (water absorption, thickness swelling) of particleboard. Thus the aim of this work is to develop Africa fan palm petioles fibre reinforced urea formaldehyde as wood substitute for particle board production.

Table 1: Designation of symbols and their meaning as used in this work

Symbol	Meaning
10H	10wt% saw dust fibre reinforced 90wt% urea formaldehyde matrix
20H	20wt% saw fibre dust reinforced 80wt% urea formaldehyde matrix
30H	30wt% saw fibre dust reinforced 70wt% urea formaldehyde matrix
40H	40wt% saw fibre dust reinforced 60wt% urea formaldehyde matrix
50H	50wt% saw fibre dust reinforced 50wt% urea formaldehyde matrix
10F	10wt% saw Africa fan palm petioles fibre reinforced 90wt% urea formaldehyde matrix
20F	20wt% saw Africa fan palm petioles fibre reinforced 80wt% urea formaldehyde matrix
30F	30wt% saw Africa fan palm petioles fibre reinforced 70wt% urea formaldehyde matrix
40F	40wt% saw Africa fan palm petioles fibre reinforced 60wt% urea formaldehyde matrix
50F	50wt% saw Africa fan palm petioles fibre reinforced 50wt% urea formaldehyde matrix

MATERIALS AND METHOD

Materials

The materials used in this work are BDH-grade urea, formaldehyde, ammonium chloride, sodium hydroxide, Saw dust and Africa fan palm petioles.

Method

Sample Collection and Preparation

Borassus aethiopum petioles were sourced from Mazhaga village, in Toto Local Government Area of Nasarawa State of Nigeria and saw dust was sourced from Samaru Sawmill, Zaria-Nigeria. They were both sun-dried for three weeks and finally reduced to 0.6mm particle size using a mechanical grinder.

Preparation of Urea Formaldehyde (UF)

400ml of 45% formaldehyde solution was measured into a clean dried 1000ml beaker with 200g of 99% urea placed on the heating mantle, 22% NaOH solution was added to moderate the pH to 8.5 and the temperature was raised in 50 min from ambient to 90 °C while maintaining pH in the range 7.6 by small additions of 22% NaOH. The temperature was maintained at 90 °C until the turbidity point is reached for 20 min. 5ml of 30% concentrated tetraoxosulphate (vi) acid (H_2SO_4) was added to adjust its acidic medium of 5.5 pH and the temperature was raised to 98°C. The pH was finally brought to 8.5 using sodium hydroxide solution to terminate the polymerization reaction (Pizzi, 2003).

Formulation of Saw Dust (SD) and Africa Fan Palm Petioles (AFPP) Composites

The saw dust (SD) and Africa fan palm petioles (AFPP) fibres particleboards were formed by mixing each fibre with urea formaldehyde separately using hand layup method until proper mixture was obtained. The percentage urea formaldehyde resin loading was varied from 10%, 20%, 30%, 40% and 50%; and 90%, 80%, 70%, 60% and 50% of the fibre respectively as shown in table 2. The amount of ammonium chloride salt that was added to each formulation as a curing agent (CA) at 5% of Urea Formaldehyde (UF) was calculated to ensure equal concentration.

Table 2: Weight fraction ratio for the composites

Sample	UF (%)	Filler (%)	CA (NH_4Cl)g
10H	10.00	90.00	0.50
20H	20.00	80.00	1.00
30H	30.00	70.00	1.50
40H	40.00	60.00	2.00
50H	50.00	50.00	2.50
10F	10.00	90.00	0.50
20F	20.00	80.00	1.00
30F	30.00	70.00	1.50
40F	40.00	60.00	2.00
50F	50.00	50.00	2.50

Curing

The composite samples were cured on a hydraulic machine with its platens electrically heated. The composites were wrapped in aluminium foil and cold-pressed into mat-form. The

composites were cut into the metal mould with dimensions (25cm length, 25cm width, and 3mm thickness) and placed between heated platens of the compression molding in an electrically heated hydraulic press at the temperature of 160°C, pressure of 12 MPa for 3mins (Pizzi, 2003).

Chemical Analysis

The analysis was conducted at Multipurpose Lab Ahmadu Bello University, Zaria, Kaduna state of Nigeria using XRF machine to test for the percentage chemical composition of oxide such as silicon oxide (SiO₂), aluminum oxide (Al₂O₃), magnesium oxide (MgO), iron oxide (Fe₂O₃) among others. The samples were determined if they are in accordance with ASTM C 618-05 standard classes of pozzolana (class N, class F, class C).

