From waste to table: assessing the biological efficacy of fertilizers derived from anaerobic digestate

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Presentation outline

1. Aim of research
2. Fertilizer production
3. Fertilizer composition
4. Extraction tests
5. Plant studies
6. Plant biometric assessment
7. Plant composition assessment
8. Conclusions
Aim of this work

The aim of this study was to evaluate the biological efficacy of fertiliser derived from the digestate. For this purpose, the following points were assessed:
- nutrient availability
- the effect of fertilizer on plant growth parameters
- effect of the fertilizer on plant nutrition
Fertilizer production

Fertilizers based on anaerobic digestate

1. Hydrolysis
   - Sulfuric acid (96%)
   - Phosphoric acid (85%)
   - Water
   - Anaerobic digestate from food waste
   - Time: 24 h
   - Ratio: 78% digestate 28% acids
   - Temperature: 25°C
   - Stirring: 400 rpm

2. Granulation methodology
   - Granulation Neutralization
     - I method
       - Alkaline ash
       - Hydrolysate
     - 2% N
   - II method
     - Hydrolysate
     - Alkaline ash
     - 13% N

3. Scale-up
   - Urea with urease inhibitor
   - DRUM GRANULATOR
   - Step I
     - Hydrolysate
   - Step II
     - Alkaline ash

4. Fertilizer testing
   - Chromium speciation analysis
   - Microbial analysis
   - Amino acids content
   - Mechanical properties
   - Extraction tests
   - Pot trials

Fig.1. Fertilizer production technology
# Fertilizer composition

## Tab.1. Fertilizer composition

<table>
<thead>
<tr>
<th>Materials</th>
<th>Macronutrients</th>
<th>Micronutrients</th>
<th>Toxics elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C [%]</td>
<td>N [%]</td>
<td>P₂O₅ [%]</td>
</tr>
<tr>
<td>FINAL FORMULATION</td>
<td>38,3</td>
<td>8,57</td>
<td>3,40</td>
</tr>
<tr>
<td></td>
<td>±3,8</td>
<td>±0,86</td>
<td>±0,51</td>
</tr>
<tr>
<td>REQUIREMENT OF EU 2019/1009 REGULATION</td>
<td>&gt;7,5%</td>
<td>&gt;2%</td>
<td>&gt;7,5%</td>
</tr>
</tbody>
</table>
Extraction tests

Extraction test

Water extraction
- EN 15958:2011
  Leachability

Neutral ammonium citrate extraction
- EN 15957:2011
  Bioavailability
Extraction tests

Tab.2. Macronutrient release

<table>
<thead>
<tr>
<th>Extraction solution</th>
<th>Ca</th>
<th>K</th>
<th>Mg</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2.43</td>
<td>10.5</td>
<td>56.4</td>
<td>3.19</td>
<td>30.9</td>
</tr>
<tr>
<td>Ammonium citrate</td>
<td>9.00</td>
<td>16.8</td>
<td>100</td>
<td>14.8</td>
<td>42.7</td>
</tr>
</tbody>
</table>

Tab.3. Micronutrient release

<table>
<thead>
<tr>
<th>Extraction solution</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.317</td>
<td>0.004</td>
<td>2.19</td>
<td>0.08</td>
</tr>
<tr>
<td>Ammonium citrate</td>
<td>10.8</td>
<td>1.48</td>
<td>22.9</td>
<td>5.06</td>
</tr>
</tbody>
</table>

Fig.2. Results of extraction tests
Plant studies

1. **Model plant**: wheat

2. **Fertilization**: control with out fertilization (W), reference mineral fertilizer with similar composition (RF), anaerobic digestate (sanitized) (AD), granular organic-mineral fertilizer (GF) – each group in 3 replications

3. **Dosage**: in relation to nitrogen requirements (170 kg N/ha): 75%, 100% and 150%

