Conference ”*New Trends in Chemistry Research*”
(NewChemRes23)
Timisoara, Romania, September 21-22, 2023

UP-SCALING THE RECYCLING PARADIGM: NOVEL THERMOPLASTIC COMPOSITES FOR STRUCTURAL APPLICATIONS MADE ENTIRELY FROM WASTE

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In recent years, a great deal of interest has been invested in innovating materials based on waste, through re- and up-cycling, intended for structural applications. Thus, academic and industrial R&D offered, and still does, new solutions to actual environmental issues, intended to limit the negative impact of pollution.

The present study is subscribed to this trend and presents new thermoplastic composites based on high density polyethylene waste (HDPE) reinforced with natural fibers from agriculture (sorghum bagasse, SB) and inorganic powders (concrete waste from demolition sites, CWP). These new composites made entirely from recycled materials have been characterized (mechanical tests, thermal properties, water sorption) in order to assess their level of performance in relation with the amount of filler and reinforcement, and to envisage their range of applications.

The experimental results indicated that SB fibers increased the elasticity of samples, expressed as improved impact strength, while CWP enhanced the hydrophobicity and the ultimate tensile strength. An optimized formulation will provide the best combination of properties for the intended applications.

PROPERTIES OF RAW MATERIALS

(HDPE and stonedust %w/w)

PROPERTY	VALUE
Chemical composition	Recycled HDPE
Granulation, mm	2 – 4
Density, at 23℃, g/cm³	0.92
Melt index (MFI), g/10 min	0.55
Melting temperature, ℃	108 – 120

Element	Estimated value
Calcium	6.44
Iron	10.50
Magnesium	6.54
Sulfur	0.21
Potassium	1.25
Silicon	21.60
Cobalt	35
Copper	43
Manganese	790
Molybdenum	<5
Zinc	92

Recycled HDPE

Sorghum baggasse

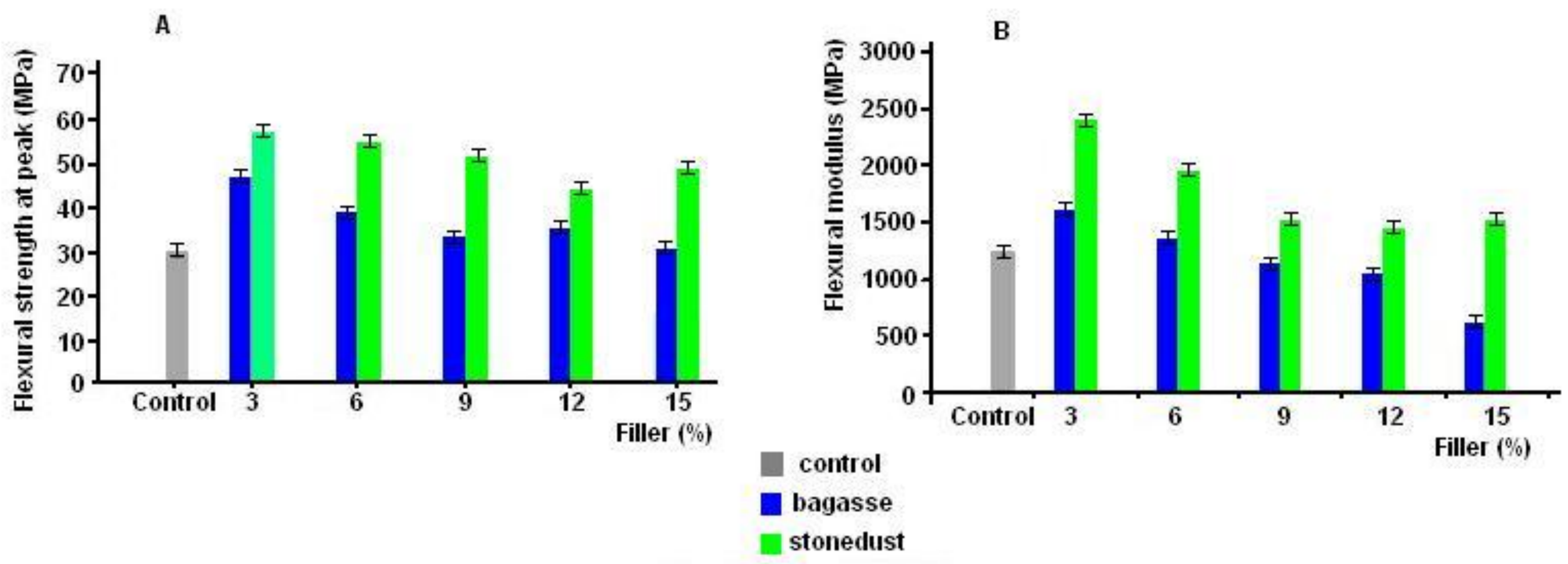
COMPOSITE PREPARATION

Extrusion
- in an extruder: Φ=20mm; L/D = 22;
- temperature: 100-160°C;

Compression molding
- samples 150x100x3 mm;
- temperature: 170°C;
- time: 7 min;
- pressure: 5 barr.

