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Research Paper

Effects of Egg and Snail Shells on Biodegradation and Tensile Properties of Waste Plastics Fabricated Thermoplastics Elastomer Composites

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Abstract
The essence of this study is to proffer solution on the degradation of the environment caused by non-degradable plastics waste. A novel approach on plastic waste management was adopted by fabricating a thermoplastic natural rubber (TPNR) composite using waste Polyethyleneterephthalate {PET}plastics and eggshell as bio-fillers to initiate degradation by microorganism.Waste Polyethylene Terephthalates (PET) was grinded andmelted blended with Natural Rubber with 40pphr of Eggshell to fabricate a Natural Rubber Thermoplastic elastomer (TPNR) composite. The resultant thermoplastic elastomer composite was prepared for soil burial for a period of 90 days to obtain percentage weight loss as an indication of biodegradation. The NR/PET composite was evaluated for tensile properties. The results obtained were of the new that the tensile strength, elongation at break and modulus decreases with increase in soil burial duration time. The eggshell as a biopolymer has been shown to initiate biodegradation. There was a reduction in tensile strength at a blend ratio of 50/50 NR/PET blend, an indication that degradation has occurred, hence tensile properties are useful tools for the evaluationof biodegradation of polymeric materials.
Keyword – *PET, Egg shell, Natural Rubber, Biodegradation, Tensile properties, Composite*

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I. Introduction

As a result of environmental concern and awareness, there is anincreased need to develop plastic materials that are biodegradable. This has led to increase in demand for natural-fibre based composites for commercial use in the industrial and commercial sector.Plastics have become a serious menace to the environment causing serious environmental pollution because of their slow degradation in the environment which takes some decades, so it's considered a non-degradable material. As a result of their non-degradable nature, they are considered as solid waste on the earth's surface.The world annual production of non-degradable plastics ranges from 350-400 million tons, out of this, about 5-13 million tons of waste plastics are released yearly into the oceans, that damage the ecological and aquatic environment (OECD., 2022). Plastic pollution in the marine environment has resulted to a minimum of 267 species of aquatic life being affected, these include turtles 86% and seabirds 44% (Valavanidis,2023).

There are various types of plastics and their variants; these include polyethylene, polypropylene, polystyrene, polyvinyl chloride, polytetra fluoroethylene, polyurethane etc. To degrade these plastics, various methods are used such as photodegradation, thermo-oxidative degradation, hydrolytic degradation and biodegradation. Compared with other degradation methods, the biodegradation method is mostly preferred because of its pollution free mechanism and eco-friendly process. In biodegradation, the process is initiated by micro-organism, i.e. bacteria, and fungi (Yang et al, 2023)

As a result of increasing environmental awareness, plastic pollution has become a serious global environmental problem. Plastic pollution alter living conditions and natural processes, reducing ecosystem ability to adapt to climate change, directly affecting millions of people and livelihood, food production capabilities and social well-being.

As technology advancement and application increases use of plastic will also increase, because of their lightweight, cheap, easy to fabricate, non-corrosion, and versatile characteristics and nature. It is projected that global production of thermoplastics will amount to 445.25 million metric time by 2025. Annual production volumes are expected to rise to approximately 590mmt by 2050 (OECD., 2022). This will therefore pose a serious environmental challenge, since their recovery and disposal have become a major challenge because of their non-biodegradable nature.

Biodegradation of plastics is now an emerging option available to solve environmental problems of plastic degradation (Thew et al, 2023). Plastics are indispensable ingredients of the modern economy. They are non-biodegradation; rapid growth of the world population has led to an increase in the demand for commodity plastics. Biodegradable plastics offer a lot of advantages such as increased soil fertility, low accumulation of bulky waste plastics in the environment and reduction in the cost of waste management (Srikanth et al, 2022). They can be recycled to useful metabolites (monomers and oligomers) by microorganism and enzymes, this is the degradation of petroleum-based plastics by biological process using enzymes and microorganisms (Orlando et al, 2023), studies have shown that polycarbonates possess some degree of biodegradability (Valavanidis, 2023). The increase in plastic waste pollution affects living organisms; biodegradation of plastics by microorganism can help to decrease the problem of environmental pollution. Biodegradation of plastics is one of the current focused areas of research on solving plastic pollution problems, (Srikanth et al, 2022; Lomwongsopon & Varrone, 2022)

