

# The Effects of Filler Contents and Particle Sizes on the Mechanical and End-Use Properties of Snail Shell Powder Filled Polypropylene

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## ABSTRACT

*Polypropylene composites of snail shell powder were prepared at filler contents, 0 to 40 wt%. The particle sizes of the snail shell powder investigated were 0.150, 0.30, and 0.42  $\mu\text{m}$ . Talc, of particle size, 0.150  $\mu\text{m}$  was used as the reference filler. The polypropylene composites were prepared in an injection moulding machine and the resulting composites were extruded as sheets. Some mechanical and end-use properties of the prepared composites were determined. Results showed that the snail shell powder improved the tensile modulus, flexural strength, and impact strength of polypropylene and these properties increased with increases in the filler content and decreases in the filler particle size. The elongation at break of the composites was however observed to decrease with increases in the filler content, and particle size. The elongation at break of talc filled polypropylene was zero, an indication of the brittle nature of polypropylene composites of talc. The hardness, water sorption (24-hr) and specific gravity of the composites were found to increase with increases in the filler content, and decreases in the filler particle size. The level of water absorbed by snail shell powder composites of polypropylene is considerably higher than that of talc filled polypropylene. The flame retardant properties of the prepared composites were however found to decrease with increases in the filler content, and particle size. Generally, snail shell powder was found to show greater property improvement over talc in the prepared composites.*

**Keywords:** Filler, Particle Size, Polypropylene, Snail Shell powder, Composite

## 1. Introduction

The past decades have witnessed increasing interest in the use of fillers in the polymer industry. Fillers greatly enhance the dimensional stability, impact resistance, tensile and compressive strength, abrasion resistance and thermal stability when incorporated into polymers. Fillers which merely increase the bulk volume, and hence, reduce price, are known as extender fillers while those which improve the mechanical properties particularly tensile strength are termed as reinforcing fillers [1-4].

Polypropylene is one of the most important polyolefin's that have wide range of applications. Presently, there has been an increase in the use of filled polypropylene in electrical and automotive engineering. This is mainly due to the excellent stiffness property which polypropylene exhibits and which enables it to substitute conventional materials in demanding engineering applications [5]. Typical fillers for polypropylene are glass fibres, glass

sphere, talc, asbestos, calcium carbonate, silica and mica. The use of mineral fillers and fibres in making polymer composites has certain drawbacks. For example, a lot of energy is required in the processing of glass fibres since their processing temperatures can exceed 1200°C. Glass fibres also tend to abrade processing equipments, and increase the density of the plastic system [6]. There has been a combined search for filler materials in compounding polypropylene and which is likely to grow with the introduction of improved compounding technology, and new coupling and compatibilizing agents that permit the use of high filler/reinforcement content [7]. As suggested by Kartz and Milewski [7], fillings up to 75 parts per hundred (pph) could be common in future.

Different filler materials have been studied for making polypropylene composites. These materials included wood, kenaf and sage fibres [8], saw dust [9], flax [10], hemp strand [11], green coconut fibre [12], and organo-montmorillonite [13]. Thus, Fan *et al.* [14] who

studied polypropylene-montmorillonite nanocomposites reported a decrease in modulus and tensile strength of the composites with increasing clay content. Similarly, Chen *et al.* [15] who investigated the properties of polypropylene filled with magnesium hydroxide reported that the addition of magnesium hydroxide improved the flame retardant property of polypropylene/magnesium hydroxide composites, but seriously deteriorated the mechanical properties. Recently, the use of snail shell powder as a filler in making polypropylene composite was reported [16]. Snail shell powder contents of 0 to 5 wt% were investigated at a powder particle size of 0.30  $\mu\text{m}$ . The properties of the polypropylene composites determined were the specific gravity, water sorption (24-hr), flammability, and hardness tests.

In the present report on further utilization of snail shell powder in filling polypropylene, the central objectives are to (i) investigate fully the properties of polypropylene composites of snail shell since the work reported above [16] was considered exploratory and limited in scope, (ii) determine the effects of snail shell powder particle size on the properties of polypropylene composites. Snail shell powder contents of 0 to 40 wt% were used in this study.

