



Preparation and Characterization of Epoxy Resin Reinforced Chicken Eggshell Particulate Composites

JAMILA BABA ALI. *¹, ZION ABOH. O², ABDULLAHI DANLADI ¹

¹Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria

² Department of Chemistry, Kaduna State University, Kaduna.

* Corresponding Author Email address: jbabaali@abu.edu.ng Phone number: 07030477419

Abstract

The aim of this study is to investigate the effects of chicken eggshell particle (CES) 250 μ m in epoxy resin (ER). The composites were prepared using the hand lay-up technique. 10 wt.%, 20 wt.% and 30 wt.% of filler (CES) loading were incorporated in vary percentage into the matrix (ER). After conditioning the samples for 24hrs, the mechanical (Tensile, Flexural, Impact and Hardness) and physical (water absorption and density) properties of the composites were determined according to ASTM standards. The tensile stress for neat ER is 46.65 MPa with the addition of egg shell particles, the tensile stress increased from 20.63 Mpa, 46.11Mpa to 38.86Mpa for 10%, 20% and 30% CES loading respectively. The tensile strain, percentage Elongation and flexural strength decreased with increase in filler (CES) loading. Hardness of the composites increased with increase in CES content, from 5.98 HRF to 6.53, 7.80 and 6.00 HRF for 10%, 20% and 30% CES content respectively. Impact strength decreased with the addition of 10% CES and gradually increased with the incorporation of 20% and 30% CES. Water absorption increases with increase in CES content and decrease in ER content and with increase in the number of days. Density of the composites also shows decrease with increase in filler content.

Keywords: Composites, Egg shell, Epoxy resin, Mechanical properties and Physical properties

1.0 INTRODUCTION

Epoxy is a widely used thermosetting resin for various applications because of its considerable good properties such as adequate adhesiveness, curing-ability with numerous hardeners, very good mechanical properties, these properties makes its among the most widely used resins in composites, surface coating industry among others (Mohammed *et al.*,2018) Epoxy resin is highly brittle and has poor impact strength these limit its utilization in coating and composites application, these limitation led to the research on the use of organic fillers with this resin to modify its properties by reducing the brittles and increasing the strength (Saeb *et al.*,2017).

Chicken eggshell (CES) is a biowaste which consist of calcium carbonate, proteins and peptide functional groups, which give it the ability to perform the function of curing assistance when mix with epoxy resin (Mohammed *et al.*,2018).

There have been several attempts to use chicken eggshell for different applications, its chemical composition and availability makes chicken eggshell a potential source of filler/reinforcement in thermoplastic and thermosetting polymer composites (Abdullah and Hussein,2011; Sharmeeni *et al.*,2018; Mayank and Ajit,2020). Report have shown, among other characteristics that chicken eggshell, it has a relatively lower density compared to mineral calcium carbonate. In composites, materials are combined to make better use of their individual's properties and minimizing their deficiencies thus, producing a material with unique properties different from that of the individual components (Haroon *et al.*,2018).

In this study, chicken egg shell particles, an organic material was utilized as filler/reinforcement in Bisphenol A epoxy resin to produce composites thereby, utilizing this waste into useful products and also reducing the problem of environmental pollution.

2.0 MATERIALS AND METHOD

Materials

The materials/equipment used for this study are; Tensometer (TYPE W), Indentec Universal hardness testing machine, Charpy impact testing machine, grinding machine (Kera by soester berg 057748 Holland) Retsch A 200 Basic sieve and shaker (250 μm), glass mould (120mm \times 120mm \times 4mm), Bisphenol A epoxy resin and amine as hardener

Method

Preparation of chicken eggshell particles

Brown chicken eggshells were collected from different tea shops and eateries in Kaduna North metropolis. The chicken eggshells were rinsed with water immediately to reduce the protein membrane and the remains were dried in a dust free area to entirely eliminate the water from the CES. The dried CES were grinded to powder form using a grinding machine before passing it through a 250-micrometer sieve mesh.

