International Journal of Scientific Research in Multidisciplinary Studies
Vol.**10**, Issue.**11**, pp.**01-07**, November **2024**
E-ISSN: 2454-9312 P-ISSN: 2454-6143
Available online at: www.isroset.org

Research Article

Investigation of Dielectric Properties of Disc-Shaped Samples Fabricated From Chicken Eggshells

Levi Oye[1*], Nsikak Edet Ekpenyong[2], Joseph Bassey Emah[3]

[1,2,3]Dept. of Physics, Akwa Ibom State University, Mkpat Enin, Nigeria

**Corresponding Author: oyelevi930@gmail.com*

Received: 16/Sept/2024; **Accepted**: 18/Oct/2024; **Published**: 30/Nov/2024

Abstract - The aim of this study was to fabricate samples from waste chicken eggshells and then assess their basic dielectric properties for possible utilization in electronic industry. Waste items such as chicken eggshells and cassava effluent were processed into calcined chicken eggshell powder (CEP) and dry cassava starch (DCS) respectively. The CEP was carefully blended in the ratio of 2:1 (by weight) into a wetting medium prepared by heating and cooling 15 % (w/v) solution of the cassava. The homogeneous mixture of the materials was cast to diameter of (1.65 ± 0.01) cm, pressed, sintered, and then diced into disc-shaped samples each having thickness of 0.25 cm. Experiments were performed on the samples at certain frequencies (1 kHz, 10 kHz, and 100 kHz) over temperature ranging from 20 ^{o}C to 50 ^{o}C. The results showed decrease in capacitance from (10.11 ± 0.02) pF to (4.14 ± 0.02) pF. Similarly, relative permittivity of the samples decreased from 13.35 to 5.47, the values which fall within the range recommended for ceramic-based capacitors. The temperature coefficients of capacitance decreased with frequency from -1.33 %/^{o}C to -1.76 %/^{o}C. The used wastes showed promising potentials for utilization in manufacturing of cheap, sustainable, and eco-friendly energy storage device like capacitor. Embarking on such undertaking could help to solve the disposal problems associated with the wastes.

Keywords - Carr's index, Capacitance, Capacitor, Cassava effluent, Relative permittivity, Waste

1. Introduction

A substance can only be regarded as waste when the owner labels it as such. Today, the rate of material use is so large that wastes generated will impact on the environment and human health globally if mismanaged. Commercial poultry is now a business that yields very fast due to the introduction of technological innovations in agriculture [1]. A typical evidence of this fact is increased eggs production witnessed within a very short duration of rearing chickens. Consequently, huge amounts of eggshells are discarded as waste from homes, restaurants, farms, and factories. On the global scale, about 2.3 million tonnes of eggshells were generated in 2018 [2] and China produced 458,448 million eggs, of which 137,534 million eggs were processed in breaking plants, leading to generation of 825,204 tonnes of eggshells [3].

Considering the ineffectiveness of solid waste management systems in developing and less-developed nations, efforts have been made at salvaging the situation via utilization of the shells for hydroxyapatite preparation in medicine [4] [5], catalytic application [6] [7], wastewater treatment [8] [9] [10], fertilizer making [11] [12] [13] [14], development of composite materials [15] [16] [17] [18], and manufacturing of electrodes [19] [20] [21]. However, waste eggshells are still majorly under-utilized. This warrants their disposal by indiscriminate dumping, landfilling, or open incineration. Observably, these approaches instead pose severe detrimental effects on the environment as well as public health [22] [23] [24] [25] [26], thereby signalling an urgent need to further explore a convenient way for their disposal.

The aim of this study is to fabricate samples from chicken eggshells and then assess their dielectric properties. This will help to ascertain their suitability for utilization as dielectric material in capacitor making. To the best of the authors' knowledge, no such scientific information has ever been reported in the literature. Chicken eggshell has very high sustainability and is readily-available, highlighting the possibility of ensuring sustainable production and development at low cost. Also, the knowledge of dielectric properties (especially capacitance, temperature coefficient of capacitance, and relative permittivity) is very crucial for industrial, electrical/electronic, biophysical and medical applications, among others [27]. The study on chicken eggshells undertaken by Robert et al. [1] was mainly on the electrical characteristics such as resistance, resistivity, thermal constant, temperature coefficient of resistance, and activation energy of the eggshell-based samples.

2. Related Work

Of recent, researchers have shown interest in utilization of certain recyclable wastes for economic benefits in electrical/electronic sector. For example, Adeniran et al. [28] found that disc-shaped samples made from the shells of Clams, Periwinkle, or Oysters possess satisfactory electrical characteristics for engineering applications. On their part, Etuk et al. [29] reported that Periwinkle, Clams, and Oyster shells are potential raw materials that could be utilized in the production of capacitors. Iboh et al. [30] concluded in their research that *raphia hookeri* is a suitable dielectric material for capacitor making. A similar finding was reported by Etuk et al. [31] based on the results of their investigation on dielectric properties of *raphia vinifera* leaflet. The membranes from the eggs of select birds were equally found to be potential dielectric materials for capacitor manufacturing [26]. Zaino et al. [32] reviewed the possibility of developing dielectric from both agricultural and bio-wastes. They noticed that rice straw exhibited dielectric constant of 3.231which simply indicates that it could serve as a promising candidate for various engineering applications with microwave signal absorbers as the most common.

