

Improvement of comprehensive bio-waste transformation and nutrient recovery treatment processes for production of combined natural products

REFERTIL BIOCHAR PROJECT RESULTS



REFERTIL = SCIENCE TO ACHIEVE INDUSTRIAL RESULTS

In a world with finite resources there is no infinite development opportunity with sustainability, unless a resource efficient circular economy is fully implemented.



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Disclaimer: The views and opinions expressed are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.



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Detection of PTEs with ICP-OES

BIOCHAR QUALITY & SAFETY ACCREDITED BIOCHAR ANALYSIS

ACCREDITED BIOCHAR ANALYSIS

As accredited laboratory partner of the REFERTIL project hundreds of different types of biochar and test samples from 11 countries have been investigated by WESSLING. Wide range of materials (biochar, soil, compost, input waste materials, plant parts) are fully analysed.

With this high number of tests the quality of the input materials and the output products were fully characterised. Measurements were directed on one hand to examine useful plant nutrients, phosphorus/carbon/nitrogen content and on other hand to the detection of potential risk factors (PAHs, potentially toxic elements, PCBs and dioxins). The priority hazardous substances PAH's are key targets to determine any biochar product quality and safety, while providing full information on pyrolysis processing technology efficiency and performance. **During pyrolysis and other thermal treatment processes PAHs are the main indicator contaminants, it's limit value has been defined as maximum 6 mg/kg for biochars.** With various biochar processing conditions it has been verified that the technology influences the quality of the product.

In spite of their similar visual appearance, the microstructure and chemical properties of the plant based biochars (PBC) and Animal Bone bioChars (ABC) are quite different but they can be analysed using the same laboratory methods.

Between appropriate treatment conditions, high quality biochars were made with low PAH19 content (< 1 mg/kg), that is already mandatory regulated and applied by some MS for soil improvers since 2006. PCBs were not detected from any biochars, but high chlorine content of the input material was also not expected. As dioxins is not detected in biochars, we have concluded that PCB presence is a good indicator of these persistent and bioaccumulative chemicals.

The Environmental Testing Laboratory of WESSLING is the first laboratory in Europe to obtain accredited status for comprehensive analyses of biochar samples (Wessling-NAT-1-1398/2012, 08.10.2014).



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3R Recycle-Reuse-Reduce zero emission pyrolysis equipment

BIOCHAR PROCESSING TECHNOLOGY IMPROVEMENTS TOWARDS ECONOMICAL INDUSTRIAL SCALE

Biochar is plant and/or animal bone biomass origin stabile carbon carboniferous and legally labeled product with functionality of solid organic fertilizer and/or solid organo-mineral fertilizer and/or organic soil improver. Biochar is a specific carbonized product obtained from specific pyrolysis process with designed quality, environmental and ecological safety, performance and character for food crop production applications.

Animal Bone bioChar (ABC) having low carbon content with full macroporous structure and as high as 30% P_2O_5 nutrient composition with sequenced release organic phosphorus fertilization effect. Plant based biochar (PBC) is stabile and high carbon content plant origin micro- and meso porous carboniferous soil improver products, with relatively high water holding, nutrient retention and C-sequestration.

Most importantly, the pyrolysis/carbonization processing technology design quality and efficiency performance is critically important element that will be reflected as unique and recognized fingerprint in the output biochar product quality and safety performance characteristics. In this context, application of schlock biochar production technology resulting schlock biochar products with low quality/safety and low market value, if any at all. Another important factor is the input material characteristics that are also reflected into the output product performance.

Sustainable biomass by-products and residues for biochar production may not compete with human food, animal feed, plant nutrition supply; and land use for human and animal food production.

The developed new generation "3R" Recycle-Reduce-Reuse pyrolysis is a zero emission thermo-chemical decomposition process. **The "3R" is high efficiently carbonizing animal and/or plant origin organic by-product and waste streams in absence of oxygen, and between material core temperature ranges from 450 °C up to 850 °C. The "3R" is original solution and industrial design for economical Recycling, Reuse and Reduce of organic by-products and waste streams.**

BIOCHAR PROCESSING TECHNOLOGY

ABC IS A RECOVERED ORGANIC P-FERTILIZER having high nutrient density (30% P_2O_5) and pure P- content

INPUT: cat. 3 bone rendering byproducts



Zero emission pyrolysis reductive thermal processing, $850\text{ }^\circ\text{C}$

Major aspects:

nutrient density,
nutrient solubility,
product safety,
economy €,
legal compliance



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ABC: Animal Bone BioChar

ABC ANIMAL BONE BIOCHAR - BIOPHOSPHATE PRODUCTS

Animal Bone bioChar "ABC" is a recovered organic P-fertiliser, made from food grade animal bone grist, having high nutrient density (30% P_2O_5) and pure P-content.