Table 1. Composites formulations

CES/ER(Wt.%)	S ₁	S ₂	S ₃	S ₄
CES	0	10	20	30
Matrix	100	90	80	70
Total	100	100	100	100

Preparation of chicken eggshell particles/epoxy resin composite

Glass molds were covered with foil paper and petroleum jelly was applied on the foil paper as a releasing agent. A calculated amount of the epoxy resin as shown in table 1. and the hardener was measured in the ratio 2:1 respectively to produce the control sample. The mixture was stirred carefully to ensure even mixing of the resin and the amine hardener and to ensure good dispersion/distribution of the filler in the matrix. The mixture was poured into the mold and allowed to pre-cure for two hours, after which pressure was applied on the sample and allowed for 24 hours to completely cure in a laboratory condition. Method adopted from (Mohammad *et al.*,2018) with little modification. The above procedure was repeated for the remaining three (3) CES reinforced samples to obtained CES/ER composites as shown in Figure 1.



Figure 1. casting of composites



Characterization of CES/ER composites

After conditioning the samples for 24hrs, they were subjected to the following tests. Density of the composites was determined according to ASTM D792 - 13; water absorption test was carried out in accordance with ASTM D2842 - 12, and Hardness test was performed with hardness tester according to ASTM 5091; Izod impact strength analysis was performed according to ASTM 6957 while Tensile stress, strain and elongation tests were carried out using Tensometer. An average of five (5) samples were analyzed and the results were recorded accordingly, Microsoft excel was used to plot the graphs.

3.0 RESULTS AND DISCUSSION

Mechanical tests

The results obtained from the tensile stress, tensile strain, and percentage elongation are represented in Figure 2, 3, and 4 below

