Effect of Bio-based Fillers on Hevea and Guayule Natural Rubber Mechanical Properties

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ABSTRACT

Natural rubber properties can be enhanced by fillers, enabling the polymeric products to be suitable for highly demanding applications. However, existing fillers are either not good reinforcing agents or are derived from non-renewable sources. In this study, 35 phr carbon black 300 was gradually replaced by specific waste-derived fillers. In general, but not always, the rubber composites tested had stronger tensile properties with smaller particle sizes at lower loadings. The tensile at break of the composites was, in some cases, superior compared to the control (35 phr Carbon Black). Reduction of particle size increased ultimate elongation as well as modulus at 500% and tensile at break, while increasing filler load increased ultimate elongation but decreased modulus at 500% and tensile at break.

INTRODUCTION

Natural rubber is a strategically-important elastomeric material, included in at least 40,000 products[1]. Fillers are polymer additives that not only reduce the cost of polymeric materials but also sometimes improve the mechanical and dynamic properties of the compounds. Traditionally used reinforcing fillers are carbon black and silica, but they both have limitations[2,3]. Consequently, there is a great need for new renewable filler materials capable of offering good reinforcing properties. It is hypothesized that bio-based fillers will generate not only physical interactions with the polymer matrix but also chemical bonding that will allow better integration of the components improving the material mechanical properties. The objective of this study was to determine the effect of low cost fillers on physical properties of cured rubber compounds made from different types of waste-derived, bio-based fillers.

METHODS

Composites Manufacture:

The effect of particle size and loading was assessed using a standard compound in which 35 phr (parts per hundred rubber) carbon black was gradually replaced w:w by specific waste-derived fillers until no carbon black remained (figure 1).

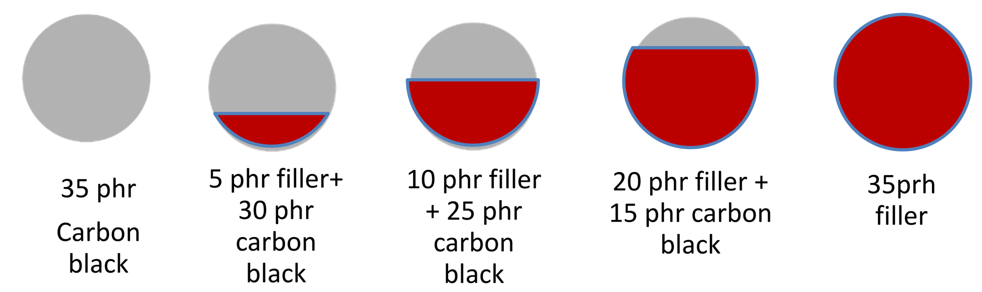

Figure 1: *Representation of composites filler content. Total load 35 phr in all composites, gray shadow carbon black content, red shadow other filler material.*

Hevea and Guayule rubber were used in these experiments. Filler materials included eggshells, carbon fly ash, processing tomato peels and guayule bagasse (figure 2). Filler particle sizes used were macro and micro. Future studies include the use of nano particles.

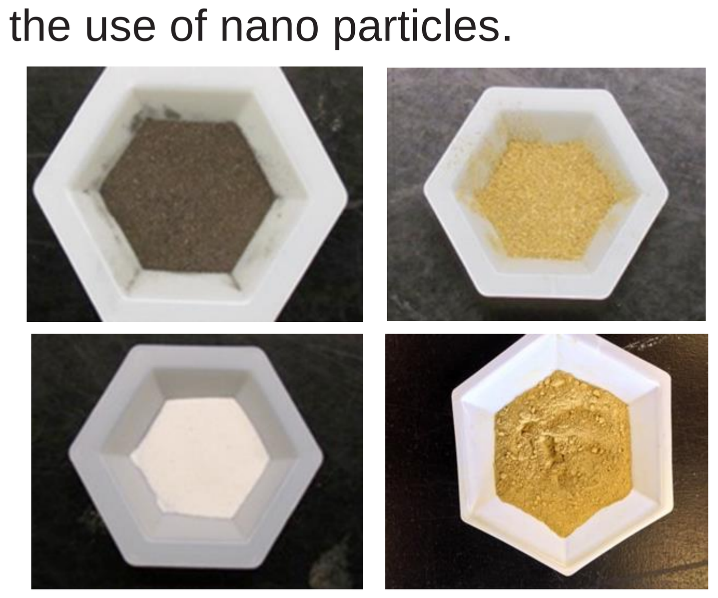

Figure 2: *Ground filler materials: on the top left carbon fly ash, on the top right Guayule bagasse, bottom left Eggshells, bottom right Tomato Peels.*

Composites Testing:

Evaluation of the tensile properties was performed using a tensiometer (Instron) following ASTM D 412.

RESULTS

Particles characterization:

Filler particle morphology was observed using SEM (figure 3).