More so, Abdelmalik et al. [33] studied the dielectric behaviors (specifically, relative permittivity and dielectric loss) of epoxy polymer with the periwinkle shell composite metal oxides at low filler concentrations over a frequency range from 200 Hz to 100 kHz. It was found that the dielectric response of the epoxy-shell microparticle powder composite displayed a decrease in the dielectric loss with micro-filler concentration, suggesting that the waste periwinkle shell could serve as a cheap resource to produce low-cost polymer composite with improved electrical insulation properties. Larguech et al. [34] performed dielectric measurements on Poly(lactic acid) (PLA) polymer, Poly(lactic acid)/Poly(butylene succinate) (PLA/PBS) blend matrix and its green composite reinforced with Jute fibers in the temperature range from 20 °C to 140 °C and frequency range from 0.1 Hz to 1 MHz. For the PLA polymer, the dielectric analyses revealed the presence of three relaxation processes which were identified to be α-mode relaxation, the dc conductivity effect, and the Maxwell–Wagner–Sillars (MWS) interfacial polarization effect. Also, it was observed that two additional dielectric relaxations (associated with β relaxation and interfacial polarization effect originating from PLA polymer and the semi-crystalline character of PBS polymer, respectively) appeared for PLA/PBS blend matrix.

Omah et al. [35] evaluated the dielectric constant of a hybrid composite developed from palm kernel shell dust and wood sawdust as reinforcements with 40 % epoxy resin as the binder. They found that as the palm kernel shell dust ratio increased from 50:50 to 90:10, the dielectric constant of the materials increased from 3.4 to 5.2. Though these values were reasonably high, as noticed, it was concluded that the best performance of the composite would be limited to low voltage applications. Mehrzad et al. [36] reported on the feasibility of utilizing metal oxides from periwinkle shells as fillers for polymer composites for high-voltage applications. Findings from the study suggested that, if the agro-waste is properly processed into possible nanosized particles, it can be a better candidate for dielectric applications.

Pereira et al. [37] examined the mechanical and insulation properties of eggshell microparticles as fillers with epoxy polymer in producing composite polymeric insulators using TiO_2 nanoparticles/epoxy as a control. They noticed that the tensile strength of 4 % eggshell filler showed a 22.4 % improvement slightly lower than that of TiO_2 nanoparticle. Also, at lower filler loadings, the composite showed a higher dielectric constant and comparable loss tangent with TiO_2 nanocomposite but the electric conductance of the eggshell at high voltages was lower than that of the TiO_2 nanocomposite giving the addition of eggshells a better advantage as a dielectric material. Fendi [38] investigated the polarizability of eggshell (ES) particulates in polyester-reinforced composites, centering the study on the development and characterization of a polymer matrix containing different volume fractions (10 to 50 wt%) of eggshell particles. The results showed that the dielectric strength, dielectric constant, and resistivity of the composites had their prime values at 40 wt%, 10 wt%, and 30 wt%, respectively. It was concluded that the dielectric constants of the ES polyester composite were lower compared with some conventional insulators and by having minimal moisture content and water absorption capacity, the composite could be a candidate material for capacitors and a good electrical insulator.

3. Experimental Method

3.1 Materials

Chicken eggshells and cassava effluent were the waste materials utilized in this study. The chicken eggs were obtained from a local poultry farm (called Songhai) in the Niger Delta Basin. The eggs were picked 12 hours after they had been laid by a particular chicken. They eggs were then stored at room temperature for 15 days before de-shelling them. The shells were washed thoroughly in water, sun-dried, and stored separately in waterproof container. These materials were obtained within Khana Local Government Area, River State, Nigeria.

3.2 Processing and Analysis of the materials.

The eggshells were crushed using Agate mortar and pestle and then sieved. Next, the sieved material was calcined at 1000 ^oC in Muffle furnace for 6 hours. On cooling to about 35 ^oC, the calcined material was pulverized in a high-energy ball miller (E_{max}, manufactured by RETSCH, GmbH) operated at 500 rpm for 5 hours. The method used Robert et al. [39] was adopted for preparation of the starch. Accordingly, the cassava effluent was stirred and allowed to settle in a plastic bucket for 24 hours, after which it was decanted to obtain the residue. The residue was dried under intense sunlight for several days until it became powdery (dry starch) and without further reduction in its weight. The eggshell powder and cassava starch were coded as CEP and DCS respectively so as to ease in their identification. Pictures of the materials are shown in Figure 1. For flowability assessment, the Carr's index of each material was determined in triplicates following the standard procedure documented in ASTM D 6393 [40].