Besides the work reported above [16], the use of snail shell powder in filling polypropylene or any other thermoplastic had not been reported in the scientific literature to our knowledge. Snail shell is a domestic waste. The waste presently does not have any known domestic application in our locality, and could be found littering dust bins in our big cities and farm yards in villages.

## 2. Materials and Method

### 2.1. Materials

The polypropylene used in this study was obtained from Eleme Petrochemical Company Limited, Rivers State, Nigeria. It has a melt flow index of 2.5 - 3.5 g/min, and density, 0.926 g/cm<sup>3</sup>. The snail shell from which snail shell powder was produced was collected locally within Owerri metropolis, Imo state, Nigeria. The shell was properly treated to remove impurities before it was crushed and sieved to three particle sizes namely, 0.150, 0.30, and 0.42  $\mu\text{m}$ . Talc which was used as a reference filler was purchased from a Chemical Store at Owerri, Imo State, Nigeria.

### 2.2. Preparation of Polypropylene Composites

The polypropylene composites of snail shell powder were prepared by thoroughly mixing 40 g of polypropylene with appropriate filler quantities (0, 5, 10, 20, 30 and 40 wt%). The polypropylene was melted and ho-

mogenized with the filler in an injection moulding machine. The resulted composites were extruded as sheets. The polypropylene composites of talc were prepared only at filler particle size, 0.150  $\mu\text{m}$ .

### 2.3. Testing

The tensile strength (ASTM D 638), tensile modulus (ASTM 1822), flexural strength (ASTM D 790-97), impact strength (ASTM D256), rock well hardness, (ASTM D 785), specific gravity (ASTM D 792), and water sorption (24-hr) (ISO 180) properties of the prepared polypropylene composites were determined using standard methods. A modification of ASTM D 4804 was used to determine the flammability rate of the composites. Since polypropylene filled or unfilled is a thermoplastic, flame spread is regarded as the rate of melt-burn, *i.e.*, the rate at which the original length of the specimen decreases as flame/heat spreads along the specimen. The flammability rate (FR) is expressed as,

$$\text{FR (mm/s)} = D_p/P_t - I_t [1]$$

where  $D_p$  = Propagation distance measured in millimetre.

$P_t$  = Flame propagation time measured in seconds.

$I_t$  = Ignition time measured in seconds.

## 3. Results and Discussion

### 3.1. Mechanical Properties

The mechanical properties of polypropylene composites prepared in this study have been determined and the results are illustrated graphically as shown in **Figures 1-5**. Talc was used as the reference filler in this study since it is one of the standard fillers in use in the plastic industry [13].

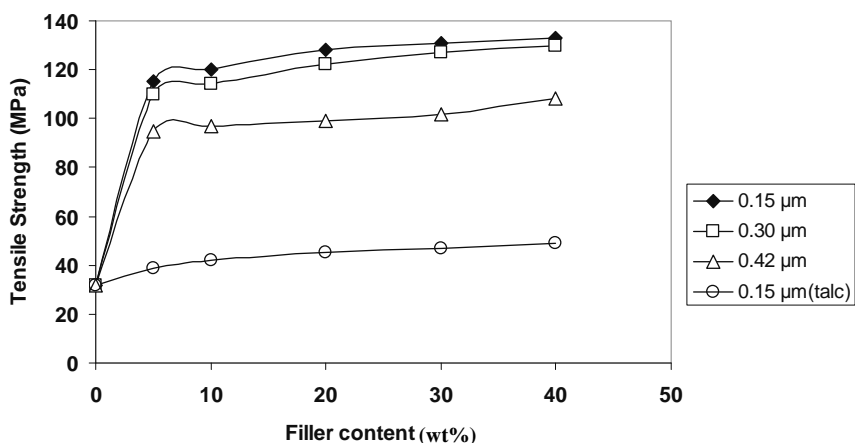
#### 3.1.1. Tensile Strength

**Figure 1** shows the effect of filler contents, and particle sizes on the tensile strengths of unfilled, and filled polypropylene. The tensile strength of polypropylene composites was observed to increase with increases in increases in snail shell powder content and particle size. From **Figure 1**, it is clear that the smaller the particle size of snail shell powder, the higher the tensile strength of the polypropylene composite at any snail shell powder content and particle size considered. The better dispersion and filler-matrix interaction may be the two main reasons or factors responsible for the observed trend. Similar observations have been reported by Bigg, [17], and Fuad *et al.* [18] for other filled systems. However, Fan *et al.* [14] reported decreases in tensile strength of polypropylene-montmorillonite composites with increases in clay content.