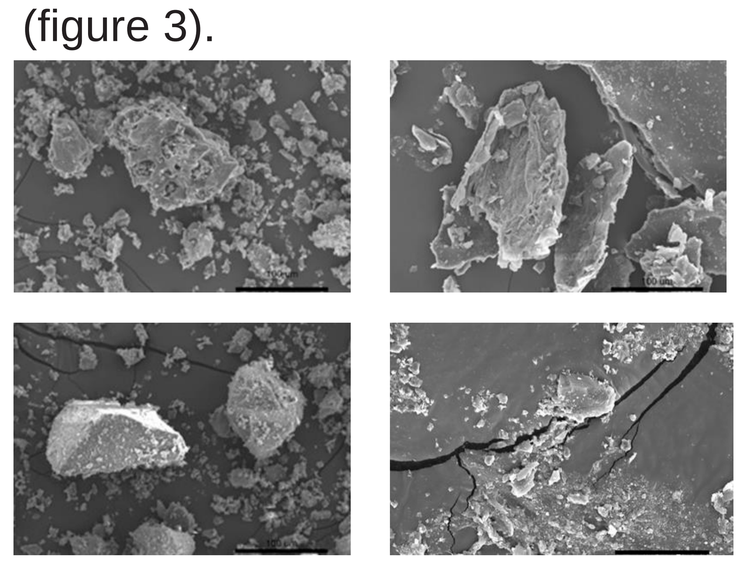

Figure 3: *SEM images of fillers particles. On the top left carbon fly ash, on the top right Guayule Bagasse, bottom left Eggshells, bottom right Tomato Peels. Scale bar 100µm*

The images show morphological differences among the particles. Carbon fly ash particles are the most porous and granular of all the particles, while Guayule bagasse presents a laminar shape that distinguishes it from the others. Eggshell particles are block-like particles while tomato peels particles present a more rounded contour.

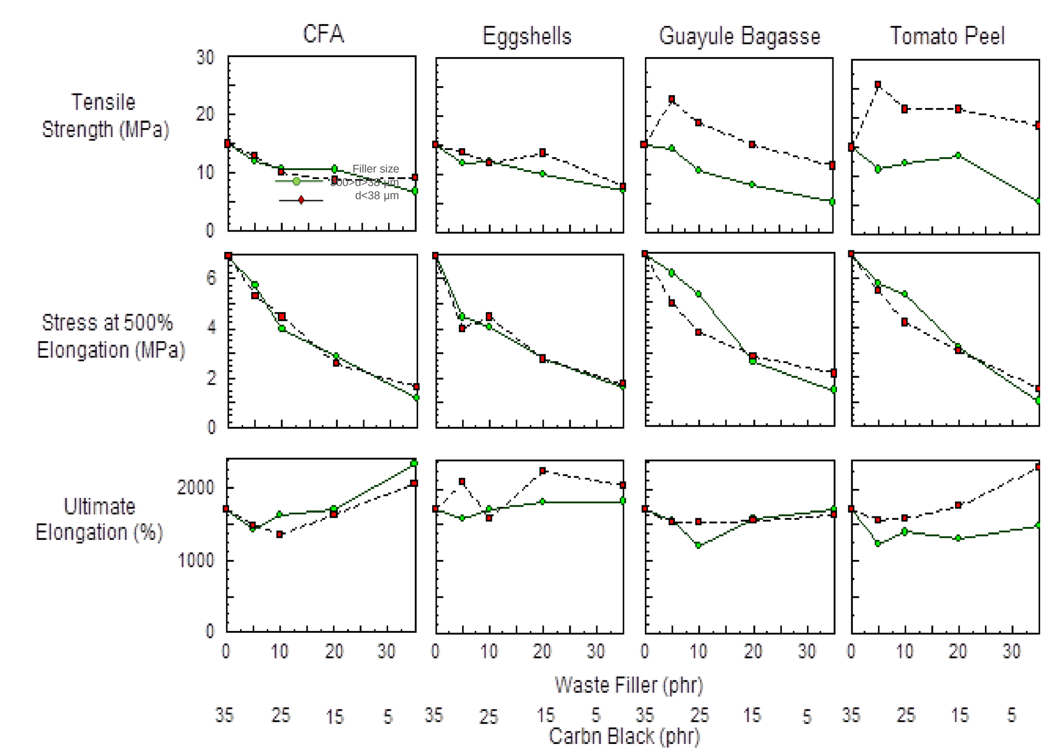

Figure 4: *Guayule Rubber Composites, tensile results*

Tensile Results:

The results indicate that for Guayule rubber, strength was increased by the composites with filler particle sizes less than 38 micron of tomato peel at all loadings, and by guayule bagasse up to 20 phr (figure 4). Stress at 500% elongation decreased as the filler loading increased and ultimate elongation increased as the filler loading rate increased.

In the case of Hevea rubber all the composites made with filler particle sizes of less than 38 µm, except eggshell, provided superior tensile strength compared to the control 35 phr carbon black (figure 6). Stress at 500% elongation decreased as the filler loading increased and ultimate elongation increased as the filler loading increased.

