Utilizing products of manure pyrolysis: biochar and carbon dioxide, to precipitate mineral nitrogen fertilizer from urine

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- Pyrolysis > 300°C converts manure into 50% biochar and 5% carbon dioxide
- Biochar supplies phosphorus, stable carbon, and buffers soil pH
- Carbon dioxide is used to precipitate ammonium bicarbonate from urine
- A dewatering process such as forward-osmosis is necessary for precipitation

Steps in urine precipitation
1. 10 L urine inflow containing ~50 g NH$_3$,$\text{-N}$
2. Adsorption of ~5% NH$_3$ –N by biochar filter
3. Forward osmosis to dewater to 1L
   a. urine is ‘feed’ solution
   b. saltwater is ‘draw’ solution
4. Exacting high osmotic pressure
5. Concentrated urine and biochar suspension
   a. 1L urine : 250 g biochar per batch
6. Sparging of pyrolytic- CO$_2$ to capture 80% urine-N
   a. 1 mole CO$_2$ : 1 mol NH$_3$,4
7. Precipitation of ~ 40 g NH$_4$HCO$_3$ on 2.5 kg char

<table>
<thead>
<tr>
<th>Pyrolysis temp. (°C)</th>
<th>Phosphorus (mg kg$^{-1}$, Mehlich-III)</th>
<th>Stable carbon after 100 yrs (%w/w)</th>
<th>pH</th>
<th>CaCO$_3$ equivalency (%w/w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>8705.71 ± 33.69</td>
<td>44.11 ± 2.09</td>
<td>8.83 ± 0.03</td>
<td>5.19 ± 1.57</td>
</tr>
<tr>
<td>400</td>
<td>9995.56 ± 11.65</td>
<td>60.54 ± 0.60</td>
<td>10.30 ± 0.01</td>
<td>7.96 ± 0.79</td>
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<tr>
<td>500</td>
<td>10243.70 ± 1405.36</td>
<td>77.07 ± 3.40</td>
<td>10.72 ± 0.01</td>
<td>8.52 ± 0.52</td>
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<tr>
<td>600</td>
<td>10586.24 ± 309.07</td>
<td>85.19 ± 0.93</td>
<td>10.26 ± 0.01</td>
<td>7.41 ± 0.52</td>
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<tr>
<td>700</td>
<td>11523.47 ± 159.33</td>
<td>92.88 ± 1.03</td>
<td>10.76 ± 0.06</td>
<td>9.25 ± 0.52</td>
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