THE USE OF RICE HUSK FOR BUILDING RESILIENT INFRASTRUCTURE FOR SUSTAINABLE INDUSTRIALIZATION

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Abstract

Increasing interest and focus is given to agro-based materials in recent years owing to environmental awareness and economic considerations. The desire for a bio-based society with sustainable products and transformative solutions to engineering problems as relating to renewable energy and no waste policy is evident. This paper discussed the use of rice husk as a reinforcing material for composites and their potential applications as substitutes in engineering manufacture. Samples of rice husk were sourced from mills in Kakuri (Kaduna State), Obudu (Cross River State) and Kwakuti (Niger State). X-Ray Fluorescence analysis of the samples showed that the percentage composition of the rice husk varied according to varying location with silicon oxide being the predominant compound. The sample obtained from Kwakuti exhibited the highest silica content of 70.30% among the tested samples. FTIR analysis on the three samples also showed that the band were located in similar range for the wave numbers. The band at 3425cm^{-1} assigned to O – H stretch of the hydroxyl groups (adsorbed water) showed that the samples possessed hydrophilic properties.

Keywords: Rice Husk, Chemical Treatment, Silica, X-Ray Fluorescence

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1.0 INTRODUCTION

Researches are currently carried out in favour of no waste policy which is being practiced by most industrialized nations who ensure that the life cycle of engineering products are always designed to favour man and the environment. These wastes can broadly be agro-based or petro-based. The consequence of not adopting green materials in our society today cannot be overemphasized. The effect of this phenomenon will make the earth in years to come inhabitable for man due to climate change and environmental impacts of utilizing non-sustainable and non-biodegradable petro-based materials. Apart from environmental and material sustainability concerns, economic and profitability requirement of engineering products are also crucial. Researchers have reported that the utilization of agro wastes and biomaterials in general is anticipated to be the emerging engineering materials not only from the technological and scientific point of view, but also from the social, economic and environment perspectives (Dagwa *et. al*, 2012). The problems associated with waste management and utilization of non-sustainable environmentally toxic materials in engineering manufacture today raises much concern leading to the need for researching into better ways of enhancing sustainability as evident in the Sustainable Development Goals (SDGs) set by the United Nations. The current need for having viable alternatives to moving Nigeria away from its present mono-industry economy has prompted the Nigerian government to encourage activities in the agricultural sector such as the cultivation of rice and setting up of integrated rice mills, especially through the offer of credit assistance to the rice segment of the economy via the anchor borrowers' programme. These efforts taken to increase rice production, processing and storage capacities over time poses the problem of managing waste that will arise from the mills. This rising investment in rice production translates to an increase in agricultural waste in the form of rice husk which can become a menace, lead to environmental problems and health hazards if not properly managed. Rice husk when burnt on farmlands poses serious threats to the earth and its inhabitants such as producing carbon dioxide from open air combustion and methane a flammable substance when left to degrade on the earth.

The drive for a sustainable society in our fast growing world cannot be over emphasized. Each day, so long as man exists, he must feed. Food which is a product of agriculture churns out a lot of waste during harvesting and processing stage. Adedeji *et al*. (2016) in their research on "Growth Trend Analysis of Rice Productivity in Nigeria" reported that the rate of productivity growth of rice has been on the increase annually. Knowing that agricultural wastes cannot be left unattended to, man's decisions on how these wastes are managed and disposed needs to be addressed, hence the need to foster sustainability of such wastes.

Rice husk which surrounds paddy grain is a by-product generated during rice milling process. Lim *et al*. (2012) reported that for each tonne of rice milled, approximately 0.23 tonnes of rice husk is produced. The milling process results in 78 percent weight of rice, broken rice and bran. The remaining 22 percent of the paddy's weight is obtained as rice husk. The husk in most cases serves as a source of fuel for rice mills to generate steam for the parboiling process. According to Magale *et al*. (2011), for every 4 tonnes of rice, 1 tonne of rice husks is yielded. Rice husks constitute about 75 percent organic volatile matter with the balance 25 percent of the husk's weight being converted to ash during the firing process and is known as rice husk ash. Rice hush ash (RHA) contains approximately 85 to 90 percent amorphous silica. Therefore, for every 1000 Kg of paddy milled, about 220 Kg (22 percent) of husk is produced and when this husk is burnt, in the boiler, it produces about 55 Kg (25 percent) of rice husk ash and 47 to 50 Kg (21 to 23 percent) of amorphous silica.