MECHANICAL PROPERTIES OF COMPOSITES

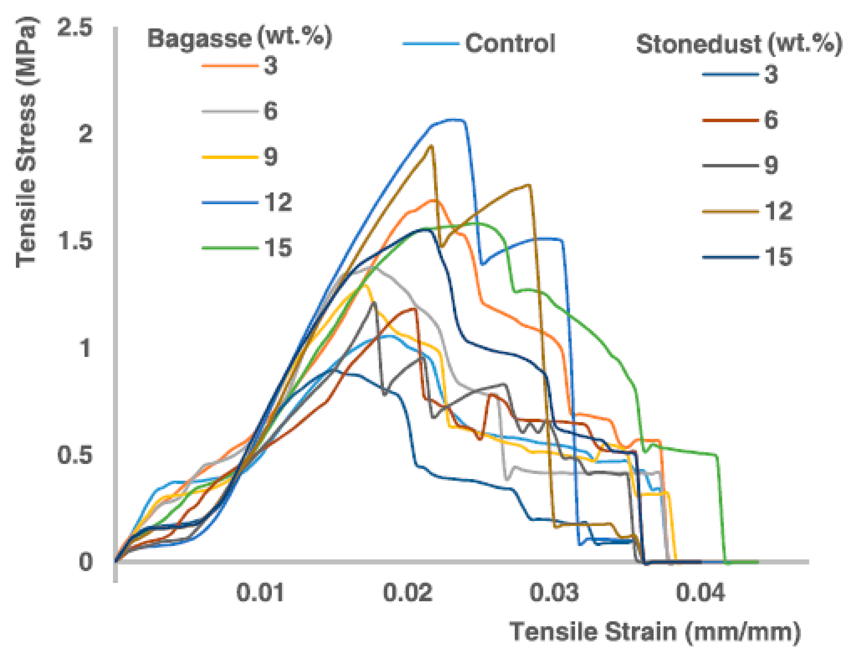
FLEXURAL PROPERTIES

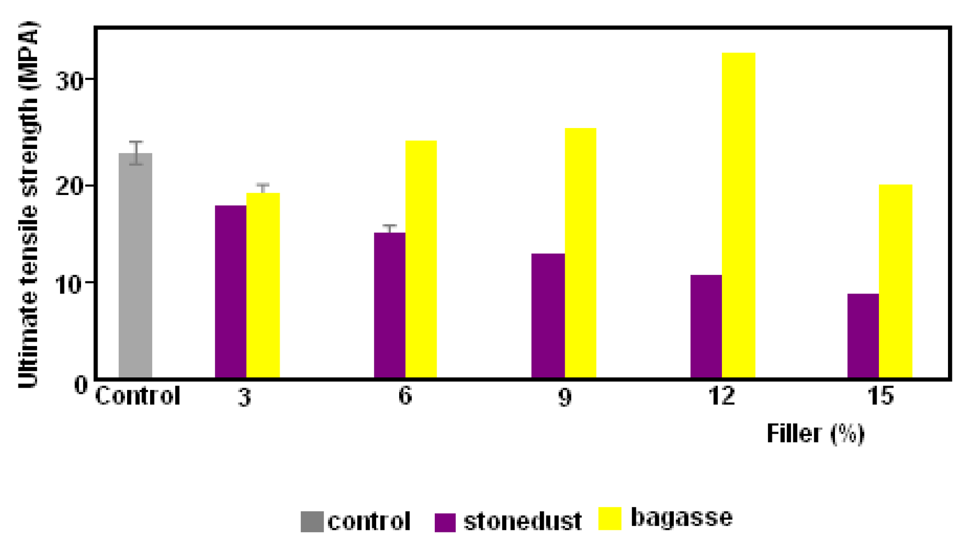


Flexural tests (A - flexural strength at peak; B - flexural modulus) of composites versus control sample

- Flexural strength at peak for the composites tends to decrease linearly as the reinforcement contents increases.
- Addition of the reinforcement has improved the flexural modulus of most of the composite samples compared to the control sample.
- Linear reduction in the composites modulus can be due to: fiber orientation and distribution, degree of bonding at the fiber-matrix interface, lay-up sequence, granulometric distribution of filler.