Plastic pollution is a serious global environmental problem. Plastic pollution can alter habitats and natural processes, reducing ecosystem's ability to adapt to climate change, directly affecting millions of people's livelihoods, food production capabilities and social wellbeing (Yang et al, 2023*).*Of recent bio-recycling of plastics by microbial enzymes has become an emerging and interesting field of research. Microorganisms have developed enormous diverse pathways in the course of their evolution and some bacterial or fungi possess great variety of enzymes that can break down the molecular chains of recalcitrant plastics (Ali, et al, 2023). In 2016, scientist in Japan discovered the bacterium *Ideonella Sakaiensis 201-F6* in a recycled yard for PET bottles. The bacterium was able to grow on PET and feed on it, from this, enzymatic biodegradation was expanded for a great range of polymers and with successful products for certain types of plastic waste (Valavanidis, 2023).

The use of bio-fillers in composite production is as a result of their environmental friendliness. Biomaterials are biodegradable, lightweight, available, recyclable and renewable, hence substituting them for synthetic materials will not only clean the environment but will also reduce the hazardous effects of climate change caused by the production and use of synthetic materials (Emadian et al, 2017). Egg and other shells have been considered as a good material for use as bio-filler for preparing polymer composites because they are environmentally friendly, inexpensive, abundant, low density and also a renewable resource (Iwanczuk and Kozlowski, 2017).

II. Materials and Methods

2.1 Materials

Waste Plastic materials made of High-Density Polyethylene (HDPE) and Polyethylene Terephthalate (PET) bottles were collected around Auchi and its environ. Natural rubber grade, NSR 10, conforming to the International technically specified rubber grade TSR-10 was obtained from the Rubber Research Institute of Nigeria, Iyanomo, Benin City, Nigeria. Egg and Snail shells were collected from Auchi and environ. Other compounding additives were of commercial grade.

2.2 Methods

PET plastic waste was grinded and shredded separately into pieces.

PET/NR blends preparation

The waste PET plastics shredded materials were melt-blended with Natural rubber, prepared in a blend ratio of 80/20,70/30, 60/40, 50/50 and 40/60 NR/PET respectively in a laboratory size two roll mill at a temperature of 70^0C -130^0C. The blending procedure adopted was the ASTM 3184-81 standard.The polymer mixture, a Thermoplastic Natural Rubber blend (TPNR) were compression molded in a rectangular steel mould to be placed between two plates of an electrically heated hydraulic press. The samples were compressed at 160^0C at 15MPa pressure for 10miuntes and allowed to cool at room temperature.

Dumbbell test pieces were produced for analysis.

2.2.1 Soil-burial degradation Test

A Soil burial test was carried out to determine the biodegradability of the TPNR composite fabricated. Dumbbell shaped specimens of definite sizes were cut from each of the blended samples. The soil burial test for biodegradationlasted for a period of 90 days. The dumbbell shaped specimen was buried in the soil at a depth of 10cm from the surface and subjected to the action of microorganisms which are normally present in the soil. The samples were removed from the soil after every two weeks, washed with distilled water, dried in air and weighed for weight loss as an indication of biodegradation. This was repeated for 90 days period. The percentage weight loss (W_L) was calculated as follows (Francesco P.L. et al 2023):

$$W_L = \frac{W_1 - W_2}{W_2} \text{ x } \%$$

W_1 and W_2 are weights before and after Soil-burial

2.2.2 Tensile Properties test

Tensile properties were evaluated for the samples using Instron3366 universal tensile testing machine according to ASTM D638. The test was performed at a cross-head speed of 500mm/min at room temperature. Three specimens per blend were used to obtain the average values for tensile properties.

Consequent upon the above, it has become necessary to adopt a safe and sustainable process by means of biodegradation of plastics using microorganisms and enzymes that contribute positively to the environment.