Jonathan (2017) reported that about 7 million metric tonnes of rice is consumed each year in Nigeria with the local production of rice being approximately 3.9 million metric tonnes. It is realistic to note that the local production of paddy in Nigeria in the last few months has increased by over 2 million metric tonnes, owing to the renewed efforts of government and private sectors towards the sustainable increase of rice production in Nigeria and agricultural development in general. Annual rice production in Nigeria as presented by the Food and Agriculture Organization (FAO) of the United Nations is on the increase. The global level of production and utilization of rice has been on a steady increase since the year 2008 from reports.

The paddy production capacity of West Africa in 2018 was forecasted to be 18.3 million tonnes. In the West African sub-region, Nigeria is the largest producer of rice as reported by the FAO in her April 2018 Rice Market Monitor (RMM) bulletin. The country's self-sufficiency drive is responsible for the increased paddy output in Nigeria which has progressed by 12 percent from 6.3 million tonnes (3.8 million tonnes, milled basis) to reach a total of 7.0 million tonnes (4.2 million tonnes, milled basis) in 2017. FAO forecasted that Nigeria will harvest 7.2 million tonnes (4.3 million tonnes, milled basis) in 2018, up to 3 percent annual increment. Figure 1 illustrates the Nigeria paddy production capacity and area in hectares.

Owing to the emerging uses of rice husk as an engineering material, it is being referred to in recent times as an industrial agricultural residue of importance (Magale *et al*., 2011) rather than a waste. Several works have reported the suitability and utilization of rice husk as biomass in energy generation (Nian-Lu *et al*., 2013), semi-conductors, solar panels and Li-ion battery anodes (Ghassan and Hilmi, 2010), manufacture of ceramics and high strength concrete as rice husk in concretes makes its stronger and more resistant to corrosion. The silica obtained from rice husk which is fundamental raw material can be utilized in industries associated with rubber, ceramics, electronics, and catalysis, pharmaceutical, dental and other applications where the use of silica is pertinent (Dongre *et al*., 2014).

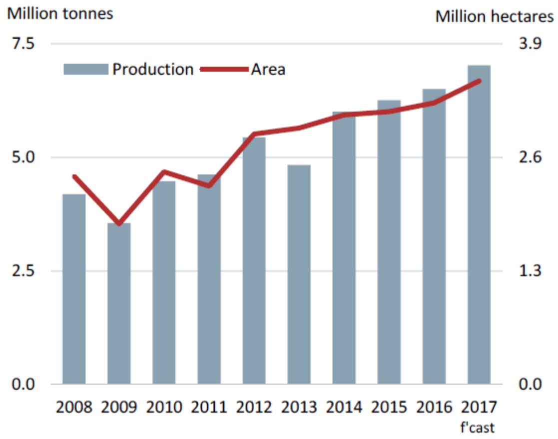

Figure 1: Nigeria's Paddy Production and Area
Source: FAO-RMM April 2018 Report

1.1 Need for Rice Husked Filled Reinforced Composites.

With growing efforts and drive towards boosting the agricultural sector in Nigeria, especially with the set-up of modern rice mills and farms, there is need to harness and properly manage the residue that will accrue from the activities to prevent any forms of environmental degradation that can result from such set ups. A common way of managing the wastes from agricultural residues is to use rice husk as filler materials in composites in its ash form or treated forms depending on the intended area of application of the product. Composites are developed by the combination of two or more materials to enhance the properties of the individual material used to form the composite. When any of the individual material is obtained from a biological source, the combination resulting in the new material is termed a biocomposite (Reza *et al.*, 2015; Fowler *et al.*, 2006).