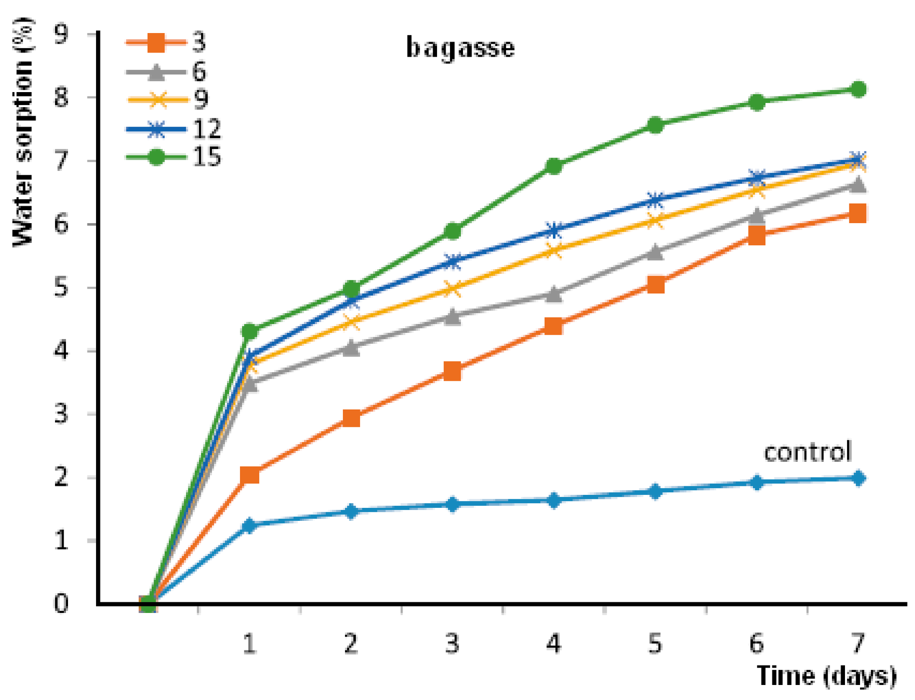
TENSILE PROPERTIES

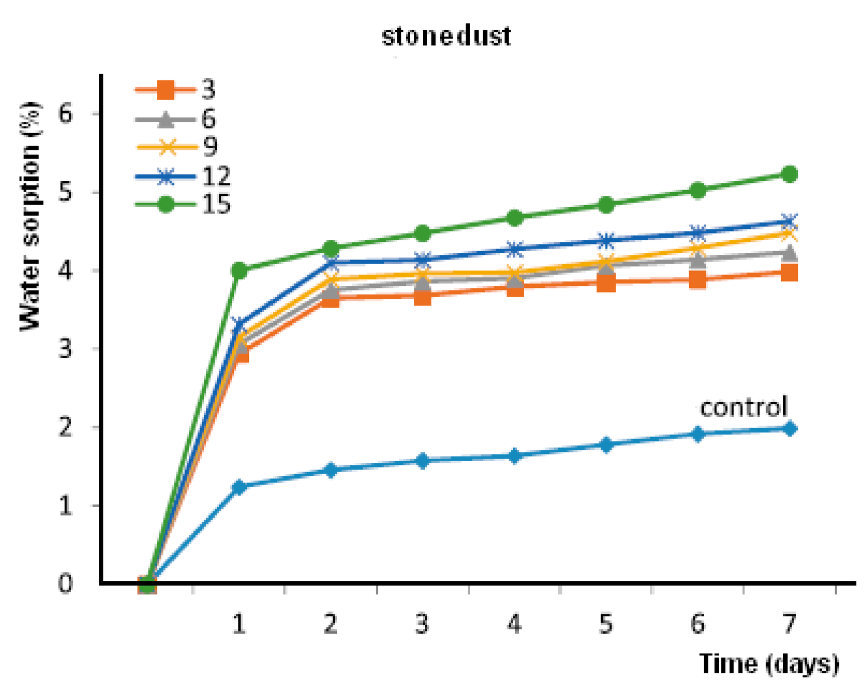




- Higher fiber content enhanced tensile properties of composites.
-Stress-strain deformation evolves in three stages:
  - an initial stage characterized by elastic deformation (Hooke’s law);
  - the second stage – yielding (material undergoes visco-elastic deformation);
  - third stage consists of a region of plastic deformation (the plastic strain increases under constant plastic stress up to material failure).

