

Abstract band

European Biochar Symposium 2011

September 26th and 27th in Halle (Saale)



Halle (Saale)

Martin – Luther University Halle /Wittenberg

Abstract band

European Biochar Symposium 2011

Scientific organizer:

Prof. Dr. Bruno Glaser

Martin-Luther-University Halle-Wittenberg

Institute of Agricultural and Nutritional Sciences

Soil Biogeochemistry

Von – Seckendorff – Platz 3

D-06120 Halle (Saale)

Organization committee:

Daniela Busch

Katja Wiedner

Further Information:

<http://www.landw.uni-halle.de/biochar2011>

Monday, 26.09.2011

Time	Speaker	Title
09:00	Gesine Foljanty-Jost (invited)	Opening
09:10	Claudia I.Kammann et al.	Biochar: A way forward to increase the GHG-efficiency of crop production?
09:40	Barbara Kitzler et al.	Biochar amendment and its effect on soil greenhouse gas fluxes
10:00	Lucatina Ercolano et al.	Hydrothermal carbonization (HTC) of sewage sludge
10:20	Daniela Busch and Bruno Glaser	Ecotoxicological risk assessment of biochars from different production processes and feedstocks
10:40	Break	
11:30	Barbara Weiner et al.	Process water of the hydrothermal carbonization of biomass and aspects of its treatment
11:50	Justin Beck	Biochar in urban farms
12:10	Jorge Paz-Ferreiro et al.	Effect of sewage sludge and sewage sludge biochar on soil biochemical activity
12:30	Elisabeth Jüschke et al.	Impact of biochar derived from hydrothermal carbonization (Hydrochar) on plant growth rates, microbial activity and soil properties
12:50	Lunch & Poster session	
15:00	Ana Gajic et al.	Short-term study on the decomposability of hydrochars in soil
15:20	Muhammad Farooq Qayyum et al.	Carbon and nitrogen dynamics in soils and soil density fractions affected by wheat straw, biochars and incubation time
15:40	Hans – Peter Schmidt et al.	Biochar as carrier for plant nutrients and microorganisms – a first approach to activation techniques
16:00	Sonja Schimmelpfennig et al.	Could biochar be possibly one solution for anthropogenic caused climate change?
16:20	Break	
17:30	Jürgen Kern and Christina Dicke	Gas fluxes in char amended soil
17:50	Daniel Fischer et al.	Carbon dynamics and stability of biochar composts
18:10	Hardy Schulz et al.	Compared Biochar and Compost effects on plant growth factors as reported for oat (<i>Avena sativa</i> L.) in a greenhouse trial
18:30	Bernd Marschner, Chris Bamminger	Stability and biological effects of pyrogenic and HTC-biochars in two soils
18:50	Dinner: Brauerei Schad	

Tuesday, 27.09.2011

Time	Speaker	Title
09:00	Cornelia Rumpel et al.	Changes of organic matter properties due to charring: impact of precursor material and production conditions
09:40	Bruno Glaser et al.	Experience from two years of biochar field experiment and implications for further research
10:00	Maria Koon et al.	Fate of carbon and nutrients after hydrothermal carbonization of lignocellulosic biomass
10:20	Benjamin Wirth et al.	Anaerobic treatment of HTC waste water
10:40	Break	
11:30	Christian Koch et al.	Chemical nature of carbonaceous materials produced by hydrothermal carbonization (HTC) and low temperature conversion (LTC)
11:50	Bernd Schottdorf	Production of Biochar in industrial quantities
12:10	Eckhart Jedicke et al.	Hydrothermal Carbonation in a peripheral, agricultural closed installation engineering – from the work of Artec GmbH
12:30	Arne Stark et al.	Hydrothermal Carbonization on the industrial scale: The CS-HTC process
12:50	Lunch & Poster session	
14:30	Gerhard Soja et al.	Yield Performance of Mustard and Barley in Biochar-amended Soils at Different Nitrogen Levels
14:50	Jim Hammond et al.	Biochar to Reduce Nitrogen Fertiliser Use and N ₂ O Emissions from On Farm Spring Barley Crops in Scotland
15:10	Hartmut Koehler	Growth effects of a Biochar- Bokashi on <i>Plantago lanceolata</i> and <i>Panicum miliaceum</i>
15:30	Mohammed Alhassan et al.	Effect of bone during fixed bed pyrolysis of biomass
15:50	Final Discussion	

Biochar: A way forward to increase the GHG-efficiency of crop production?

Dr. Claudia I. Kammann

Fertile soil to grow food clearly is not only a finite resource on our planet, its area decreases due to soil degradation and global warming. With an increasing, energy hungry world population to feed the value of fertile soils grows: hedgefunds started to buy land in African countries as a "save investment" - alarming news. More intensive agriculture usually means more greenhouse gas (GHG) emissions, e.g. when the stock of ruminant animals grows (meat consumption); when large areas are dedicated to wet rice production (both increase CH₄ emissions); when soil organic C is lost as CO₂ due to non-sustainable land management or soil degradation; or when soil N fertilization promotes the emissions of N₂O, a stable GHG with 298 times the cumulative radiative forcing over 100 years than the same amount of CO₂. In addition, the conversion of natural ecosystems to agricultural land has already reduced the global CH₄ uptake (= CH₄ sink) by methanotrophic bacteria by 30% or more. The more reactive nitrogen (N_r) humankind injects into soils and ecosystems the more N₂O will be produced while the CH₄-sink will diminish; the anthropogenic fixation of N₂ into reactive N already exceeds the natural fixation.