The desire to domesticate manufacture of engineering components in Nigeria and to also foster a drive towards sustaining a bio-centred society where materials utilized are environmentally favourable is a subject of paramount interest. It is very necessary to strengthen and stabilize the growth of the Nigerian manufacturing industries through machine parts development using indigenous technologies and locally viable materials which yield import substitution products while establishing future investments strategy.

Channeling efforts towards using agricultural residues such as rice husk in promotion of indigenous technology and domesticating the manufacture of most engineering components used in the building, manufacturing, electronics, automobile, oil and gas industries will aid the sustenance of a friendly environment and also boost the economy of Nigeria.

This paper hopes to compliment various findings from investigations conducted in relation to the use of bio-based fillers in a matrix of waste polymers as substitutes for engineering materials. Conventional polymer composites have non-biodegradable characteristics and are harmful to man therefore utilizing bio-based fillers and matrix which are eco-friendly allows several issues relating to the environment to be solved.

Sustainability requirement of engineering materials is no longer restricted to metals, ceramics and polymers alone. The world today is in search of not just eco-friendly materials but also materials that are sustainable in every way that can satisfy the requirements of man. This is evident in United Nations (UN) Sustainable Development Goals (SDGs) of year 2030 Agenda for sustainable development adopted at the UN world summit in September 2015.

1.2 Treatment of Rice Husk for Use as a Reinforcement Material

It has been reported from various studies that natural fibres used as fillers in composites usually exhibit poor mechanical and physical properties if not chemically treated with appropriate concentration and reagent. The chemical treatment helps to reduce improve properties of the composite by reducing to minimum the lignin and hemicellulose components of natural fibres thereby improving the interfacial interaction between the filler and matrix thus increasing the bond strength. Rice husk lies within the category of fillers that possess hydrophilic properties and needs to be chemically treated to improve bonding characteristic needed for the desired composites' functionality. Treatment of rice husk has been reported to improve the filler to matrix interfacial interaction of resulting composites and also improve the quality of silica content produced by reducing carbonaceous materials. Treated rice husk has been utilized in several applications to improve the mechanical properties of composites due to its intrinsic silica content (Reza *et al.*, 2015; Kumagai and Matsuo, 2013). Syed *et al.* (2009) reported that in order to improve the marketability of rice husk ash as a product, it has to possess more amorphous silica than crystal silica that can be used as a filler in polymeric and ceramic composites.
Amorphous silica of high purity, small particle size and high surface area has tremendous potential as an adsorbent and catalyst support in different chemical synthesis. In order to prepare amorphous silica of high purity, treatment of rice husk with various chemicals before and after combustion was attempted in many previous works. In combustion processes, silica is usually made available either as lechatelerite (amorphous form) or as cristobalite (crystalline form). Javed *et al.*

(2010) stated that to obtain high purity amorphous silica, rice husks needs to undergo chemical treatment.

Rice husk ash is a more marketable product if it has more amorphous silica than crystalline silica, also high purity amorphous silica possessing minute particle size and high surface area have been reported to have excellent potential as an adsorbent. Crystalline silica is less reactive and proclaimed carcinogenic. Amorphous silica is more reactive and posses no harmful effect (Patil *et al*., 2014). Rohani *et al*. (2016) produced high purity amorphous silica (SiO_2) with particle sizes ranging from 0.50 μm to 0.70 μm from rice husk. They investigated the effect of burning same on quality of silica produced, for temperature ranges between 500^{o}C to 900^{o}C. They reported that the effect of the temperatures on production of silica was very little especially for temperatures above 600^{o}C and that amorphous silica of high purity of over 99% was obtained under controlled burning conditions at 600^{o}C for 2 hours. They also stated that pre-treatment of rice husk was beneficial to the quality of amorphous silica produced.
Chandrasekhar *et al*. (2003), Reddy and Marcelina (2006), Zhang and Malhotra (1996) stated that the burning of rice husk at controlled temperature below 800^{o}C results in ash with silica majorly in its amorphous form. Nair et al. (2008) reported from their investigations that rice husk samples burnt at a temperature of 500^{o}C or 700^{o}C not exceeding 12 hours yielded ashes with no significant amount of crystalline silica. They also reported that samples with short burning time between 15 to 360 minutes produced rice husk ash that was high in carbon content despite the high incinerating temperature of 500^{o}C to 700^{o}C. According to Costa et al. (2003), the burning of rice husks yields either white rice hush ash having a very high silica content or black rice husk ash with low silica content. The variation is due to the combustion conditions. Excessive temperature or long residence time always leads to a fused crystallized matter having no useful properties.