Ash Content Determination

The mass (M_{DRY}) of the dry fibres was weighed using digital weighing balance into a known weight of crucibles and then heated in a muffle furnaces at 500°C for 5 hour and weighed (M_{ASH}) according to M11/7 (ABTCP,1974C)

$$\% \text{ Ash (dry basis)} = \frac{M_{\text{ASH}}}{M_{\text{DRY}}} \times 100$$

Where:

M_{ASH} refers to the mass of the ashed samples

M_{DRY} refer to the original masses of the dried samples.

Moisture Content

The mass (w) of the fibres was weighed using digital weighing balance and then oven – dried at 105°C for 5 hour and weighed, drying and weighing was repeated until a constant mass (D) was attained according to (Asafu-Adjeye, 2012). The moisture content (MC) was then calculated according to the formula: MC = (W – D)/D x 100%

Where: MC = moisture content, W = weight of the fibres before oven drying and D = weight of the fibres after oven drying.

Physical Property Test

Water Absorption Test

Water absorption test was carried out according to ASTM D570 (Klyovov, 2007) with oven dried known weight sample of dimension 25 x 25x 3 mm immersed in water at room temperature for 24 hours. The sample was removed and cleaned with dried cloth and then reweighed using a digital weighing balance. The dried weight before (W_i) immersion and weight after (W_f) immersion was calculated and then the percentage water absorbed by each samples was also calculated using the formula below:

$$W = \frac{W_f - W_i}{W_f} \times 100$$

where: W = water absorption; W_f = final weight after absorption; W_i = initial weight before absorption

Thickness Swelling Test

Thickness swelling test tests was carried out in accordance with ASTM D-1037 (1999) standard. The dried known thickness of sample with dimension 25 x 25 x 3mm was immersed

in water at room temperature for 24h. The sample was removed and cleaned with dried cloth and weighed. The thickness before (T_i) immersion and thickness after (T_f) immersion was calculated and then the percentage water absorbed by each samples was also calculated as well, using the formula below:

$$W = \frac{T_f - T_i}{T_f} \times 100$$

where: T = thickness swelling; T_f = thickness swelling after absorption; T_i = thickness swelling after absorption

RESULTS AND DISCUSSION

Characterizations of the Fillers

Preliminary Determination of Chemical Composition of the Fillers (SD and AFPP)

Table 1 shows the chemical composition of SD and AFPP. The major oxides detected were silicon oxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3). The result shows that SD fibre contains 32.64% SiO_2 , 5.48% Al_2O_3 and 2.42% Fe_2O_3 while AFPP fibre contains 41.54% SiO_2 , 4.60% Al_2O_3 , 4.31% Fe_2O_3 . The combined proportion of these oxides was observed to be 40.54% lower than 78.89% (Omotosho *et al.*, 2018) for SD and 50.45% for AFPP fibres respectively. AFPP fibre contains higher oxide composition than SD fibre, which could be as a result of difference in lignocellulosic materials because different lignocellulosic materials contain different chemical properties. The above result indicated that AFPP has better oxide composition than SD. This may improve the glue bonding and promote higher interfacial adhesion between particles and matrix. Since the total oxide combination ($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$) in both fibres are less than 70% as stipulated in ASTM C618. These confirmed that AFPP and SD fibres cannot be used as pozzolanic material.

Table 3: Oxides composition of saw dust and Africa fan palm petioles fibre

S/N	Oxides	SD Conc.wt (%)	AFPP Con.wt (%)
1	Na_2O	0.00	4.067
2	MgO	1.839	2.050
3	Al_2O_3	5.481	4.604
4	SiO_2	32.641	41.541
5	P_2O_5	5.122	5.159
6	SO_3	4.788	4.626
7	K_2O	10.780	12.086
8	CaO	34.763	13.100
9	TiO	0.350	1.157
10	Cr_2O_3	0.014	0.025
11	Mn_2O_3	0.199	0.182
13	ZnO	0.040	0.020
14	SrO	0.115	0.036

Ash and Moisture Determination

The table shows the results of ash content and moisture content of the fibres. The ash content in AFPP was observed to be slightly higher than in SD. This could be as a result of the presence of silica in the back of AFPP which was determined to be 41.54% compared to 32.64%

of SD. According to Ndazi (20007), the presence of high concentration of silica hides the reactive sites for adhesion with polar adhesive thus affect the bond formation. This may contribute to the small differences that may arise in mechanical and physical properties of the particleboard.

