2024 NORTH AMERICAN BIOCHAR CONFERENCE — USBI — CALIFORNIA, USA

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Lessons learned from biochar-plastic composites development

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Carlos A Diaz-Acosta

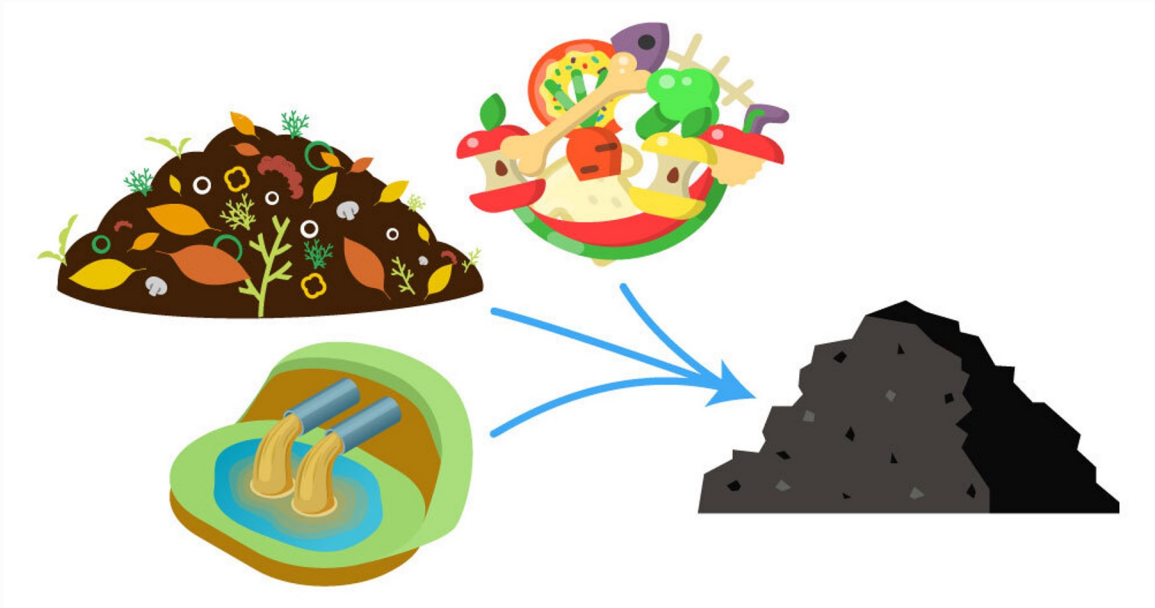
Thomas A Trabold

February 14th, 2024

Applications of Biochar

- Valorization of organic waste
- Multiple applications proved by literature (Bartoli et al. 2020)
- Agent of circular economy and carbon sequestration

(Draper K, 2015)

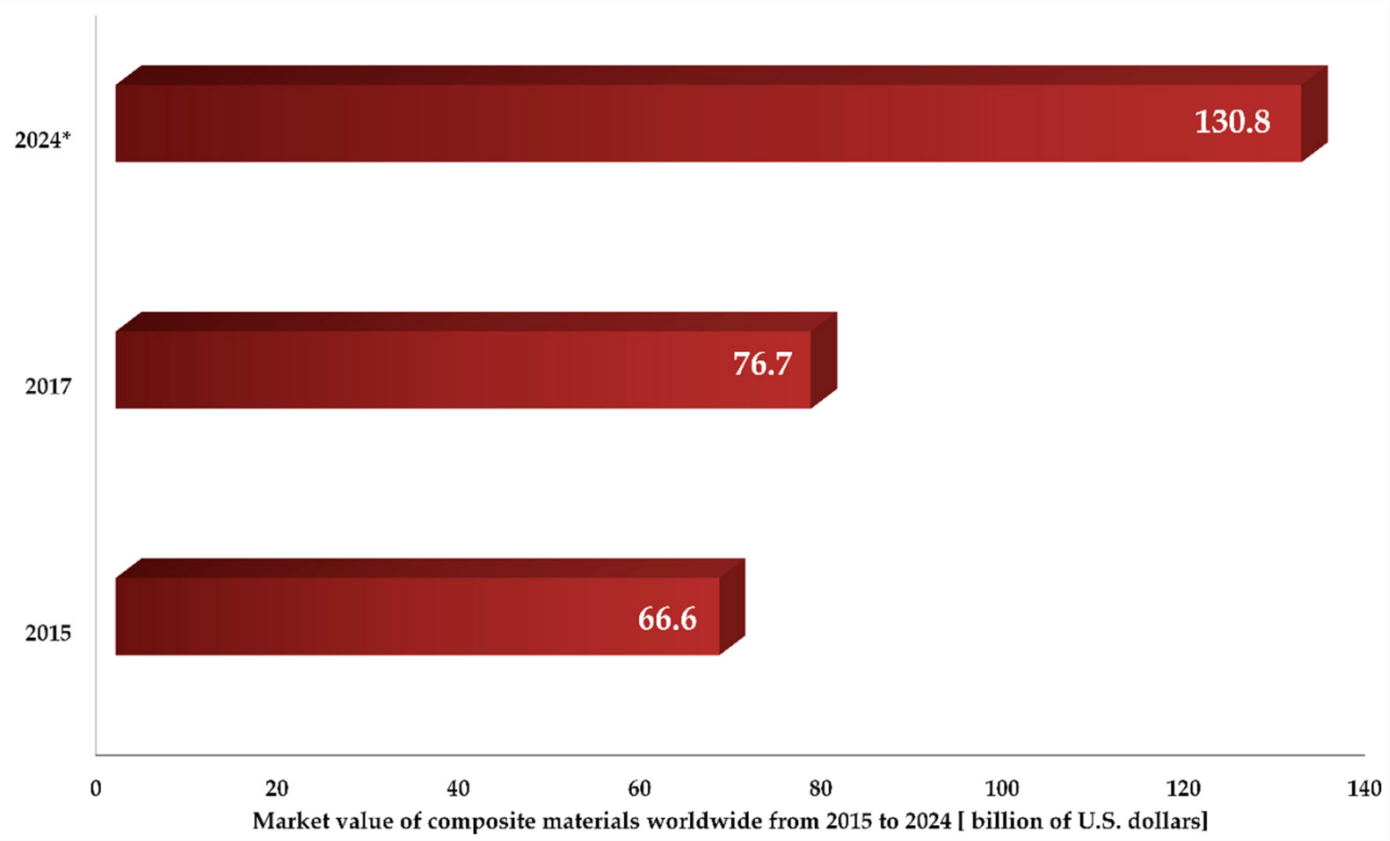


Biochar feedstocks

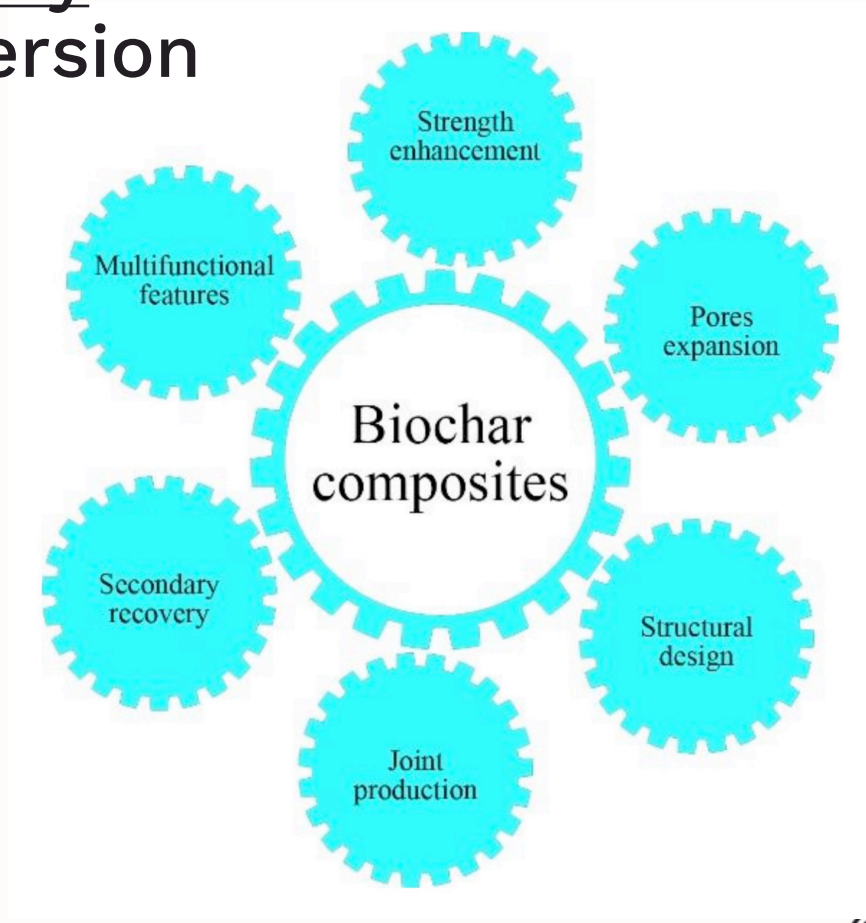
https://www.rit.edu/sustainabilityinstitute/blog/what-biochar-and-how-it-made

Biochar in plastics?