Several works have recommended mercerization as an effective means of modifying cellulosic content in natural fibre (rice husk inclusive) thereby enhancing their interfacial interaction and bond strength with their matrix in composites. Dicker *et al.* (2014) stated that the most commonly used alkali in mercerization is sodium hydroxide (NaOH) or potassium hydroxide (KOH). However, this recommendations may not hold for all natural fibres as emerging researches show varying properties for natural fibres treated with different concentrations of NaOH. Ndazi *et al.* (2007) reported chemical modification of rice husk using sodium hydroxide solution for the purpose of improving its adhesion and interfacial filler to matrix bonding characteristic of rice husk in composites. From the investigation, they reported a decrease in thermal stability of NaOH treated husk which was an indication of possible degradation of rice husk by the concentrated NaOH used. Unfavourable properties exhibited by NaOH treated rice husks may be as a result of the formation of sodium silicate which is soluble in water and is produced by reaction between the sodium hydroxide and silica in rice husk. According to a study, Zhixuan *et al.* (2016) stated that use of NaOH treatment gives better delignification performance when compared with H_2O_2 pretreatment while combined $NaOH/H_2O_2$ treatment is more effective in the removal of hemicellulose and lignin from the rice husk.
Similarly, Ndazi *et al*. (2007) observed a decrease in silica vibration band with increased sodium hydroxide concentration for treated rice husk samples. They reported that NaOH reacted with silica in rice husk thereby eliminating the silica component of it by degrading the silicon – cellulose membrane during disintegration thus contributing to absence of increasing

OH group's band after alkali treatment. Javed *et al*. (2010) in the treatment of rice husk fibres with 0.001N potassium permanganate ($KMnO_4$) solution reported that FTIR result showed presence of O –Si – O weak bond due to presence of $KMnO_4$. They noted that bands 461cm^{-1} to 476cm^{-1} was assigned to O –Si – O stretching vibration while bands at 3427cm^{-1} to 3636cm^{-1} was due to hydroxyl groups and bands 1632cm^{-1} to 1647cm^{-1} belonging to the C – O group.
They also reported that the bands of high intensity indicates weak bond strength and those with low intensity indicates high bond strength. High stretching and bending vibrations were as a result of weak bonds in O – Si – O. Bending vibrations in O – Si – O are as a result of strong bonds. Furthermore, they noted that low vibration indicated the formation of crystals in ashes obtained with increased bond strength translates to an increase of silica in its crystalline form. Also, Van *et al.* (2014) in a research reported that absorption peaks at 1101cm^{-1}, 944cm^{-1} and 470cm^{-1} implied presence of silica in the sample of which no trace of it was found in the activated carbon they produced from rice husk.

Rahman *et al.* (2010) in their study titled effect of chemical treatment on rice husk reinforced polyethylene composites utilized benzene diazonium salt in acid, alkali and neutral media. Reports from the research showed that rice husk treated in alkaline media at all mixing ratios yielded higher values and better dispersion of filler in the matrix of polyethylene when compared with that of the acidic media having a pH of 6 and the neutral media. They also reported that chemical treatment of rice husk significantly improved mechanical properties of the developed composites.

2.0 Materials and Method

Rice husk samples were been obtained from three different locations in Nigeria. The locations include Obudu in Cross River State, Kwakuti in Niger State and Kakuri in Kaduna State. Samples collected were characterized using X-Ray Fluorescence (XRF) and Fourier Transform Infrared Spectroscopy (FTIRS). Results from the XRF investigation showed that samples had varying amounts of elemental oxides. This variation may be due to location factor, climatic condition, fertilizers used and nature of the soil.

3.0 RESULTS AND DISCUSSION

The XRF result of the samples are presented in Table 1.