SD has higher moisture content (7.17%) than AFPP (5.27%). High moisture content of the fibres can lead to the development of high vapour pressure in boards leading to delamination or “blows” and too little will lead to poor heat transfer in the press and incomplete resin cure, resulting in poor mechanical properties according to (Mark, 2016). AFPP has better moisture content (5.27%) than SD with (7.17%), this is related to the work of Mark, (2016) which revealed that moisture content of chips or fibres in the region of 2.5% gives better mechanical and physical properties.

Table 4: Effect of Ash and Moisture of the SD and AFPP fibre for composites formulation

	SD	AFPP
Ash content (%)	10.00	12.00
Moisture content (%)	7.17	5.27

Physical Properties of Particle Boards made from SD and AFPP.

Water Absorption

Figure 1 shows that the percentage water absorption of the SD filler composite shows steady decrease as the percentage resin increases. Similarly, the percentage water absorption of the AFPP composites decreased as the percentage resin increases. The increased water absorption with increased weight fraction of reinforcement may be attributed to the increase in surface area of the reinforcement in the UF matrix, leading to increased number of pores. Similar observation has been reported by (Ghosh and Nayak, 2006; Dhakal *et al.*, 2006; Svetlana *et al.*, 2011; Jacob *et al.*, 2018). However, optimum results were observed at 50% weight fraction reinforcement for both AFPP and SD composites. AFPP particleboards showed better resistance to water absorption with 1.94 %, than SD particleboards with 6.78 %. This could be as a result of high proportion of the combined oxides in AFPP (50.45%) fibre than SD (40.54%) fibre.

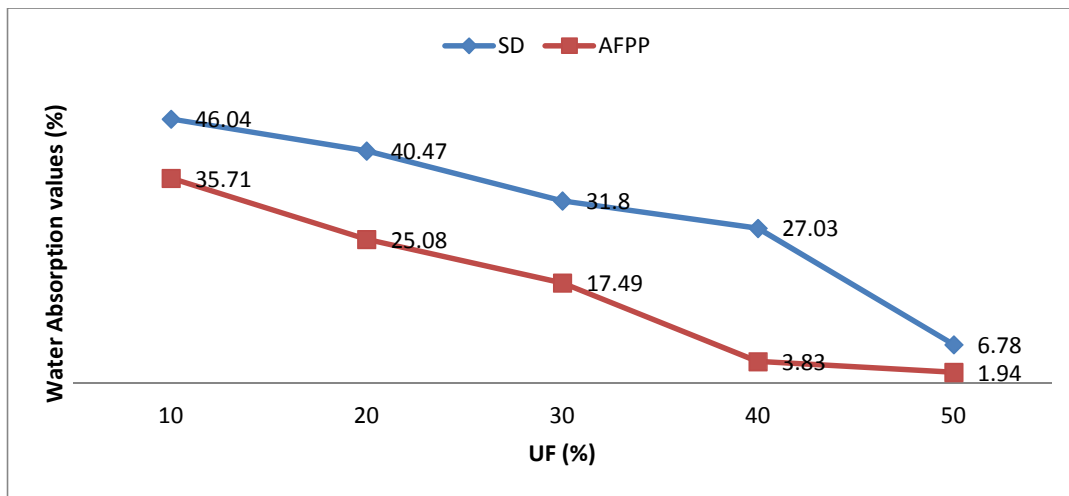


Figure 1: Water absorption behaviours of AFPP and SD

Thickness Swelling

Figure 2 shows, the thickness swelling (TS) of particleboards which is the measure of its dimensional stability in humid environment. The TS of the SD composites shows decrease in TS as the percentage of UF resin increases with the maximum of 8.80% at 30% resin composition; this could be as a result of poor fibre distribution in the UF matrix during mixing. Similarly, the thickness swelling of the AFPP composites decreased as the percentage resin increased. The increased TS with increased weight fraction of reinforcement may be attributed to the increase in surface area of the reinforcement for water absorption, leading to swelling of the fibres. Similar observation has been reported (Mamza *et al.*, 2014). Optimum results were observed at 50% weight fraction reinforcement for both AFPP and SD composites. TS of AFPP (0.90%) particleboards showed better dimensional stability than SD (2.59%) particleboards. This may be as a result of better interfacial bonding in AFPP composites than SD composites.