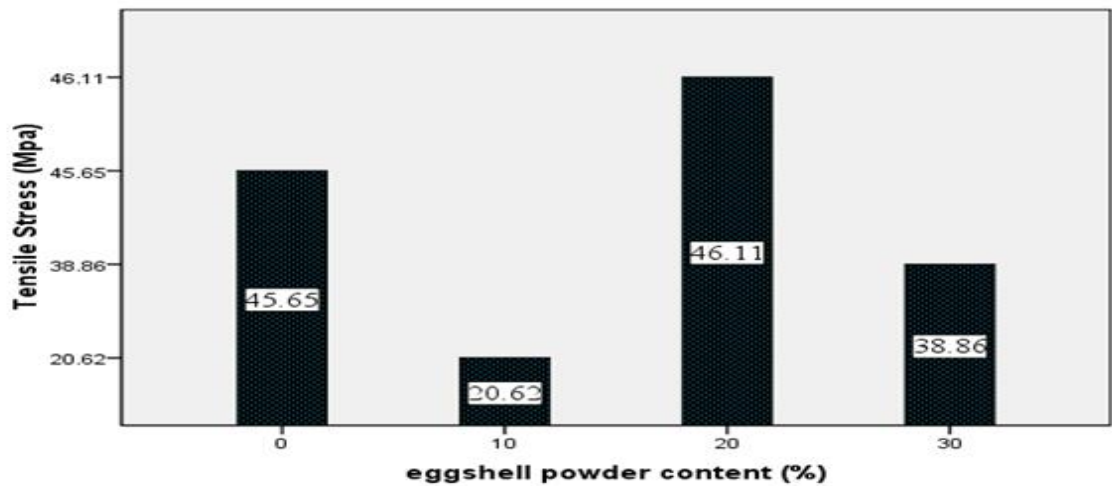


Figure 2. Tensile Stress against eggshell particles composites

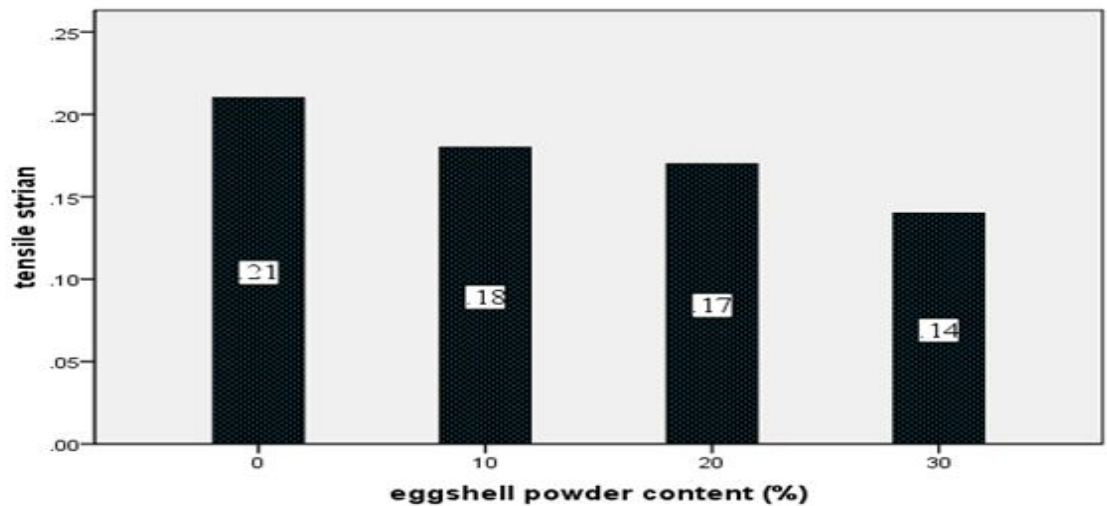


Figure 3. Tensile Strain against eggshell particles composites

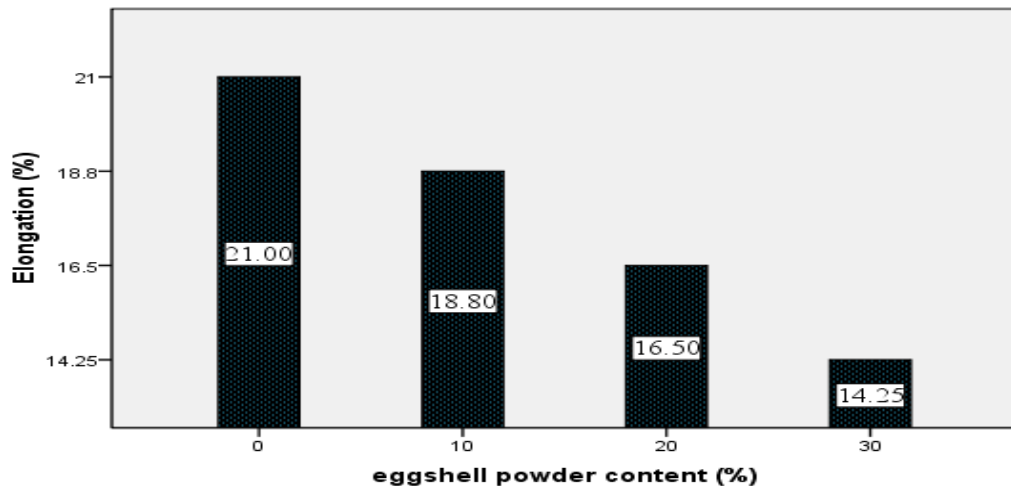


Figure 4. Elongation against eggshell particles composites

It was observed that the tensile stress of the composites decreased initially with the addition of 10% CES, with subsequent addition of the filler up to 20%, tensile stress of the composites increased from 20.63Mpa to 46.22MPa. The increase in strength of these composites corresponds to the ability of the filler to absorb the stress transferred to it by the polymer at 20% filler loading, the composite would be able to withstand more load before rapturing. This behaviour is similar to the results reported by (Abdullah and Hussein,2011; Hassan, 2012; Mohammad *et al.*, 2018; Mayank and Ajit, 2020) in their study of eggshell/epoxy resin composites, they associated the increase in strength to the good interaction between ES/ER.