Thus our goal must be to produce higher crop yields at lower greenhouse gas emission "costs". This can be achieved by either (i) increasing yields at the same GHG emission level per unit of land area, (ii) by producing the same yield more efficiently at lower GHG emission costs, or (iii) in the ideal case by both, a higher yield at lower GHG emissions.

Here, biochar comes into play - it may offer a pathway for more efficient N_r use since it has often, but not always, been shown to (a) improve crop yields, (b) enhance the N use efficiency of plants, (c) reduce N leaching and in particular to (d) reduce N₂O emissions from biochar-amended soils. Recent results even suggest that biochar may be used as a filter material absorbing NH₃ (e.g. animal housing) which can be used as a carbon-based fertilizer later on.

In my talk I will give an overview on biochar effects on GHG producing processes in soil, summarize the most recent results and hypotheses including the mechanisms assumed to be responsible for the observations. In addition we will show own results, including the first GHG flux measurements performed on Brazilian Terra preta soils in the lab (versus near-by Ferralsols) or GHG flux measurements on German soils from charcoal-making places (Siegerland), compared to adjacent soils. One of the most important questions is if aged biochars will *still* reduce N₂O emissions from soils, in particular when their soil organic carbon content has increased. Results of N₂O emissions from compost-amended versus biochar-compost-amended soils will also be presented, because composting may represent an accelerated biochar-ageing process. Finally, we will identify open questions that need to be addressed to explore and successfully "sharpen" biochar as a tool to improve the crop-yield to GHG-cost ratio of agricultural production.

Biochar amendment and its effect on soil greenhouse gas fluxes

M. Klinglmüller^{1,2}, B. Kitzler¹, J. Bücken³, B. Wimmer³, A. Watzinger³, F. Zehetner², G. Soja³ and S. Zechmeister-Boltenstern^{1,2}

A major reason for the application of biochar to soils is the mitigation of the greenhouse gas carbon dioxide (CO₂) by increasing long-term soil carbon sequestration. To evaluate this practice as a sustainable, future mitigation strategy, the soil-atmosphere flux of CO₂ but also of non-CO₂ greenhouse gases have to be considered. The gases of interest are nitrous oxide (N₂O) and methane (CH₄) with a global warming potential of 298 and 25, respectively. Strategies to optimize biochar qualities and amendment levels for specific soil types and bioclimatic zones have to be developed in order to maximize carbon sequestration, while increasing plant production and decreasing environmental risks such as nutrient leaching and soil greenhouse gas emissions.

This study aims at the evaluation of GHG fluxes from different biochar qualities (straw, wood mix and vineyard pruning), different application rates (1 M-%, 3 M-%), different soil types (sandy and loamy), biochar-treated versus nontreated soils + N-fertilizer and planted vs. non-planted soil. Gas flux measurements were conducted at several stages of plant development in order to compare the effect of different biochar qualities on GHG emissions.

The closed chamber technique was used, gas samples were taken after 0, 5, 10 and 20 minutes and analysed by gas-chromatography. Our hypothesis was that biochar-treated and non-treated soils would show significant differences in soil GHG emission. In agreement with our hypothesis, we found a significant effect of biochar on N₂O, CO₂ and CH₄ fluxes depending on a range of factors such as the biochar feed stock, soil type and fertilization.

Addresses of the Authors

¹Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, Seckendorff-Gudent-Weg 8, 1130 Wien, Austria

²Universität für Bodenkultur, Institut für Bodenforschung, Peter Jordan-Str. 82, 1190 Wien, Austria

³AIT Austrian Institute of Technology GmbH, Konrad Lorenz-Str. 24, 3430 Tulln, Austria

Contact: DI. Dr. Barbara Kitzler, barbara.kitzler@bfw.gv.at

Mo 26.09.2011 10:00

Hydrothermal carbonization (HTC) of sewage sludge

Lucatina Ercolano¹, Kimmo Palmu¹, Caroline Dornelles de Azevedo⁴, Claudia vom Eyser², Christoph Glasner³, Joachim Behrendt¹, Ralf Otterpohl¹, Jochen Türk²

¹Technical University of Hamburg Harburg,
Institute of Wastewater Management and Water Protection

²Institut für Energie und Umwelttechnik e.V. (IUTA)

³Fraunhofer UMSICHT

⁴University of Sao Paulo, Brasil

Biomass conversion processes have been in the focus of research activities as well as of public interest since recent years. The carbonization of biomass residuals has a strong potential to become an efficient process for production of chars for CO₂-sequestration. Wet pyrolysis, called hydrothermal carbonization (HTC), enables efficient conversion of a great variety of biomass feedstock like sewage sludge into biochar. Raw and fresh char needs to be further processed for a use as soil ameliorant.

