Liquid guayule natural rubber, a sustainable processing aid, improves the processability and mechanical properties of natural and synthetic rubber composites

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INTRODUCTION

- Naphthenic oil (NO) is widely used as a processing oil in rubber compounds to reduce mix viscosity and make the compound ingredients easier and faster to mix, with less energy [1].
- NO is refined from petroleum oil, so sustainable alternatives are desired.
- Guayule is a alternative source of natural rubber (NR), which is native to Mexico and Texas [2][3].
- Liquid guayule natural rubber (LGNR) may be a sustainable alternative to NO.

AIM

- Renewable LGNR, produced by thermal degradation of guayule natural rubber latex (GNRL) may improve the processability, sustainability and mechanical properties of natural and synthetic rubber composites, compared to petroleum-based NO (Fig. 1.).

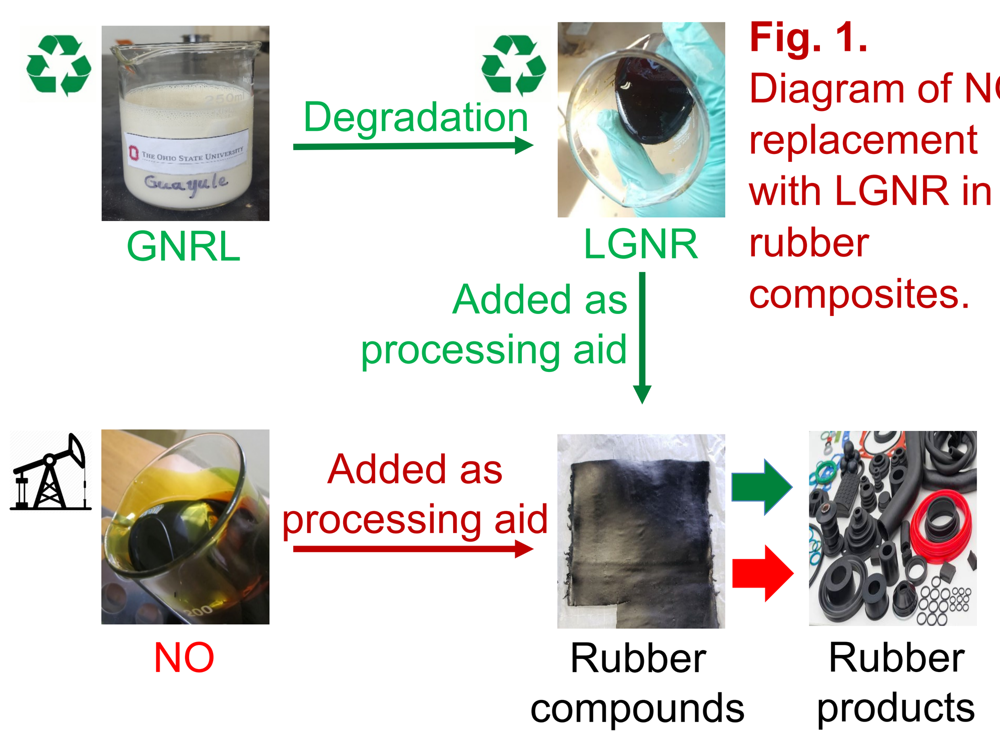

Fig. 1. Diagram of NO replacement with LGNR in rubber composites.

METHODS

- The effects of LGNR on rubber composites were compared to NO and no processing aid.
- 20 phr (parts per hundred rubber) processing aids were added to compounds made with carbon black (CB) filled natural rubbers (*Hevea* natural rubber (HNR) and guayule natural rubber (GNR)), and synthetic rubber (styrene butadiene rubber (SBR)).
- The rubber compounds were mixed with 11.5 phr sulfur based curing packages and 2 phr antioxidant (6PPD) in an internal rubber mixer for 15 min, then processed 9 times through a rubber mill, then cured in a heated press.

Cured samples were assessed by the following analyses:

- Energy consumption analysis
- Thermal gravimetric analysis
- Tensile tests
- Durability tests
- Fracture surface measurements

RESULTS AND DISCUSSION

Energy consumption and mechanical properties

- LGNR can act as a plasticizer, similar to NO, and both reduced compounding energy consumption.
- NO reduced tensile strength. In contrast, LGNR increased tensile strength.
- Both NO and LGNR increased elongation at break, and decreased the modulus and hardness.
- The LGNR composites stretched further before breaking and softened the composites significantly less than NO.

