A Preliminary Study on Chemical and Physical Properties of Coconut Shell Powder as an Enhancer in Building Ceilings for Construction Industry: A Mini Review

J O Dirisu1*, O S I Fayomi1,2, S O Oyedepo1 and E T Akinlabi3
1Department of Mechanical Engineering, Covenant University. P.M.B 1023, Ota, Ogun State, Nigeria
2Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, P.M.B. X680, Pretoria, South Africa.
3Department of Mechanical Engineering Science, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa

*joseph.dirisu@covenantuniversity.edu.ng; ojosundayfayomi3@gmail.com

Abstract. It is necessary to carry out study on the historical behaviour of coconut shell (CS) on different kind of materials so as to appraise its potential in utilizing industrial waste for building ceiling. A study of the characteristics of coconut shell as an additive on metals and materials as reported in literature will help forecast its performance on service. The trend of waste to wealth, smart manufacturing and eco-friendliness of product have been a focal area of research to proffer an enabling environment and enhanced lifestyle for human. This paper therefore explores the potential of this agro waste, its thermo-mechanical properties, chemical composition and its application to the industry.

Keywords: coconut shell, ceiling, manufacturing, eco-friendliness, thermos-mechanical

1. Introduction
The study of agricultural and industrial waste utilization in research community is progressive with the wave of technological development. The advantages are not farfetched such as utilizing land mass that are supposed to be occupied by these waste, pollution reduction, enhanced human and aquatic lives, economic prosperity due to job creation and fuel efficiency in the automobile industry. A waste is a material considered to be unusable and thus discarded. The method of disposal may be discriminate or indiscriminate [1]. A waste can be eco-friendly or hazardous. It is eco-friendly if it is not harmful to the eco-system and human. It is also biodegradable such as agricultural wastes. It is hazardous if it is ignitable, corrosive, toxic and reactive. Ignitable type can be a liquid with a flash point ranging to 140°F [2]. It can be a solid type if it burns vigorously and has a spontaneous ignition. Corrosive waste is acidic which attack steel grades reducing its service life [3]. Reactive type is exothermic in nature and will become violent when it interacts with water releasing toxic gasses. Toxic type will contain undesirable elements such as lead and benzene in water that is consumed eco-habitats [4-5].

Waste emanates from activity of man due to negligent of its proper disposal, management and utilization. Activities such as venting off industrial effluent to the atmosphere without the practice of effluent treatment and recyclability [6]. This currently occurs in area where industries are situated within domestic settlements causing inhalation of these noxious gasses. The ripple effect will be unwelcome ailment in the organs of humans and shorten life expectancy. Here there is a direct understanding that while steel degrade, human and aquatic lives also degrade per time due to indiscriminate disposal of hazardous waste. The emission from vehicles that have reached its salvage value and should be banned
but allowed to operate due to weak enforcement of law will also contribute to hazardous waste contribution to the atmosphere thus reducing the oxygen level meant to sustain the ecosystem. Activities such as the use of generators in countries with poor energy system, poor housekeeping, slags from metal casting, oil spillage, pesticide can amongst others are donors to waste in our environment [7-8].

2. Waste management, Conversion and Utilization

Waste management is the conscious habit of waste utilization and waste conversion [9]. Waste management comes to fore to as a result of the challenge of abundant agro-industrial waste that are needed to be downsized so as not to infect the eco-environmental system. The environment is relieved of waste settlement and pathogen explosion [10-12]. Zacho and Mosgaard [14] pointed attention to the fact that waste can be reduced effectively when individual is engaged in making it their duties and responsibilities. An aspect of waste management spotted out is recycling [15-18]. Municipal solid waste management becomes a challenge if there is land scarcity, population growth, insufficient expertise and inadequate infrastructure [19-27]. Agricultural waste provides a waste utilization prospect [28-29]. Agro waste such as rice husk, coconut shell, sugarcane straw, corn cob, wheat straw amongst others were used to produce bioethanol [30-32]. Agricultural waste was used for the following: to remove heavy metal by the application wall nut [33-34]; removal of dye and activated carbon preparation [35]; removal of chromium (VI) from aqueous solution [36-37]; enzyme production [38-39]; building construction [40]; green coconut wax was used as a flame retardant in textile industry [41].