III. Results and Discussion

3.1. Soil burial degradation Result.

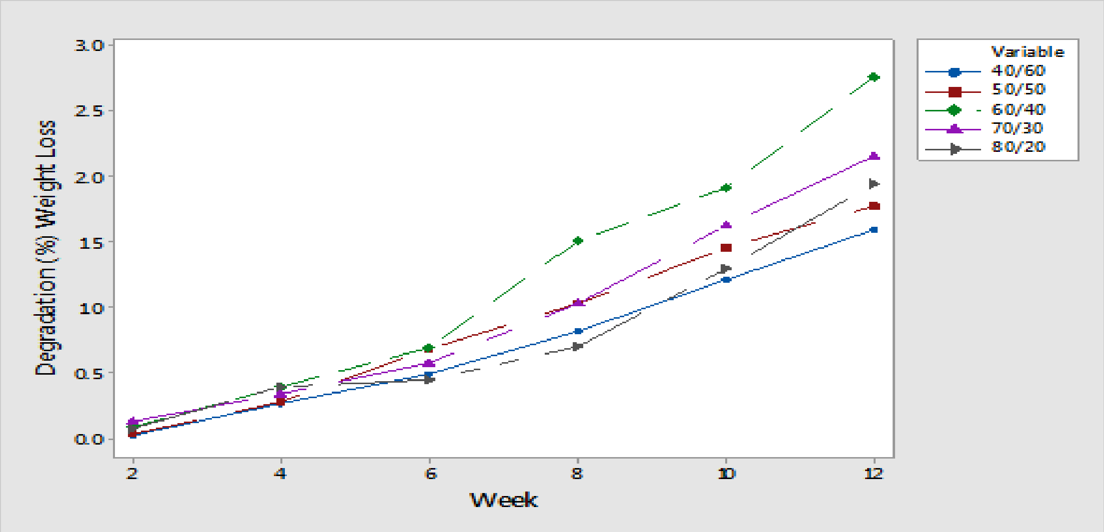


Fig.3.1 Effects of Egg shell on the degradation of NR/PET Thermoplastic Elastomer.