During each determination schedule, 100 g of the material was weighed by means of digital balance (Model CS 2000) and then transferred to a 100 cm^3 glass measuring cylinder. The bulk volume occupied by the material at that instant was noted before the cylinder was tapped 50 times using a tapping rod and the material's tapped volume was noted as well. Bulk density and tapped density were determined by taking the ratio of mass to the respective volumes [27]. The Carr's index was then computed thus

$$CI = \left[1 - \left(\frac{\rho_b}{\rho_t}\right)\right] \; 100\ \% \qquad (1)$$

where CI = Carr's index, ρ_b = bulk density, and ρ_t = tapped density

Figure 1. Pictures of the eggshells, CEP, and DCS

3.3 Preparation of Disc-shaped Samples

The DCS was mixed with water to obtain a 15 % $\frac{w}{v}$ solution. The solution was put in a steel can and heated with the aid of an electric hotplate (E4102 WH). While being heated, the mixture was stirred gently until it became mildly gummy. At that moment, the heating was discontinued and the heated mixture was allowed to cool before it was used as a wetting liquid in fabricating the samples. During the fabrication, the CEP was blended very carefully into the liquid in the ratio of 2:1 by weight. The resulting homogeneous mixture was cast in a mold of diameter (1.65 ± 0.01) cm and subjected to uniaxial pressing at 7.0 x 10^2 MPa for 90 minutes. This was followed by sintering of the pressed material in air at 1000 ^oC for 1 hour before it was diced with the aid of dicing saw into disc-shaped samples each of thickness 0.25 cm. Three samples were prepared and tested.

3.4 Testing of the Samples

One sample was tested at a time by engaging the sample in a holder, equipped with a pair of nickel electrodes (each measuring 10 mm x 8 mm x 1 mm) and two lead terminals. The sample was positioned such that it rested on its length in the cavity of a cylindrical aluminium block placed on the heating element of the hotplate. Figure 2 shows the components of the setup used for capacitance measurement in this work. A digital thermometer (Model 305 calibrated, equipped with type-K probe) was used for monitoring and measuring the temperature of the sample. The thermometer probe was clamped, ensuring that its tip firmly contacted one cross-section of the sample. Cotton wool was used to lag the electrodes and tip of the probe. This was considered necessary to ascertain that during each measurement schedule, changes in the capacitance values were due to heat absorbed by the sample only. The lead terminals of the holder were connected to the probes of the LCR meter (9183, Lutron) for sample's capacitance measurements. The control dial of the hotplate was adjusted to a level that enabled slow heat flow via the aluminium block into the sample. Measurement of the sample's capacitance was commenced from 20 ^oC and continued at 5 ^oC intervals until the temperature reached 50 ^oC. All the samples were similarly tested, ensuring that the process variables were not altered and the same set of apparatus was used throughout the testing session. The electrodes in the sample holder were made of nickel.

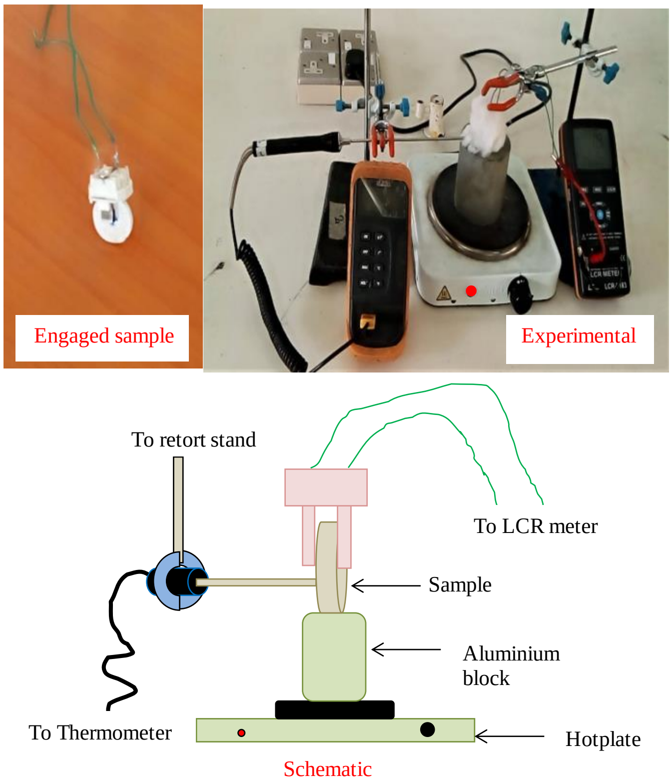

Figure 2. Setup used for the capacitance measurement

Properties determination

For each temperature and frequency, the mean and standard error values of the capacitance were computed. From the plot of capacitance (using the mean values) against temperature, the temperature coefficient of capacitance was deduced in accordance with the Japanese Industrial Standards (JIS) and Electronic Industries Alliance (EIA) and based on the relation

$$C_t = \left(\frac{C_m - C_o}{C_o \Delta T}\right) \; 100\ \% \qquad (2)$$

where C_t = temperature coefficient of capacitance, C_o = capacitance value at reference temperature, ΔT = difference between maximum operating temperature and reference temperature values, and C_m = capacitance value at operating temperature..

The relative permittivity value was calculated using the formula [41] [42] [43]

$$C = \varepsilon_r \varepsilon_o \left(\frac{A}{d}\right) \qquad (3)$$

where C = mean capacitance value, A = cross-sectional area of the sample, d = sample's thickness, ε_r = relative permittivity of the samples, and ε_o = permittivity of free space (8.85 x 10^{-12} Fm^{-1}).

4. Results and Discussion

Table 1 shows the results of the Carr's index evaluation for the CEP and DCS. It is obvious that the mean values are less than 15 %. According to the assertion by Carr [44] and submission by Kanig et al. [45], such values signify high flowability. By implication, the CEP and DCS have good flow property and so, can ensure content uniformity in the studied samples. Thus, they are suitable for manufacturing of the samples as implemented in this study.