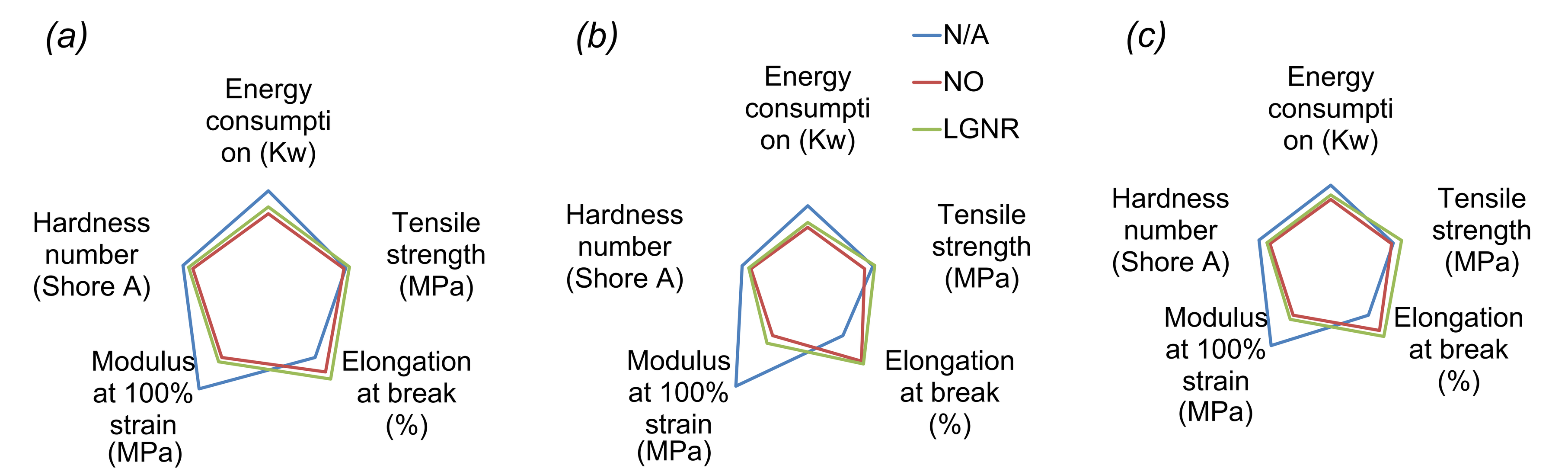

Fig. 2. Energy consumption and mechanical properties of rubber composites made with and without processing aids (NO and LGNR). (a) HNR composites; (b) SBR composites; (c) GNR composites.

Durability

- LGNR maintained better thermal stability of rubber composites than NO, although both were less stable than rubber compounded without processing aids.
- Higher retention of tensile strength and elongation at break indicated that LGNR protected against rubber aging.
- LGNR maintained or even improved ozone resistance of the composites, while NO reduced ozone resistance.
- The LGNR aging protection may be due to oxidized LGNR molecules produced by thermal degradation of GNRL.
- NO and LGNR had little effect on aged hardness.

