REFERTIL:
RECYCLING TREATED ORGANIC WASTE AS BIO-CHAR PRODUCTS BY IMPROVED 3R ZERO EMISSION PYROLYSIS TECHNOLOGY

Edward Someus

http://www.refertil.info
http://www.3ragrocarbon.com

Biochar for high efficient bio-waste resource utilization
INTRODUCTION

TERRA HUMANA Ltd.: Specialized Pyrolysis and carbon product Science and Technology development & knowledge/competence center in Hungary since 1989. Coordinator and key S&T RTD performer for five large scale EU FP5, FP6, FP7 & CIP-ECO pyrolysis and carbon product development since 2002.

REFERTIL: FP7 consortium (11 partners from 10 countries) for pyrolysis, biochar ad compost advanced developments. EU policy support organization for FRr.
DEFINITIONS:
Advanced PYROLYSIS for biochar production

History: since 1980’s over 30 large scale pyrolysis developments made, most of them failed.

New generation Pyrolysis

• is a zero emission thermo-chemical decomposition process of plant and/or animal origin organic waste and by-products in the absence of oxygen, under vacuum and between material core temperature ranges from 450 °C up to 850 °C.

• transforms organic materials into three different components: (1) gas, (2) liquid or (3) solid in different proportions depending upon both the feedstock and the pyrolysis conditions used.

• Slow pyrolysis (carbonisation) with relative long residence time could be applied for biochar production.

• Fast pyrolysis (relative short residence time) is designed for bio-oil production.

REFERTIL: recycling treated organic waste as compost and bio-char products
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WHAT IS BIOCHAR?

BIOCHAR MATERIAL is:
• plant and/or animal bone biomass origin,
• *stabile carbon carboniferous material*
• for Authority permitted open ecological soil enhancement use and
• eco-safe carbon negative application.

BIOCHAR PRODUCT is:
• a labeled and full value chain safe product
• with producers product responsibly guarantees,
• meets the EU and US “End of Waste” criteria.

INPUT SUSTAINABLILITY CRITERIA: The feed material:
• is not from primarily and secondarily land use.
• *is not competing with human food and animal feed.*
• logistic is environmentally, climate protection and economically sustainable at the same time.

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WHAT IS NOT BIOCHAR? – I.

- Biochar is **NOT a fine ground charcoal**, and/or
- biochar is **NOT labile carbon** material that application is rapidly promoting GHG developments, and/or
- biochar is not carbon material that does **NOT meet quality** to be put into open ecological soil environment, and/or
- made from input feed material, that is originating from primer and secondary land use products, and/or the feed material use is competing with human and/or animal food supply and/or food crop plant production nutrient supply, and/or
- made from input **feed material that is not from living, or recently living organisms** and containing any ecotox substances (IMPORTANT: when biochar is used in dose 10 t/ha, than the concentration limits of the possible exotox substances are 10x multiplied VS when dose is 1 t/ha only) and/or
- the **pyrolysis process is not towards zero emission performance**, and/or
What is Not Biochar? – II.

- The pyrolysis process is not energy self-sustaining, and/or
- The pyrolysis – biochar production - process is not Government Authority permitted and controlled operation, and/or
- The biochar material open ecological soil environment industrial scale application is not Government Authority permitted and controlled operation, and/or
- The overall life cycle of the process (input material, process, biochar use) is having more negative environmental impact than total benefit, and/or
- The biochar product having no labelled producers responsibility performance, and/or
- The output biochar product economical value and free market valorization is not based on common market demands and commercialization process, e.g. biochar economical valorization may not be based on grants, subsidies, and/or unclear carbon trade programmes.

Biochar is NOT a labile carbon
Feedstock characteristics and physical/chemical properties to be considered

1. **Particle size distribution**
2. **Bulk density**: low mass density is causing logistical problem (collection, transport and storage).
3. **Moisture content**:
   - critical for storage and pre-treatment strategies
   - Pyrolysis technology is suited to low moisture content (below 18 % w/w)
4. **Ash content, pH**
5. **Sustainability of feed material**
6. The Potential Toxic Elements (PTEs) and organic pollutants should be minimized. The majority >85% of the PTEs concentration level will be multiple increased in the char only by factor approx. 3x-5x.

The input material characteristic is always reflected into the output products.
Sustainability of feed material for biochar production

1. Biochar feed materials **does not compete with human food, animal feed and plant nutrition supply**. Production biochar from low economical value by-product biomass should not create competition for land use for human and animal food production.