The traditional method of utilizing sewage sludge in agriculture effectively closes the loop of nutrients. Since sewage sludge contains (apart from nutrients like nitrogen, phosphorus and potassium) many for the food chain undesirable substances as heavy metals and Pharmaceuticals and Personal Care Products (PPCPs), application of sewage sludge to agricultural soils is continuously monitored. It is expected that through HTC processing organic pollutants are converted with organic matter to char and other organic fractions. Furthermore it is expected that the char is slowly degraded in soil, resulting in reduced greenhouse gas (GHG) emissions.

In our presentation we will show the qualities of HTC-treated sewage sludge and bark (pine). We will especially point out to which extend macro-nutrient (nitrogen and phosphorus) can be stored in the produced biochar. Since our research is focusing on nutrient recycling we will show the potential for recovery after HTC from sewage-sludge, fermentation residuals (corn) and bark. Additionally we are going to present preliminary results of a biotoxicity assessment of HTC-chars from sewage sludge and bark. Previous research has indicated phytotoxic potential of fresh HTC-chars (Kammann, 2010) due to this fact the chars have been pre-treated through co-composting with fresh municipal compost in various ratios (1:1, 1:4, 1:8). We are going to present results on phytotoxic-gases (related to volatile organic compounds desorbing from char surface), germination tests with cress and barley and a worm avoidance test. The intention for assessing biotoxic or beneficial effects of HTC-chars on plants was to determine whether a use of HTC-treated sewage sludge as a soil ameliorant in agriculture could be possible.

Acknowledgement

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Ecotoxicological risk assessment of biochars from different production processes and feedstocks

Daniela Busch and Bruno Glaser

Martin-Luther University Halle-Wittenberg, Institute of Agricultural and Nutritional Sciences, Soil Biogeochemistry, von-Seckendorff-Platz 3, 06120 Halle, Germany

Corresponding author: Daniela.busch@landw.uni-halle.de

Biological monitoring approaches are presented as a short and easy way for the ecological risk assessment of biochars from different production processes and feedstocks. We present first results of a micro nucleus test with *Tradescantia sp.* (Trad MCN test) for assessment of potential genotoxic effects of biochars on pollen cell chromosomes. The effects are shown as chromosomal aberrations. Based on VDI guideline 3975 and diverse publications (e.g. Mišik et al. 2011) we adapted a test system suitable for biochars. Because of the fact that pH values of biochars and HTC materials differ from 4 to 10 and for exclusion of simple pH effects, biochars were adjusted to pH 5.5 for all treatments. Exposition time was extended from 6 to 24 hours and the number of counted flowers was increased from 5 to 8, because of very high scatter in first results. Especially chars from hydrothermal carbonization processes showed some significant effects in higher amounts of chromosomal aberrations in tetrad stage of pollen cells.

These results led us to carry out another test to detect possible influences on germination and growth, especially with biochars showing genotoxic effects. In this test the pH value was left unchanged. During the test all effects on development of seedlings in dependency of different addition rates of two different materials will be monitored and documented. In all phases of development the test plants will be reviewed about damage in tissues, growth and development. Although the pH value of HTC material-added soils changed after 5% addition rate, a growth inhibition was observed already at 2.5 % char addition while for all pyrolysis-derived biochars conversed effects could be observed.

Observed effects will be correlated with possible toxic contaminants such as polyaromatic hydrocarbons (PAH), polychlorinated dibenzodioxins and furans (PCDD/PCDF) (see poster presentation of Wiedner et al.).

Mo. 26.09.2011 11:30

Process water of the hydrothermal carbonization of biomass and aspects of its treatment

Barbara Weiner, Igor Baskyr, Jürgen Pörschmann, Frank-Dieter Kopinke

Helmholtz-Zentrum für Umweltforschung - UFZ, Department für Technische Umweltchemie,
Permoserstr. 15, 04318 Leipzig

The hydrothermal carbonization (HTC) is an exothermic process, in which biomass in an aqueous suspension is transformed into biocoal (biochar) at temperatures between 180 and 250°C under elevated pressure. A fraction of the organic carbon, which yields depend on the kind of biomass used and the process conditions, such as temperature, pH-value, and redox potential of the educts, is dissolved in the obtained aqueous phase. This dissolved organic matter (DOM) can have a broad molecular weight distribution, ranging from low molecular weight organic acids to high molecular weight condensation products.

Various biomass-educts have recently been studied, such as waste materials from agriculture, brewing, and wood and paper materials. However, the main focus has been on the produced biochars and little attention has been paid to the process waters. Therefore, DOM utilization remains a challenging task.

Herein, a recycling of the process waters from HTC of cellulosic materials will be discussed with regard to the mass balance of the employed bio-materials, and the reduction of the amounts of potentially harmful low molecular weight organic molecules.

Moreover, the potential for the degradation of trace organic pollutants, such as pesticides and pharmaceuticals, under HTC conditions will be presented. These can be present in the employed waste (agricultural) biomass or in the process waters. Scope and limitations will be discussed on a few examples of pesticides.

Furthermore, a concept for the design of a deep well reactor technology for a continuous HTC process combined with recycling of the process waters is introduced. The feedstock is hereby brought in the reactor as suspension, where reductive HTC conditions aim at high yields of the produced biochar. A subsequent change to oxidative conditions might favor the decrease of the DOM concentration.