Higher value applications enhances the economic viability of thermochemical conversion



(Bartoli et al, 2020)



Zhang, Q. et al. (2020)

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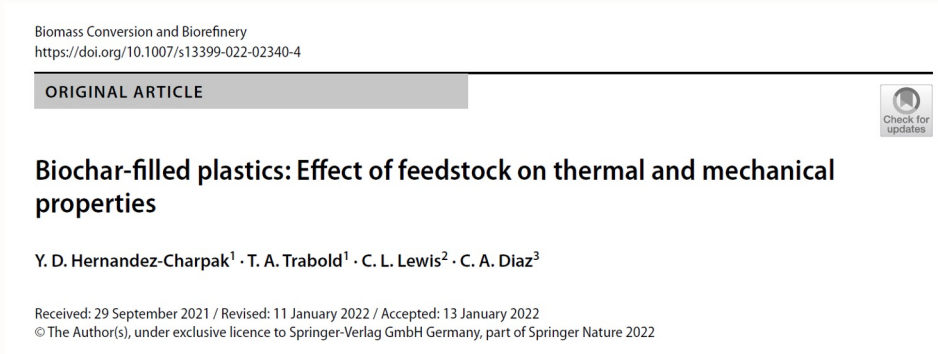
BC properties for the plastic application

- Physical properties
  - Surface Area (pore size)
  - Moisture content
- Loading amounts
- Particle size
- Thick composites
  - Compress molding
- Plastic films
  - Agriculture mulch films



Biomass Conversion and Biorefinery
https://doi.org/10.1007/s13399-022-02340-4

ORIGINAL ARTICLE

Check for updates

Biochar-filled plastics: Effect of feedstock on thermal and mechanical properties

Y. D. Hernandez-Charpak[1] · T. A. Trabold[1] · C. L. Lewis[2] · C. A. Diaz[3]

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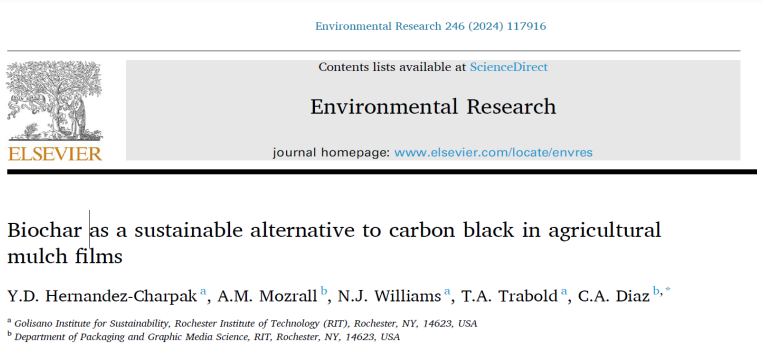

Environmental Research 246 (2024) 117916

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ELSEVIER

Biochar as a sustainable alternative to carbon black in agricultural mulch films

Y.D. Hernandez-Charpak[a], A.M. Mozrall[b], N.J. Williams[a], T.A. Trabold[a], C.A. Diaz[b,*]

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Sustainable Chemistry and Pharmacy 35 (2023) 101223

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Effect of biochar content and particle size on mechanical properties of biochar-bioplastic composites