3.2 Tensile Properties Results

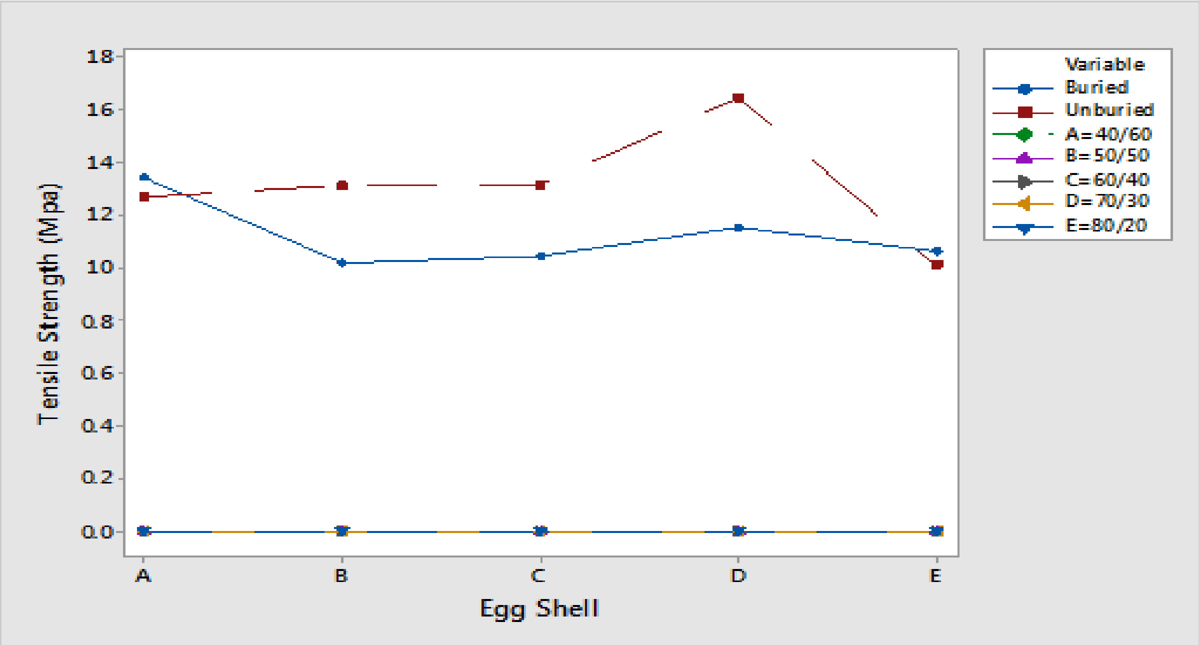
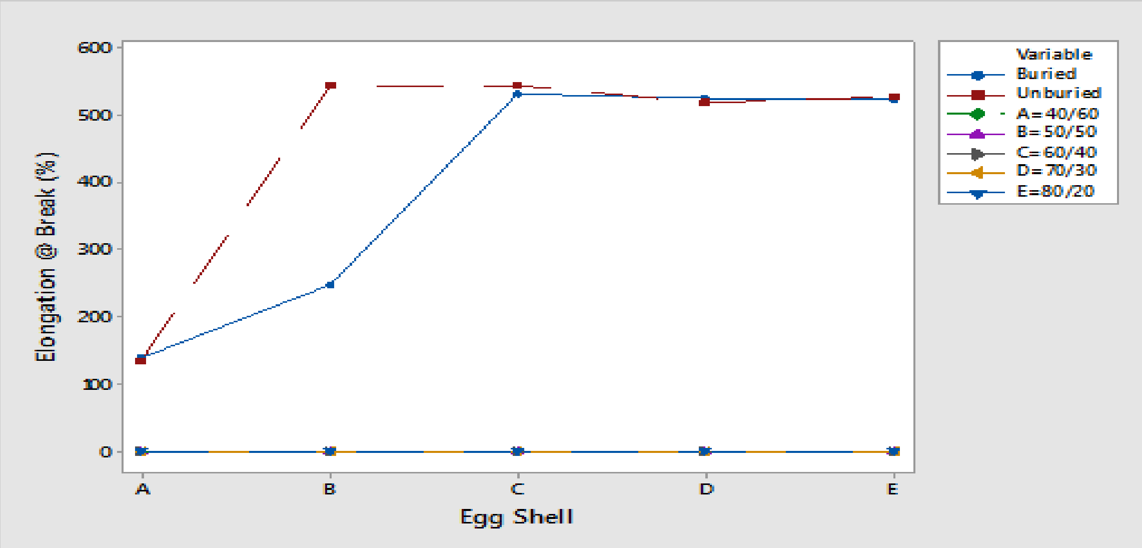


Fig.3.2 Effects of Egg shell on the Tensile strength of NR/PET Thermoplastic Elastomer