Table 1. Results of Carr's index measurements

Material code	Carr's index (%)			
	1	2	3	Mean ± S.e
CEP	9.04	9.01	8.97	9.01 ± 0.02
DCS	11.43	11.38	11.41	11.41 ± 0.02

S.e = standard error

It can be seen in Table 2 that increase in temperature reduces the capacitance of the samples notwithstanding the frequency. This implies that greater charge could be collected at lower frequencies if the sample is used as a dielectric. Umanah et al. [41] reported a similar observation for periwinkle shell-based disc samples. For a change in the temperature over the considered range, the mean capacitance decreases by 39.96 %, 40.86 % and 47.93 % at 1 kHz, 10 kHz, and 100 kHz respectively. The capacitance obtained at 30 °C and 1 kHz is similar to the value at 20 °C and 100 kHz, thus signifying that the sample can exhibit the same dielectric behavior under such conditions of temperature and frequency. It is observed that, for the temperature and frequency extremes considered in this research, all the capacitance values of the samples lie between 0.5 pF and 1600 pF which is the range noted by Schultz [46] for ceramic materials. This simply portrays that the sample could be used alternatively for ceramic dielectric in capacitor applications.

Table 2. Capacitance of the samples per temperature and frequency

Temperature, T (℃)	Capacitance, $C(10^{-12}$ F) per frequency, f		
	$f = 1\ kHz$	$f = 10\ kHz$	$f = 100\ kHz$
20.0	10.11 ± 0.02	8.42 ± 0.04	7.93 ± 0.03
25.0	8.38 ± 0.04	7.74 ± 0.02	7.38 ± 0.04
30.0	7.93 ± 0.03	7.02 ± 0.03	6.83 ± 0.02
35.0	7.49 ± 0.04	6.77 ± 0.04	5.92 ± 0.03
40.0	6.97 ± 0.04	6.29 ± 0.02	5.21 ± 0.03
45.0	6.44 ± 0.06	5.83 ± 0.03	4.69 ± 0.04
50.0	6.07 ± 0.04	4.98 ± 0.03	4.14 ± 0.02

It is clear from Figure 3 that the capacitance exhibits a polynomial relationship with temperature at each of the frequencies. At 30 °C, the capacitance at frequency of 10 kHz differs more from the value at 1 kHz than 100 kHz. But between 35 °C and 45 °C, the reverse is observed. Beyond 35 °C, the reverse tendency occurs. All these observed tendencies are due to the influence of temperature on the samples. When temperature increases, the degree of freedom (disorder) of dipoles also increases thereby causing the dipoles to have a hard time to arrange themselves. This gives rise to decrease in the capacitance at higher temperatures.

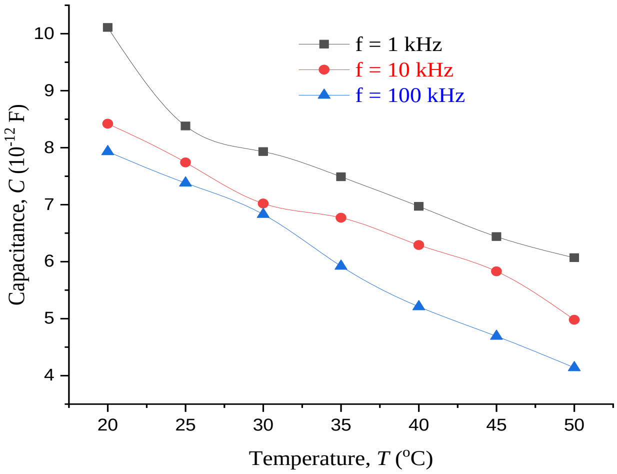

Figure 3. Capacitance - temperature relationship for the sample

The relative permittivity of the samples also decreases with increasing temperatures as can be seen in Table 3. This may be attributed to the trend exhibited by the sample's capacitance as temperature changes. Meanwhile, relative permittivity correlates positively with capacitance. Etuk et al. [29] reported decrease in relative permittivity from 12.52 to 2.84 as frequency changes from 1 kHz to 100 kHz for samples made from oyster shells. It can be deciphered that the relative permittivity values obtained for the samples in this study agree very well with those found for the disc-shaped samples based on oyster shells. As such, they can serve the same function as dielectric material. High relative permittivity value is advantageous in that it reduces consumption of power, ensures faster operation, and enhances higher memory density. It is noteworthy that relative permittivity is very essential when designing capacitors and other circumstances where a material might be needed for introduction of capacitance into a circuit. While a material with low relative permittivity is suitable for electrical insulation, a dielectric for capacitor application ought to have high relative permittivity so that the capacitor dimensions can be minimized. In the instant case, the samples fit either way, though temperature and frequency have influence on the relative permittivity as noticed.

Table 3. Relative permittivity of the samples per temperature and frequency

Temperature, T (℃)	Relative permittivity, ε_r per frequency, f		
	$f = 1\ kHz$	$f = 10\ kHz$	$f = 100\ kHz$
20.0	13.35	11.12	10.48
25.0	11.07	10.22	9.75
30.0	10.48	9.27	9.02
35.0	9.89	8.97	7.82
40.0	9.21	8.31	6.88
45.0	8.51	6.64	6.20
50.0	8.02	6.55	5.47

The influence of temperature on relative permittivity of the samples, as illustrated in Figure 4 below, produces trends that are similar to the cases with capacitance as earlier noted. The observed behavior is possible because density, as well as degree of crystallinity and other properties of the sample affect its relative (dielectric) permittivity. Considering relative permittivity as an indication of an insulating material's ability for concentration of electric flux, it can be stated that the sample has the capability to provide a density of electric flux appropriate enough for it to be used as a dielectric in capacitor making. As the relative permittivity is high between 25 °C and up to about 30 °C, it points to the fact that it is possible to notice very promising performances from energy device (like capacitor) made from the sample for electronic applications. Storing of electrical energy in capacitors is through electrostatic charge storage mechanism [47].