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Composite development

Mixing

10% weight in:
PLA 4043D
PCL Capa 6800
PP SV258

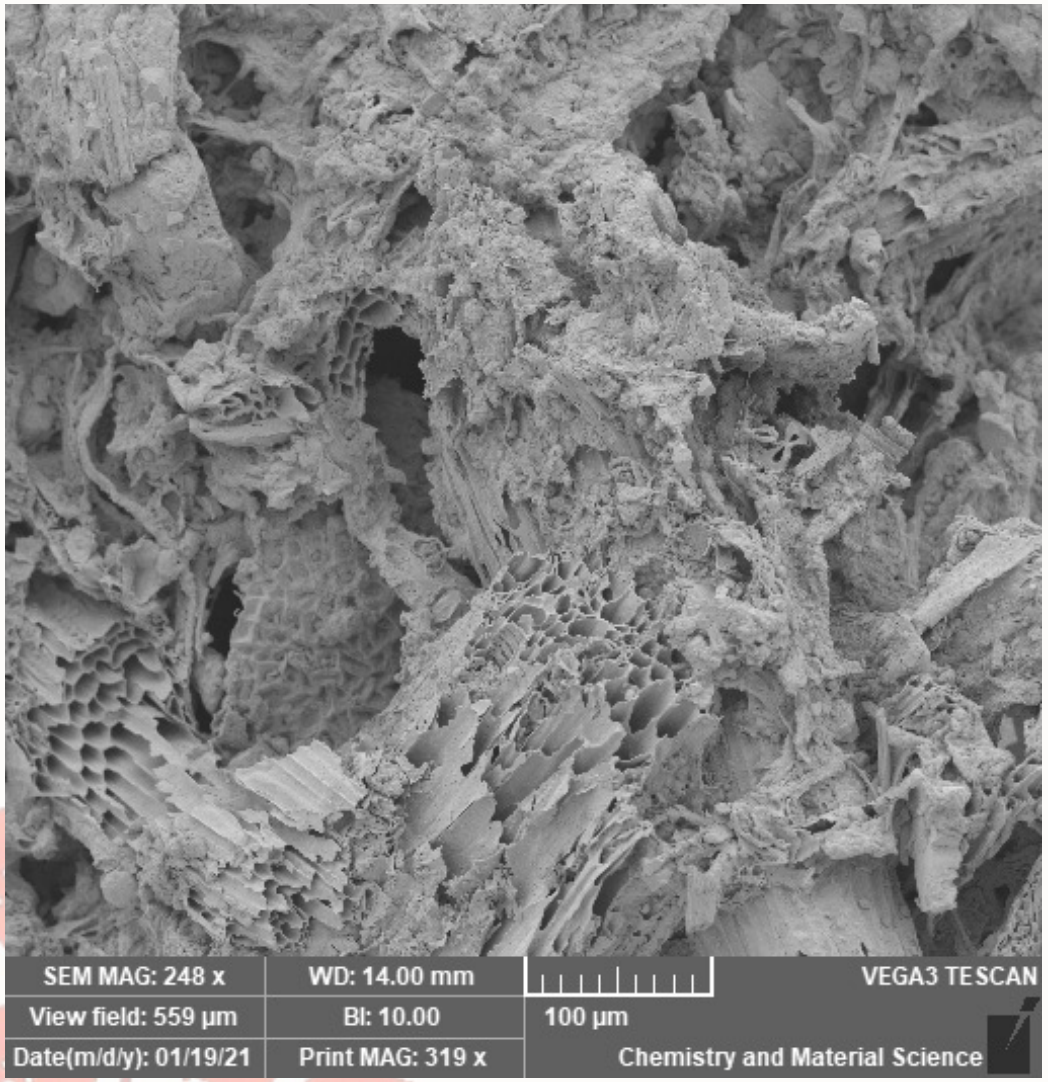
Pressing

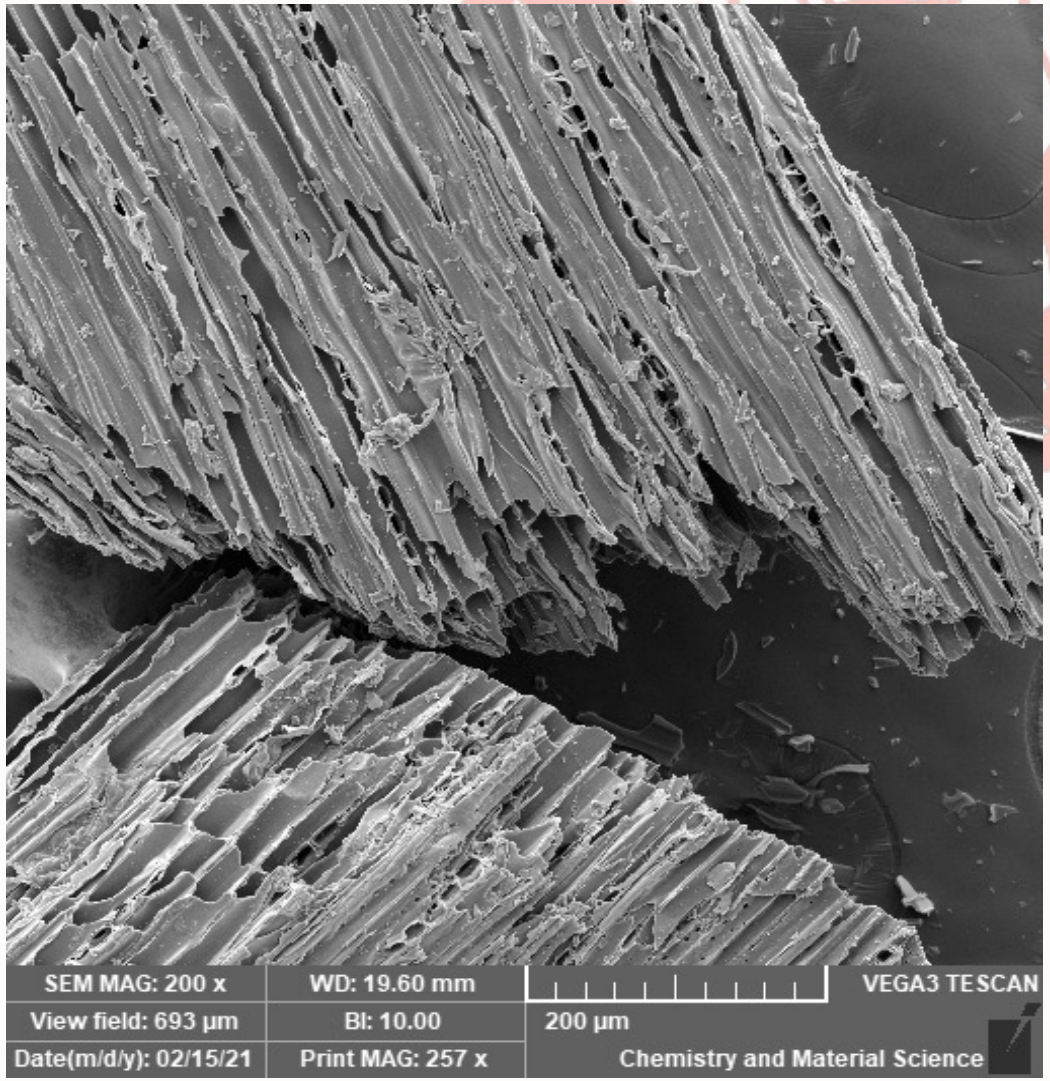
PLA: 190°C
PCL: 100°C
PP: 190°C
50 rpm

PLA: 200°C
PCL: 110°C
PP: 200°C

Biochar	Bioplastics
Moisture	Chemical
Surface Area	Mechanical
Pore size	Thermal
Particle Size	SEM microscopy
SEM microscopy	RV