The rendering industrial origin food grade category 3 animal bone grist processed ABC is a macroporous organic fertilizer with as high as 92% pure calcium phosphate and 8% carbon content only. ABC is NPK formulation optimized for significant enhancing of soil microbiological life, having high water holding and macromolecular organic nutrient retention. The fully safe ABC is used at low doses (100–600 kg/ha) and in cases when justified even up to 1,000 kg/ha.

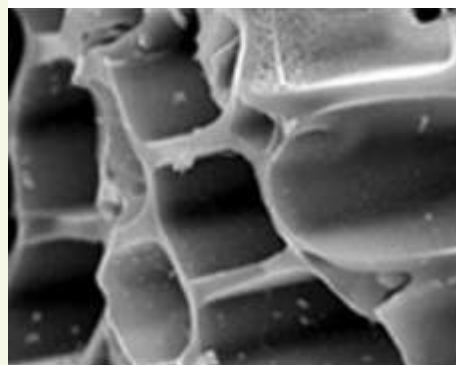
Therefore the ABC product functionalities are organic fertilizer, soil improver, growing medium and/or fertilising product blend. The substitution of phosphate import by recovered Phosphorus is an important goal for the European agriculture already in short term. The imported mineral Phosphorus agri substitution potential by bio ABC in European dimension is >5% (>75,000 t/y P_2O_5) in short term (<2025) and up to >20% in long term (>2030).

ABC IS A RECOVERED ORGANIC P

**Animal Bone bioChar (ABC)
Organic Phosphorus fertiliser,
soil improver, growing media:**

- Made from food grade category 3 bones.
- 92% mineral content and 8% Carbon.
- 30% P_2O_5 and 38 – 42 %CaO + Mg, K.
- Controlled release direct organic fertiliser with different formulation options.
- **Dose: 0.1t/ha - <math><1\text{ t/ha}</math>.**

ABC: macroporous
50-63,000 nm



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BIOCHAR STANDARDIZATION AND EU LAW HARMONIZATION SUMMARY OF THE REFERTIL POLICY SUPPORT WORK

As biochar is irrevocably applied in open ecological soil systems, therefore only qualified, safe and EU/MS Authority permitted biochar to be applied. The aim is to ensure the biochar quality and safety that are fully consistent with the EU Directives and Regulations. **Any biochar manufacturing and product applications require mandatory EU/MS Authority permits.** Moreover biochar manufacturing, import, placing on the

REFERTIL recommended Biochar parameters	ORGANIC P FERTILISER	SOIL IMPROVER
Potential toxic elements (mg/kg)		
As	10	10
Cd	1.5	1.5
Cr	100	100
Cu	200	200
Pb	120	120
Hg	1	1
Ni	50	50
Zn	600	600
Organic pollutants		
PAHs (mg/kg)	6	6
PCB 7 (mg/kg)	0.2	0.2
PCDD/F (ng/kg I-TEQ)	20	20
Bulk density	declaration	declaration
Dry matter content	>80%	>60%
pH	6 - 10	6 - 10
Total Organic C	declaration	20%
N and K total	declaration	declaration
Total P (P ₂ O ₅)	>25%	declaration
Total Ca, Mg	declaration	declaration
Germination inhibition assay	No inhibition	No inhibition
Phytotoxicity	No phytotoxicity	No phytotoxicity
Agronomic efficiency	Should be proved	Should be proved

market and use above 1 t/year capacity require approved REACH registration as well.

Voluntary biochar certificates having no legal effects and technical validity.

Fertilisers Regulation (EC No. 2003/2003) is only regulating the mineral fertilizers and not applicable to biochar products. REFERTIL provided a strong policy support for the EU Commission in revision of the Fertiliser Regulation and inclusion of biochar as safe organic fertiliser/soil improver.

The legal and economical sustainability of the biochar under market based commercial conditions has been evaluated.

Harmonized and standardized analytical measurements developed for determination of the physical-chemical properties, Potentially Toxic Elements (PTEs) content and Organic Pollutants of the biochar materials. **Biochar EU quality and safety criterion system has also been set up** which is maximizing the PTEs and Organic Pollutant content for safe applications. Detailed policy support report has been submitted to the Commission. **The REFERTIL biochar is Authority permitted.**

BIOCHAR STANDARDISATION



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Greenhouse bioassay with
Rhododendron plant