Mo. 26.09.2011 11:50

Biochar in Urban Farms

Justin Beck

Community Climate Action Plan, Sonoma County, California, USA <http://www.coolplan.org/>

The urban farm can be as simple as a tomato plant on your balcony or it can be an ambitious, for profit venture like those of The Vertical Farm (<http://www.verticalfarm.com/>). Why not add biochar to the mix?

Urban farms that add biochar will be helping to sequester GHG emissions and will be finding a great way to re-use bio waste. What are the economics of using biochar in an urban farm? What are the distribution issues? Can urban revitalization projects be a part of this conversation?

Effect of sewage sludge and sewage sludge biochar on soil biochemical activity

J. Paz-Ferreiro¹, G. Gasco¹, B. Gutierrez¹, A. Méndez²

¹ Departamento de Edafología, ETSI Agrónomos, UPM, Madrid

² Departamento de Ingeniería de materiales, ETSI Minas, UPM, Madrid.

E-mail address: jpaz@udc.es

Sewage sludge disposal is made mostly is land which could pose a threat to ecosystems as it can result on higher heavy metals in soils. However, using sewage sludge for biochar production could be a sound environmental process to recycle the former. Thus, we have studied the effect of a biochar obtained from sewage sludge on soil biochemical properties in an Umbrisol, using two doses of biochar and comparing these results with the control soil and with soils amended with the same two doses of sewage sludge. Properties assessed included microbial biomass C, soil respiration, net N mineralization dehydrogenase, α -glucosidase, phosphomoeesterase and arylsulphatase. The response of these properties was highly variable. When using the geometric mean of enzymes activities (GMea) as an integrative index of soil quality it was found an increase of soil quality for the soils amended with the higher dose of biochar with respect to the control soil. On the contrary, high doses of sewage sludge resulted in a reduced soil quality.

Mo. 26.09.2011 12:30

Impact of biochar derived from hydrothermal carbonization (Hydrochar) on plant growth rates, microbial activity and soil properties

Elisabeth Jüschke, Gerd Gleixner

The sequestration of carbon in agricultural soils by addition of thermally modified organic materials, e.g. from plant biomass, influences the natural soil carbon cycle. To combine carbon sequestration and increased soil fertility would be a perfect alliance for the world's climate problem and the reestablishment of degraded soils for agricultural uses. Research studies performed with laboratory produced biochar mainly derived by pyrolysis (Pyrochar) from different managed processes as fast or slow pyrolysis or by the use of different temperatures, showed generally positive potential mechanisms on soil fertility. Increase of nutrient storage, water holding capacity, structured habitats for soil microorganisms, e.g. mycorrhiza, and of soil pH as well as a decrease of nutrient leaching (Atkinson et al. 2010) are discussed as main mechanisms for soils amended with pyrochar. In respect to the biochar produced by the process of hydrothermal carbonisation (hydrochar) only few data about potential soil effects are available until now. Rillig et al. (2010) describe plant growth of *Taraxacum* and *Trifolium* and the root colonisation with arbuscular mycorrhiza in a greenhouse experiment with HTC-material from beet root chips mixed in different rates into a Luvisol. These authors could detect deleterious effects on plant growth, at least at higher addition rates and a stimulation of mycorrhiza.

Until now it remains unknown how stable such charred material will stay in the soil. After two month incubation of hydrochar amended soils in a greenhouse experiment, Steinbeiss et al. (2009) could show that the mean residence times of such processed chars is in the decadal timeframe. A study by Rillig et al. (2010) describing different greenhouse experiments recommends a cautious approach in the use of materials produced by HTC.

In this presentation, two experiments will be described to evaluate the impact of hydrochar on plant germination and growth, soil chemistry and soil biology under greenhouse conditions conducted with two different temperate soils. In the first experiment four differently treated hydrochars deriving from one original char were compared to an unamended control as well as a fertilised control in two soils with two crops (summer wheat and summer colza). Beside the original HTC, a pH adapted pH7 variant, a washed and a centrifuged variant were analysed. The second experiment was performed to evaluate dose rate effects in one of these two soils under growth of summer wheat. Differences in plant growth and especially differences between these two soils could be seen, especially with respect to time.

By the end of September also first results from a running field experiment will be available and the status will be reported.

Mo. 26.09.2011 15:00

Short-term study on the decomposability of hydrochars in soil

A. Gajić, H.-J. Koch

In a field and laboratory study a variety of hydrochars was investigated regarding their stability against decomposition in soil. Hydrochar production conditions differed in temperature (180-250 °C), reaction time (4-12 h), and parent material (sugar beet pulp and beer draff as model substances). Hydrochars were applied to the soil in rates of 10 t ha⁻¹ (field) and equivalent to 30 t ha⁻¹ (laboratory).

Decomposition of the hydrochars was quantified by measuring CO₂ release using NaOH traps. The CO₂ emission was determined by titration of the excess NaOH to pH 8,8 with HCl. In the field, the hydrochars were mixed with the soil in April 2010. CO₂ measurements were continuously conducted from April to September 2010, when sugar beet was grown, and April to July 2011 in subsequent winter wheat. The laboratory experiment was performed for a period of four months after hydrochar application to the soil at 60 % max. water holding capacity and 22 °C.