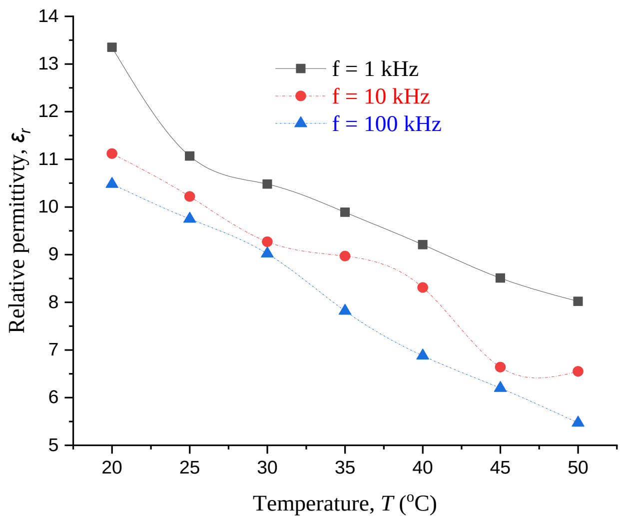

Figure 4. Variation of relative permittivity with temperature of the sample

Table 4 shows the temperature coefficients of capacitance obtained for the samples. All the coefficients are negative and this can be attributed to the decreasing tendency the samples exhibit in capacitance with increasing temperatures. The coefficients that are based on JIS exceed those premised on the EIA standard because of the difference in the minimum temperature stipulated in those standards. Meanwhile, the JIS requires 20 °C whereas the EIA recognizes 25 °C as the minimum temperature limit, thus warranting a larger change in capacitance in the case of the JIS than the EIA standard. However, it appears performances that are very satisfactory could be realized if the sample is used within audio frequency range as a dielectric in the manufacturing of energy devices like capacitors. It is obvious that even under the influence of electromagnetic radiation, the samples can perform well based on the obtained temperature coefficients of capacitance. Bhuva, and Jethva [48] asserted that as electromagnetic radiation passes through a given material, its intensity increases.

Table 4. Temperature coefficient of capacitance of the samples

Frequency, f (kHz)	$C_t(\%/℃)$	
	JIS	EIA
1.0	-1.33	-1.10
10.0	-1.37	-1.44
100.0	-1.59	-1.76

5. Conclusion and Future Scope

The results of the experiments performed in this work have revealed that waste eggshells and cassava starch can be processed into materials with acceptable flow property for manufacturing purposes. As temperature varied from 20 °C to 50 °C within the frequency limits of 1 kHz and 100 kHz, disc-shaped samples fabricated from the CEP and DCS exhibited capacitances (4.14 pF to 10.11 pF) that fall within range recommended for ceramic-based capacitors. The relative permittivity values (5.47 to 13.35) as well as temperature coefficients of capacitance of the samples signified that satisfactory performance could be achieved from energy storage device produced using the samples as a dielectric. Thus, putting the waste chicken eggshells and cassava effluent into production cycle can help to solve their disposal problem and at the same time, ensure availability of cheap, sustainable, and environmentally-friendly electronic products for engineering applications. For future research in this direction focus could be on how the eggshell storing time influences the dielectric properties of the samples.

Data Availability

All data are with the corresponding author.

Conflict of Interest

The authors declare that they have no conflict of interests regarding this paper's publication.

Funding source

There was no explicit support for this study from the public, corporate or non-profit organizations.

Authors' Contributions

Levi Oye: Created the methodology for the research, analyzed the data, and wrote the first draft of the manuscript.

Nsikak Edet Ekpenyong: Contributed to the final version's permission for submission, gave critical feedback on the manuscript's structure and contents, and served as the lead supervisor.

Joseph Bassey Emah: Reviewed and edited the document to make sure it was coherent and very clear, helped to proofread and approve the submission of the finished version.

Acknowledgements

None

References

[1] U.W. Robert, S.E. Etuk, O.E. Agbasi, U.A. Iboh, S.S. Ekpo, "Temperature-Dependent Electrical Characteristics of Disc-shaped Compacts fabricated using Calcined Eggshell Nano powder and Dry Cassava starch," *Powder Metallurgy Progress*, Vol. **20**, No. **1**, pp. **12 – 20**, **2020**.

[2] T.A.E. Ahmed, G. Kulshreshtha, M. Hincke, "Value-added uses of eggshell and eggshell membranes," *in Eggs As functional Foods and Nutraceuticals for Human Health, ed. J. Wu (London: The Royal Society of Chemistry)*, pp.**359–397**, **2019**. https://doi/org/10.1039/9781788013833

[3] FAO, "Livestock Primary," *FAOSTAT*, Rome: FAO, **2020**.