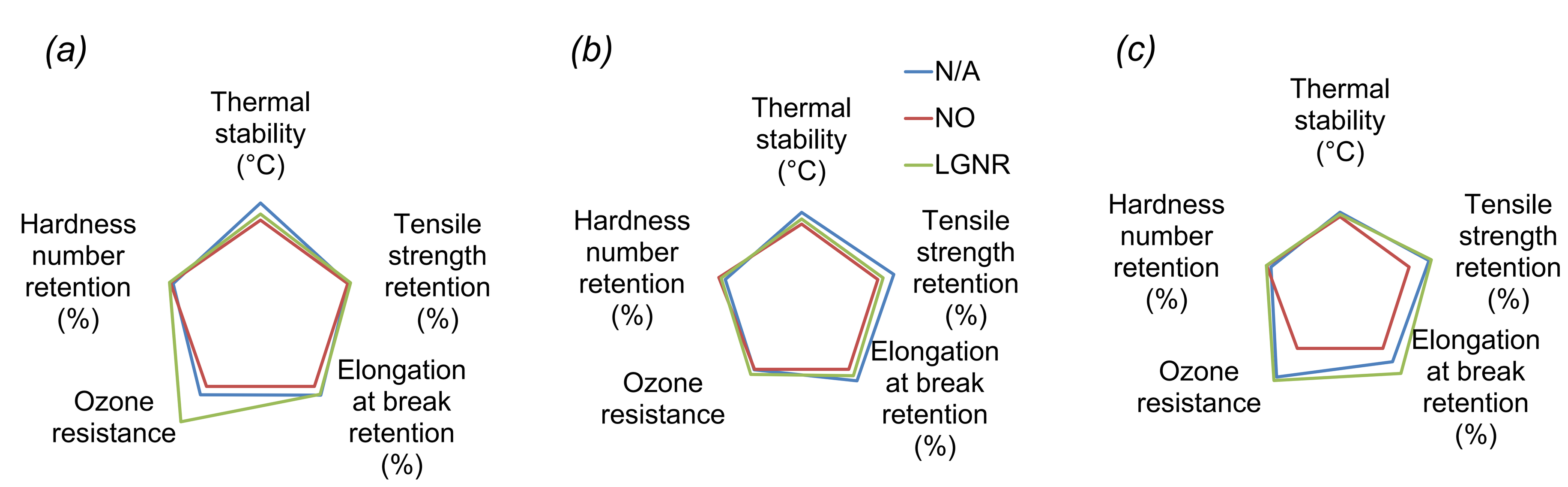

Fig. 3. Thermal stability, ozone resistance and aged mechanical properties rubber composites filled with and without processing aids (NO and LGNR). (a) HNR composites; (b) SBR composites; (c) GNR composites.

Stress-strain curves

- LGNR enhanced elongation at break and tensile strength due to a strong LGNR-rubber interaction.
- The toughness of all three rubber composites were enhanced by LGNR (larger integral area).
- The LGNR curve had a steeper slope than the NO and GR curves for SBR composites, which can be explained by strain-induced crystallization of LGNR (Fig. 4 (b)).

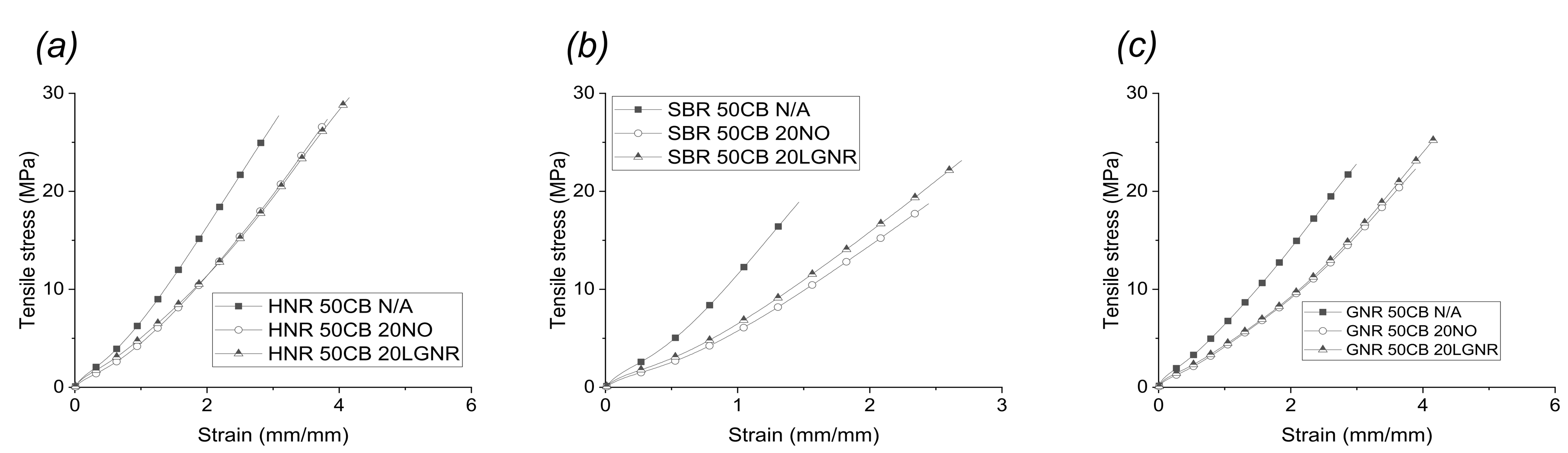

Fig. 4. Tensile stress-strain curves of rubber composites filled with and without processing aids (NO and LGNR). (a) HNR composites; (b) SBR composites; (c) GNR composites.