2.1 Coconut fibre and its thermomechanical characteristics

Coconut, cocos nucifera, is a tropical fruit consumed in many countries [42-47,84,86-87,94]. Figure 1 below shows coconut, its shell and fibre. Its profile is composed of lignin and cellulose. Its usefulness in the medical field gave it a name called tree of life. It is useful as an antibiotic, an antioxidant [48], an antiviral, has an antifungal effect, used as a lotion, toothache repellent and diabetes inhibitor. It serves as a better biodiesel than conventional diesel [49-50,88]. Coconut waste was used to remove methyl blue from aqueous solution [51-52]. Every part of coconut is utilisable such as the strand, meat, water and the shell. Coconut water is a vital growth supplement [53,85] used by plant scientists and health practitioners [54]. Coconut shell, an agro waste, shows a better compressive strength than palm kernel when mixed with concrete according to Olanipekun et al. [55]. It was recommended by Gunasekaran et al. [56] as an aggregate for concrete pipe due to its appreciable test pressure compared to conventional concrete pipe [57-58]. Coconut shell is proven to bond well with cement paste [59-60]. The tensile and flexural strength of coconut filler increase as the percentage weight is increased [61-63]. Coconut shell improves the tensile properties of polyester composite while snail shell showed a better thermal stability when compared together under similar condition [64-66]. There was improvement in thermal stability of carbon black produced from coconut shell compared to epoxy resin without additive [67-69]. The size, shape, volume content and chemical composition of fillers such as coconut shell influence the mechanical properties such as stiffness, deformability, strain energy and elasticity of developed composite material [70-71]. Strength and impact energy were inversely proportional as the volume of coconut filler was increased in epoxy matrix [72,89-90,92]. Treated unsaturated polyester (USP) with treated coconut shell using sodium hydroxide (NaOH) showed a higher strength than untreated USP. Coconut shell powder interaction with epoxy resin and Twaron CT716 fabric is paving way as a ballistic reinforcement due to light weight, improved strength and high energy absorption [73]. Coconut shell powder was reported to increase the glass transition temperature and also enhanced thermal stability of polylactic acid biocomposites [63]. Coconut shell powder with 30% mixture served as a filler to ultrahigh molecular weight polyethylene yielding good toughness [74]. The toughness of a brittle material such as polyester and resin can be improved by the introduction of filler such as coconut powder. The mechanical properties of the composite material strongly dependent on the orientation of the fibre or filler. This has impact on the modulus of elasticity, failure stress and maximum strain [75,93]. Filler serves as an enhancer to the mechanical and physical properties of materials expected to perform remarkably at a preferred condition [76].
3. Chemical properties of coconut fibres with application

In order to study the character of a material, we need to study its behaviour at microscopic stage where the electron can only be detected by powerful equipment such as the scanning electron microscope (SEM). There was enhanced interfacial interaction and wettability between coconut shell and unsaturated saturated polyester as studied under SEM [77]. There was reported good interfacial interaction between coconut shell fibre and epoxy resin [78,72,79,91]. Poor interfacial interaction between coconut particle and low density polyethene matrix occur using maximum of 25% of the composite this resulted to reduced mechanical strength [80]. Coconut ash was observed to have similar chemical characteristics with fly ash and rice husk [81]. The mesocarp of cocos nucifera finds its usefulness in the synthesis of silver nanoparticle that can be used as an insecticide [82]. Silicone oxide was extracted from coconut husk which showed up to 11% content in the husk and up to 90% when treated with chemical [83].

Conclusion

Reinforcement of base material with filler served as an enhancer to the mechanical properties and aesthetic outlook of composites. The strength of composites using coconut shell as reinforcement is influenced by the size and orientation of the fibre. The mixing ratio of coconut shell should be delimited at marginal percentage so as not to support combustion. The mechanical and bond properties of coconut fibres make it a potential filler for building ceiling composite. An in-depth study of the thermal and combustion characteristics of the specific coconut fibre and its composites is necessary to infer its suitability in building industries.

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References

[1] Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science, 347*(6223), 768-771.