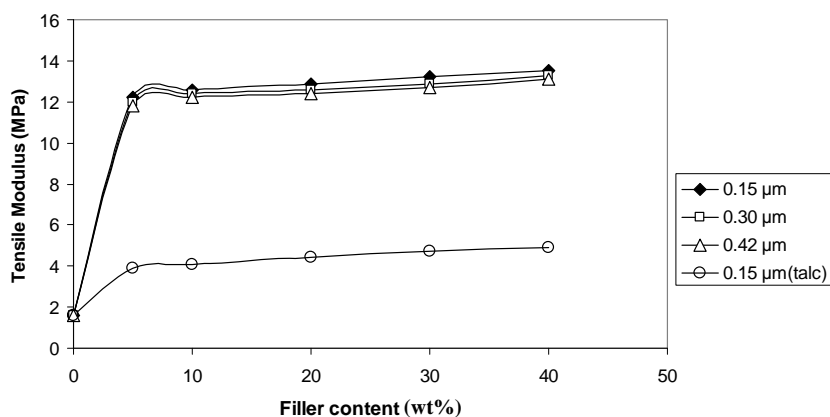
### 3.1.2. Tensile Modulus

**Figure 2** illustrates the effects of snail shell powder content, and particle size on the tensile modulus of prepared polypropylene composites. Like was observed on the effect of filler content and particle size on the tensile

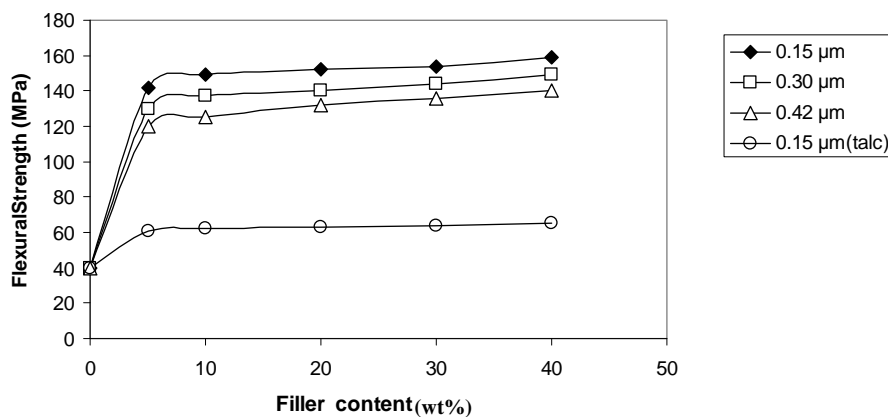
strength of filled polypropylene, the modulus of the composites increased with increases in filler content and filler particle size. This observation highlights the fact that the incorporation of fillers into polymer matrix improves the stiffness of the composites [19]. The snail



**Figure 1.** Tensile strength versus filler content for polypropylene composites at different filler particle size.



**Figure 2.** Tensile modulus versus filler content for polypropylene composites at different filler particle size.



**Figure 3.** Flexural strength versus filler content for polypropylene composites at different filler particle size.

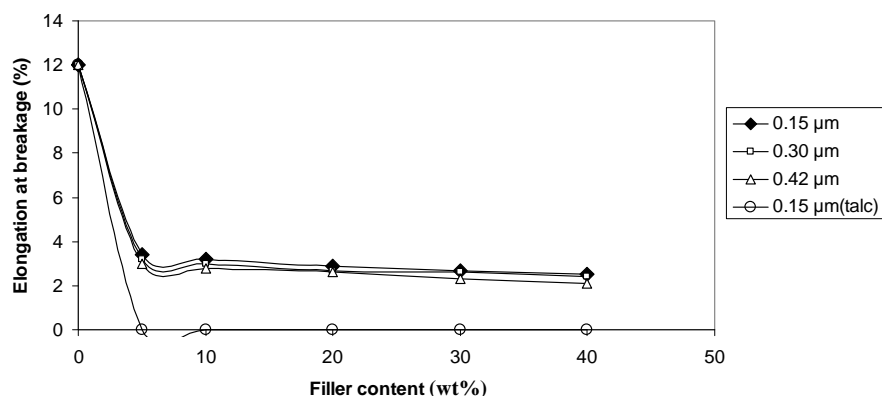


Figure 4. Elongation at breakage versus filler content for polypropylene composites at different filler particle size.