2. **Low feedstock production costs and inputs** needed.

3. **Feedstock availability**: seasonal and yearly round availability.

4. **Environmentally sustainable feed material logistics**. The environmental and human health impact of logistics storage should be minimized.

5. **Economically sustainable feed material availability**: price and long term supply contract and logistical cost.

6. **Feedstock quality and safety**: low Potential Toxic Element Content.
ABC is:

- Food grade animal bone biomass SAFE origin.
- **Full value P** natural fertilizer.
- No Potential Toxic elements (No Cadmium, No Uranium).
- **Supporting all types of cultivations**, including GMO and/or non GMO based, organic and/or low input farming.
- **Eco-safe** carbon negative application.
- **Economical** end user application.
- Supporting **low carbon economy**.

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**Biochar product:**
**Organic fertilizer or soil improver?**

<table>
<thead>
<tr>
<th>BIOCHAR</th>
<th>P₂O₅</th>
<th>N</th>
<th>K₂O</th>
<th>CaO</th>
<th>NUTRIENT CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal bone charcoal</td>
<td>28-30</td>
<td>&lt;0.1</td>
<td>0.4-0.8</td>
<td>30-42</td>
<td>HIGH</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(recycled N +5-6%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant Based Biochar</td>
<td>0.01-0.3</td>
<td>0.3-1</td>
<td>0.1-1</td>
<td>0.2-6</td>
<td>LOW</td>
</tr>
</tbody>
</table>

*If the nutrient content is low, the dose/ha is high → higher load of contaminants to the land*

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### Plant based biomass VS. animal bone feedstocks

<table>
<thead>
<tr>
<th></th>
<th>PLANT BASED</th>
<th>ANIMAL BONE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td><strong>Low:</strong> 100 – 300 kg/m³</td>
<td><strong>High:</strong> 650 – 670 kg/m³</td>
</tr>
<tr>
<td>Biochar yields</td>
<td><strong>Low:</strong> 15-30%</td>
<td><strong>High:</strong> 45-50%</td>
</tr>
<tr>
<td>Feedstock cost</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Transportation cost per ton</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Alternative supply</td>
<td>High</td>
<td>Few</td>
</tr>
<tr>
<td>Material handling</td>
<td><strong>Costly:</strong> large volume, bulky and high storage requirement</td>
<td><strong>Medium</strong> cost</td>
</tr>
<tr>
<td>Fire protection system</td>
<td>Costly</td>
<td><strong>Medium</strong> cost</td>
</tr>
<tr>
<td>Sensitivity for moisture content</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

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Critical pyrolysis conditions for safe and quality biochar products

• The feedstock used combined with the pyrolysis conditions determine the properties, both physical and chemical of the final biochar products.

• Processing of ABC and animal by-products require far higher know how/technology level and high tech, than traditional pyrolysis process for plant based or waste materials.

• Critical parameters for quality and safety of the biochar:
  • Input material characteristics
  • Engineering design performance of the pyrolysis technology (heat and mass transfer efficiency in the equipment)
  • Treatment conditions (material core temperature, residence time and pressure conditions) and auxiliary systems.

There is no one fit for all solution
<table>
<thead>
<tr>
<th></th>
<th>PLANT BASED BIOCHAR (PBC)</th>
<th>ANIMAL BONE BIOCHAR (ABC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAR YIELDS</td>
<td>Low: 20-30%</td>
<td>High: 45-50%</td>
</tr>
<tr>
<td>GAS-VAPOUR YIELDS</td>
<td>High</td>
<td>Low (highly depending on input)</td>
</tr>
<tr>
<td>PYROLYSIS OIL CHARACTERISTICS</td>
<td>pyrolysis oil</td>
<td>bone oil</td>
</tr>
<tr>
<td>ECONOMIC VALUE OF PYROLYSIS OIL</td>
<td>Relatively low economical value associated with high treatment cost.</td>
<td>Medium – low economical value associated with high treatment cost.</td>
</tr>
</tbody>
</table>
Synfuel production

a) When **pyrolysis gas-vapour** is condensed, than the gas is yielding liquids (crude and unprocessed pyrolysis oils that containing the input moisture content as well) and crude non-condensable gases.

b) **Synthetic fuel or synfuel** is a liquid fuel, or gaseous fuel that can be processed from refined the pyrolysis gas-vapour (from the condensed crude pyrolysis oils and crude non-condensable gases), with catalytic conversion or steam reforming.

