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Aging of Poly(3-Hydroxybutyrate-Co-3-Hydroxyhexanoate)-Based Biocomposites under Accelerated Photo-Oxidation

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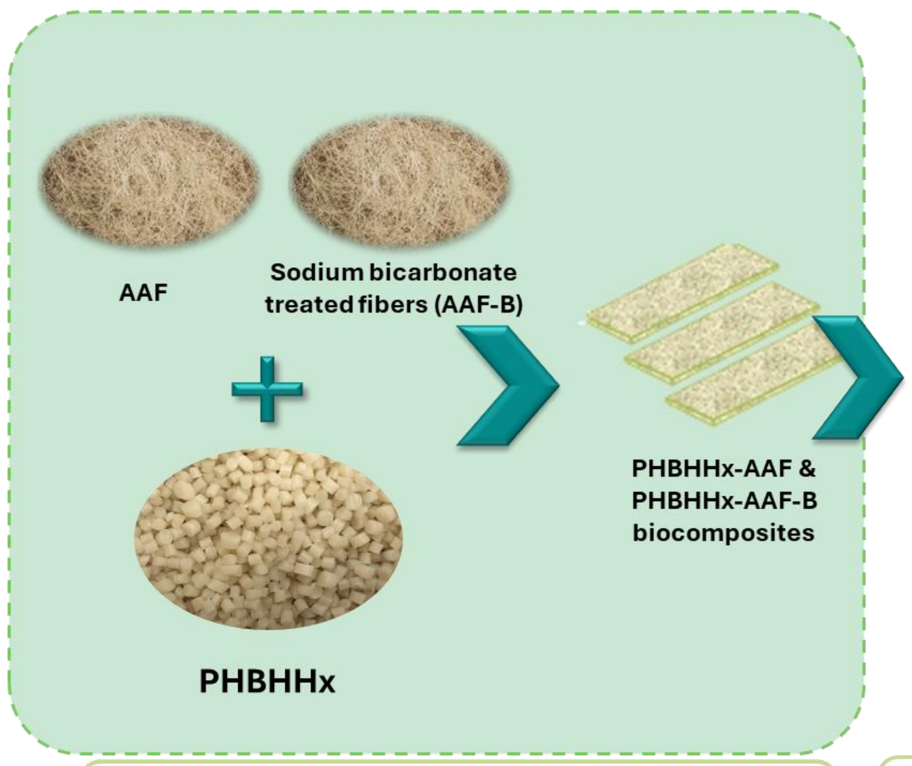
INTRODUCTION & AIM

- Global environmental awareness and government regulations have spurred academic and industrial researchers to produce eco-friendly, sustainable, and biodegradable composite materials [1]. In this context, poly(3-Hydroxybutyrate-Co-3-Hydroxyhexanoate) (PHBHHx) and natural fiber biocomposites are crucial for developing high-performance, fully biodegradable alternatives to conventional plastics [2].
- However, a significant challenge impeding their widespread application is the uncertainty regarding their long-term durability, particularly under ultraviolet (UV) radiation encountered during service life. The inherent photo-sensitivity of biopolymers, coupled with the weak interfacial adhesion between the hydrophobic matrix and hydrophilic fibers, can lead to premature embrittlement, cracking, and loss of mechanical properties [3].
- Additional treatments in biocomposites manufacturing include various chemical treatments of the natural fiber and coupling agent utilization. Such types of treatments play significant role in solving the poor interfacial adhesion between the fiber and matrix which is the main drawback of bio-composite production [4].
- This study addresses the challenge of fine-tuning the photooxidative aging of polyhydroxyalkanoate biopolymers like PHBHHx. The primary objective is to determine how Agave Americana fibers (AF) influence this process. Operationally, we will prepare biocomposites with 30 wt.% AF via melt compounding, treating the fibers with sodium bicarbonate ($NaHCO_3$) to assess the impact of surface modification. The accelerated photooxidation of these composites will then be evaluated in a SEPAP 24-48 enclosure up to 216h.

METHOD



Biocomposites elaboration by internal mixing and compression molding

Accelerated UV test using SEPAP 24-48 enclosure for 216 hours, with regular sampling every 24h

Brabender plasticorder mixer

Carver hydraulic press for thermocompression

RESULTS & DISCUSSION

- Color changes are driven by competing mechanisms: bleaching from chain scission (in neat polymer) and yellowing/browning from fiber oxidation in biocomposites, with treatment reducing the latter (Fig.1).