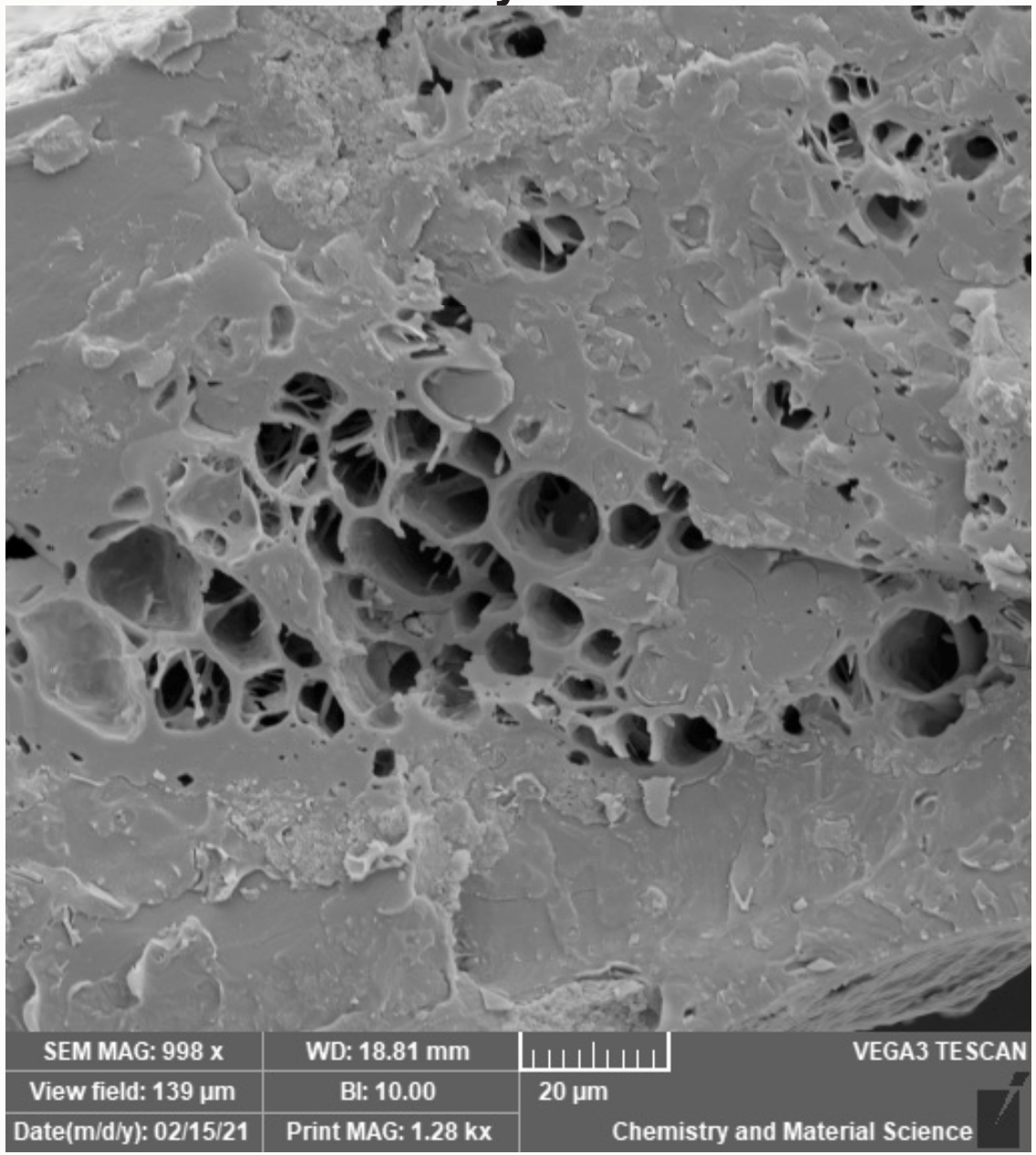
Composite development



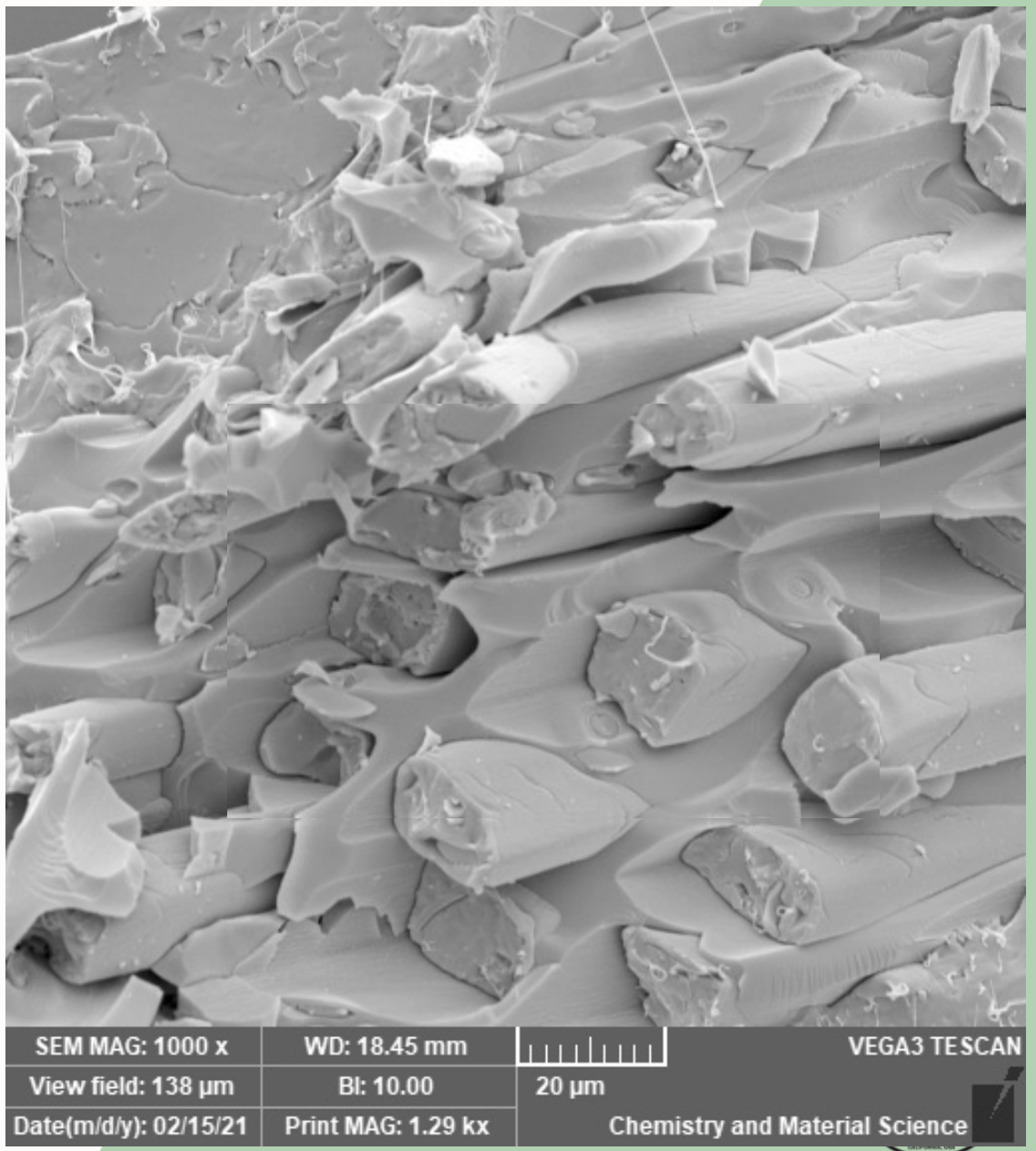


Dairy Manure		Wood chips
19.3±1.7m²/g	Surface Area	47.4±3.0 m²/g
24.9±0.6 µm	Pore Radius	21.3±0.4 µm
6%	Moisture Content	2.5%

PLA-DM


SEM MAG: 998 x
WD: 18.81 mm
VEGA3 TESCAN
View field: 139 µm
BI: 10.00
20 µm
Date(m/d/y): 02/15/21
Print MAG: 1.28 kx
Chemistry and Material Science

PLA-WC


SEM MAG: 1000 x
WD: 18.45 mm
VEGA3 TESCAN
View field: 138 µm
BI: 10.00
20 µm
Date(m/d/y): 02/15/21
Print MAG: 1.29 kx
Chemistry and Material Science

What did we learn?

- Polymeric matrix and biochar feedstock **interact** and cannot be treated separately.

- **Moisture** is an additional key parameter to characterize biochar for the plastic filling application

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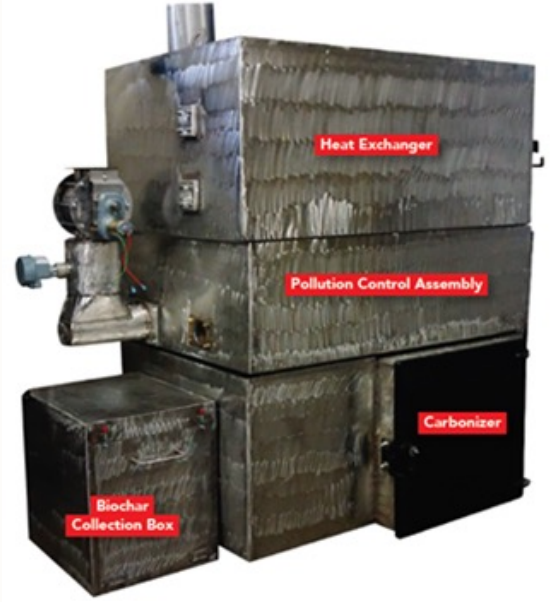
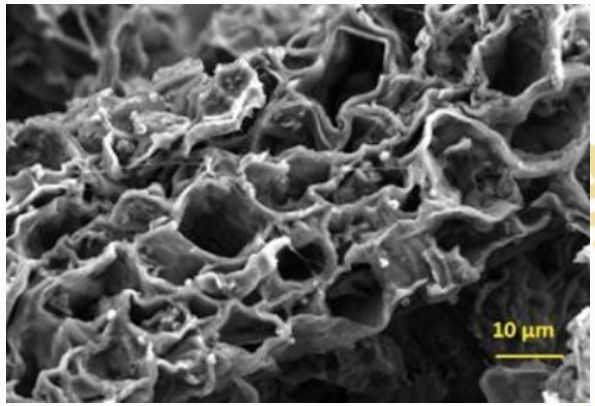
Can we adjust the BC properties?

Coffee grounds from RIT cafeteria

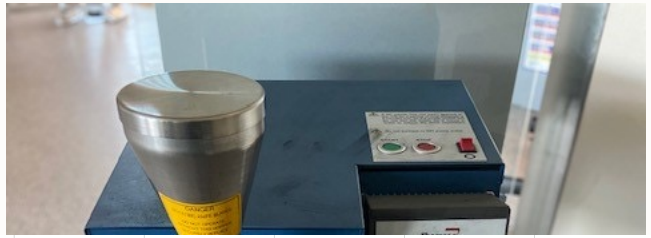
Dehydration for 10 hours

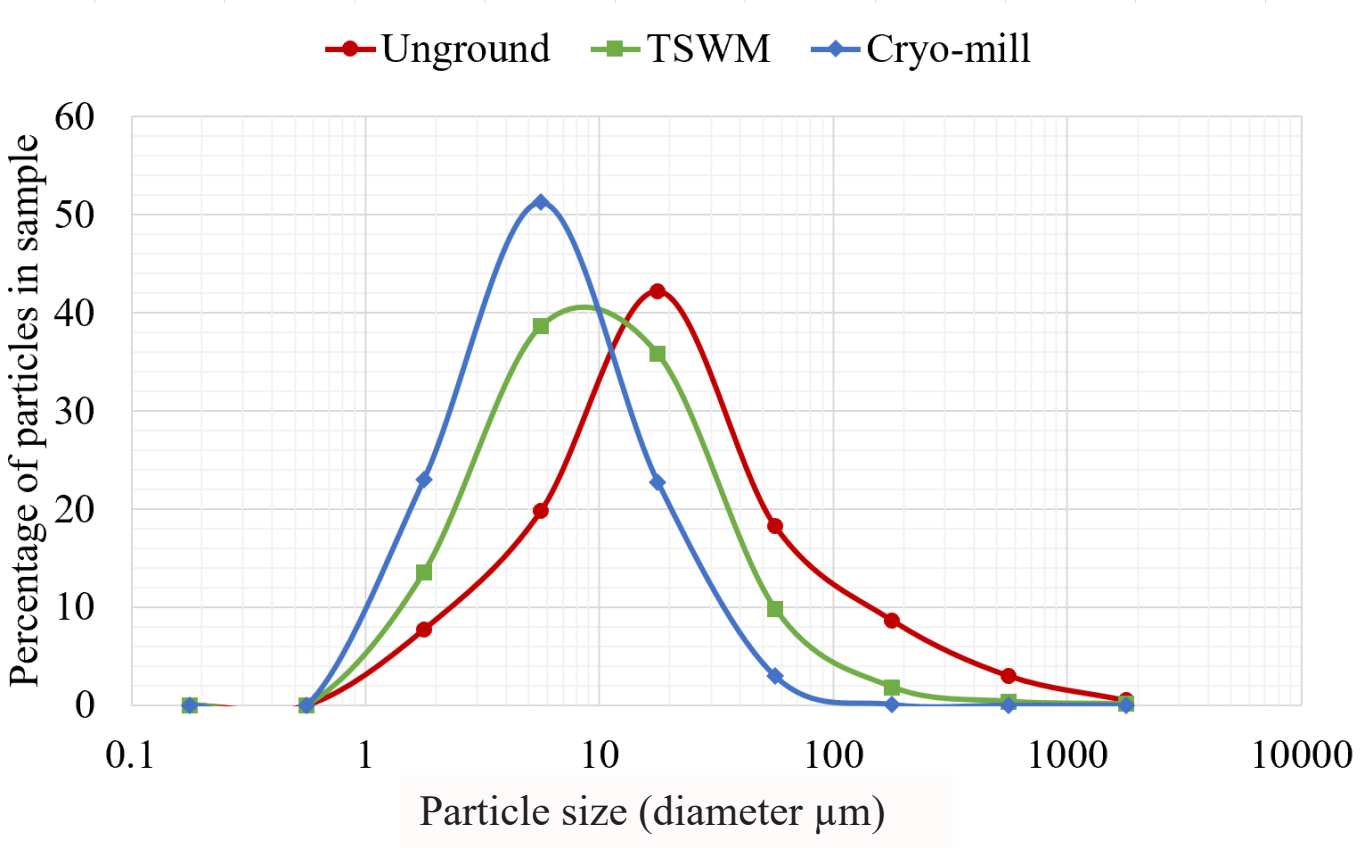
Biogenic Refinery at 800±25°C with feed rate of 5 kg/hr