In the first two to four weeks, the hydrochar incorporation substantially increased the CO₂-C release compared to the untreated control. Subsequently, the CO₂-C release rates from hydrochar equated with the control treatment, suggesting a labile and a stabile fraction of carbon in hydrochar. Raised temperature as well as longer reaction time during the production process resulted in significantly higher hydrochar stability against decomposition. Feedstock effect was just small. The results indicate that the production process of hydrochar can be optimized for maximum carbon sequestration.

Mo. 26.09.2011 15:20

Carbon and nitrogen dynamics in soils and soil density fractions affected by wheat straw, biochars and incubation time

Muhammad Farooq Qayyum*, Diedrich Steffens, Hans Peter Reisenauer, and Sven Schubert
Address: Institute of Plant Nutrition, Research Centre for BioSystems, Land Use and Nutrition. Justus Liebig University, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany.

**E.Mail : farooq.qayyum@ernaehrung.uni-giessen.de*

The extraordinary role of biochar in soil carbon (C) sequestration and soil fertility is under focus of research. The objectives of our experiment were to study the effects of biochar application on the C and nitrogen (N) dynamics in soil organic matter fractions. Three soils (Oxisol, Alfisol topsoil, and Alfisol subsoil) were amended with three various biochars (charcoal, hydrothermal carbonization coal from bark (HTC), and low temperature conversion coal (LTC) from sewage sludge), in comparison to wheat straw and a control treatment. Each amendment was applied at rate of 11.29 g C kg⁻¹ soil. Soils were incubated over a period of 2 years. Amendments were analyzed for physical and chemical properties prior to addition in soil. Soil samples taken after 365 d were analyzed for density fractionation to retrieve free fraction, intra-aggregate fraction, and particle bound fraction. Total C and N were determined in organic fractions by elemental analyzer. Fourier transformation spectroscopy (FTIR) was performed to observe changes occurred during incubation in all fractions. The results showed that after 365 d of incubation, mainly biochar application resulted in a significant increase of total C in soils. High C concentration was recorded in free and intra-aggregate fractions of biochars that suggest their recalcitrant nature. The LTC was the only treatment which showed significantly higher C and N in particle bound fraction as compared to control. Soil analyses after 365 d of incubation showed no significant differences in total N between treatments of Oxisol. The FTIR-spectra of the soil density fractions showed that only slight change of infrared spectra occurred in HTC treatment retrieved from soils (decrease in absorption intensity at wavelength 2920 cm⁻¹ (indicating decrease of aliphatic methyl and methylene functional groups), and addition of absorption bands at 1032 cm⁻¹ (smectite or Si-O), and 3620 – 3527 cm⁻¹ (Si-O-H). Furthermore, during the incubation period of 1 – 2 years a strong CO₂-C mineralization was measured in the HTC treatment in Alfisol topsoil. Here, the C mineralization was in the same range as in the straw treatment. Hence it seems that HTC is not suitable for C sequestration in soil.

Biochar as carrier for plant nutrients and microorganisms – a first approach to activation techniques

Hans-Peter Schmidt, Delinat-Institut

The soil ameliorating potential of biochar is strongly linked to its impact on nutrient cycling dynamics, sorption capacity and to its ability to change the habitat function for the soil fauna. However, as shown in multiple studies, the addition of pure biochar to agricultural soils will not always have benefits; rather it may even reduce plant growth caused by the (initial) immobilisation of plant nutrients.

This capacity may be used to our advantage: The very potent sorption dynamics of biochar could potentially make it an effective carrier for plant nutrients and plant-root symbiotic microorganisms. At the Delinat-Institute, we tried a variety of methods of charging biochars with organic and mineral plant nutrients as well as with potentially beneficial microorganisms. This includes the use of biochar as bulk agent in aerobic composting, in malolactic fermentation and as pre-treatment for liquid manure, but also formulations of mineral carbon-fertilizers. The biochar products were tested in pot trials and also in larger-scale field trials. Results and experiences of these trials as well as different activation methods will be explained. A short overview of the potential of industrial designing of potential biochar-based products will be given.

Could biochar be possibly one solution for anthropogenic caused climate change?

Sonja Schimmelpfennig & Claudia Kammann, Justus-Liebig-University Gießen

If biochar proves to add to the stable carbon pool in soils by simultaneously improving soil conditions and promoting plant growth, it would turn out to be a fabulous tool to counteracting anthropogenic climate change and its hazardous consequences. Nevertheless, scientific evidence of the long-term impacts of biochar on soil and environment is still ongoing. The Giessen field trial on the risk assessment of different material (miscanthus feedstock, hydrothermally carbonized miscanthus and pyrolyzed miscanthus) in grassland is one of the few studies to look at the stability of biochar in temperate soils. We present preliminary results of the field trial which has been accompanied by a laboratory experiment. We look at greenhouse gas emissions and carbon isotope ratios of the different treatments, complemented by biochar characterizing parameters and growth rates from plant experiments. Data from the laboratory study showed significantly higher CO₂ fluxes of the feedstock- and HTC-amended soils, whereas emissions from biochar amended soils were not different from the control soil. N₂O emissions between the treatments varied strongly, with the feedstock amended soil showing the highest emission rates.

