Biochar as a sustainable alternative of Carbon Black for opacity in Agricultural Mulch Films

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Thomas Trabold
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Agricultural Mulch Films (AMFs)

- Increase yield (Iqbal et al., 2020)
- Less water use (Iqbal et al., 2020) (Espí et al., 2008)
- Less pesticides and herbicides (Iqbal et al., 2020) (Espí et al., 2008)
- Avoids erosion (Iqbal et al., 2020) (Espí et al., 2008)
- >2 million t/year (Inglis et al., 2015)
- Most of it is polyethylene (PE) based.

Benefits of mulching (adapted from Iqbal et al., 2020)
Biodegradable Mulch Films (BMFs)

- Biodegrades in the soil saving the labor of collection.
- Same agronomic performance
- Do not behave in the same way with traditional additives and fillers. (Hernandez-Charpak et al., 2022)
- Can biochar fulfill the roles of processing additive and opacity filler?

Carbon black

- Fossil fueled based
- Used only for opacity, up to 4 wt. %
- Interest in literature to displace it (Bélanger et al., 2023; Meisel et al., 2022)

Opacity

- Depending on film thickness and filler concentration (Zhao et al., 2022)
Opacity determination

<table>
<thead>
<tr>
<th>Carbon Black opaque films</th>
<th>Biochar opaque films</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 wt. %</td>
<td>2 wt. %</td>
</tr>
<tr>
<td>4 wt. %</td>
<td>4 wt. %</td>
</tr>
<tr>
<td>6 wt. %</td>
<td>6 wt. %</td>
</tr>
<tr>
<td>8 wt. %</td>
<td>8 wt. %</td>
</tr>
<tr>
<td>12 wt. %</td>
<td>12 wt. %</td>
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<tr>
<td>15 wt. %</td>
<td>15 wt. %</td>
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</tbody>
</table>

Under 50.4 µm
DSC, TGA, Mechanical, Opacity
Fit for use (FFU) between 12 and 15 wt. % BC
Life Cycle Assessment (LCA) Techno economical Analysis (TEA)

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

ISO 14040
ISO 14044

(Matthews et al 2015)

(Langhorst et al 2022)
### Global Warming Impact

<table>
<thead>
<tr>
<th>Category</th>
<th>Global Warming impact</th>
<th>All the others</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCI methods</td>
<td>IPCC v1 GWP 2021 (including uptake)</td>
<td>ReCiPe 2016 Midpoint Hierarchical</td>
</tr>
</tbody>
</table>

### Source of data

<table>
<thead>
<tr>
<th>Source of data</th>
<th>Biochar production</th>
<th>Carbon Black production</th>
<th>PBAT production</th>
<th>Transport</th>
<th>Plastic extrusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCA</td>
<td>Sahoo et al. 2021</td>
<td>Ecoinvent v3 as Meisel et al., 2022 and Haylock et al, 2018</td>
<td>Schrijvers et al. 2014</td>
<td>Ecoivent v3 as Choi et al, 2018</td>
<td>Choi et al, 2018</td>
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<td></td>
<td>Bergman et al. 2022</td>
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<tr>
<td>TEA</td>
<td>Sahoo et al. 2021</td>
<td>Own purchase and Haylock et al, 2018</td>
<td>Own Purchase</td>
<td>Sahin et al, 2009</td>
<td>Haylock et al, 2018</td>
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<tr>
<td></td>
<td>Bergman et al. 2022</td>
<td></td>
<td></td>
<td></td>
<td>Cimpan et al, 2016</td>
</tr>
</tbody>
</table>

### Cradle-to-gate

- Goal and Scope
- Life Cycle Inventory (data)
- Life Cycle Impact Assessment
- Sensitivity Analysis

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Films with a theoretical 75% opacity

Cradle-to-gate impact [kg CO2 eq/ha]

Filler production (either CB; either BC)
PBAT production
Others raw materials (chemicals, electricity, fuel, etc.)
Transportation
Blown film plastic production
AMF manufacture
Upstream
Cradle-to-gate for AMF for 1ha

BC formulations
15 %w
12 %w
8 %w
3 %w
CB Mechanical limit
Industry Standard
Empirical samples

GWP at 75% opacity

>100 µm

25.4µm
41.1µm
29.9µm
50-100 µm

500 1000 1500 2000 2500 3000 3500
Cradle-to-gate cost [$/ha]
Our results are sensitive to the PBAT impact and cost.