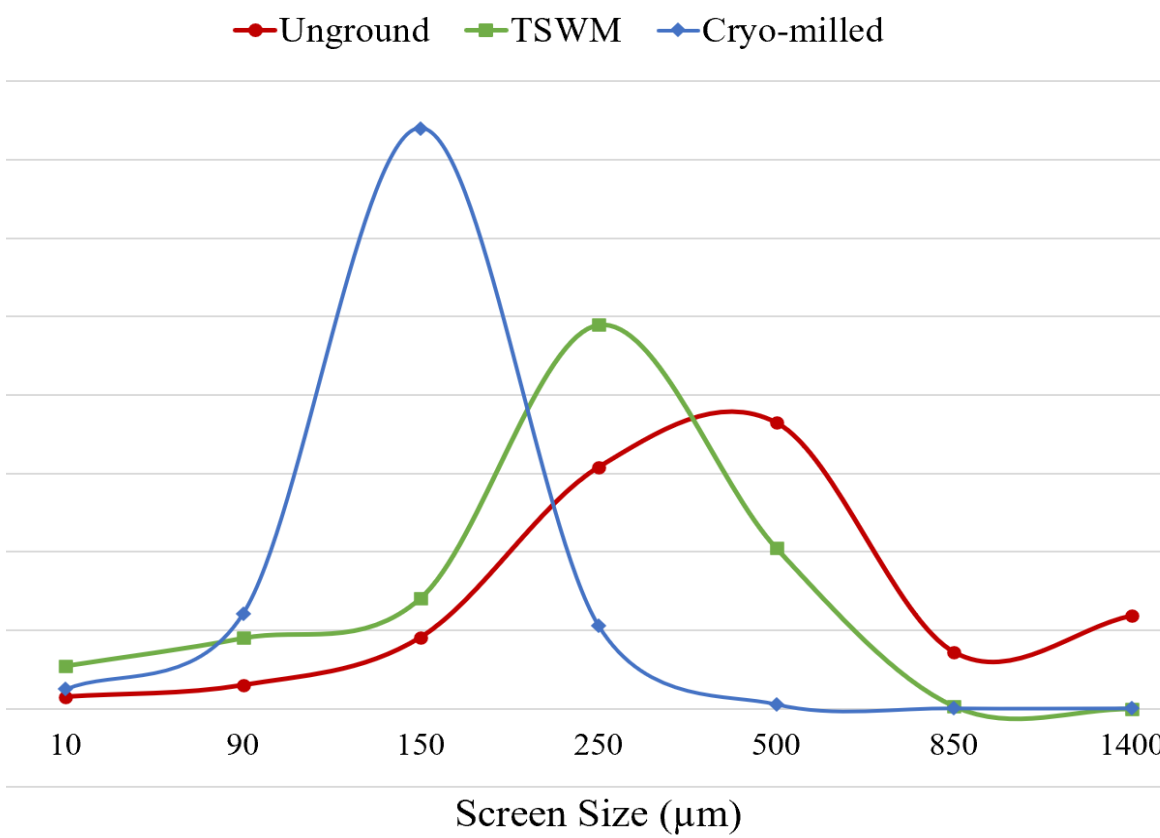




Improvement







2-factor experiment

BC loadings (% weight)	5	10	15	20

BC sizes
As is
TSWN
Cryo

- Composite properties
- Processing properties

Bioplastics
Mechanical
Thermal
SEM
Plastogram

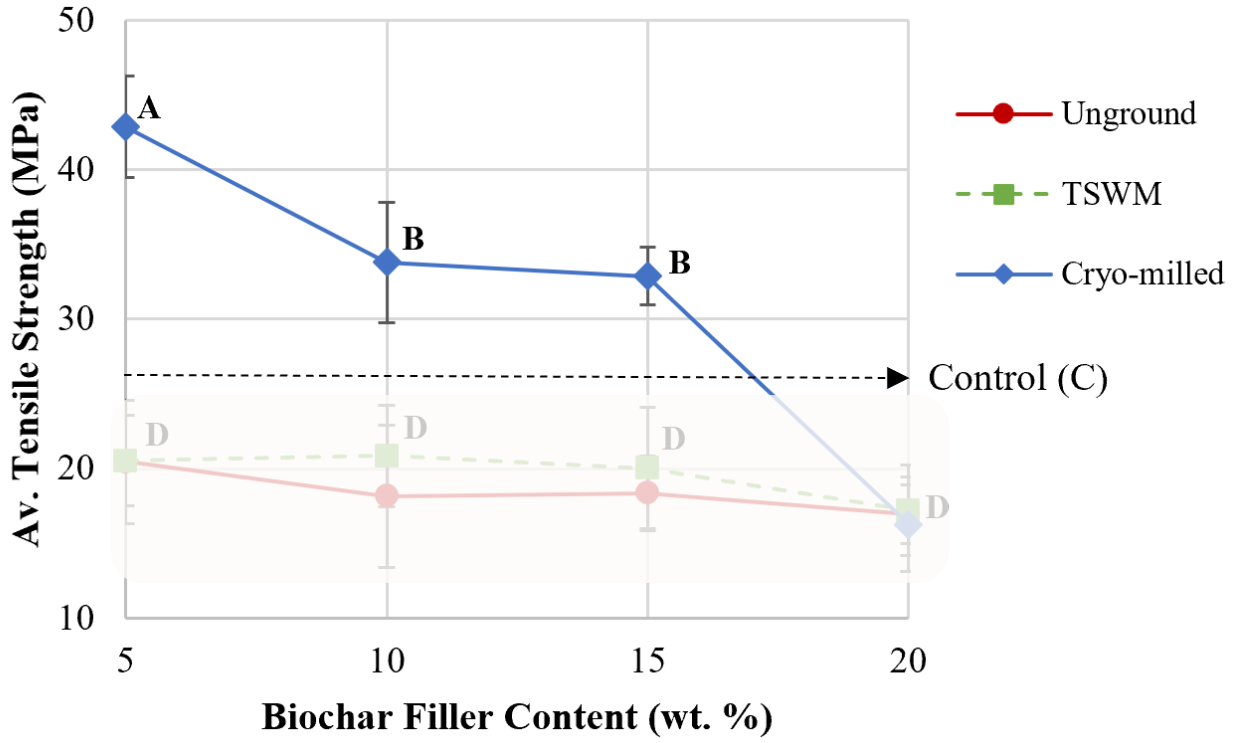
Sustainable Chemistry and Pharmacy 35 (2023) 101223

Improvement

ELSEVIER

Effect of bio
of biochar-bi

A.M. Mozrall [a], Y
[a] Department of Packaging a
[b] Golisiano Institute for Susta

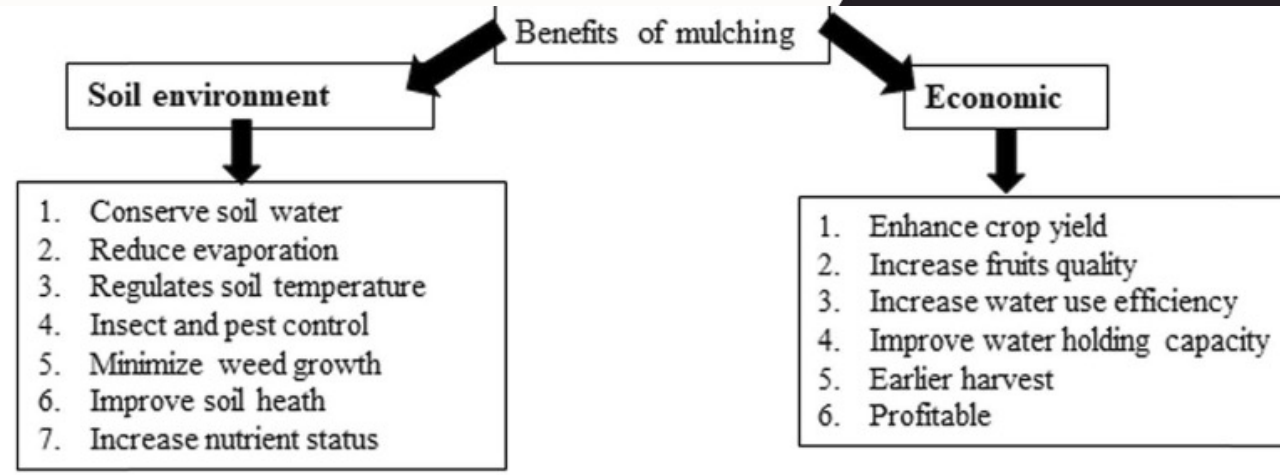


Particle size influences the **interfacial adhesion** between BC and the analyzed matrix. **This effect fades away** with loading.