[2] LaGrega, M. D., Buckingham, P. L., & Evans, J. C. (2010). *Hazardous waste management*. Waveland Press

[3] Fayomi, O. S. I. (2015). Chemical interaction, interfacial effect and the microstructural characterization of the induced zinc–aluminum–Solanum tuberosum in chloride solution on mild steel. *Research on Chemical Intermediates, 41*(4), 2393-2405

[4] Blackman Jr, W. C. (2016). *Basic hazardous waste management*. Crc Press.

[5] Dirisu, J. O., Oyedepo, S. O., Fayomi, O. S. I., Okokpujie, I. P., Asere, A. A., Oyekunle, J. A., & Abioye, A. A. (2018). Effects of Emission Characteristics on Elemental Composition of Selected PVC Ceiling Materials. *Materials Focus, 7*(4), 566-572.

[6] Rhyner, C. R., Schwartz, L. J., Wenger, R. B., & Kohrell, M. G. (2017). *Waste management and resource recovery*. CRC Press.

[7] Zeng, X., Duan, H., Wang, F., & Li, J. (2017). Examining environmental management of e-waste: China's experience and lessons. *Renewable and Sustainable Energy Reviews, 72*, 1076-1082.

[8] Zeng, X., Yang, C., Chiang, J. F., & Li, J. (2017). Innovating e-waste management: From macroscopic to microscopic scales. *Science of the Total Environment, 575*, 1-5.

[9] Yeomans, J. S., & Huang, G. H. (2015). An evolutionary grey, hop, skip, and jump approach: generating alternative policies for the expansion of waste management. *Journal of Environmental Informatics, 1*(1), 37-51.

[10] Chauhan, A., & Singh, A. (2016). Healthcare waste management: a state-of-the-art literature review. *International Journal of Environment and Waste Management, 18*(2), 120-144.

[11] Ziraba, A. K., Haregu, T. N., & Mberu, B. (2016). A review and framework for understanding the potential impact of poor solid waste management on health in developing countries. *Archives of Public Health, 74*(1), 55.

[12] Hossain, M. S., Santhanam, A., Norulaini, N. N., & Omar, A. M. (2011). Clinical solid waste management practices and its impact on human health and environment–A review. *Waste management, 31*(4), 754-766.

[13] Nemathaga, F., Maringa, S., & Chimuka, L. (2008). Hospital solid waste management practices in Limpopo Province, South Africa: A case study of two hospitals. *Waste management, 28*(7), 1236-1245.

[14] Zacho, K. O., & Mosgaard, M. A. (2016). Understanding the role of waste prevention in local waste management: A literature review. *Waste Management & Research, 34*(10), 980-994.

[15] Ervasti, I., Miranda, R., & Kauranen, I. (2016). A global, comprehensive review of literature related to paper recycling: A pressing need for a uniform system of terms and definitions. *Waste management, 48*, 64-71.

[16] Sadef, Y., Nizami, A. S., Batool, S. A., Chaudary, M. N., Ouda, O. K. M., Asam, Z. Z., ... & Demirbas, A. (2016). Waste-to-energy and recycling value for developing integrated solid waste management plan in Lahore. *Energy Sources, Part B: Economics, Planning, and Policy, 11*(7), 569-579.

[17] Shrivastava, P., Mishra, S., & Katiyar, S. K. (2015, December). A Review of Solid Waste Management Techniques using GIS and Other Technologies. In *2015 International Conference on Computational Intelligence and Communication Networks (CICN)* (pp. 1456-1459). IEEE.

[18] Yong, J. Y., Klemeš, J. J., Varbanov, P. S., & Huisingh, D. (2016). Cleaner energy for cleaner production: modelling, simulation, optimisation and waste management. *Journal of Cleaner Production, 111*, 1-16.

[19] Pokhrel, D., & Viraraghavan, T. (2005). Municipal solid waste management in Nepal: practices and challenges. *Waste Management, 25*(5), 555-562.