[4] B.N.A. Alhussary, G. Taqa, A.A.A. Taqa, "Preparation and characterization of natural mano hydroxyapatite from eggshell and seashell and its effect on bone healing," *Journal of Applied Veterinary Sciences*, Vol. **5**, pp. 25 – 32, **2020**.

[5] R. Salama, M. Khashaba, D. El Rouby, "Histomorphometric evaluation of a nano-sized eggshell-containing supplement as a natural alloplast: An animal study," *The Saudi Dental Journal*, Vol. **31**, pp. **375 – 381**, **2019**.
[6] N. Mansir, S.H. Teo, U. Rashid, M.I. Saiman, Y.P. Tan, G.A. Alsultan, Y.H. Taufiq-Yap, "Modified waste eggshell derived bifunctional catalyst for biodiesel production from high FFA waste cooking oil. A review," *Renewable and Sustainable Energy Reviews*, Vol. **82**, pp. **3645 – 3655**, **2018**.
[7] N. Tshizanga, E.F. Aransiola, O. Oyekola, "Optimization of biodiesel production from waste vegetable oil and eggshell ash," *South African Journal of Chemical Engineering*, Vol. **23**, pp. **145 – 156**, **2017**.
[8] H.H.W. Jusoh, N.A. Kasan, H. Manan, N.M. Nasir, F.H.M. Yunos, S. Hamzah, A. Jusoh, "Chicken Eggshell as an Innovative Bioflocculant in Harvesting Biofloc forAquaculture Wastewater Treatment," *Journal of Renewable Materials*, Vol. **11**, No. **5**, pp. **2322 – 2332**, **2022**. https://doi.org/10.32604/jrm.2023.026086
[9] S.A. Jahan, M.Y.A. Mollah, S. Ahmed, M.A.B.H. Susan, "Nano-hydroxyapatite prepared from eggshell-derived calcium-precursor using reverse microemulsions as nanoreactor," *Materials Today: Proceedings*, Vol. **4**, pp. **5497 – 5506**, **2017**.
[10] J. Makuchowska-Fryc, "Use of the eggshells in removing heavy metals from waste water-the process kinetics and efficiency," *Ecological Chemistry and Engineering S*, Vol. **26**, pp. **165 – 174**, **2019**.
[11] A. Commey, M. Mensah, "An experimental study on the use of eggshell powder as a pH modifier: Production of lime from eggshells," *International Journal of Innovative Science and Research Technology*, Vol. **4**, pp. **766 – 768**, **2019**.
[12] V.T. Wijaya, S.S. Teo, "Evaluation of eggshell as organic fertilizer on sweet basil,"*International Journal of Sustainable Agricultural Research*, Vol. **6**, pp.**79 – 86**, **2019**.
[13] T. Radha, G. Karthikeyan, "Hen eggshell waste as fertilizer for the growth of phaseolus vulgaris (cow pea seeds)," *Research Journal of Life Sciences, Bioinformatics Pharmaceutical and Chemical Sciences*, Vol. **5**, pp. **398 – 406**, **2019** ,
[14] A. Wazir, Z. Gul, M. Hussain, "Comparative study of various organic fertilisers effect on growth and yield of two economically important crops, potato and pea," *Agricultural Sciences*, Vol. **9**, pp. **703 – 717**, **2018**
[15] S.K. Dwiwedi, A.K. Srivastava, K. Sugimoto, M. Chopkar, "Microstructural and Mechanical Characterization of Chicken Eggshell-Reinforced Al6061 Matrix Composites," *Open Journal of Metal*, Vol. **8**, pp. **1 – 13**, **2018**. https://doi.org/10.4236/ojmetal.2018.81001.
[16] N. Tangboriboon, L.O. Mulsow, W. Sangwan, A. Sirivat, "Semi-Rigid composite foams of calcium sodium aluminosilicate from eggshells embedded in polyurethane," *International Polymer Processing*, Vol. **33**, pp. **2 – 12**, **2018**
[17] M. Lubis, M.H.S. Ginting, N. Dalimunthe, D. Hasibuan, S. Sastrodihardjo, "The influence of chicken eggshell as fillers on biocomposite acrylic resin for denture based," *In 180. IOP Conference series: Materials science and engineering*, pp. **1 – 8**, **2017**
[18] R.A. Mohammed, "PMMA-Eggshell composite preparation and studying mechanical properties as a dental material," *Journal of Engineering and Sustainable Development*, Vol. **24**, pp. **30 – 47**, **2020**.
[19] M. Minakshi, H. Visbal, D.R.G. Mitchell, M. Fichtner, "Bio-waste chicken eggshells to store energy," *Dalton Transactions*, Vol. **47**, **16828**, **2018**. https://doi.org/10.1039/c8dt03252a
[20] X. Yuan, L. Wu, X. He, K. Zeinu, L. Huang, X. Zhu, H. Hou, B. Liu, J. Hu, J. Yang, "Separator modified with N, S co-doped mesoporous carbon using eggshell as template for high performance lithium-sulfur batteries," *Chemical Engineering Journal*, Vol. **320**, pp. **178 – 188**, **2017**
[21] W. Zhang, B. Zhang, H. Jin, P. Li, Y. Zhang, S. Ma, J. Zhang, "Waste eggshell as bio-template to synthesize high capacity δ-MnO_2 nanoplatelets anode for lithium ion battery," *Ceramics International*, Vol. **44**, pp. **20441 – 20448**, **2018**
