

Agro-Industrial Residues as High Performance Alternative fillers for Natural Rubber Composites

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ABSTRACT

Agricultural and industrial food processing residues are generated in large quantities, yet most of them lack a valuable application and are treated as wastes that require costly disposal. In this study, we successfully made natural rubber composites containing waste-derived fillers as partial and complete replacements of petroleum-derived carbon black N330. Most of the composites containing micro sized fillers, especially those containing eggshells and processing tomato peels, had excellent properties up to a 57% replacement of carbon black. The tensile strength of these composites was, in some cases, superior to composites made solely with carbon black. Statistical comparison of the results indicates that, in general, high tensile properties combined with good flexibility, can be achieved by composites with smaller particle size at low loadings. Our results indicate that these fillers may be used to tailor product performance.

INTRODUCTION

About 50,000 different products are made with natural rubber, most of them containing fillers to improve the performance of the final material. Fillers are also used as diluent to reduce cost of rubber products by reducing the amount of the more expensive polymer. Currently, the main source of fillers for natural rubber is petroleum-derived carbon black, a non-renewable source. Global consumption of this material reached 11.8 million metric tons in 2013¹, and demand is increasing in parallel with rubber demand although new environmental regulations are causing reductions in production capacity in North America². Approximately 90% of carbon black production is used in rubber industry³. Waste-derived materials represent a highly abundant; environmentally-friendly, renewable, yet not well understood source of filler for rubber products. The objective of this study was to investigate the effect of different low cost, waste-derived fillers, as partial or full replacements of carbon black, on the mechanical properties of natural rubber.

METHODS

Composites Manufacture:

The effect of different types of waste-derived fillers, particle size and loading, was determined using a standard compound formulation (Table 1) in which 35 phr (parts per hundred rubber) carbon black N330 was partially or completely replaced by a specific waste-derived filler.

Hevea and Guayule rubber were used in these experiments. Filler materials (figure 1) were ground to macro (300<d>38 μ m) and micro (d<38 μ m) particle size distributions. Composites made with carbon black with no other filler, and unfilled vulcanized rubber compound were used as reference materials.

Material	Quantity (phr)
Natural rubber	100
Carbon black	35 30 25 15 0
Filler	0 5 10 20 35
Sulfur	3.5
Zinc Oxide	5
Butyl benzothiazole sulfonamide (TBBS)	0.75
Stearic acid	1

Table 1: compounding formulation used to prepare natural rubber composites.

Composites Testing:

Tensile properties were measured using a tensiometer (Instron), following ASTM D412. Composites were grouped through cluster analysis. Multiple means comparison Tukey-Kramer test, at a significance level α of 0.05, was also performed.

Figure 1: Waste-derived materials used as fillers for natural rubber composites.

RESULTS

Superior or comparable reinforcement to that of carbon black was achieved by partial replacement of carbon black with 5 and 10 phr of micro sized waste-derived material. As the amount of waste-derived filler in the composite increased above 5 phr tensile strength, 300% modulus and hardness decreased while elongation at break increased. However, the mechanical properties of unfilled vulcanized natural rubber were considerably improved with the incorporation of the different waste-derived fillers alone.

Different combinations of properties resulted from the modification of waste-derived filler/carbon black ratio in the composite, type of waste-derived filler and its particle size (figure 2), suggesting that product tailoring may be possible. Potential applications for guayule composites in cluster 1 and 2 and hevea composites in clusters 3 and 4 include rubber bands and insulating rubber tapes.

Guayule composites in cluster 3 and hevea composites in cluster 1 are good candidates for more demanding applications such as tire components. Potential uses for guayule composites in cluster 4 and hevea composites in cluster 2 include rubber surgical drainage tubes.

Insulating materials, namely insulating line hose, blankets, sleeves and gloves are some of the potential usage of guayule composites grouped in cluster 5 and hevea composites in cluster 5. Guayule composites in cluster 6 meet the requirements for elastomeric seals for joining concrete structures.