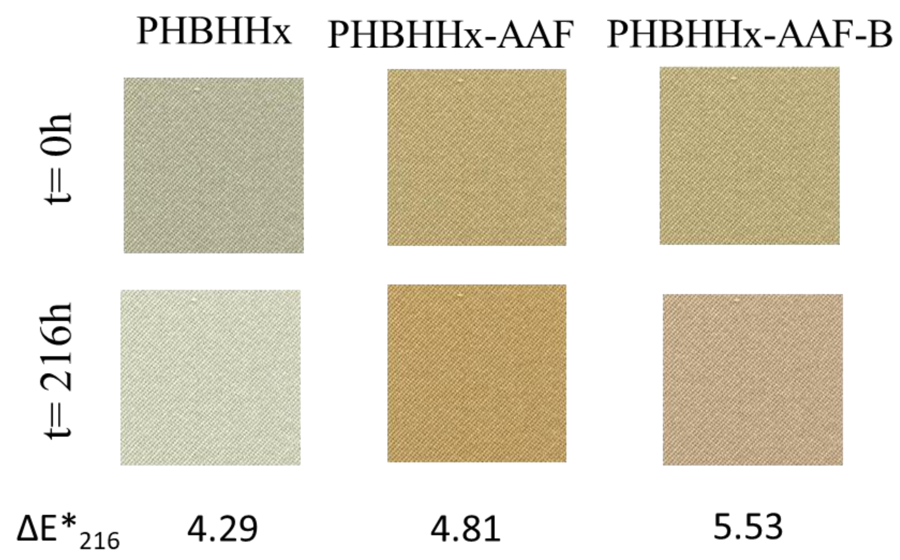


Figure 1: Visual comparison of the chromatic evolution of PHBHHx and PHBHHx-based biocomposite samples before and after 216h of Accelerated UV test.

- An initial increase in crystallinity due to chemo-crystallization is observed, but is short-lived in composites with untreated fibers, which suffer accelerated amorphous phase degradation.
- The primary benefit of the sodium bicarbonate treatment is the creation of a more stable fiber-matrix interface, which slows down the propagation of oxidative damage and preserves the material's properties.

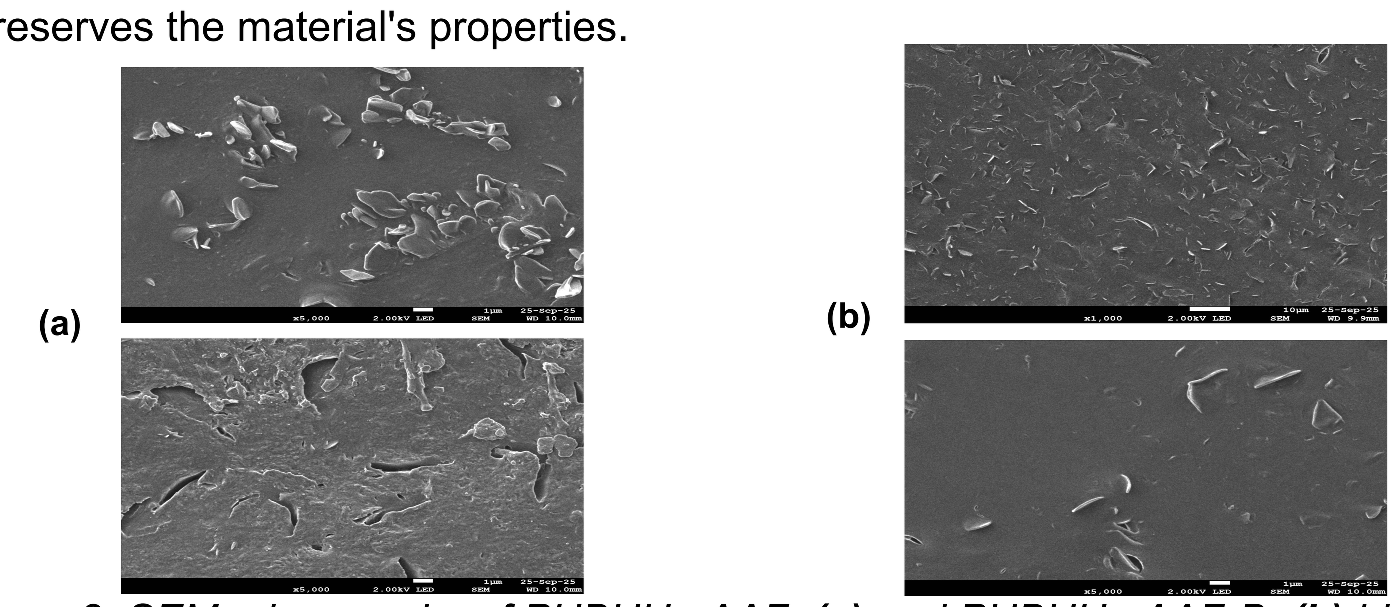


*Figure 2: SEM micrographs of PHBHHx-AAF: **(a)** and PHBHHx-AAF-B: **(b)** biocomposites before exposure and after 216h of accelerated UV test.*

CONCLUSION

- Surface treatment of agave fibers with sodium bicarbonate is crucial for enhancing the photo-oxidative stability of PHBHHx biocomposites.
- Untreated Fibers accelerate degradation, causing severe discoloration (browning) and a rapid loss of thermal integrity.
- Sodium bicarbonate treatment mitigates these negative effects, leading to a more controlled color evolution and stabilized thermal and chemical properties over the aging period.
- The study successfully demonstrates that the fine-tuning of photooxidative aging in PHBHHx can be achieved through the strategic use of surface-treated natural fibers.

FUTURE WORK / REFERENCES

- Future work will focus on correlating the observed chemical and thermal changes with the evolution of mechanical properties to assess the practical service life of these materials.
- Furthermore, the efficiency of combining the sodium bicarbonate treatment with a UV stabilizer will be explored to develop highly photostable biocomposites.
- Finally, natural weathering studies and a life cycle assessment are recommended to validate the accelerated aging data and evaluate the environmental benefits of this approach.

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