Table 1: XRF Results of the Rice Husk Samples

OXIDE (%)	OBUDU RH	KAKURI RH	KWAKUTI RH
SiO_2	43.500	65.440	70.300
Al_2O_3	0.003	0.006	0.001
Fe_2O_3	13.500	9.910	0.100
MgO	2.110	1.040	4.000
CaO	39.000	17.230	18.000
Na_2O	0.600	4.200	0.100
TiO_2	0.080	0.030	0.000
P_2O_5	0.400	0.010	0.980
MnO	0.300	0.020	0.010
K_2O	0.500	2.020	5.600

Physical examination as relating to the colour brightness of the rice husks sourced from the three locations were distinct. The brightness of the rice husks for the 3 different sources in increasing order respectively were Obudu RH, Kakuri RH and Kwakuti RH as shown in Figure 2. The brightness as observed from the physical examination in relation to silica content shows that a brighter rice husk is likely to possess more SiO_2.

Figure 2: Physical Examination of the samples

The results obtained from the XRF analyzer revealed that the chemical composition of the rice husks before treatment changes with varying factors such as farm location, kind and quantity of fertilizer used, climatic conditions and the nature of the soil. This is in line with reports presented by Chandrasekhar *et al*. (2003) who reported that the composition of rice husks chemically varies from specimen to specimen. FTIR analysis for the 3 samples are shown in Figure 3. Spectra from FTIR analysis showed that the band for all samples are located in similar range for the wave numbers and the band at 3425cm^{-1} is assigned to O – H stretch of the hydroxyl groups (adsorbed water). Interfacial bonding properties of the samples can be improved through chemical treatments.