Rubber-filler interaction

- The holes in the fracture surface were formed by filler debonding, which was especially pronounced in SBR composites with NO.
- The rough fracture surface of LGNR filled SBR composites indicated strong rubber-filler interaction.
- The rubber “strings” in LGNR filled SBR composites confirmed strong LGNR-CB and LGNR-SBR interactions (Fig. 5 (c)).

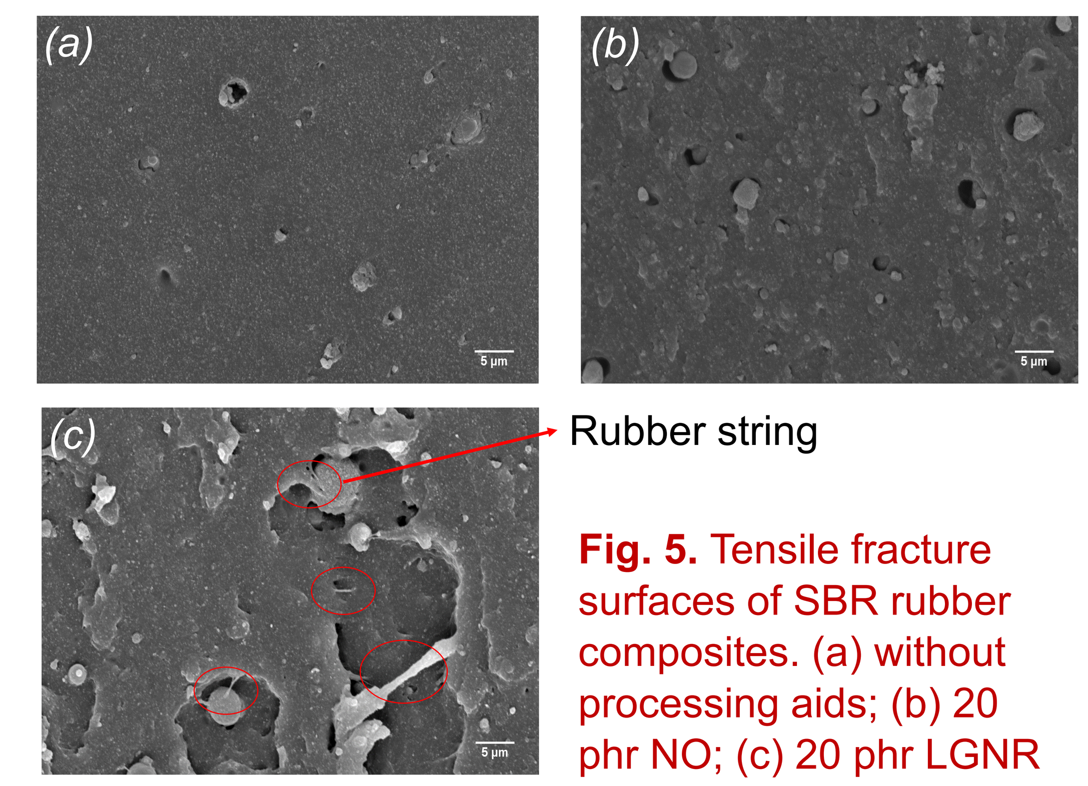

Fig. 5. Tensile fracture surfaces of SBR rubber composites. (a) without processing aids; (b) 20 phr NO; (c) 20 phr LGNR

CONCLUSIONS

- LGNR effectively improved rubber processability.
- LGNR maintained or improved the mechanical properties of HNR, SBR and GNR composites – NO caused deterioration.
- LGNR formed an additional crosslinking network between the polymers of each type of rubber.
- LGNR provided better aging resistance than NO.
- LGNR renewable processing aids can improve the sustainability of the rubber industry.

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