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Gas fluxes in char amended soil

Jürgen Kern and Christiane Dicke

Leibniz-Institut für Agrartechnik Potsdam-Bornim (ATB)

One of the most crucial points of biochar application to soil is its recalcitrance, which accounts for the long-term carbon sequestration. Therefore this study was designed to get information about the behavior of biochars in soil. Besides two carbon-rich soil substrates peat and Terra Preta, three different biochar types (chars from hydrothermal carbonization of poplar wood, pyrolysis of pine wood and gasification of pine wood) were mixed with a carbon-poor sand.

Aerobic long-term incubations run over a period of 1.5 years in order to measure the accumulated concentrations of CO₂ and N₂O. Over this time most CO₂ per gram carbon of the original substrate was released in the pure sandy soil followed by mixtures of the same sand with Terra Preta and with peat. Two to three times lower was the gaseous CO₂-C accumulation rate in the char/sand mixtures. Relatively high CO₂ amounts were released from the HTC char during the first four months of incubation. After that time in all three char/sand mixtures CO₂ release followed a linear pattern for more than one year. If this trend would continue, the carbon reservoir of the chars from HTC, gasification and pyrolysis will be exhausted after 25, 30 and 44 years, respectively.

High rates of N₂O emission were found in the pure sandy soil with a mean value of 24 ng N₂O-N per g carbon and per day during the study period of 1.5 years. In the char/sand mixtures N₂O emission was reduced by 7 to 11 times compared to the pure sandy soil. Particularly the chars, which derive from HTC were most effective in N₂O reduction.

It may be concluded that the chars under study have a recalcitrance of at least several decades. Continuation of this study will give more information to specify the half-life time of biochars.

Carbon dynamics and stability of biochar composts

– An evaluation of six successive composting experiments with biochar indicating sustainable solutions for modern resource management and climate protection

Daniel Fischer^{1*}, Gabriel Ananda Erben², Gerald Dunst³ and Bruno Glaser¹

¹ *Terrestrial Biogeochemistry, Martin-Luther-University Halle-Wittenberg, von-Seckendorff-Platz 3, 06120 Halle, Germany.*

² *Department of Soil Physics, University of Bayreuth, D-95440 Bayreuth, Germany*

³ *Sonnenerde GmbH, Oberwarterstraße 100, A-7422 Riedlingsdorf, Austria*

* Corresponding author: daniel.fischer@landw.uni-halle.de

Driven by global warming and population growth, increasing human pressure and resource demand force conversion of natural ecosystems to agricultural land while degrading soils currently under agricultural use. This man-made crisis leads to a vicious circle, further aggravating global warming, soil degradation, erosion, loss of humus and nutrients leaching. Therefore, sustainable concepts for an increased agricultural productivity and for an intelligent material flow management are urgently needed to reduce or prevent human environmental impacts especially caused by current practice of industrial farming. However, agriculture must not be regarded only as a cause of climate change, but most of all as a potential partner for solutions, if mitigation and adaption techniques are sustainably utilized, serving both environment and society. A key factor for sustainable farming practice is the maintenance or increase of soil organic matter inducing positive ecosystem services such as increased productivity, nutrient and water storage, intact buffer and filter capacity, rooting, aeration and habitat for soil organisms. Furthermore, a remarkable amount of atmospheric carbon dioxide can be naturally fixed in soils by increasing soil organic matter level and applying adequate humus-conserving technologies, promoting climate protection. One efficient way of achieving higher soil organic matter level represents compost application. By this mean organic waste can be efficiently processed while the final, humus-like and stable substrate contributes to amelioration by improving physical, chemical and biological properties of amended soils in general. However, up to now reported C sequestration potential due to compost management is limited in terms of C use efficiency and long-term C preservation even combined with organic farming and no till management. In this respect, we assume that combined application of proper biochar and composting technologies represents a promising option to enhance material properties resulting in a much better C sequestration potential due to the long-term stability of biochar. In order to evaluate this hypothesis, six successive composting experiments with biochar amendments have been accomplished varying in compost feedstocks (green cuttings, biowaste, sewage sludge etc.), biochar materials (activated carbon, charcoal, Pyreg biochar), biological processing (aerobe decomposition and anaerobe lactic acid fermentation) as well as applied biochar amounts. In

this connection, the main objective of our research consisted in testing the following questions:

- 1) Is biochar substantially more recalcitrant than native organic matter also during composting?
- 2) Does biochar induce negative priming effects regarding mineralization rate of compost organic matter during the composting process?
- 3) Does anaerobic lactic acid fermentation with EM-preparations reduce compost organic matter mineralization losses?
- 4) Does biochar amendment additionally reinforce fermentation-induced negative priming of compost organic matter?

For this purpose, piles were weighted to establish a mass balance. Contents of total organic (TOC) and black carbon (BC) were measured before and after processing, in order to identify the distinct carbon pools of biochar and compost feedstock within the mixtures. Furthermore, elemental composition of the biochar compost products have been analysed and finally visualized by plotting H/C vs. O/C atomic ratios according to Van Krevelen indicating the chemical reactivity and stability characteristics of the analysed samples.