Case study: BC in mulch film?

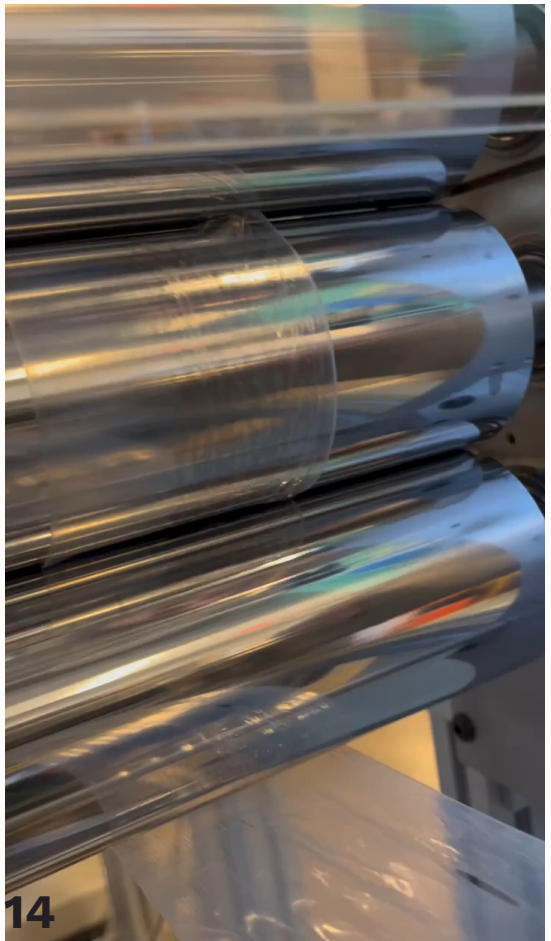
- Agricultural plastics, i.e. **mulch films**
- **Weed control** through opacity
- What roles can **biochar** fulfill?

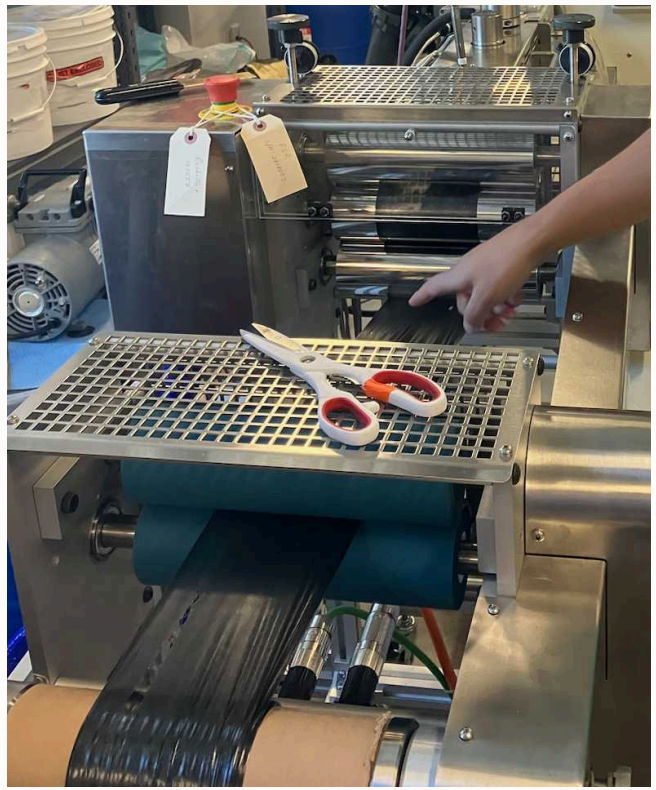
Benefits of mulching (adapted from Iqbal et al., 2020)



BC as an opacifier

- **Carbon black** is the traditional additive we need to compare BC

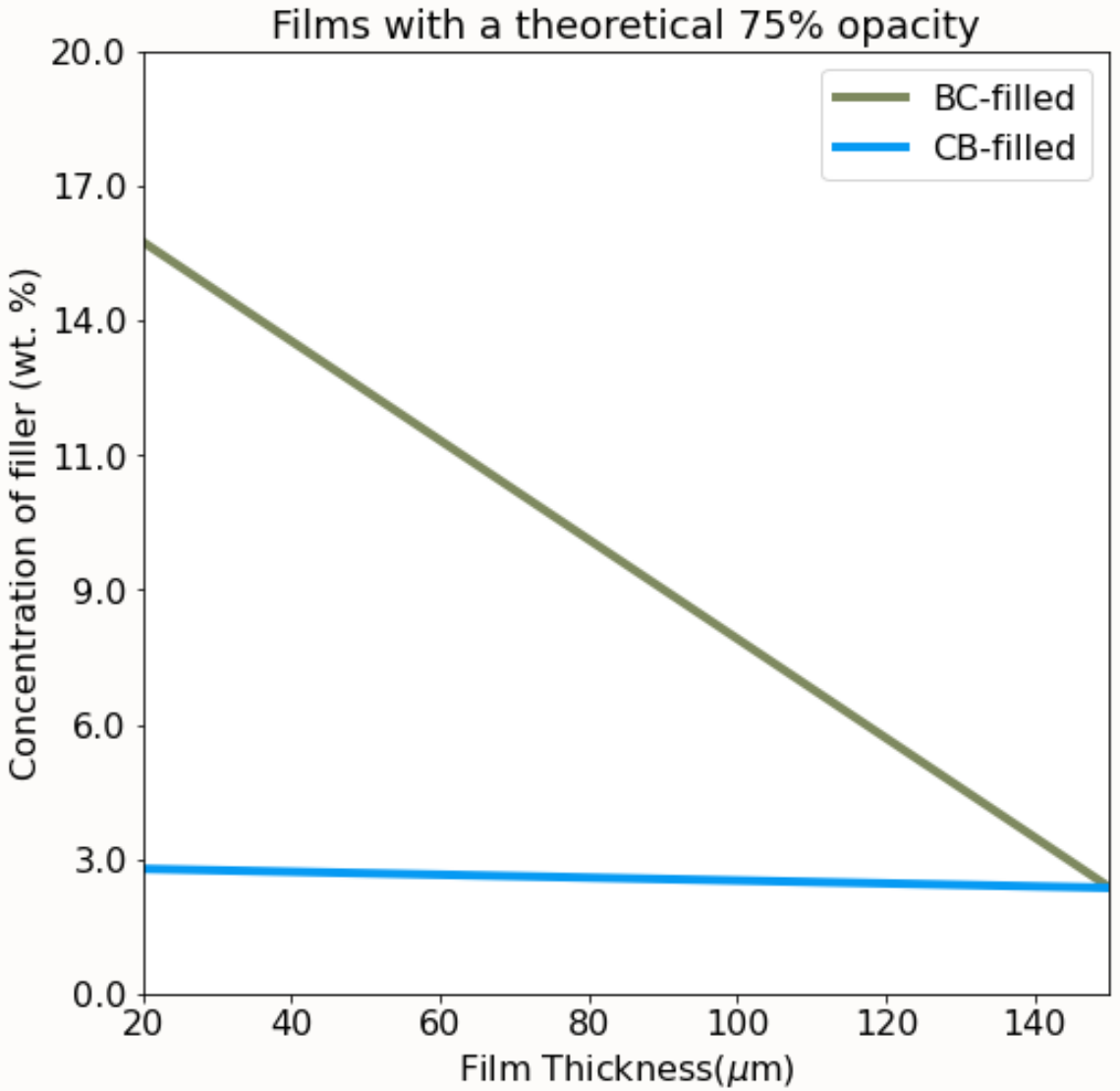




Carbon Black opaque films	Biochar opaque films
2 wt. % 4 wt. %	2 wt. % 4 wt. % 6 wt. % 8 wt. % 12 wt. % 15 wt. %
Under 50.4 µm	
Thermal, Mechanical, Opacity	