Percentage elongation represents the result of tensile strain in percentage. It was observed that the elongation of the material decreased with increase in the filler content as shown in figure 4. The material becomes less flexible and cannot withstand much work done to it in the form of stretching. This can be attributed to the decrease in ductility of the material as the filler increased. This shows that, the application of these composites in areas of stretching is not advisable similar decrease was observed by Hassan, (2012).

FLEXURAL STRENGTH TEST

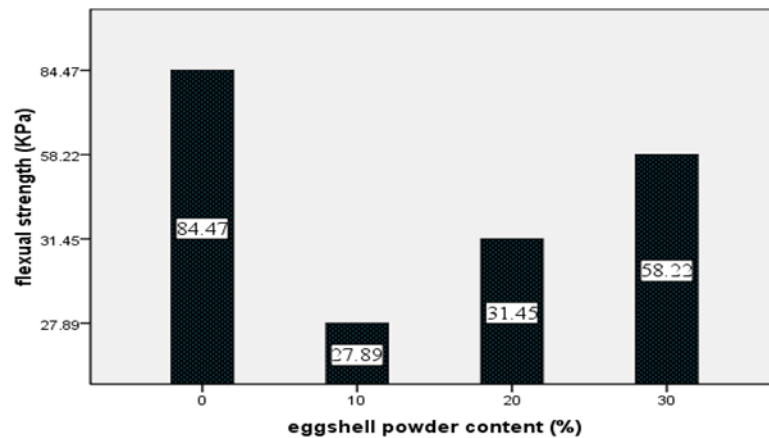


Figure 5: Flexural strength against eggshell particles composites

The results obtained from the flexural strength are represented in flexural stress (modulus of rupture) and the values are represented in figure 5 above. A progressive increase in filler loading led to increase in the flexural strength of the material after an initial drop in value for the control to 10% filler content from 84.47 to 27.89KPa. The increase showed a maximum at 30% filler content. The increase in strength can be attributed to the increase in good interfacial bonding between the CES and the ER, the proper dispersion of the CES in the matrix structure thus, increasing the bending ability of the material just before it yields Kai *et al.*, (2018) reported similar results of increase in flexural strength in their studies of the thermal/mechanical properties of epoxy/basalt composites.

HARDNESS TEST

The results for the hardness test are shown in Figure 6.

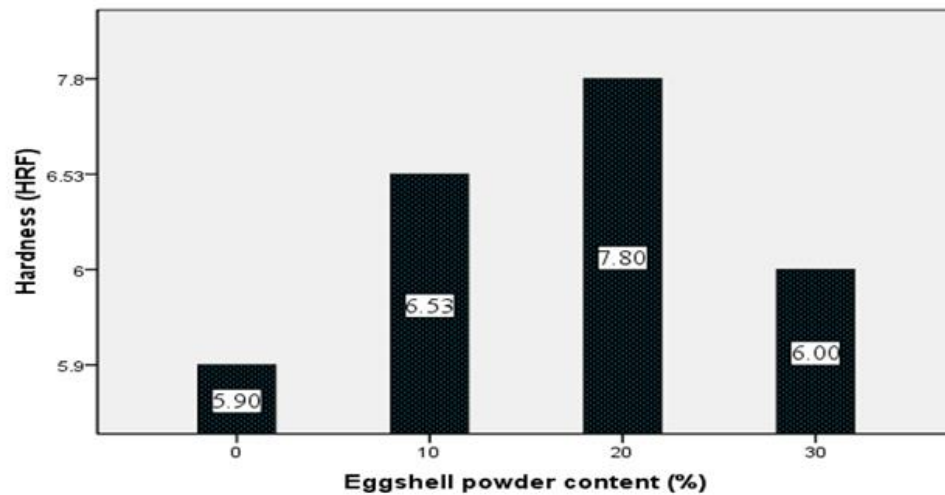


Figure 6: Hardness against eggshell particles composites

IMPACT STRENGTH TEST

The results obtained from the impact energy test are shown in figure 7.