Mon 26.09.2011 18:10

Compared Biochar and Compost effects on plant growth factors as reported for oat (*Avena sativa* L.) in a greenhouse trial

Hardy Schulz^{1*} and Bruno Glaser¹

¹ Soil Biogeochemistry, Martin-Luther-University Halle-Wittenberg, von-Seckendorff-Platz 3, 06120 Halle, Germany

* Corresponding author: hardy.schulz@landw.uni-halle.de

Keywords: *biochar, climate change mitigation, soil amendment, soil fertility, Terra Preta, pot trial*

Since ten years there is a major increase in research concerning biochar applications to soils trying to mimic effects known from Terra Preta do Indio (Glaser 2002). So far there are only experiments known which apply mere biochar or biochar mixed with other amendments just before the application to soils, whereas our experiment uses biochar which was blended with fresh organic material and underwent the whole composting procedure leading to the first known composted biochar. As pure biochar is not directly enriching the soil with nitrogen (Glaser 2002, Birk 2011); while elevating the C/N-ratio it might even decrease N-availability (Bridle & Pritchard 2004) which is supposed to be smoothed if combined with nutrient rich compost. Our hypothesis is that the process of composting activates the carbon surface generating a reactive substance for soil amendment (Lehmann and Joseph 2010) which later serves a nutrient source and nutrient retention agent likewise. Therefore we ordered composted biochar mixes (from commercial compost factory www.Sonnenerde.at) with biochar fractions rising stepwise from 2.5% to 50% from which we established a four replicate full random block design pot trial on a loamy and on a sandy soil using pure compost and null treatments as controls. The measured seed weight of applied *Avena sativa* L. plants showed very different results on sandy soil compared to the loamy soil. Whereas compost on loam showed a seed weight 2 times higher than on pure loam control and seed weights 1.6 times higher compared to compost with highest biochar amounts, on sand the pure compost was even slightly less productive than pure sand control (factor: 0.8) and the highest biochar applications yielded 13.8 times the seed harvest of the sand compost (10.4 times sand control). We will try to present possible explanations based on TOC, TN, pH, NO₃, NH₄ and electrical conductivity data.

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Stability and biological effects of pyrogenic and HTC-biochars in two soils

Chris Bamminger¹, Elisabeth Juschke², Bernd Marschner¹

¹Ruhr-University Bochum, Institute of Geography, Dept. Soil Science/Soil Ecology,
Universtaetsstr. 150, 44780 Bochum, Germany

²Max-Planck Institute of Biogeochemistry, Hans-Knoell-Str. 10, 07745 Jena, Germany

The feasibility of the currently discussed option of CO₂-sequestration through incorporation of biochars into soils strongly depends on the long-term stability of the biochars and on the lack of negative effects on soil properties. While much is already known about changes in chemical and physical soil properties after biochar incorporation, effects on microbial and enzyme activities have been rarely studied.

In this study the stability of maize derived biochar in soils was examined in a 59 day long incubation of soil samples with additions of different biochar qualities and amounts through respiration measurements. Selected treatments were additionally incubated with a substrate addition of glucose at day 50 of incubation. Microbial biomass was determined at day eight and at the end of the incubation. It is also planned to determine $\delta^{13}\text{C}$ contents before and after incubation for calculating balances and to measure enzyme activities.

The laboratory experiment was conducted with a forest soil (Ah) provided by the Max-Planck-Institute of Biogeochemistry (MPI) in Jena and an arable soil (Ap) sampled from a farmland of an organic farmer in Witten. In addition, forest soil samples with aged HTC-biochar from a past phytotox experiment with spring wheat were used. The fresh biochar additions were carried out with a biochar produced by slow pyrolysis of corn silage, one fabricated by hydrothermal carbonization of corn silage (HTC-biochar) and a commercial mixture of compost and pyrogenic biochar (Palaterra®). These materials were added to the forest soil and the arable soil at rates that increased the native SOC content by 20% and 40%. The first results show that the samples with added young HTC-biochar have a higher respiratory loss of carbon dioxide until reaching the basal respiration than the other treatments. Moreover the microbial biomass after the incubation of the samples with HTC-biochar is higher. In September, the C-balances and enzyme activities will also be available.

Changes of organic matter properties due to charring: impact of precursor material and production conditions

Cornelia Rumpel

CNRS, BIOEMCO, Campus AgroParisTech, Thiverval-Grignon, France

Biochar is known to consist of condensed aromatic carbon, which may be difficult to degrade by the soil microbial biomass and therefore most likely to contribute to long-term carbon sequestration in soil. Moreover, biochar may due to its inherent properties be able to ameliorate the soils physical and (micro-) biological properties. Biochar produced during natural fires as well as industrial procedures has been characterised by various physical and chemical methods. The aim of this keynote lecture is to give an overview about the biochar characteristics and to relate them to their production conditions.