[20] Metin, E., Eröztürk, A., & Neyim, C. (2003). Solid waste management practices and review of recovery and recycling operations in Turkey. *Waste management, 23*(5), 425-432.
[21] Hazra, T., & Goel, S. (2009). Solid waste management in Kolkata, India: Practices and challenges. Waste management, 29(1), 470-478.
[22] Guerrero, L. A., Maas, G., & Hogland, W. (2013). Solid waste management challenges for cities in developing countries. Waste management, 33(1), 220-232.
[23] Al-Khatib, I. A., Monou, M., Zahra, A. S. F. A., Shaheen, H. Q., & Kassinos, D. (2010). Solid waste characterization, quantification and management practices in developing countries. A case study: Nablus district–Palestine. Journal of environmental management, 91(5), 1131-1138.
[24] Kofoworola, O. F. (2007). Recovery and recycling practices in municipal solid waste management in Lagos, Nigeria. Waste management, 27(9), 1139-1143.
[25] Jin, J., Wang, Z., & Ran, S. (2006). Solid waste management in Macao: practices and challenges. Waste management, 26(9), 1045-1051.
[26] Tozlu, A., Özahi, E., & Abuşoğlu, A. (2016). Waste to energy technologies for municipal solid waste management in Gaziantep. Renewable and Sustainable Energy Reviews, 54, 809-815.
[27] Wallace, T., Gibbons, D., O'Dwyer, M., & Curran, T. P. (2017). International evolution of fat, oil and grease (FOG) waste management – A review. Journal of environmental management, 187, 424-435.
[28] Eriksson, M., Strid, I., & Hansson, P. A. (2015). Carbon footprint of food waste management options in the waste hierarchy–a Swedish case study. Journal of Cleaner Production, 93, 115-125.
[29] Salesmdeeb, R., zu Ermgassen, E. K., Kim, M. H., Balmford, A., & Al-Tabbaa, A. (2017). Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options. Journal of cleaner production, 140, 871-880.
[30] Sarkar, N., Ghosh, S. K., Bannerjee, S., & Aikat, K. (2012). Bioethanol production from agricultural wastes: an overview. Renewable energy, 37(1), 19-27.
[31] Paredes, C., Bernal, M. P., Cegarra, J., & Roig, A. (2002). Bio-degradation of olive mill wastewater sludge by its co-composting with agricultural wastes. Bioresource Technology, 85(1), 1-8.
[32] Najafi, G., Ghobadian, B., Tavakoli, T., & Yusaf, T. (2009). Potential of bioethanol production from agricultural wastes in Iran. Renewable and Sustainable Energy Reviews, 13(6-7), 1418-1427.
[33] Orhan, Y., & Büyükgüngör, H. (1993). The removal of heavy metals by using agricultural wastes. Water Science and Technology, 28(2), 247-255.
[34] Khan, N. A., Ibrahim, S., & Subramaniam, P. (2004). Elimination of heavy metals from wastewater using agricultural wastes as adsorbents. Malaysian Journal of Science, 23(1), 43-51.
[35] Kadirvelu, K., Kavipriya, M., Karthika, C., Radhika, M., Venilamani, N., & Pattabhi, S. (2003). Utilization of various agricultural wastes for activated carbon preparation and application for the removal of dyes and metal ions from aqueous solutions. Bioresource technology, 87(1), 129-132.
[36] Demirbas, E., Koby, M., Senturk, E., & Ozkan, T. (2004). Adsorption kinetics for the removal of chromium (VI) from aqueous solutions on the activated carbons prepared from agricultural wastes. Water Sa, 30(4), 533-539.
[37] Kulcu, R., & Yaldiz, O. (2004). Determination of aeration rate and kinetics of composting some agricultural wastes. Bioresource Technology, 93(1), 49-57.
[38] Jecu, L. (2000). Solid state fermentation of agricultural wastes for endoglucanaseproduction. Industrial Crops and Products, 11(1), 1-5.
[39] Akpinar, O., Erdogan, K., & Bostanci, S. (2009). Enzymatic production of xylooligosaccharide from selected agricultural wastes. Food and Bioproducts Processing, 87(2), 145-151.
[40] Joshua, O., Olusola, K. O., Busari, A. A., Omuh, I. O., Ogunde, A., Amusan, L. M., & Ezenduka, C. J. (2018). Dataset on investigating for pozzolanic activity in coconut shell ash (CSA) towards a sustainable construction. Data in Brief.
[41] Teli, M. D., Pandit, P., & Basak, S. (2018). Coconut shell extract imparting multifunction properties to ligno-cellulosic material. Journal of Industrial Textiles, 47(6), 1261-1290.
[42] Rodrigues, S., & Pinto, G. A. (2007). Ultrasound extraction of phenolic compounds from coconut (Cocos nucifera) shell powder. *Journal of Food Engineering, 80*(3), 869-872.