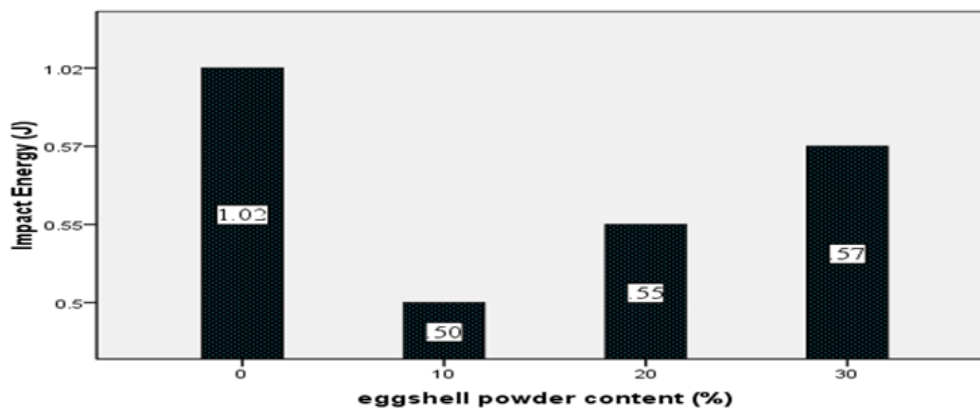


Figure 7: Impact energy against eggshell particles composites

From the result above it can be seen that the hardness of the material increased with increase in filler content from 10% - 20% filler loading 5.90HRF, 6.53HRF to 7.80 HRF (for 0%, 10% and 20% filler loading respectively) and

dropped afterwards at 30% filler content to (6.00HRF) but still with a value above that of the control sample. This can be attributed to the increase in the stiffness of the material with increase in filler content making the material a harder composite. It can be seen that filler materials are sometimes not required in a large quantity so as to maintain the blend between filler and matrix and this could be the reason for the drop-in hardness at 30% eggshell powder content and it could also be attributed to the saturation of the resin by the filler. The impact energy of the materials decreased from 1.02J of the 0% eggshell particles content to 0.5J at 10% eggshell particles content. It showed a 50% decrease then a subsequent increase in the impact energy to 0.55J at 20% eggshell content and 0.57J at 30% eggshell particles content. With the addition filler (CES) in the matrix structure, there was a disturbance in the 3-dimensional network of the matrix and reduction in the mobility of the polymer, this reduced the interfacial adhesion of the polymer and filler and hence, decreased the ability of the composites to absorb shock (Maxwel and Hinckel, 2012; Pavan *et al.*,2018)

PHYSICAL TESTS

Density

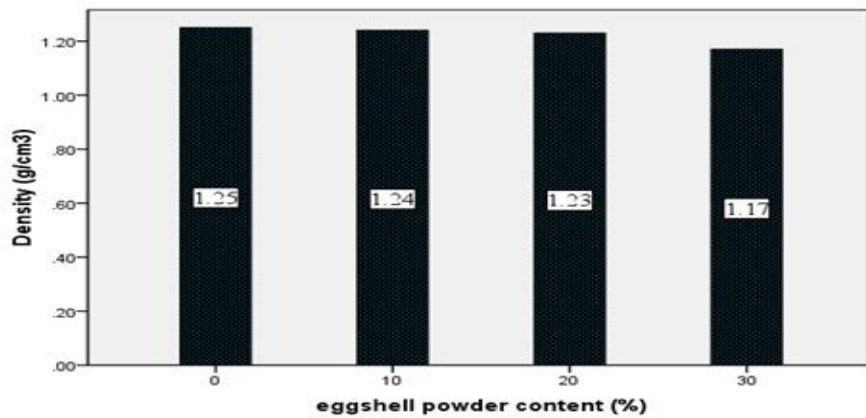


Figure 8: Density against eggshell particles composites

WATER ABSORPTION

The water absorption capacity of the composites is represented as percentage water absorption and below are the results obtained over 18 days.