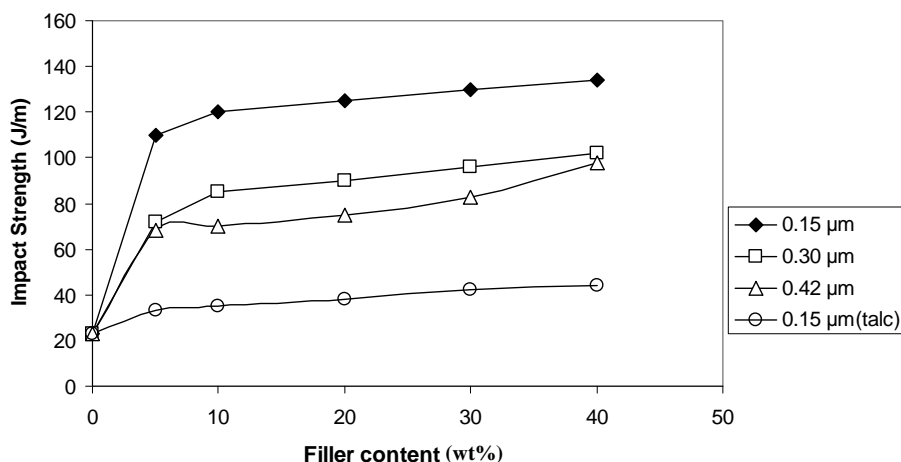


Figure 5. Impact strength versus filler content for polypropylene composites at different filler particle size.

shell powder exhibited higher tensile modulus on the composites than talc, the reference filler.

### 3.1.3. Flexural Strength

From **Figure 3**, the flexural strength of polypropylene composites is observed to increase with increases in filler content, and decreases in filler particle size.

Embu *et al.* [20] who studied the effect of mica content on the mechanical properties of polypropylene composites reported increases in the flexural strength of the composites with increases in mica content. The present study shows that snail shell powder is superior to talc in improving the flexural strength of polypropylene.

### 3.1.4. Elongation at Break

**Figure 4** shows that the elongation at break for snail shell powder-polypropylene composites decreases with increases in filler content at any given filler particle size considered.

Fillers can be considered as structural elements embedded in the polymer matrix, and at the concentrations of the filler used (0 - 40 wt%), the contents might not be

high enough to significantly restrain the polypropylene molecules. Consequently, highly localized strains might have occurred at the concentrations investigated, causing dewetting between polypropylene and the filler, and thus, leaving essentially a matrix that is not ductile. Such a reduction in elongation at break of a composite with increases in filler content, irrespective of filler particle size has been reported by Ismail *et al.* [21]. **Figure 4** shows that the elongation at break of the polypropylene composites decreases with increases in the filler particle size. It is very interesting to note that in the present investigation, talc filled polypropylene did not exhibit any elongation at break, an indication that talc filled polypropylene is brittle and would not be suitable for some of the applications of polypropylene composites.

### 3.1.5. Impact Strength

The impact strength of polypropylene composites of snail shell powder at a particular filler particle size was observed to increase with increases in snail shell powder content (**Figure 5**).

The increase in impact strength of the prepared composites was very remarkable for snail shell powder composites of polypropylene than was for talc. This remarkable performance indicates that snail shell powder was more effective in distributing the applied stress over a large volume at the base of the notch, and which helped to prevent propagation of cracks by carrying large part of the load in the area under the crack. The increase in impact strength of a polymer composite with increase in filler content has been reported in the literature [17]. The impact strength of the prepared composites for particular filler and at a given filler content was observed to decrease with increase in filler particle size. Thus, increasing the particle size of snail shell powder at a given filler content probably increased the level of stress concentration in the composites with the resultant decrease in impact strength.