Polymer-Filler interface:

Polymer-filler interface is observed in figure 5.

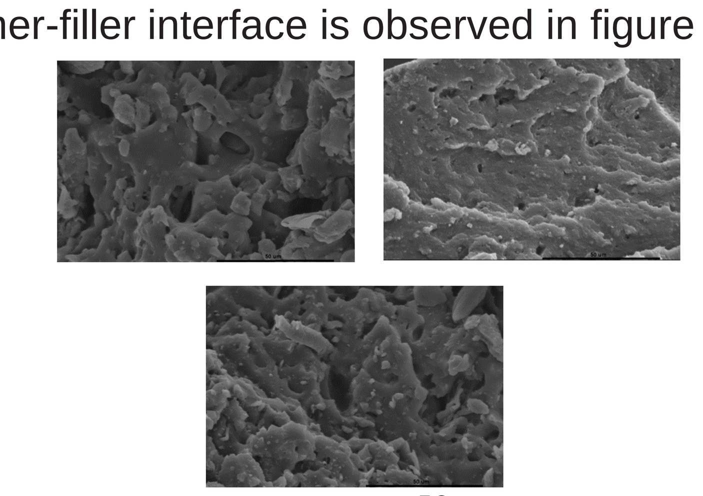

Figure 5: *SEM images of polymer-filler interface. On the top left Guayule rubber with Bagasse filler, 35 phr, particles size d<38 µm. On the top right Hevea Rubber with Tomato peels filler, 10 phr, particle size d<38 µm. Bottom Hevea rubber with Bagasse filler, 35 phr, particles size d<38 µm*

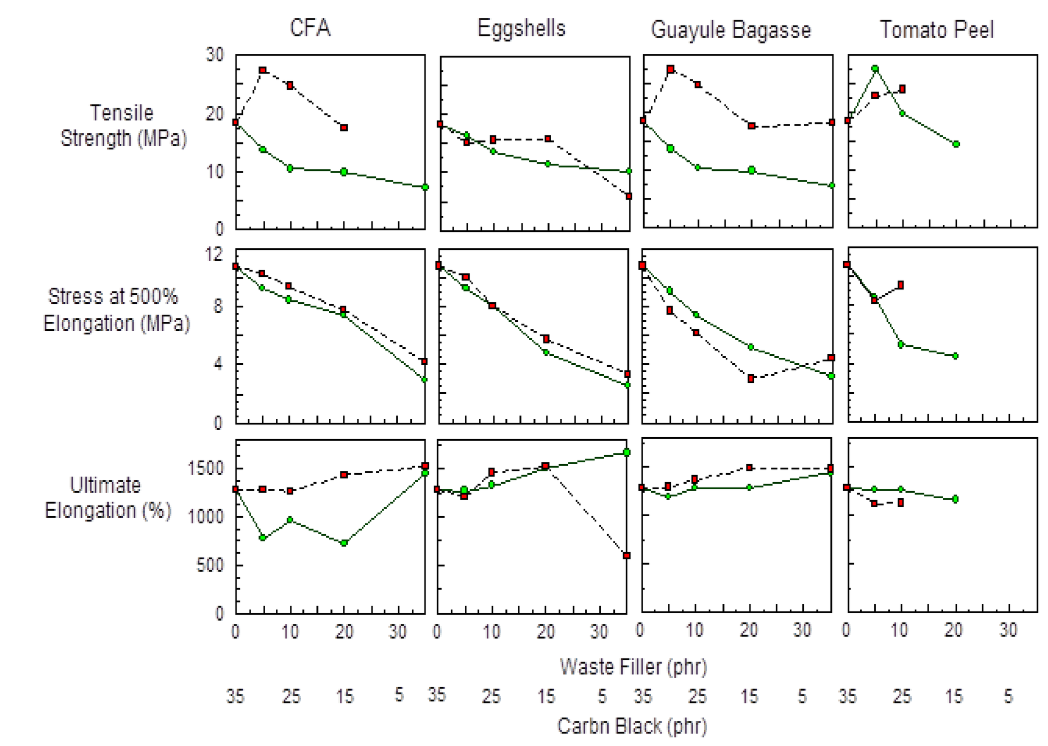

Figure 6: *Hevea Rubber Composites, tensile results*

CONCLUSIONS AND DISCUSSION

In general, but not always, the rubber composites tested had stronger tensile properties with smaller particle sizes at lower loadings. The tensile at break of the composites was, in some cases, superior compared the control (35 phr Carbon Black). Reduction of particle size increased ultimate elongation as well as modulus at 500% and tensile at break, while increasing filler load increased ultimate elongation but decreased modulus at 500% and tensile at break. Several filled materials had physical properties acceptable for industrial products. The use of these fillers can create novel materials and decrease cost of manufacture by utilizing other industrial byproducts.

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