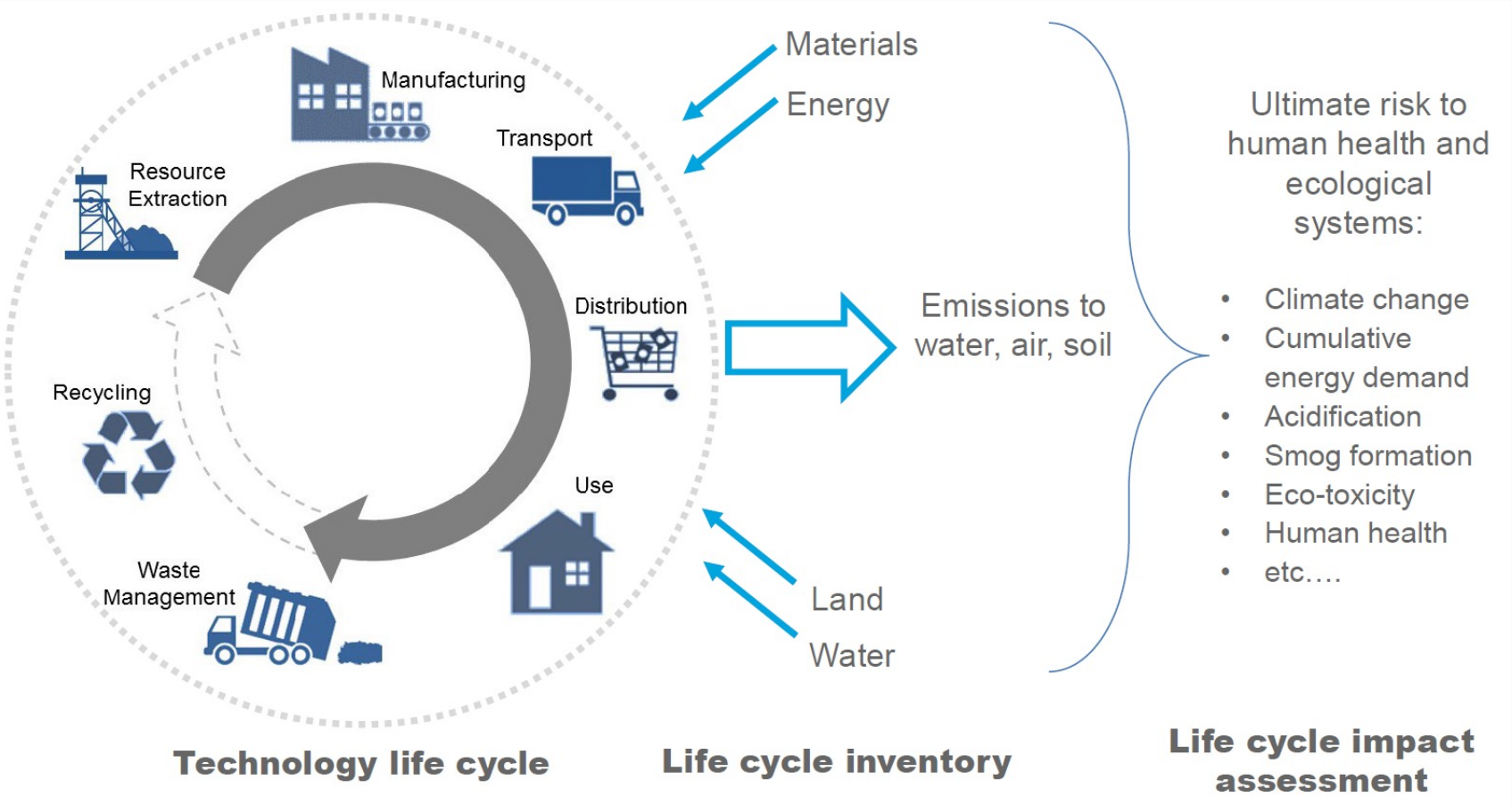
Mechanical Properties

Opacity


Films with a theoretical 75% opacity
BC-filled
CB-filled
Concentration of filler (wt. %)
20.0
17.0
14.0
11.0
9.0
6.0
3.0
0.0
20
40
60
80
100
120
140
Film Thickness(μm)

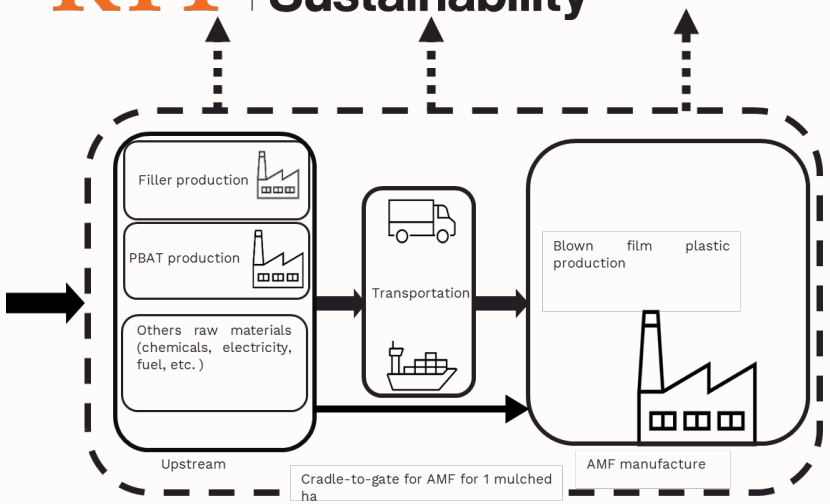
Life Cycle Assessment (LCA) Techno economical Analysis (TEA)

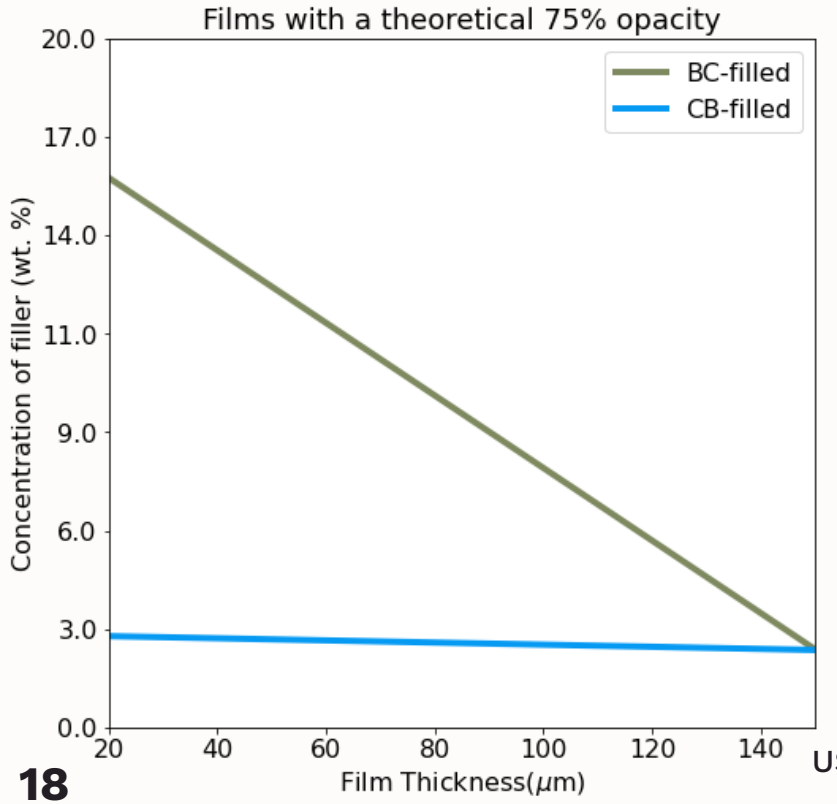
ISO 14040
ISO 14044



(Langhorst et al 2022)

- Goal and Scope
  - Boundaries
  - Functional Unit
  - Impact Assessment Methods
- Life Cycle Inventory (data)
- Life Cycle Impact Assessment
- Sensitivity Analysis