4. **Duration**: 30 days

Fig.3. Plant tests
Plant biometric assessment

Tab.4. Results of biometric assessment

<table>
<thead>
<tr>
<th>Group</th>
<th>N dose</th>
<th>Stem length</th>
<th>Chlorophyll</th>
<th>Root length</th>
<th>Root area</th>
<th>Root diameter</th>
<th>Fresh root mass</th>
<th>Fresh steam mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>cm</td>
<td>mg/m²</td>
<td>cm</td>
<td>cm²</td>
<td>mm</td>
<td>g</td>
<td>g</td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>19.1 ± 4.5&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>347 ± 27&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>377 ± 56</td>
<td>45.9 ± 9.6</td>
<td>0.387 ± 0.042</td>
<td>3.32</td>
<td>5.90</td>
</tr>
<tr>
<td>RF</td>
<td>75</td>
<td>33.9 ± 8.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>419 ± 39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>387 ± 122</td>
<td>52.6 ± 13.6</td>
<td>0.440 ± 0.042</td>
<td>4.91</td>
<td>21.3</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>34.0 ± 6.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>394 ± 3935</td>
<td>481 ± 187</td>
<td>60.6 ± 21.2</td>
<td>0.408 ± 0.039</td>
<td>6.37</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>37.0 ± 5.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>428 ± 21&lt;sup&gt;b&lt;/sup&gt;</td>
<td>326 ± 81</td>
<td>42.7 ± 7.4</td>
<td>0.425 ± 0.048</td>
<td>5.42</td>
<td>20.2</td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>19.1 ± 4.5&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>347 ± 27&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>377 ± 56</td>
<td>45.9 ± 9.6</td>
<td>0.387 ± 0.042</td>
<td>3.32</td>
<td>5.90</td>
</tr>
<tr>
<td>AD</td>
<td>75</td>
<td>30.2 ± 9.1</td>
<td>405 ± 40</td>
<td>467 ± 117</td>
<td>53.5 ± 15.0</td>
<td>0.362 ± 0.020</td>
<td>3.86</td>
<td>11.4</td>
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<tr>
<td></td>
<td>100</td>
<td>27.2 ± 9.7</td>
<td>405 ± 40</td>
<td>409 ± 118</td>
<td>54.7 ± 10.8</td>
<td>0.436 ± 0.056</td>
<td>3.37</td>
<td>9.38</td>
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<tr>
<td></td>
<td>150</td>
<td>30.2 ± 7.3</td>
<td>401 ± 40</td>
<td>377 ± 129</td>
<td>47.9 ± 17.9</td>
<td>0.437 ± 0.132</td>
<td>3.78</td>
<td>12.3</td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>19.1 ± 4.5&lt;sup&gt;a,b,c&lt;/sup&gt;</td>
<td>347 ± 27&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>377 ± 56</td>
<td>45.9 ± 9.6</td>
<td>0.387 ± 0.042</td>
<td>3.32</td>
<td>5.90</td>
</tr>
<tr>
<td>GF</td>
<td>75</td>
<td>36.0 ± 7.1&lt;sup&gt;a,c&lt;/sup&gt;</td>
<td>422 ± 24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>376 ± 169</td>
<td>47.9 ± 18.8</td>
<td>0.412 ± 0.056</td>
<td>4.35</td>
<td>14.2</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>34.6 ± 6.9&lt;sup&gt;b,d&lt;/sup&gt;</td>
<td>437 ± 39&lt;sup&gt;b&lt;/sup&gt;</td>
<td>291 ± 148</td>
<td>43.7 ± 19.0</td>
<td>0.506 ± 0.097</td>
<td>4.39</td>
<td>16.4</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>19.1 ± 1.8&lt;sup&gt;c,d&lt;/sup&gt;</td>
<td>420 ± 50&lt;sup&gt;c&lt;/sup&gt;</td>
<td>241 ± 106</td>
<td>28.5 ± 8.5</td>
<td>0.413 ± 0.121</td>
<td>2.10</td>
<td>9.21</td>
</tr>
</tbody>
</table>
Plant biometric assessment