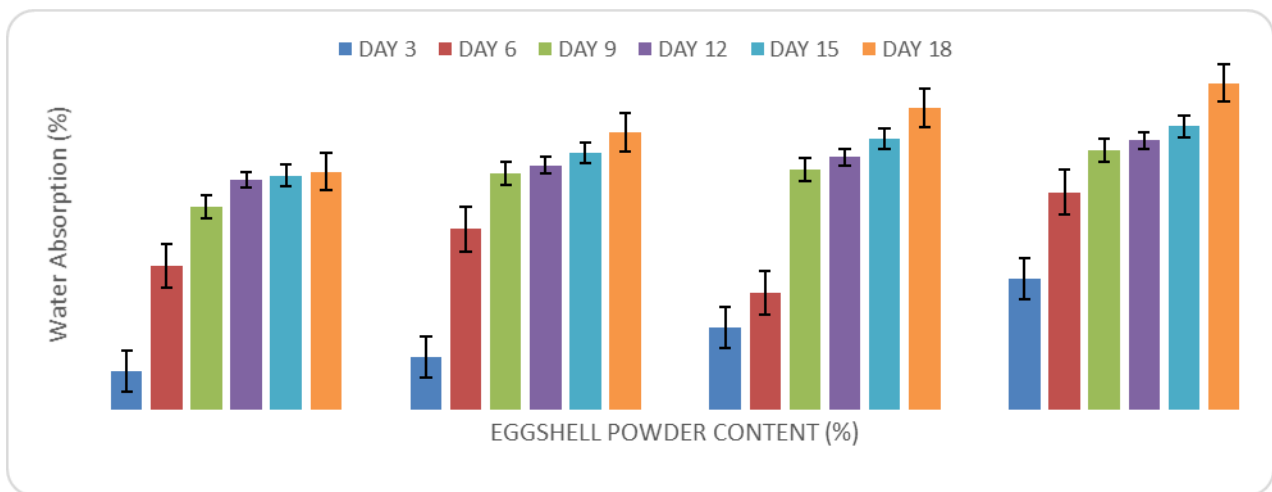


Figure 9: Water absorption against eggshell particles composites



From Figure 8 above, it can be seen that as the composition of the eggshell particles increase the density of the material decreases and as such the composite with the highest filler has the least density and this can be attributed to the fact that the CES has lower density, the addition of CES between the matrix (ER) structure led to a decreased in weight of the composites. The noticeable decrease in the density of the composites as the filler composition increase is a good attribute since low density is one of the benefits/ good properties of fibre/polymer composite material and makes it applicable in areas where light-weight materials are needed such as fan blade, partition walls among others. Decrease in density was also reported by (Patricio,2007; Hassan 2012).

The results clearly showed that water absorption increases progressively with increase in CES content. All samples except the pure epoxy resin composite showed a high rate of water absorption at the beginning of the test, with time the pure control sample gradually starts to absorb water. It was observed that from day 9 to 18 days of the experiment, the rate of water uptake reduced as compared to day 3 to day 9 which showed higher water uptake this could be that the samples were beginning to attain saturation as such, the rate of water absorption of the composites decrease.

Epoxy resin on its own is a thermoset with very little pores and has a very low affinity for water molecules (Hamdi *et al.*,2018). The eggshell powder is organic in nature and hence has affinity for water molecules and this increases the hydrophilic properties of the composites (Sharmeeni *et al.*,2018). Hence, as the content of the CES increases, the organic content in the polymer increases and this led to a corresponding increase in the percentage water absorption of the resulting composites with increase in number of days. As the water absorption increase, micro-organism present in the water act on the filler and degrade it gradually creating pore/void within the composites thus, creating stress centres that will initiate failure of the composites with the application of little stress. Water absorption has advance effect on the mechanical properties of composites because it reduces the strength of the material as the material stay longer in water (Abdullah and Hussein, 2011; Hassan, 2012), limiting the application of these prepared composites to indoor usage.