[43] Rodrigues, S., Pinto, G. A., & Fernandes, F. A. (2008). Optimization of ultrasound extraction of phenolic compounds from coconut (Cocos nucifera) shell powder by response surface methodology. *Ultrasonics Sonochemistry, 15*(1), 95-100.

[44] Liyanage, C. D., & Pieris, M. (2015). A physico-chemical analysis of coconut shell powder. *Procedia Chemistry, 16*, 222-228.

[45] Solangi, A. H., & Iqbal, M. Z. (2011). Chemical composition of meat (kernel) and nut water of major coconut (Cocos nucifera L.) cultivars at coastal area of Pakistan. *Pak. J. Bot, 43*(1), 357-363.

[46] Amoo, I. A. (2004). Effect of roasting on the chemical composition of coconut (Cocos nucifera) seed flour and oil. *Journal of Food, Agriculture and Environment, 2*(3), 18-20.

[47] Jackson, J. C., Gordon, A., Wizzard, G., McCook, K., & Rolle, R. (2004). Changes in chemical composition of coconut (Cocos nucifera) water during maturation of the fruit. *Journal of the Science of Food and Agriculture, 84*(9), 1049-1052.

[48] Fonseca, A. M. D., Bizerra, A., Souza, J. S. N. D., Monte, F. J. Q., Oliveira, M. D. C. F. D., Mattos, M. C. D., & Lemos, T. L. (2009). Constituents and antioxidant activity of two varieties of coconut water (Cocos nucifera L.). *Revista Brasileira de Farmacognosia, 19*(1B), 193-198.

[49] DebMandal, M., & Mandal, S. (2011). Coconut (Cocos nucifera L.: Arecaceae): in health promotion and disease prevention. *Asian Pacific Journal of Tropical Medicine, 4*(3), 241-247.

[50] Sundaram, E. G., & Natarajan, E. (2009). Pyrolysis of coconut shell: An experimental investigation. *The Journal of Engineering Research [TJER], 6*(2), 33-39.

[51] Hameed, B. H., Mahmoud, D. K., & Ahmad, A. L. (2008). Equilibrium modeling and kinetic studies on the adsorption of basic dye by a low-cost adsorbent: Coconut (Cocos nucifera) bunch waste. *Journal of Hazardous Materials, 158*(1), 65-72.

[52] Din, A. T. M., Hameed, B. H., & Ahmad, A. L. (2009). Batch adsorption of phenol onto physiochemical-activated coconut shell. *Journal of Hazardous Materials, 161*(2-3), 1522-1529.

[53] Assa, R. R., Konan, J. K., Prades, A., Nemlin, J., & Koffi, E. (2010). Physicochemical characteristics of kernel during fruit maturation of four coconut cultivars (Cocos nucifera L.). *African Journal of Biotechnology, 9*(14), 2136-2144.

[54] Yong, J. W., Ge, L., Ng, Y. F., & Tan, S. N. (2009). The chemical composition and biological properties of coconut (Cocos nucifera L.) water. *Molecules, 14*(12), 5144-5164.

[55] Olanipekun, E. A., K. O. Olusola, and O. Ata. "A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates." *Building and environment* 41.3 (2006): 297-301.

[56] Gunasekaran, K., Kumar, P. S., & Lakshmipathy, M. (2011). Mechanical and bond properties of coconut shell concrete. *Construction and building materials, 25*(1), 92-98.

[57] Kanooja, A., & Jain, S. K. (2017). Performance of coconut shell as coarse aggregate in concrete. *Construction and Building Materials, 140*, 150-156.

[58] Gunasekaran, K., Annadurai, R., Chandar, S. P., & Anandh, S. (2017). Study for the relevance of coconut shell aggregate concrete non-pressure pipe. *Ain Shams Engineering Journal, 8*(4), 523-530.

[59] Gunasekaran, K., Annadurai, R., & Kumar, P. S. (2012). Long term study on compressive and bond strength of coconut shell aggregate concrete. *Construction and Building Materials, 28*(1), 208-215.

[60] Gunasekaran, K., Annadurai, R., & Kumar, P. S. (2015). A study on some durability properties of coconut shell aggregate concrete. *Materials and Structures, 48*(5), 1253-1264.