c) **Syngas**, or synthesis gas, is a fuel gas mixture consisting primarily of hydrogen, carbon monoxide, and very often some carbon dioxide, which is often processed by steam reforming.

d) **Producer gas** is a generic term referring to:
   - Wood gas: produced in a gasifier.
   - Town gas: manufactured gas, originally produced from coal.
   - Syngas: as a fuel source or as an intermediate for the production of other chemicals.
### “3R” Recycle-Reduce-Reuse
Zero Emission Pyrolysis technology
TRL Technology Readiness Level

<table>
<thead>
<tr>
<th>TRL</th>
<th>Description</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>basic principles observed</td>
<td>1983 +</td>
</tr>
<tr>
<td>2</td>
<td>technology concept formulated</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>experimental proof of concept</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>technology validated in lab</td>
<td>Pilot plant</td>
</tr>
<tr>
<td>5</td>
<td>technology <strong>validated</strong> in relevant environment</td>
<td>Year 1990 +</td>
</tr>
<tr>
<td>6</td>
<td>technology <strong>demonstrated</strong> in relevant environment</td>
<td>1991 +</td>
</tr>
<tr>
<td>7</td>
<td>system <strong>prototype</strong> demonstration in operational environment</td>
<td>Field demo plant 2002 - 2005</td>
</tr>
<tr>
<td>8</td>
<td><strong>system complete and qualified</strong></td>
<td>Year 2005-2015</td>
</tr>
<tr>
<td>9</td>
<td><strong>industrial system</strong> proven in operational environment, competitive manufacturing of key enabling technology and products</td>
<td>Year 2015-2016 Commercial biochar production</td>
</tr>
</tbody>
</table>

Research & Technical Development Road Train
“3R” Zero Emission Pyrolysis technology

3R pyrolysis pilot TRL5 plant in Hungary 1991

The new 3R technology open new technical, low carbon economical, environmental, climate protection and qualified green industrial job creation possibilities.

3R pyrolysis field demo TRL8 plant in Hungary 2015

- continuously operating
- indirectly heated rotary kiln system,
- reductive thermal treatment processing
- up to 850°C material core temperature.

Safer - better - less costly - more ecological

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“3R” BIOCHAR PRODUCTION TECHNOLOGY
PERFROMACE and SUSTAINABILITY INDICATORS

1. **Productivity.** Continuous and automated production: improved energy efficiency (high efficient energy conversion process) and safety.

2. **Reductive thermal processing** performance.

3. **Total emission** performance = ZERO. **Full recovery and valorisation of by-products** (including bio-oil) for improved economics and environmental performance (towards zero emission performance).


5. **Feed flexibility** and sustainability.

6. Long term **meet all strict and comprehensive environmental norms and industrial standards**

7. Industrial solution **comprehensiveness**.

8. Comprehensive industrial **safety** and **continuous quality control of the labelled biochar** output products.

9. Maintaining **producers extended responsibility and legal liability** for the biochar products.

10. Maintaining EU and MS Authority **biochar production and biochar application permits**.

11. **Rational CAPEX** capital expenditure investment and **OPEX** operational and maintenance expenditure costs with high added value production performance.

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“3R” Carbon Refinery Markets

- Soil Improver
- Organic P fertilizer
- Growing media

**FERTILIZER:** The ABC Animal Bone bioChar is full value P natural fertilizer, premium product, primarily for horticultural farming SAFE FOOD production.

** ADSORBENT:** High efficient macroporous adsorbent.
ACKNOWLEDGEMENT

The 3R pyrolysis technology and ABC product development has been co-funded by the European Union since 2002.

Thank you European Commission.
Thank you Hungarian Government.

We would like to express our gratitude to the European Commission who supported the 3R pyrolysis technology and biochar product development projects since 2002 and the Hungarian Government supports since 2010. The 3R development has been built up step by step from TRL1-TRL9, whereas several key important projects have been the coherent and integrated building stones of the past decade, which systematic efforts resulted a fully matured and comprehensive industrial solution by 2015.

REFERTIL pyrolysis science to achieve results
THANK YOU!

CONTACT:

Mr. Edward Someus
Coordinator & key technology designer for the European Union Commission REFERTIL programme
http://www.refertil.info
E-mail: biochar@3ragrocarbon.com
http://www.agrocarbon.com

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