[22] U.W. Robert, S.E. Etuk, J.B. Emah, O.E. Agbasi, U.A. Iboh, "Thermophysical and Mechanical Properties of Clay-Based Composites developed with Hydrothermally Calcined Waste Paper Ash Nanomaterial for Building Purposes," *International Journal of Thermophysics*, Vol. **43**, No. **5**, pp. b, **2011**. https://doi.org/10.1007/s10765-022-02995-1
[23] S.E. Etuk, U.W. Robert, O.E. Agbasi, "Investigation of heat transfer and mechanical properties of *Saccharum Officinarum* leaf boards," *International Journal of Energy and Water Resources*, Vol. **6**, No. **1**, pp. **95 – 102**, **2021**. https://doi.org/10.1007/s42108-021-00123-7
[24] U.W. Robert, S.E. Etuk, O.E. Agbasi, U.S. Okorie, A. Lashin, "Hygrothermal properties of sandcrete blocks produced with raw and hydrothermally-treated sawdust as partial substitution materials for sand," *Journal of King Saud University – Engineering Sciences*, **2021**. https://doi.org/10.1016/j.jksues.2021.10.005
[25] S.A. Ekong, D.A. Oyegoke, A.A. Edema, U.W. Robert, "Density and water absoion coefficient of sandcrete blocks produced with waste paper ash as partial replacement of cement," *Advances in Materials Science*, Vol. **22**, No. **4**, pp**. 85 – 97**, **2022**. https://doi.org/10.2478/adms-2022-0021
[26] U.W. Robert, S.E. Etuk, O.E. Agbasi, S.A. Ekong, Z.T. Abdulrazzaq, A.U. Anonaba, "Investigation of Thermal and Strength Properties of Composite Panels Fabricated with Plaster of Paris for Insulation in Buildings," *International Journal of Thermophyics*, Vol. **42**, No. **2**, pp. **1 – 18**, **2021**. https://doi.org/10.1007/s10765-020-02780-y.
[27] S.E. Etuk, U.W. Robert, J.B. Emah, O.E. Agbasi, "Dielectric properties of eggshell membrane of some select bird species,"*Arabian Journal for Science and Engineering*, Vol. **46**, No. **1**, pp. **769 – 779**, **2020**. https://doi.org/10.1007/s13369-020-04931-7.
[28] A.O. Adeniran, A.O. Akankpo, S.E. Etuk, U.W. Robert, O.E. Agbasi, "Comparative study of electrical resistance of disc-shaped compacts fabricated using calcined clams shell, periwinkle shell and oyster shell nanopowder", *Kragujevac Journal of Science*, Vol. **44**, pp. **25 – 36**, **2022**. https://doi.org/10.5937/KgJ.
[29] S.E Etuk, A.O. Adeniran, U.W. Robert, A.O. Akankpo, O.E. Agbasi, "A Novel of Dielectric Properties of Discs Fabricated from Nanopowder of Calcined Clams, Periwinkle, and Oyster Shells," *Polytechnica*, **2023**. https://doi.org/10.1007/s41050-022-00039-z.
[30] U.A. Iboh, U.W. Robert, G.P. Umoren, U.S. Okorie, "The effect of frequency variation on dielectric constant of *raphia hookerie," Journal of Renewable Energy and Mechanics*, Vol. **3**, No. **2**, pp. **53 – 58**, **2020**. https://doi.org/10.25299/rem.2020.vol3(02).4433.
[31] S.E. Etuk, S.S. Ekpo, U.W. Robert, O.E. Agbasi, E.A. Effiong, "Dielectric properties of *Raphia fiber* from Epidermis of young *Raphia vinifera* leaflet," *Acta Technica Jaurinensis*, Vol. **15**, No. **2**, pp. **91 – 98**, **2022**. https://doi.org/10.14513/actatechjaur.00648
[32] N. Zainol, N. Mustafa, N.H. Aziz, A.N. Azman, M.S.A. Karim, " Dielectric materials development using bio-waste: a review," *Journal of Electrical Systems and Information Technology*, **10:47**, **2023**. https://doi.org/10.1186/s43067-023-00117-x
[33] A.A. Abdelmalik, A. Sadiq, U. Sadiq, "Low Dielectric Loss Epoxy Polymer Composite from Periwinkle Shell Microparticles," *Journal of Physical Science*, Vol. **31**, No. **1**, **2020**
[34] S. Larguech, A. Triki, M. Ramachandran, A. Kallel, "Dielectric properties of jute fibers reinforced poly (lactic acid)/poly (butylenes succinate) blend matrix," *Journal of Polymers and the Environment*, Vol. **29**, No. **4**, pp. **1240 - 1256**, **2021**
[35] A.D. Omah, B. Ezeike, C. Ocheri, P.O. Offor, I.C. Ezema Ike-Eze, S.V. Egoigwe, O. Nwoke, "Electrical Insulative Properties of Some Agro-waste Materials: Palm Kernel Shell Dust and Wood Saw Dust Hybrid Composite," *Journal of Materials and Environmental Science*, Vol. **14**, No. **7**, pp. **867 - 877**, **2023**.
[36] S. Mehrzad, E. Taban, S. Parham, S. Seyed Ehsan, K. Ali, "Sugarcane bagasse waste fibers as novel thermal insulation and sound-absorbing materials for application in sustainable buildings," *Building and Environment*, Vol. **211**, **108753**, **2022**. https://doi.org/10.1016/j.build env.2022.108753