[61] Sapuan, S. M., Harimian, M., & Maleque, M. A. (2003). Mechanical properties of epoxy/coconut shell filler particle composites. *Arabian Journal for Science and Engineering, 28*(2), 171-182.

[62] Bledzki, A. K., Mamun, A. A., & Volk, J. (2010). Barley husk and coconut shell reinforced polypropylene composites: the effect of fibre physical, chemical and surface properties. *Composites Science and Technology, 70*(5), 840-846.
[63] Chun, K. S., Husseinsyah, S., & Osman, H. (2012). Mechanical and thermal properties of coconut shell powder filled polylactic acid biocomposites: effects of the filler content and silane coupling agent. *Journal of Polymer Research, 19*(5), 9859.

[64] Adeosun, S. O., Akpan, E. I., & Akanegbu, H. A. (2015). Thermo-mechanical properties of unsaturated polyester reinforced with coconut and snail shells. *International Journal of Composite Materials, 5*(3), 52-64.

[65] Adeosun, S. O., Gbenebor, O. P., Akpan, E. I., & Udeeme, F. A. (2016). Influence of organic fillers on physicochemical and mechanical properties of unsaturated polyester composites. *Arabian Journal for Science and Engineering, 41*(10), 4153-4159.

[66] Abdul Khalil, H. P. S., Jawaid, M., Firoozian, P., Zainudin, E. S., & Paridah, M. T. (2013). Dynamic mechanical properties of activated carbon–filled epoxy nanocomposites. *International Journal of Polymer Analysis and Characterization, 18*(4), 247-256.

[67] Khalil, H. A., Firoozian, P., Bakare, I. O., Akil, H. M., & Noor, A. M. (2010). Exploring biomass based carbon black as filler in epoxy composites: Flexural and thermal properties. *Materials & Design, 31*(7), 3419-3425.

[68] Mantia, F. L., Morreale, M., & Ishak, Z. M. (2005). Processing and mechanical properties of organic filler–polypropylene composites. *Journal of applied polymer science, 96*(5), 1906-1913.

[69] Tongpoothorn, W., Sritutta, M., Homehan, P., Chanthai, S., & Ruangviriyachai, C. (2011). Preparation of activated carbon derived from Jatropha curcas fruit shell by simple thermo-chemical activation and characterization of their physico-chemical properties. *Chemical engineering research and design, 89*(3), 335-340.

[70] Sajith, S., Arumugam, V., & Dhakal, H. N. (2017). Comparison on mechanical properties of lignocellulosic flour epoxy composites prepared by using coconut shell, rice husk and teakwood as fillers. *Polymer Testing, 58*, 60-69.

[71] Singh, A., Singh, S., & Kumar, A. (2013). Study of mechanical properties and absorption behaviour of coconut shell powder-epoxy composites. *International Journal of Materials Science and Applications, 2*(5), 157-161.

[72] Akindapo, J. O., Harrison, A., & Sanusi, O. M. (2014). Evaluation of mechanical properties of coconut shell fibres as reinforcement material in epoxy matrix. *International Journal of Engineering Research & Technology (IJERT), 3*(2), 2337-2348.

[73] Risby, M. S., Wong, S. V., Hamouda, A. M. S., Khairul, A. R., & Elsadig, M. (2008). Ballistic Performance of Coconut Shell Powder/Twaron FabricAgainst Non-armour Piercing Projectiles. *Defence Science Journal, 58*(2), 248-263.

[74] Pradhan, S. K., Dwarakadasa, E. S., & Reucroft, P. J. (2004). Processing and characterization of coconut shell powder filled UHMWPE. *Materials Science and Engineering: A, 367*(1-2), 57-62.

[75] Retnam, B. S. J., Sivapragash, M., & Pradeep, P. (2013). Effect of Fiber Orientation and Filler Material on Tensile and Impact Properties of Natural FRP. *European Journal of Scientific Research, 99*, 55-60.

[76] Durowaye, S. I., Lawal, G. I., Akande, M. A., & Durowaye, V. O. (2014). Mechanical properties of particulate coconut shell and palm fruit polyester composites. *Int J Mater Eng, 4*(4), 141-147.