### 3.1.6. Hardness

At a given filler particle size, the hardness of polypropylene composites was observed to increase with increase in the amount of filler incorporated into polypropylene (**Figure 6**).

This result indicates enhancement of abrasion and impact strength of the composites. Generally, the hardness of the composites could be observed to decrease with increase in the particle size of the filler at a given filler content. Such a decrease in the hardness of polypropylene composites with increases in filler particle size was reported by Kokta *et al.* [22].

### 3.1.7. Water Sorption (24-hr)

The water sorption (24-hr) indices of polypropylene composites are shown in **Figure 7**. All the composites showed increases in water absorption with increase in filler content at all the filler particle sizes investigated.

Unlike all the other property parameters of the prepared composites discussed, the variation of water absorption with snail shell powder content and particle size is not much, an indication that water absorption by snail shell powder composites of polypropylene does not depend strongly on the filler content or particle size. All the prepared snail shell powder composites of polypropylene sorbed more water than that of talc, the reference filler. Generally, the level of water absorption observed for snail shell powder composites of polypropylene is considerably higher than those for other mineral filled systems. Although, water absorption could lead to a decrease in the end-use applications of these composites, there is reason to believe that by understanding the limitations and benefits of these composites, snail shell powder is not likely to be ignored by the plastic industry for use in formulating plastic products.

### 3.1.8. Specific Gravity

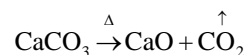
**Figure 8** shows a general increase in the specific gravity of the composites with increases in filler content at any given filler particle size considered.

However, there was a general decrease in the specific gravity of the composites with increase in snail shell powder particle size at any given snail shell powder content considered. The increase in the specific gravity of snail shell powder composites of polypropylene with a reduction in filler particle size could be attributed to the greater uniform distribution of the small sized filler in the matrix. It is interesting to note that the specific gravity of glass, talc, and mica filled polypropylene are 1.23, 1.27, and 1.26 respectively [23], values which are less than those of snail shell powder filled polypropylene.

### 3.1.9. Flame Propagation

The rate of burning of the prepared composites of polypropylene at any given particle size of the snail shell powder considered was generally observed to decrease with increase in snail shell powder contents (**Figure 9**).

The above result indicates that the flame retardant property of polypropylene is enhanced by snail shell powder. Snail shell powder filled polypropylene was observed to reduce the rate of burning of polypropylene more than talc. The present flame retardant property of the snail shell powder investigated could be attributed to the following factors. Snail shell powder, like most other shells consists mostly of calcium carbonate [24]. On heating/application of flame, calcium carbonate decomposes according to the equation,



with the evolution of carbon dioxide (CO<sub>2</sub>) which does not support combustion. The more snail shell powder is incorporated into polypropylene, the more the quantity of calcium carbonate (CaCO<sub>3</sub>) in the composites, and the less, the tendency of the composite to burn since CO<sub>2</sub> is a good fire extinguisher. Further more, as a filler, the snail shell powder particles interact with the resin macromolecules. The adsorption of the macromolecules on the filler surfaces which would result in better chain alignment, also contributes significantly to the filler's flame retardant property. The net result of all these would be an intimate union between the filler particle and the binder. This is expected to raise the thermomechanical properties such as T<sub>m</sub> of the composite as against the unfilled polypropylene.

In this study, the effect of filler particle size on the flame retardant property of snail shell powder is not very apparent since all the particle sizes investigated exhibited similar flame retardant property.

## 4. Conclusions

The mechanical and end-use properties of snail shell powder filled polypropylene have been determined in this study. Snail shell powder has shown greater property improvement over talc in the prepared composites. The specific gravity and hardness of snail shell powder filled polypropylene were observed to increase with increases in filler content, and decreases in filler particle size. The flame retardant property of polypropylene is greatly enhanced at high filler content, and filler particle size. With the exception of talc filled polypropylene, all the prepared composites investigated showed significant water absorption in a 24-hr water sorption test. The present study has highlighted the benefits of using snail shell powder as a filler for polypropylene. The results obtained suggest that the scope of application of polypropylene can be greatly broadened with the use of snail shell powder as a filler.

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