EFFECTS OF BIOCHAR AND COMPOST APPLICATIONS ON FORMATION AND FUNCTION OF MYCORRHIZAL SYMBIOSES

MICROBIAL STRATEGIES FOR BIOCHAR

The Leibniz University of Hannover has the objective to combine biochar and compost products with inocula of arbuscular (AMF) and ericoid mycorrhizal fungi (ERMF), with the aim to improve plant tolerance against abiotic and biotic stress. A number of isolates of AMF and ERMF mycorrhizal fungi are tested in combination with biochar and compost in tagetes and rhododendron plants regarding mycorrhizal colonization and functioning. Only in special combinations of composts/biochars with mycorrhizal fungi a hindered mycorrhizal formation could be detected. Functioning of mycorrhizal fungi was defined as growth promotion by AMF and anti-phytopathological effects of ERMF. **Composts and ABC biochar can support plant growth and health by their nutrients and anti-pathogenic effects. In special combinations with mycorrhizal fungi a synergistic increase of these effects was observed.** The living micro-organisms in composts obviously play a role in these interactions. An important technical aspect for the use of AMF/compost products in plant production is the shelf life of AMF inoculum in compost: final mixtures must be stored for some time before distribution and use on farm. The selected mycorrhizal fungi can be combined with composts or biochars without problems and usefully applied.

DEVELOPMENT OF FUNGAL INOCULATION STRATEGIES

Terra Humana Ltd. has successfully developed different microbiological strategies and ABC-fungal inoculum technology for compost activator and compost nutrient enrichment application.

BENEFICIAL EFFECTS OF BACTERIAL INOCULANTS

In trials carried out by DLO, Wageningen UR, a bacterial strain, 4.4.1, was introduced into the potting soil directly, or indirectly via compost or biochar. This bacterial strain has the capacity to inhibit growth of plant pathogenic fungi and to make phosphorus available for plant growth. The strain protected the tomato seedlings against infection, resulting, on average, in 48% more healthy plants. It also promoted the uptake of Phosphorus (P) by the tomato seedlings.



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REFERTIL potting trials in Italy

USE OF COMPOST AND BIOCHAR IN AGRICULTURE: FIELD EXPERIENCES FROM THE REFERTIL PROJECT

Compost and biochar evaluation trials were started in 2014 by REFERTIL in several European Countries, under different soil and climatic conditions:

- The Netherlands (Wageningen UR): strawberry and tomato in greenhouse;
- Italy (UNITO-Agroinnova): tomato, pepper, zucchini, lettuce, cucumber in nursery, greenhouse and open field;
- Slovenia (KOTO): strawberry in open field;
- Ireland (Renetech): cereal crops in open field;
- Denmark (SEGES): barley and other cereal crops;
- Hungary (TERRA): vegetables and cereal crops in open field.

The aim of the trials was to validate the developed transformation and recycling technologies, the compost and biochar potential for reduction of the mineral fertiliser use, the effects for crop productivity, enhanced soil health, improved nutrients availability to plants and suppression of soil-borne plant pathogens.

Summary results of the REFERTIL field trials:

- Animal bone char (ABC) can be used as organic fertilizer (100-400 kg/ha) and mixed in growing media (0.1-5% v/v).
- High quality compost can be used as soil improver (5-30 t/ha) and mixed in growing media (1-20% v/v). Where beneficial effect improved by biochar mix.
- Nutrients present in compost and biochar products are taken up by tomato plants: organic by-products are successfully recycled and replaces the use of mineral P and K fertilizers in agricultural crop production.
- Green waste compost with a relatively low nutrient content can be used as organic amendment to substitute peat in potting soil and showed the capacity to enhance suppressiveness of the substrate.
- Mycorrhiza, nutrient solubilising bacteria and fungus can be combined with the application of ABC biochar and compost products in agriculture and horticulture.

BIOCHAR EVALUATION TRIALS

ABOUT THE REFERTIL PROJECT

REFERTIL provided EU-28 standardized, advanced, and comprehensive bio-waste treatment and nutrient recovery process improvements towards zero emission performance with eco-safe output biochar/compost products. The works covered fields from applied science into economical industrial scale ups, industrial technology engineering, proven demonstrations for the benefits and interests of the SME farmers. **REFERTIL is conversion of biochar science into industrial practice. Comprehensive and detailed biochar policy, law harmonization system and common quality standard requirements and recommendations worked out** for the EC related to the revision of the Fertilisers Regulation.

During the REFERTIL project 34 tons of different types of biochar and 600 tons of compost samples produced under optimized process conditions as demonstration. **ABC Animal fertilizer with 30% P₂O₅ plant based biochar is soil content.** Biochar formulation strategy for fungi, bacteria and mycorrhizal fungi developed. **REFERTIL** Biochar and compost products successfully tested, demonstrated and validated in six countries under different climatic, soil and cultivation conditions.

Comprehensive accredited laboratory evaluations made for all the material streams. The improved output biochar/compost products were safe, economical and standardized. ABC containing right proportion of Bio-NPK that can be economically and beneficially used by SME farmers for market competitive productions. **Biochar technical, economical, carbon cost, environmental, social and climate mitigation analysis for benefits and risks made**, including biochar business plan and industrial implementation feasibility for EU and Australia under market competitive conditions. **As a result, both food and environmental safety is improved, while a new circular bio-economy is generated.**

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