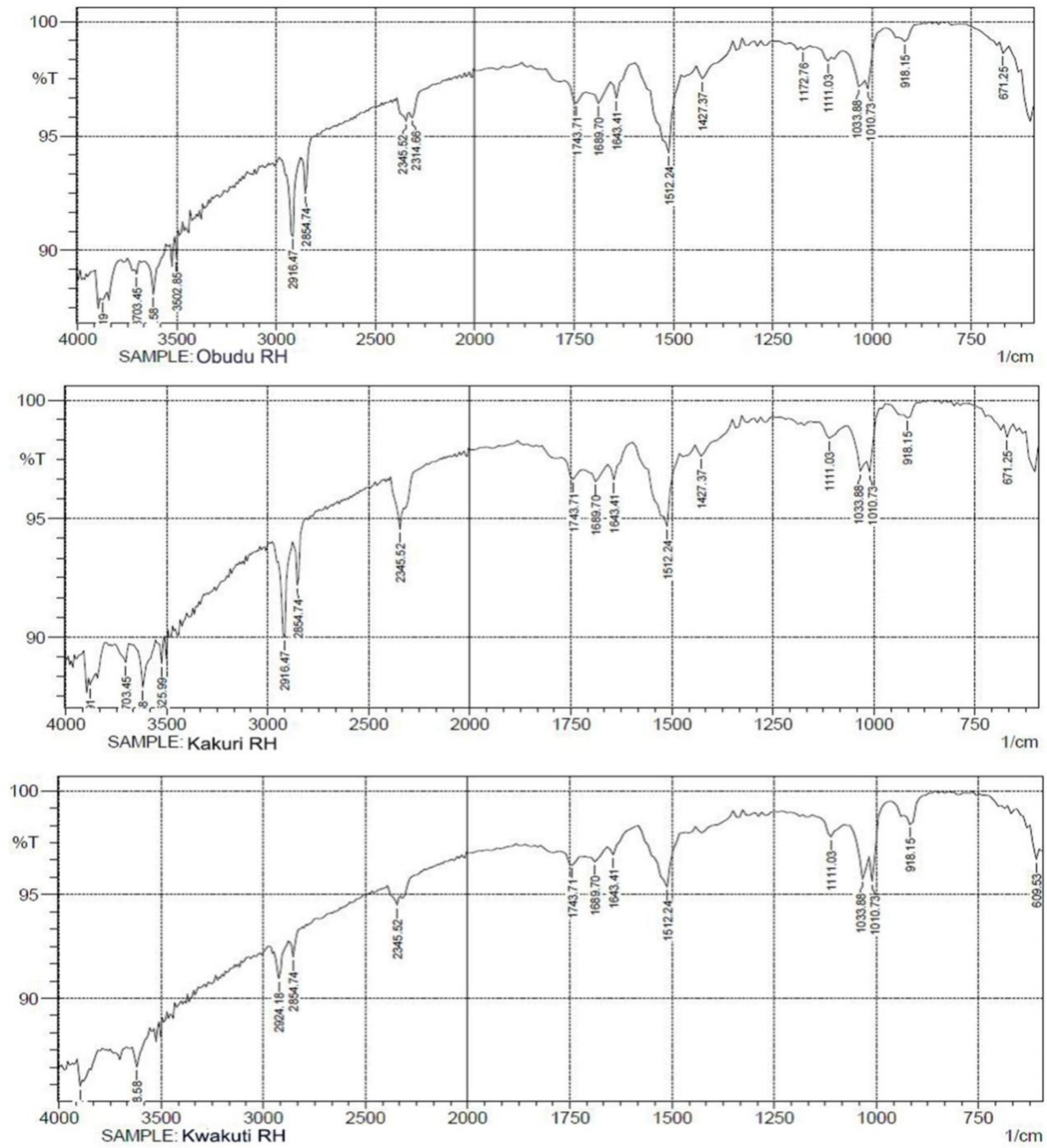

Figure 3: Fourier Transform Infrared Spectroscopy (FTIRS) Analysis for the 3 Samples

4.0 CONCLUSION

Industrial production activities are the major employment hub of developing nations which yields substantial manufacturing value per capita to the nation. Results expected if rice husk is explored and utilized as an engineering material will lead to increasing levels in domesticated manufacture of high quality industrial products by developing countries and mitigate the problems associated with utilization of non-sustainable/non-biodegradable materials. The resulting products are anticipated to conquer the modern global market thereby contributing to Goal 9 (Industry, Innovation and Infrastructure) of the United Nations. This will certainly be in favour of economic prosperity, social inclusion and environmental sustainability. Using agricultural residues to develop eco-friendly engineering products allows several issues relating to man, his environment and his social well-being to be solved. The presence of silica in rice husk makes it a suitable material for development of composites finding applications in the oil and gas, automobile, structural and electronic industries.

Acknowledgement

The authors acknowledge the financial support from the Petroleum Technology Development Fund (PTDF).

REFERENCE

Adedeji, I. A., Jayeola, S. A., & Owolabi, J. O. (2016). Growth Trend Analysis of Rice Husk Productivity in Nigeria. Global Advanced Research Journal of Agricultural Science, 5(10), 391-398.

Chandrasekhar, S., Satyanarayan, K. G., Pramada, P. N., & Raghavan, P. (2003). Review processing, properties and applications of reactive silica from rice husk an overview. Journal of Materials Science, 38(15), 3159-3168.

Costa, H. M., Visconte, L. L. Y., Nunes, R. C. R., & Furtado, C. R. G. (2003). Rice-Husk-filled Natural Rubber II. Partial Replacement of Commercial Fillers and the Effect on Vulcanization Process. *Journal of Applied Polymer Science.* 87, 1405-1413.

Dagwa, I. M., Builders, P. F., & Achebo, J. (2012). Characterization of palm kernel shell powder for use in polymer matrix composites. International Journal of Mechanical & Mechatronics Engineering, 12(04), 88-93.

Dicker, M. P. M., Peter, F. D., Anna, B. B., Guillaume, F., & Mark, K. H. (2014). Green Composites: A review of material attributes and complementary applications. *Composites Part A*, 56, 280-289.

Dongre, R., Meshram, J., & Patil, R. (2014). Characterization and Application of Silica Synthesized from Rice Husk. *Journal of Advances in Science and Technology*. 14(2), 165-168.

Fowler, P. A., Hughes J. M., & Elias, R. M. (2006). Biocomposites: Technology, Environmental Credentials and Market Forces. *Journal of the Science of Food and Agriculture*, 86(12), 1781-1789.