[77] Salmah, H., Marliza, M., & Teh, P. L. (2013). Treated coconut shell reinforced unsaturated polyester composites. *International Journal of Engineering & Technology, 13*(02), 94-103.

[78] Sarki, J., Hassan, S. B., Aigbodion, V. S., & Oghenevweta, J. E. (2011). Potential of using coconut shell particle fillers in eco-composite materials. *Journal of Alloys and Compounds, 509*(5), 2381-2385.

[79] Deshpande, S., & Rangaswamy, T. (2014). Effect of fillers on E-glass/jute fiber reinforced epoxy composites. *Int. Journal of Engineering Research and Applications, 4*(8), 118-123.

[80] Agunsoye, J. O., Isaac, T. S., & Samuel, S. O. (2012). Study of mechanical behaviour of coconut shell reinforced polymer matrix composite. *Journal of materials characterization and Engineering, 11*(8), 774-779.
[81] Madakson, P. B., Yawas, D. S., & Apasi, A. (2012). Characterization of coconut shell ash for potential utilization in metal matrix composites for automotive applications. *International journal of engineering science and technology*, 4(3), 1190-1198.

[82] Roopan, S. M., Madhumitha, G., Rahuman, A. A., Kamaraj, C., Bharathi, A., & Surendra, T. V. (2013). Low-cost and eco-friendly phyto-synthesis of silver nanoparticles using Cocos nucifera coir extract and its larvicidal activity. *Industrial Crops and Products*, 43, 631-635.

[83] Anuar, M. F., Fen, Y. W., Zaid, M. H. M., Matori, K. A., & Khaidir, R. E. M. (2018). Synthesis and structural properties of coconut husk as potential silica source. *Results in Physics*, 11, 1-4.

[84] Santosso, U., Kubo, K., Ota, T., Todokoro, T., & Maekawa, A. (1996). Nutrient composition of kopyor coconuts (Cocos nucifera L.). *Food Chemistry*, 57(2), 299-304.

[85] Abad, M., Noguera, P., Puchades, R., Maquieira, A., & Noguera, V. (2002). Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. *Bioresource technology*, 82(3), 241-245.

[86] Obasi, N. A., Ukadilonu, J., Eze, E., Akubugwo, E. I., & Okorie, U. C. (2012). Proximate composition, extraction, characterization and comparative assessment of coconut (Cocos nucifera) and melon (Cucumis melo L.) seeds and seed oils. *Pakistan Journal of Biological Sciences*, 15(1), 1.

[87] Tan, T. C., Cheng, L. H., Bhat, R., Rusul, G., & Easa, A. M. (2014). Composition, physicochemical properties and thermal inactivation kinetics of polyphenol oxidase and peroxidase from coconut (Cocos nucifera) water obtained from immature, mature and over-mature coconut. *Food Chemistry*, 142, 121-128.

[88] Hasanah, U., Setiaji, B., Triyono, T., & Anwar, C. (2012). The chemical composition and physical properties of the light and heavy tar resulted from coconut shell pyrolysis. *The Journal of Pure and Applied Chemistry Research*, 1(1), 26-32

[89] Sareena, C., Ramesan, M. T., & Purushothaman, E. (2012). Utilization of coconut shell powder as a novel filler in natural rubber. *Journal of Reinforced Plastics and Composites*, 31(8), 533-547.

[90] Güru, M., Atar, M., & Yıldırım, R. (2008). Production of polymer matrix composite particleboard from walnut shell and improvement of its requirements. *Materials & Design*, 29(1), 284-287.

[91] Rahman, M. M., & Khan, M. A. (2007). Surface treatment of coir (Cocos nucifera) fibers and its influence on the fibers’ physico-mechanical properties. *Composites Science and Technology*, 67(11-12), 2369-2376.

[92] Evans, M. R., Konduru, S., & Stamps, R. H. (1996). Source variation in physical and chemical properties of coconut coir dust. *HortScience*, 31(6), 965-967.

[93] Varma, D. S., Varma, M., & Varma, I. K. (1984). Coir fibers: Part I: Effect of physical and chemical treatments on properties. *Textile Research Journal*, 54(12), 827-832.

[94] Deosthale, Y. G. (1981). Trace element composition of common oilseeds. *Journal of the American Oil Chemists Society*, 58(11), 988-990.