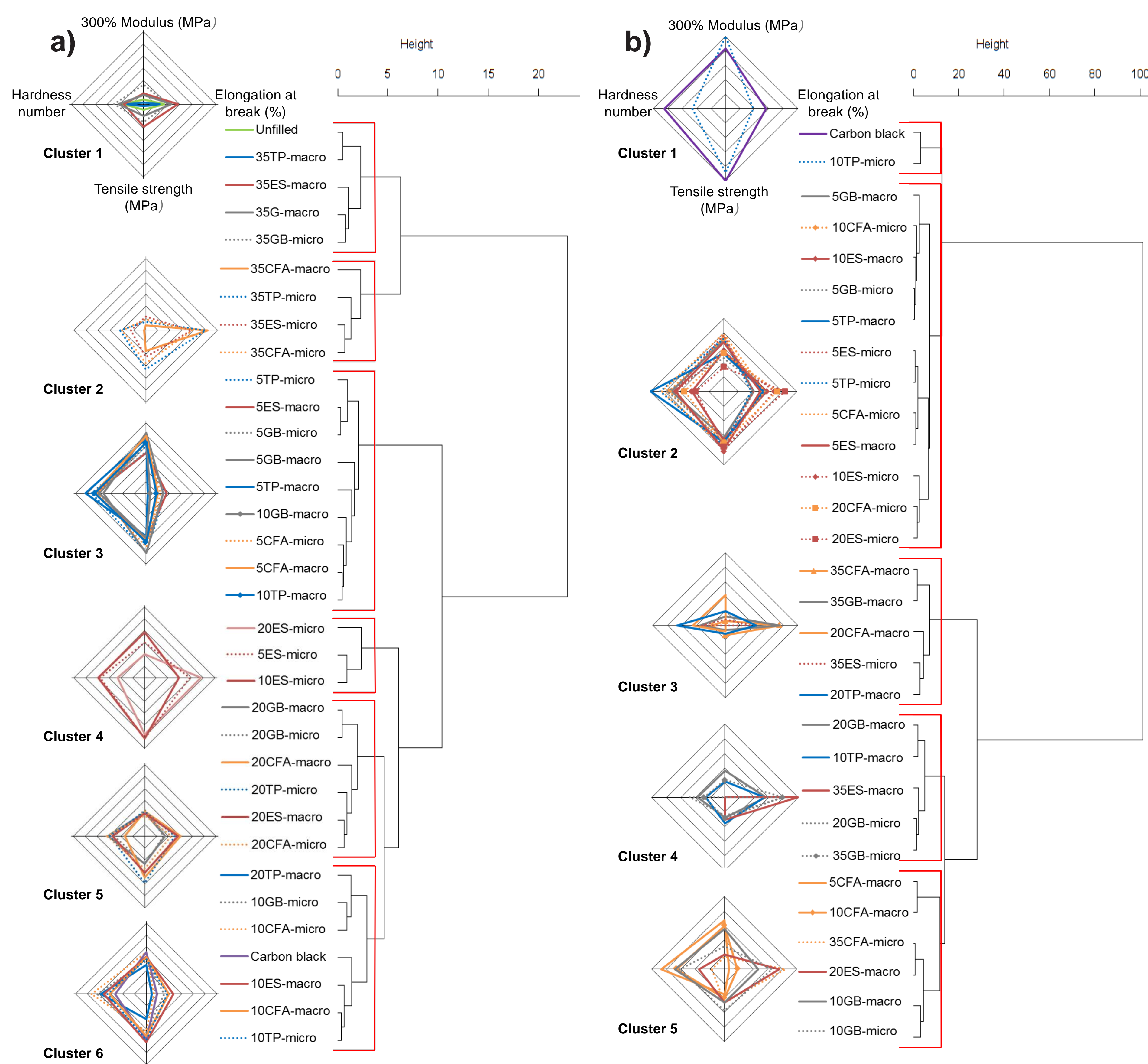


Figure 2: Dendrogram and radar charts obtained from hierarchical cluster analysis of different formulations a) guayule rubber composites, b) hevea rubber composites. Composite labels represent the amount of waste-derived filler in the sample, filler type and particle size. Total amount of filler (carbon black plus waste-derived filler), in all samples was 35 phr. Filler type: carbon fly ash (CFA), guayule bagasse (GB), eggshells (ES), processing tomato peels (TP).

CONCLUSIONS

Agro-industrial residues can be used as polymer fillers. These materials not only are generated in very high volumes, which ensures their continuous availability, but also can help to improve the sustainability of rubber products by replacing or reducing the amount of petroleum-derived carbon black. Modification of filler used resulted in composites with novel combinations of mechanical properties. Consequently, these fillers can be added not only to reduce cost, but to target specific performance requirements for elastomeric products.

- 1 Notch consulting, Inc. 2015. Carbon black and silica in the tire markets challenges and opportunities. Proceedings of the Tire Technology Expo, Cologne, Germany, 10-12 February.
- 2 Rubber and Plastic News. 2014. King: U.S. tire industry may face carbon black shortage http://www.rubbernews.com/article/20140513/NEWS/30505_9983.
- 3 International carbon black association. 2004. Carbon black users guide. <http://www.carbon-black.org/files/carbonblackusersguide.pdf>.

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