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

For mono-layer AMF BC is not a sustainable alternative of CB for opacity.

The cost and environmental impact are driven by the polymer used.

Assumptions of our work:
- Opacity variability is based on experimental data, produced with only one type of BC
- Same horticultural benefit from the two options
Thank you!

Questions?

References!
References


Maeno, 2006
Particle distribution using ASTM D2862

Mean particle size

\[ \mu = 119.0 \text{ \(\mu\text{m}\)} \]
<table>
<thead>
<tr>
<th>Block</th>
<th>Category</th>
<th>Description</th>
<th>Value</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC (1 tonne)</td>
<td>Material Input from Technosphere</td>
<td>Bark chips, wet, measured as dry mass {RoW}</td>
<td>5932 kg</td>
<td>Feedstock needed (Bergman et al. 2022)</td>
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<tr>
<td></td>
<td>Energy input from Technosphere</td>
<td>Diesel, burned in Agricultural machinery {GLO}</td>
<td>641.7 MJ</td>
<td>18L of diesel combusted at LHV*. (Bergman et al. 2022)</td>
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<td></td>
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<td>Heat, central or small scale, natural gas {RoW}</td>
<td>0.31 MJ</td>
<td>From the burn of 8L of propane/NG**. (Bergman et al. 2022)</td>
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<tr>
<td></td>
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<td>Electricity, onsite boiler, hardwood</td>
<td>3336 kWh</td>
<td>From the burn of 834kg of woody biomass assuming at LHV*. (Bergman et al. 2022)</td>
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<tr>
<td></td>
<td>Emissions</td>
<td>Carbon Dioxide, biogenic</td>
<td>9.49E3 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
</tr>
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<td></td>
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<td>Carbon Monoxide, biogenic</td>
<td>3.46 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<td>Methane, biogenic</td>
<td>0.753 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<td>Nitrogen Oxides</td>
<td>9.73 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<td>Particulates, &lt;10 um</td>
<td>6.82 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<td>Particulates, &lt;2.5 um</td>
<td>0.055 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<td></td>
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<td>Particulates</td>
<td>5.19 kg</td>
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<td></td>
<td></td>
<td>Propane</td>
<td>1.89 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
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<tr>
<td></td>
<td></td>
<td>Sulfur dioxide</td>
<td>0.157 kg</td>
<td>Supplemental information of (Sahoo et al. 2021)</td>
</tr>
<tr>
<td>PBAT (1 kg)</td>
<td>Material inputs from Technosphere</td>
<td>1,4-Butanediol</td>
<td>0.41 kg</td>
<td>Table 4 of (Schrijvers et al. 2014)</td>
</tr>
<tr>
<td>Copy block from PET granulate, supposing a 90% efficiency</td>
<td></td>
<td>Terephthalic acid</td>
<td>0.33</td>
<td>Table 4 of (Schrijvers et al. 2014)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adipic acid</td>
<td>0.37</td>
<td>Table 4 of (Schrijvers et al. 2014)</td>
</tr>
</tbody>
</table>
Ozone Formation, Human Health

Ozone Formation, terrestrial eutrophication
Functionality not equivalent between HTT and Carbon Black.

(Meisel et al., 2022)
Water consumption at 75% opacity

- BC formulations
- CB formulations
- 15%w
- 12%w
- 8%w
- 3%w
- Empirical samples
- Industry Standard
- CB Mechanical limit
- BC Mechanical limit

Cradle-to-gate impact [m3/ha] vs. Cradle-to-gate cost [$/ha]