4.0 Conclusion

Chicken eggshell/epoxy resin composites were successfully prepared using handlay-up techniques. The Mechanical and physical properties of the composites were determined according to ASTM standards and the following conclusions were drawn;

1. The tensile stress of the composites decreased initially and increased steadily with increasing with an increase in CES content.
2. The hardness value increased with increasing amount of filler with a maximum value at 20% weight composition.
3. The impact energy and flexural strength values decreased with increasing amount of the filler content
4. The density of the composites decreased in with increase in % composition of CES content.
5. The values for water absorption increased with increase in % composition of CES and with increasing number of days

5.0 REFERENCES

- Abdullah A. and Hussein, R. D. (2011). Water absorption and mechanical properties of high-density polyethylene/egg shell composite. *Journal of Basrah Researches (Sciences)*, 37(3A), 36 – 42.
- Hamdi, W.J, Habubi, N.F. (2018). Preparation of epoxy chicken eggshell composite as thermal insulation. *Journal of the Australian Ceramic Society*.54, 231–235 (2018). <https://doi.org/10.1007/s41779-017-0145-4>
- Hassan V. A. (2012). Development of Polyester/Eggshell Particulate Composites. *Tribology in Industry*, 34(4), 217 - 225. Retrieved from www.tribology.fink.rs



- Haroon M, Lia V, Massimo B, Alessandro P. (2018). Mechanical properties and strain monitoring of glass-epoxy composites with graphene-coated fibers. *composites part A*. <https://doi.org/10.1016/j.compositesa.2017.12.023>. 1359-835. Elsevier.
- Kai F, Wenyan L, Zhenqing W, Zhiwei D and Bin Y. (2018). Thermal and Mechanical Properties of Bamboo Fiber Reinforced Epoxy Composites. *Journal of Polymers*, 10, 608; doi:10.3390/polym10060608
- Maxwell T. Hinckel, Y. N.N. (2012). The eggshell: structure, composition and mineralization. *Frontiers in Bioscience*, 17, 1266-1280
- Mayank and, Ajit K. N.S. (2020). Processing and interfacial effect of gelatin gel on coconut jute reinforced egg shell bio-composite. *Materials today proceedings*. <https://doi.org/10.1016/j.matpr.2019.12.129>
- Mohammad R. S, Hadi R, Milad N, Seyed Mohammad R. P, Hossein A.K, Debora P. (2017). Cure kinetics of epoxy/chicken eggshell biowaste composites: Isothermal calorimetric and chemorheological analyses. *Progress in Organic Coatings*. <https://doi.org/10.1016/j.porgcoat.2017.10.018>
- Patricio Toro, R. Q.-P. (2007). Eggshell, a new bio-filler for polypropylene composites. *Materials Letters*, 61(22), 4347- 4350.
- Pavan H, Manjunath S, Gowri S. M.C, Mohan N.S. (2018). Investigation on Effect of Egg Shell Powder on Mechanical Properties of GFRP Composites. *Materialstodayproceedings*, Volume 5, Issue 1, Part 3, Pages 3014-3018 .<https://doi.org/10.1016/j.matpr.2018.01.101>.
- Saeb M.R, Rastin H, Nonahal M, Ghaffari M, Jannesari A, Formela K. (2017). Cure kinetics of epoxy/MWCNTs nanocomposites: Nonisothermal calorimetric and rheo-kinetic techniques, *Journal of Applied Polymer Science*, DOI: 10.1002/app. 4522.
- Sharweeni M, Yamuna M, Mathialagan M, Hanafi I.(2018). Development of HDPE-modified eggshell composite. *Polymer composites*, retrieved from wiley onlinr library.volume 38 , Pages 1630-1637. <https://doi.org/10.1002/pc.24108>