Ghassan, A. H., & Hilmi, B. M. (2010). Study on Properties of RHA and its Use as Cement Replacement Material. Material Research, 13(2), 185-190.

Javed, S. H., Naveed, S., Feroze, N., Zafar, M., & Shafaq, M. (2010). Crystal and Amorphous Silica from $KMnO_4$ Treated and Untreated Rice Husk. *Journal of Quality and Technology Management*, 6(1), 81-90.

Jonathan, E. (2017, August 8). Achieving Self Sufficiency in Rice Production. Thisday Newspaper, Retrieved from https://www.thisdaylive.com/index.php/2017/08/08/achieving-self-sufficiency-in-rice-production/

Kumagai, S., & Matsuo, Y. (2013). Composite Produced from Rice Husk and Chopped Carbon Fiber without using any Binders. *Industrial Crops and Products.* 43(1), 640-647.

Lim, S. I., Wu, T. Y., Sim, Y. S., Lim, P. N., & Clarke, C. (2012). Biotransformation of Rice Husk into Organic Fertilizer through Vermicomposting. Ecological Engineering, 41(41), 6-64.

Magale, K. R. R., Andre, L. C., Daiane, B. B., Tele, M. R., Lucelia, R. A., Gaspar, H. K., & Aytrton, F. M. (2011). Silica from rice husk ash as an additive for rice plant. Journal of Agronomy, 10(3), 99-104.

Ndazi, B. S., Karlsson, S., Tesha, J. V. & Nyahumwa, C. W. (2007). Chemical and Physical Modification of Rice Husk for use as Composite Panel. *Elsevier Composites: Part A: Applied Science and Manufacturing*, 38, 925-935.

Nair, D., Fraaij, A., Klaassen, A., & Kentgens, A. (2008). A structural investigation relating to the pozzolanic activity of rice husk ashes. *Cement and Concrete Research*, 38(6), 861-869.

Nian, L., Kaifu, H., Matthew, T. M., Jie, Z., & Yi, C. (2013). Rice husks as a sustainable source of nanostructured silicon for high performance Li-ion battery anodes. Scientific Reports 3, 1-7. doi: 10.1038/srep01919

Patil, R., Dongre, R., & Meshram, J. (2014). Preparation of Silica Powder from Rice Husk. *Journal of Applied Chemistry*, 26-29.

Rahman, M. R., Islam, M. N., Huque, M. M., Hamdan, S., & Ahmed, A. S. (2010). Effect of Chemical Treatment on Rice Husk Reinforced Polyethylene Composite. *BioResources*, 5(2), 845-869.

Reddy, D. V., & Marcelina, B. S. (2006). Marine durability characteristics of rice husk ash-modified reinforced concrete. *International Latin American and Caribbean Conference for Engineering and Technology*, 1-10.

Reza, A., Azman, H., Khaliq, M., & Zainoha, Z. (2015). Rice Husk Filled Polymer Composites. *International Journal of Polymer Science*, 1-32. doi: 10.1155/2015/501471

Rohani, A. U., Rosiyah, Y., & Seng, N. G. (2016). Production of High Purity Amorphous Silica from Rice Husk. *Procedia Chemistry*, 19, 189-195.

Syed H. J., Tajwar S., Shafaq M., Zafar, M., & Kazmi, M. (2009). Characterization of Silica from Sodium Hydroxide Treated Rice Husk. *Journal of Pakistan Institute of Chemical Engineers*, 37, 97-101.

Van, K. L., & Thi, T. T. L. (2014). Activated Carbon Derived from Rice Husk by NaOH Activation and its Application in Supercapcitor. *Progress in Natural Science: Materials International*, 24, 191-198.

Zhang, M. H., & Malhotra, V. M. (1996). High-performance concrete incorporating rice husk ash as a supplementary cementing materials. *ACI Materials Journal*, 93(6), 629-636.

Zhixuan, W., Jiaying, L., John, P. B., Klaus, H., & Gordon, M. (2016). A comparison of chemical treatment methods for the preparation of rice husk cellulosic fibers. *International Journal of Environmental & Agriculture Research*, 2(1), 67-77