[37] L. Pereira, R. Mafalda, J.M. Marconcini, G.I. Mantovani, "The use of sugarcane bagasse-based green materials for sustainable packaging design," *In: Smart innovation system technology*,**2014**. https://doi.org/10.1007/978-81-322-2229-3_10

[38] A.M. Fendi, "Dielectric properties of carbon from cassava starch synthesized from hydrothermal process," *Journal of Physics: Conference Series*, Article **1028**:012018, **2018**. https://doi.org/10.1088/1742-6596/1028/1/012018

[39] U.W. Robert, S.E. Etuk, G.P. Umoren, O.E. Agbasi, "Assessment of Thermal and Mechanical properties of composite board produced from coconut (*cocos nucifera)* husks, waste newspapers and cassava starch," *International Journal of Thermophysics*, Vol.**40**, No.**9**, Article **83**, **2019**. https://doi.org/10.1007/s10765-019-2547-8

[40] ASTM D 6393 "Standard Test Method for Bulk Solids Characterization by Carr's Indices," *ASTM International*, West Conshohocken, PA, **2021**

[41] E.I. Umanah, N.E. Ekpenyong, A.O. Akpan, "Electrical and Dielectric Properties of discs fabricated using periwinkle shell nanopowder and dry cassava starch," *Buletinul Institutului Politehnic Din Iaşi,* Vol. **68**, No.**72**, pp.**7–20**, **2022**. https://doi.org/10.2478/bipmf-2022-0001

[42] B.L. Thereja, *Basic Electronics Solid State*, S. Chand and Company Ltd, New Delhi, p. **63**, **2008**

[43] R.S. Sedha, *A Textbook of Applied Eklectronics*, 2nd edn., S. Chand and Co. Ltd, New Delhi, p. **30/126**, **2008**.

[44] J.L. Kanig, L. Lachman, H.A. Lieberman, *The theory and practice of industrial pharmacy*, 3rd edn. Philadelphia, Germany, **1989**.

[45] R.L. Carr, "Evaluating Flow Properties of Solids," *Chemical Engineering*, Vol. **72**, pp. **163 – 168**, **1965**.

[46] M.C. Schultz, *Grob's Basic Electronics*, 11th edn, McGraw-Hill Companies, New York, pp.**478–480**, **2011**. ISBN 978-0-07-122137-5

[47] S.E. Umoru, "Hybrid supercapacitor for energy storage devices: A Review," *Journal of Physics and Chemistry of Materials,* Vol. **10**, No.**4**, pp.**24 – 35**, **2023**

[48] H. Bhuva, H.O. Jethva, "EDAX, Thermal, UV-Vis and SHG studies of pure and creatinine doped KDP crystals," *Journal of Physics and Chemistry of Materials,* Vol.**10**, No.**1**, pp.**1 – 6**, **2023**.

AUTHORS PROFILE

Mr. Levi Oye earned his PDG in Physics from Akwa Ibom State University in 2021. He is currently studying for his MSc in the Department of Physics at Akwa Ibom State University (Nigeria). He is a member of Nigerian Institute of Science Laboratory Technology (NISLT). His research focuses on Valorization of wastes (particularly chicken eggshells and cassava effluents/residues) to energy storage device for engineering applications. Specifically, dielectrics and capacitor making are the major targets in this waste recycling undertaking.

Dr. Nsikak Edet Ekpenyong obtained his BSc in Physics from University of Uyo (Nigeria) in 1999, MSc in Artificial Intelligence from University of Edinburgh (United Kingdom) in 2007, and a PhD in Electrical Engineering from University of Manchester (United Kingdom) in 2013. He is currently working as a Senior Lecturer in Department of Physics at Akwa Ibom State University (Nigeria). He has served as Departmental Co-ordinator of Students Industrial Work Experience Scheme (SIWES) and Time Table Officer. He is a member of the Nigeria Institute of Physics as well as Physics Writers Series Creation Nigeria. His research interests include Image processing with emphasis on hyperspectral images, computer vision, machine learning and pattern recognition as applied to imaging and quantum computing. He has many years of teaching and research experience with engagement in supervision of undergraduates/postgraduate research students. Also, he has published more than 15 research papers in reputed national and international journals and they are available online.

Dr. Joseph B. Emah holds a Ph.D. in Nano Electronics Engineering from the University of Surrey, UK, an MSc in Condensed Matter Physics from the University of Ibadan, and a BSc in Physics from the University of Calabar (Nigeria). He is currently an Associate Professor in Physics Department at Akwa Ibom State University (Nigeria). With many years of teaching and research experience, Dr. Emah has authored/co-authored numerous publications in national and international journals, including the Applied Physics Letters, Journal of Electronic Materials, and European Physical Journal Plus. His research interests span nano electronics, condensed matter physics, and materials science. Dr. Emah is a member of the Nigerian Institute of Physics. Within the university, he has served in various capacities, including Head of Department (Physics), Director of Students Industrial Work Experience Scheme (SIWES), and membership in several committees. Dr. Emah has presented papers at international conferences, including the International Conference on Organic Electronics (ICOE) and the International Conference on Material for Energy.