The EN 312-3 (EN, 2003) standard for TS after 24h requires values below 13%. Thus, none of the particleboard formulations resulted in TS above the maximum as stipulated by this standard. ANSI A208.1 (ANSI, 1993) only specifies TS maximum value for boards applied in manufactured home decking, which should be below 8%; hence the formulations proposed in this work meet the requirements for this application. Therefore AFPP can be a better substitute for SD in the manufacturing of particleboards for home decking.

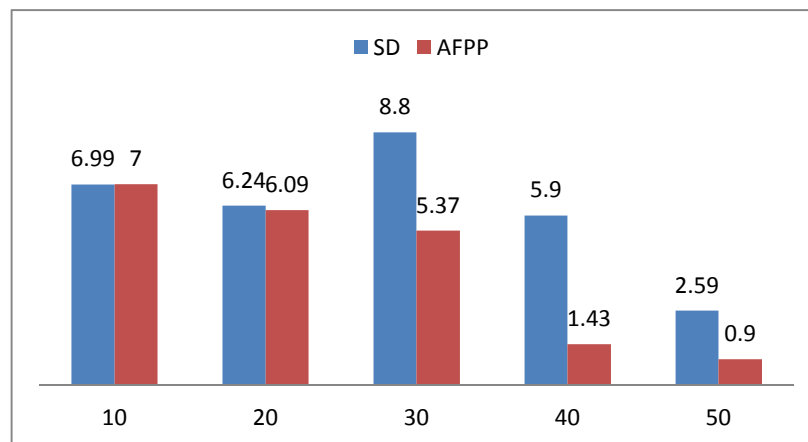


Figure 2: Thickness swelling behaviours of AFPP and SD

CONCLUSIONS

Particleboard from AFPP and SD reinforced UF was successfully developed and characterized, the following conclusions were made. AFPP have improved thickness swelling 0.90%, water absorption 1.94% compared to the conventional particleboards from SD with thickness swelling 2.59%, water absorption 6.78% at 50% reinforcement which shown to be optimum. Therefore as a result of that AFPP particleboards may be used in commercial scale for producing door / window panels, book shelf, false ceiling, and home decking among others.

RECOMMENDATIONS

1. More research should be carried out on Africa Fan Palm so that small scale and large scale industries can be set up for particleboards production across the country as a substitute for wood products. This can provide job for teaming Nigeria youth.
2. Moreso, further analysis should be carried out on the combined aggregate of the Africa fan palm petioles and its leaves as reinforcement for particleboard production.

ACKNOWLEDGEMENT

The authors are grateful to Directorate of Research and Development, Nigerian Institute of Leather and Science Technology, Zaria and Staff of Strength of Materials Laboratory, Department of Mechanical Engineering for providing us with equipment used in this research.

REFERENCES

- Abdulkareem, S. A. and Adeniyi, A. G. (2017). Production of Particleboards Using Polystyrene and Bamboo Wastes. *Nigerian Journal of Technology*, 36(3), 788 – 793.
- Alireza, S. A. G. (2010). Water absorption and thickness swelling behaviour of polypropylene reinforced with hybrid recycled newspaper and glass fibre. *Applied composite materials*, 17, 183-193.
- Asafu-Adjeye, O. A. (2012). Characterization of the Physico-Mechanical Properties of the Different Zones of *Borassus Aethiopum* (Mmaa Kube). A Case Study of kumasi Ghana, MPhil Thesis. Kwame Nkrumah University of Science and Technology.
- Associação Brasileira Técnica De Celulose E Papel, (1974). ABTCP M11/77: Teor de cinzas. São Paulo.
- ASTM (American Society for Testing Materials), 1999. Standard test methods for evaluating properties of wood-based fiber and particle panel materials static tests of timbers, D 1037- 93, ASTM, Philadelphia, PA.
- ASTM C 618, Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- Bailey, L. H. and Bailey E. Z. (1976). Hortus Third i–xiv, 1–1290. MacMillan, New York.
- Biol, U. and Cagri, O. (2017). The Effect of Hardener on Adhesive and Fibreboard Properties. *Wood research*, 62(1), 27-36.
- Dhakar, H. N., Zhang, Z. Y. and Richardson, M. O. W. (2006). Effect of water absorption on the mechanical properties of hemp fibre reinforced unsaturated polyester composites. *Journal of Composites science and technology*
- European Committee for Standardization. EN 312: Particleboards-Specifications. Brussels, 2003.
- Eze, I. O., madufor, I. C. and Obidiegwu, M. U. (2013a). A comparative Study of some Mechanical Properties of bamboo powder filled Virgin and Recycled Low Density Polyethylene Composites. *Academic Research International* 4(1), 420-430
- Ghosh, S. K. and Nayak, L. K. (2006). Date-palm leaf particle boards – a wood substitute for various applications *International Journal Agricultural. Sciences*. 2(2), 421-424.
- Gupta, M. K. (2018). Effect of Variation in Frequencies on Dynamic mechanical properties of Jute fibre Reinforced Epoxy Composites *Journal of Materials and Environmental Sciences*, 9(1), 100-106.