WATER SORPTION PROPERTIES



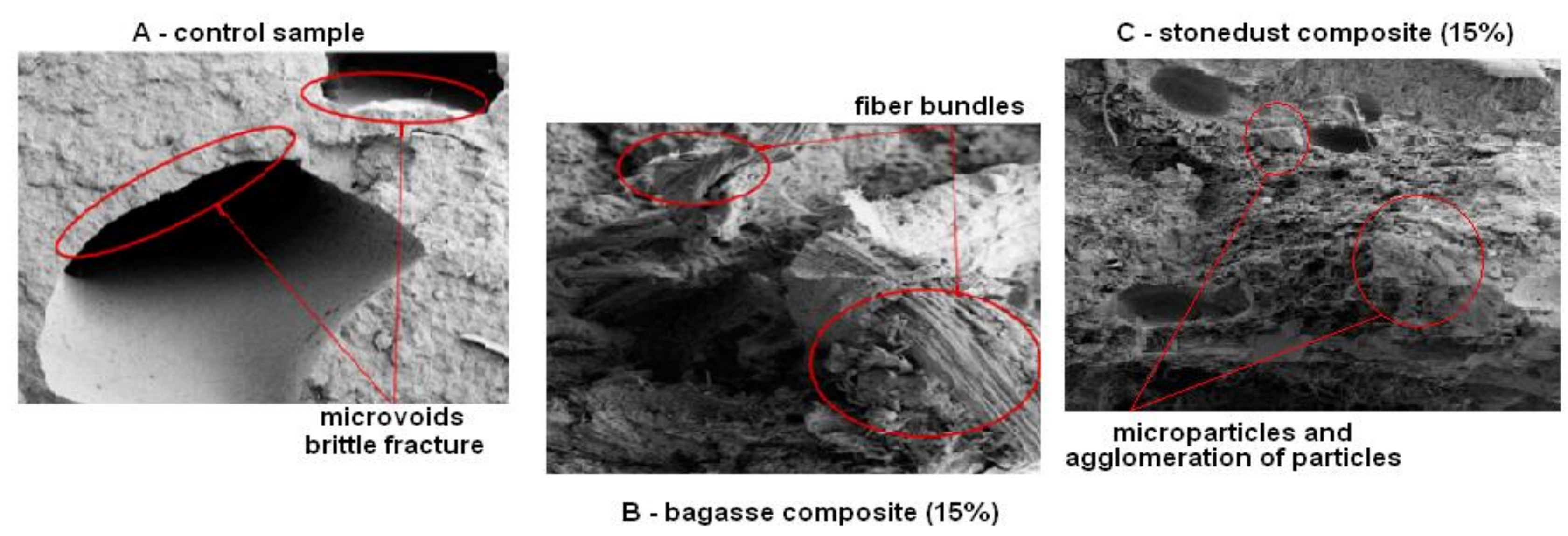


All composites absorbed more water than the HDPE control sample.

The variation of water sorption seemed to be linear: the higher the filler content, the higher the water content.

The hydrophil/hydrophob balance strongly influenced the amount of water retained by the composite samples.

MORPHOLOGY STUDY



SEM micrographs (90x) of selected samples

High content of different filler entailed different effects:
- bagasse contributed to the load bearing capacity due to the increase in elastic properties of the composite;
- stonedust caused agglomeration of particles, yielding in an increased stiffness of the composite expressed by a reduced load bearing capacity.

CONCLUSIONS

- **processing parameters must be optimized in order to achieve composites with a better dispersion of filler within the polymer matrix;**
- **compatibilization techniques must be considered for improved interfacial interactions;**
- **flexural properties were enhanced in HDPE-stonedust composites;**
- **tensile properties and hydrophilic character were improved in HDPE-bagasse composites;**
- **combination of the two fillers can allow better results in terms of mechanical and sorption properties.**

ACKNOWLEDGEMENT

The authors gratefully acknowledge the contribution and support of
Dr. Madalina Zanoaga (“Petru Poni” Institute of Macromolecular Chemistry, Iasi, Romania)
and
Dr. Yevgen P. Mamunya (Institute of Macromolecular Chemistry, Kiev, Ukraine)
to this study.