XFig.3.3 Effects of Egg shell on the Elongation at Break of NR/PET Thermoplastic

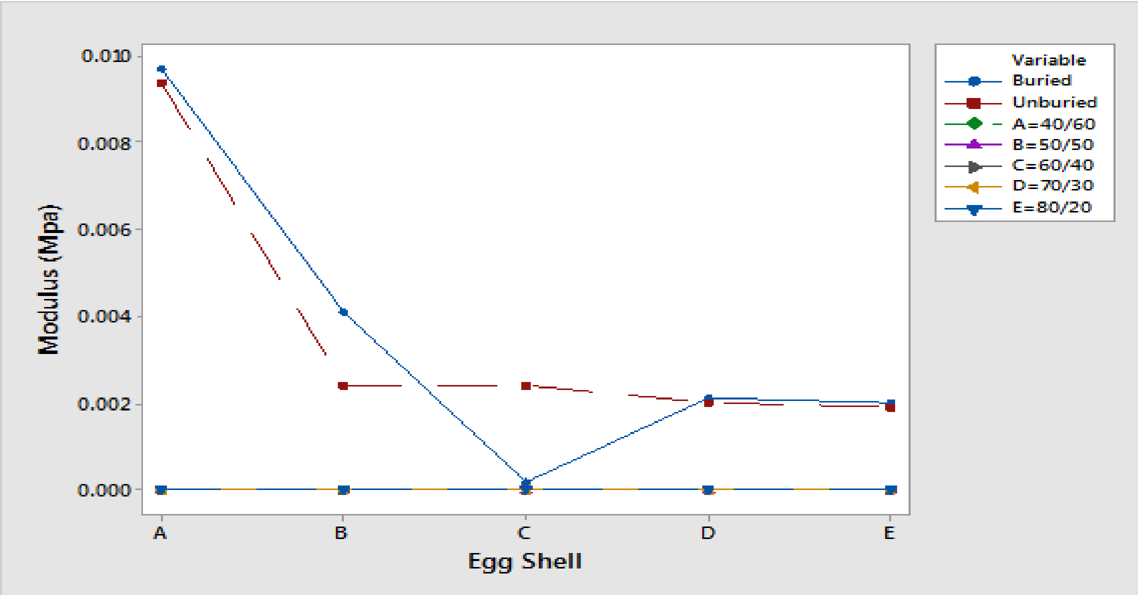


Fig.3.4 Effects of Egg shell on Modulus of NR/PET Thermoplastic

Soil burial test was carried out to know the effect of egg shell powder on the biodegradation of NR/PET and soil burial test lasted for12weeks.

As soil burial time increases from the 2nd week to the 12th week, the percentage weight loss and biodegradation increases. The increase in biodegradation is as a result of a molecular weight reduction producing oligameric chains as reported by Francesco P.L. et al (2023), they were of the view that the biodegradation results in polymer bearing hydrophilic chain ends, which are easily removed from the matrix and susceptible to attack by microorganisms present in the soil.

From fig. 4.1, the rate of weight loss is an indication of biodegradation increases as the ratio of Polyethylene Terephtalate (PET) increases. The egg shell powder being a biopolymer has shown to initiate biodegradation. As reported by Obasi et al(2023) degradation of biopolymers occur due to quitting of the biomaterial sites, in this case the egg shell are quitted which are former occupied by either microbes, water or other hydrophilic substances. The hydrophilic nature of the composite causes swelling and accelerates biodegradation. The egg shell can be degraded by microorganism in the soil.From fig. 4.2 the result shows that for the unburied sample, there is an increase in the tensile strength at point D, where the blend ratio of NR/PET is 70/30, before decreasing, this is as result of the effect of the tensile properties of natural rubber which has a predominant effect over PET in the matrix of the composite. The soil burial has an effect on the degradation of the TPNR elastomer as evidenced in figure 4.2 showing a reduction in the tensile strength which is an indication of degradation of the tensile properties of the TPNR composite. There is a noticeable reduction in the tensile strength of the composite at a blend ratio of 50/50 NR/PET composition which equally confirm that degradation has taken place in the composites.

Similar results were reported by Ibrahim et al (2018) that mechanical properties of green composites experience gradual deterioration during composting. They stated that during soil burial, the fibre in the composites passed through degradation process as evident in weight loss leading to easy breakage of the molecular chains under tensile force. They equally postulated that microbial activities during soil burial tend to weaken the interfacial effect on the fibres leading to decreasing in tensile strength of the material. This postulation has also manifested in our work as shown on the result of the effect of soil burial on the buried and unburied sample as illustrated in figure 4.2.The decrease in tensile properties was due to pits and voids which occur as a result of microorganisms attack on the composites resulting weight loss as an evidence of degradation. The pits and voids act as stress concentrator leading to decrease in tensile strength and modulus (Obasi et al, 2023).

The unburied sample exhibited the highest elongation at break as shown in fig 4.3 with the highest elongation at break exhibited by 50/50 sample blended ratio of NR/PET, while the buried sample showed lower elongation at break of the sample B at 50/50 blend ratio with an elongation at break of about 250%. There is also a similar trend of reduction in tensile properties of buried samples showing that degradation by microorganism actually took place as evidence in the reduction of tensile properties. The young modulus of the unburied and buried samples also exhibited a similar trend of reduction in tensile properties as also reported by *(Lomwongsopon andVarrone,2022).*

IV. Conclusion.

The study has shown that eggshell as a biofibre can initiate degradation on thermoplastic elastomer which are naturally non degradable polymer. The result further revealed that degradation affects tensile properties of polymer, hence tensile properties is a useful tool for the evaluation of biodegradation of polymeric materials. The soil burial results revealed that blend ratio composition of thermoplastic elastomer have consequences on the rate of degradation of thermoplastic elastomer.

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Conflict of interest: The authors declare no conflict of interest.

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