- Ibrahim, B. Cengiz, G. and Hulya, K. (2005). The manufacture of particlenoards using sunflower stalks (*helianthus annuusi.*) and poplar wood (*populous alba l.*) *Journal of composite materials*, 39(5).
- Jacob, J., Mamza, P. A. P., Ahmed, A. S. and Yaro, S. A. (2018). Mechanical and Viscoelastic Properties of Plantain Powder Reinforced Recycled High Density Polyethylene Composites. *Nigeria Journal of Polymer Science and Technology*, 13(2), 55-66
- Khazaei, J. (2007). Water absorption characteristics of three wood varieties. *Cercetaria gronomice in Moldova*. 41(2), 134
- Klyosov, A. A. (2007). Wood-Plastic Composite. John Wiley and Sons Inc., New Jersey, US.
- Mamza, P. A. P., Emmanuel, C. E., Gimba, E. C. and David, E. A. (2014). Comparative Study of Phenol Formaldehyde and Urea Formaldehyde Particleboards from Wood Waste for Sustainable Environment. *International Journal of Scientific & Technology Research*, 3 (9).
- Mark, H. (2016). CHEM-E2105 Wood and Wood Products Manufacture of wood-based panels (manufacturing dry-formed wood-based composites: particleboard, medium density fibreboard etc.)
- Naguib, H. M., Kandil, U. F., Hashim, A. I., and Boghdadi, Y. M. (2015). Effect of Fibre Loading on the Mechanical and Physical Properties of Gren Bagasse-Polyester Composite. *Elsevier Journal of Radiation Research and Applied Sciences*, 8, 544-548
- Ndazi, B. S., (2007). Chemical and physical modifications of rice husks for use as composite panels. *Composites Part A: Applied Science and Manufacturing, Bristol*, 38, 925-935.
- Ogbuagu, A. S., Ekpunobi, U. E., Onwuka, T. N. and Okeye, N. H. (2013). Pulp and Paper Making Potential of Palmyra Fruit Fiber *Borassus Flabelifar*. *Der Chemical Sinica*, 4.
- Omotosho, O. O., Mamza, P. A. P. and Abba, H. (2018). Characterization and properties of rice husk ash & saw dust ash reinforced epoxy hybrid composite .*Nigeria Journal of Polymer Science and Technology*, 13, 44-54
- Pizzi, A. 2003a: Urea-formaldehyde adhesives. Pizzi A., Mittal K. L. (Ed.) Handbook of adhesive technology. Second edition (613-631) Marcel Dekker Inc., New York, 1024.
- Sarkodie, A. J., Squire, A. S., Kretchy, A. I. (2015). *Borassus aethiopum*, A Potential Medicinal Source of Antioxidants, Anti-Inflammatory and Antimicrobial Agents. *Herbal Medicine*, 2(1).
- Sharma, N., Sharma, S., Guleria, S. P. and Batra, N. K. (2015). Mechanical Properties of Urea Formaldehyde Resin Composites Reinforced with Bamboo, Coconut and Glass Fibres. *International Journal of Soft Computing and Engineering*, 5(2), 66-71
- Srinivasababu, N., Kumarb, J. S. and Reddyc, K. V. K. (2014). Manufacturing and Characterization of Long Palmyra Palm/ *Borassus Flabellifer* Petiole Fibre Reinforced Polyester Composites. *Procedia Technology*, 14, 252 – 259
- Svetlana, B., Ossi M. and Timo, K. (2011). Properties of wood fibre-polypropylene composites: effect of wood fibre source. *Applied composites materials*. 18, 101-111
- Tay, C. C., Mohd, S. O. and Sinin, H. (2013). Water Absorption and Thickness Swelling Behavior of Sago Particles Urea Formaldehyde Particleboard. *International Journal of Science and Research* 3, 358