Filler production
PBAT production
Others raw materials (chemicals, electricity, fuel, etc.)
Transportation
Blown film plastic production
Upstream
AMF manufacture
Cradle-to-gate for AMF for 1 mulched ha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BC-filled
CB-filled
Concentration of filler (wt. %)
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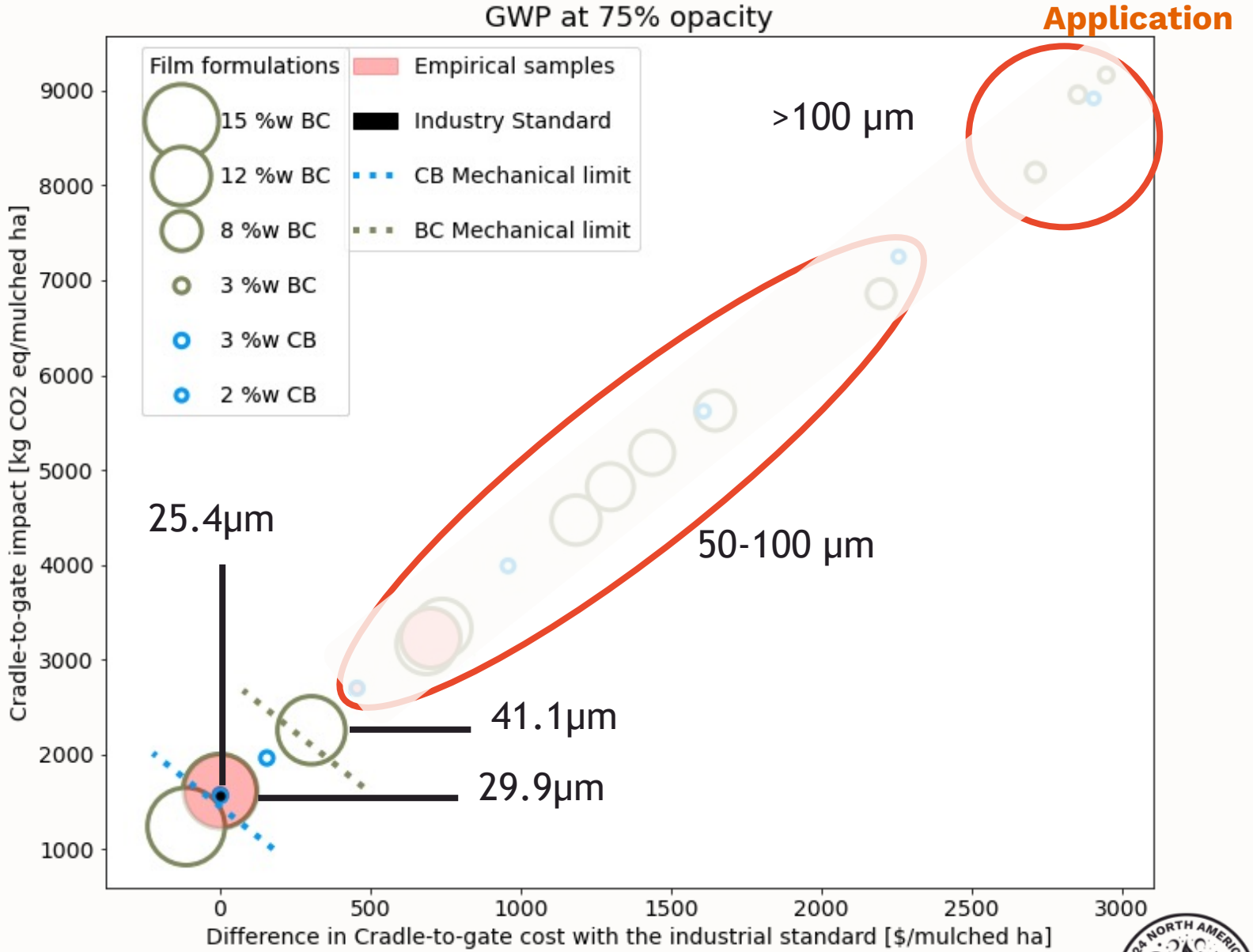
20.0
17.0
14.0
11.0
9.0
6.0
3.0
0.0
20
40
60
80
100
120
140


GWP at 75% opacity
Film formulations
15 %w BC
12 %w BC
8 %w BC
3 %w BC
3 %w CB
2 %w CB
Empirical samples
Industry Standard
CB Mechanical limit
BC Mechanical limit
>100 μm
50-100 μm
25.4μm
41.1μm
29.9μm
Cradle-to-gate impact [kg CO2 eq/mulched ha]
Difference in Cradle-to-gate cost with the industrial standard [$/mulched ha]
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
500
1000
1500
2000
2500
3000

Impact allocation Sensitivity analysis

Our results are sensitive to the **PBAT** impact and cost

Filler (either BC or CB) has little effect on overall results

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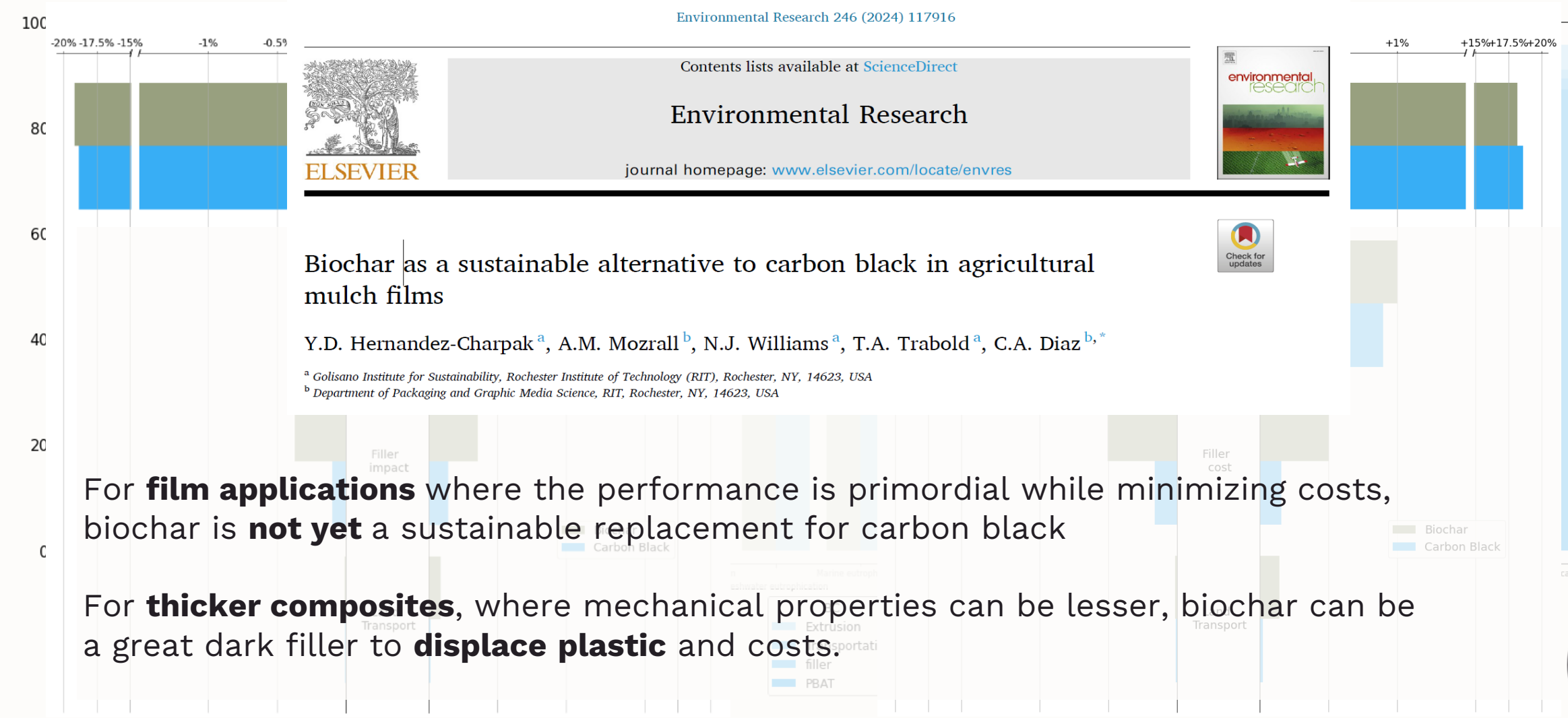

For **film applications** where the performance is primordial while minimizing costs, biochar is **not yet** a sustainable replacement for carbon black

For **thicker composites**, where mechanical properties can be lesser, biochar can be a great dark filler to **displace plastic** and costs.

Conclusions

- There is a **synergy between biochar feedstock and polymeric matrix**. As the right match of biochar and polymer can enhance the performance of the composite.
- The key properties for the plastic filling application are the **particle size, moisture, porosity**.
- It is important to understand the **role of biochar in the composite.** Biochar is a viable additive and filler for **thick composites**, where the mechanical properties are **not** the driver of the application.

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Thank you!
Questions?

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NEW YORK STATE OF OPPORTUNITY. Empire State Development

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