Fig. 4. Stem length
Fig. 5. Stem biomass
Plant biometric assessment

Fig. 6. Root length
Plant biometric assessment

Fig. 7. Root area
Plant biometric assessment

Fig. 8. Root mass
Plant biometric assessment

Fig. 9. Root diameter
Plant biometric assessment

Fig. 10. Chlorophyll content
## Plant biomass analysis

### Tab.5. Results of biomass analysis

<table>
<thead>
<tr>
<th>Group</th>
<th>N dose</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Cu</th>
<th>Mn</th>
<th>Zn</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>mg/kg d.m.</td>
<td>%</td>
<td>mg/kg d.m.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>1.26 ± 0.13</td>
<td>5180 ± 777</td>
<td>3.89 ± 0.58</td>
<td>6.74 ± 1.01</td>
<td>35.0 ± 5.3</td>
<td>64.4 ± 9.7</td>
<td>221 ± 33</td>
</tr>
<tr>
<td>RF</td>
<td>75</td>
<td>1.89 ± 0.19</td>
<td>9130 ± 1370</td>
<td>5.32 ± 0.79</td>
<td>10.9 ± 1.6</td>
<td>45.3 ± 6.8</td>
<td>71.9 ± 10.8</td>
<td>226 ± 34</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>1.97 ± 0.20</td>
<td>9520 ± 1430</td>
<td>5.21 ± 0.78</td>
<td>5.94 ± 0.89</td>
<td>52.2 ± 7.8</td>
<td>70.5 ± 10.6</td>
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<td>2.55 ± 0.25</td>
<td>12400 ± 1860</td>
<td>5.15 ± 0.77</td>
<td>6.16 ± 0.93</td>
<td>60.3 ± 9.0</td>
<td>82.3 ± 12.3</td>
<td>217 ± 33</td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>1.26 ± 0.13</td>
<td>5180 ± 777</td>
<td>3.89 ± 0.58</td>
<td>6.74 ± 1.01</td>
<td>35.0 ± 5.3</td>
<td>64.4 ± 9.7</td>
<td>221 ± 33</td>
</tr>
<tr>
<td>AD</td>
<td>75</td>
<td>2.84 ± 0.28</td>
<td>3770 ± 566</td>
<td>4.53 ± 0.67</td>
<td>8.00 ± 1.20</td>
<td>35.6 ± 5.3</td>
<td>152 ± 23</td>
<td>250 ± 37</td>
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<tr>
<td></td>
<td>100</td>
<td>3.01 ± 0.30</td>
<td>3600 ± 539</td>
<td>4.45 ± 0.66</td>
<td>4.84 ± 0.73</td>
<td>42.9 ± 6.4</td>
<td>58.3 ± 8.7</td>
<td>462 ± 69</td>
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<tr>
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<td>3.86 ± 0.39</td>
<td>3910 ± 587</td>
<td>5.34 ± 0.79</td>
<td>4.85 ± 0.73</td>
<td>43.6 ± 6.5</td>
<td>65.3 ± 9.8</td>
<td>356 ± 53</td>
</tr>
<tr>
<td>W</td>
<td>-</td>
<td>1.26 ± 0.13</td>
<td>5180 ± 777</td>
<td>3.89 ± 0.58</td>
<td>6.74 ± 1.01</td>
<td>35.0 ± 5.3</td>
<td>64.4 ± 9.7</td>
<td>221 ± 33</td>
</tr>
<tr>
<td>GF</td>
<td>75</td>
<td>2.52 ± 0.25</td>
<td>4360 ± 654</td>
<td>4.78 ± 0.71</td>
<td>5.62 ± 0.84</td>
<td>36.5 ± 5.5</td>
<td>60.0 ± 9.0</td>
<td>519 ± 78</td>
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<td>3.26 ± 0.33</td>
<td>5110 ± 767</td>
<td>4.90 ± 0.73</td>
<td>8.60 ± 1.28</td>
<td>41.9 ± 6.3</td>
<td>78.2 ± 11.7</td>
<td>424 ± 64</td>
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<tr>
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<td>150</td>
<td>3.84 ± 0.38</td>
<td>6170 ± 925</td>
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<td>10.8 ± 1.63</td>
<td>40.0 ± 6.0</td>
<td>86.8 ± 13.0</td>
<td>708 ± 106</td>
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</table>
Conclusion

1. The obtained fertilizer meet the quality requirements of the legislation.

2. The resulting fertilizer are characterised by favourable availability of nutrients.

3. The resulting fertilizers have a positive effect on plant growth parameters in the early growth stage and on plant nutrition.

4. Biological effectiveness should be assessed over the full growing season.
Conversion of anaerobic digestates from biogas plants: Laboratory fertilizer formulation, scale-up and demonstration of applicative properties on plants

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\textsuperscript{b} Department of Biochemistry and Food Microbiology, Wrocław University of Environmental and Life Sciences, Wrocław, Lower Silesia, 51-630, Poland
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Fig.11. Published paper
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Thank you for your attention!