Physical and chemical properties of biochar are highly dependent on their production conditions. For exemple, pyrolysis production conditions lead to alkaline biochars, whereas biochar produced through hydrothermal carbonization tend to be acidic. It was suggested that cation exchange capacity is pH dependent for biochars produced at lower temperatures. Biochars acidity, negative charge and compexation ability was found to decrease with production temperature. These findings suggest that biochars produced at lower temperatures will be better to increase soil CEC while application of high temperature biochars will raise soil pH. Higher production temperatures also increase the nanopore surface area of biochars.

Moreover, charring temperature as well as precursor material has an impact on the chemical composition and reactivity of biochars. Charring induces aromatisation of organic molecules, preferential loss of cellulose and preservation of lignin and lipids. Biochar produced in the laboratory, during natural fires and during industrial procedures from various sources was shown to represent a large chemical heterogeneity, consisting of thermally altered biomacromolecules with N, O and likely also S substitutions. Highly condensed soot and graphitic polyaromatic domains play a minor role in chars produced at temperatures below 700°C. Nitrogen containing molecules are transforme d into heterocyclic compounds during charring. It was shown that nitrogen contained in biochar is more susceptible to acid hydrolysis and chemical oxidation than carbon. Moreover, redistribution of biochar into physical fractions seems to control their reactivity. Biochar produced from herbaceous material seems to be more allocated to small particle size fractions presenting high reactivity, whereas biochar produced from wood tend to allocate in coarse fractions with comparable lower reactivity.

These findings suggest that the large variations in biochar properties due production conditions and precursor material must be considered when evaluating their effect on soil fertility and carbon sequestration.

Tue 27.09.2011 09:40

Experience from two years of biochar field experiment and implications for further research

Bruno Glaser, Hardy Schulz, Daniel Fischer, Herbert Miethke

Martin-Luther University Halle-Wittenberg, Institute of Agricultural and Nutritional Sciences, Soil Biogeochemistry, von-Seckendorff-Platz 3, 06120 Halle, Germany

Corresponding author: bruno.glaser@landw.uni-halle.de

Current mitigation efforts of global climate change such as Carbon Capture and Storage (CCS) and land use change (especially no tillage agriculture, desertification control and agriculture to pasture conversion) are ineffective in reducing anthropogenic CO₂ emissions. Most promising techniques do not only remove atmospheric CO₂ but also use it (Carbon Capture and Use, CCU). Such techniques comprise use of solid carbon (biochar) for soil improvement. The existence of terra preta proves that this is principally possible in the long term (for millennia). The question is whether we are able to successfully copy and apply the terra preta concept under temperate (European) conditions.

For this purpose, two biochar field experiments were installed in Germany. The first biochar field experiment in Germany was established on 29.04.2009 in NE Germany (Petershagen, 52° 29' 43,35" N, 14° 26' 22,66" E) in one of the most arid regions of Germany (mean annual precipitation 430 mm). Soil type is a sandy dystric Cambisol with low soil fertility and water storage capacity. The one hectare field comprised five different treatments in five-fold replication: Control, compost (33 Mg ha⁻¹) plus increasing biochar amounts (0, 5, 10 and 20 Mg ha⁻¹). Results indicate increasing plant growth, cation exchange capacity, soil organic matter contents and water storage capacity with increasing biochar amount.

Tue 27.09.2011 10:00

Fate of carbon and nutrients after hydrothermal carbonization of lignocellulosic biomass

Maria Koon, Jan Mumme, Mamadou Diakit 
Leibniz Institute for Agricultural Engineering - Potsdam
+49 0331 5699 922
mkoon@atb-potsdam.de

Biogas production from the anaerobic fermentation of agricultural wastes such as corn silage or wheat straw generate a byproduct, called digestate, with a high moisture content but also a valuable, nutrient content and carbon fraction. Another form of energy crop is poplar which is attractive due to its ability to grow in various climates and in short-rotation-forestry. However, moisture content and material mass present challenges in the final application of these products.

Therefore, the substrates poplar, wheat straw, and digestate derived from wheat straw are the focus of this study on the hydrothermal carbonization process as a treatment method. They are carbonized in a 1L reactor at four temperatures (190, 210, 230, 250 C), each with a six-hour reaction time, excluding heating and cooling phases. As the project goals for final material use focus on agricultural field applications, chemical analysis was conducted on the carbon, nitrogen, and phosphorus concentration of the solid phase. Select sample analysis of the fluid phase for total organic carbon (TOC), phosphorus (P), Total Kjeldahl Nitrogen (TKN), and chemical oxygen demand (COD) was conducted.

Results show a high, positive correlation between carbon, nitrogen, phosphorus concentrations in the solid phase and increasing temperature. Final carbon concentrations (dry, ash free) range from 54 -75%. However, while all materials show similar trends, actual nutrient recovery rates differ among input substrates. Char yields decrease with increasing reaction temperature, but are highest for digestate and lowest for poplar wood and ranging from 66-37% when considering all materials. The pH was approximately 4, but showed no significant correlation with reaction temperature. A mass balance experiment shows that 95% of the initial mass input is recovered in the final solid and liquid phases.

For these experiments it is concluded that the carbon concentration of the final char does not depend on the initial feedstock, but simply the initial carbon concentration of the material and reaction temperature.

ANAEROBIC TREATMENT OF HTC WASTE WATER

Benjamin Wirth^{1,2}, Jan Mumme¹

1 Leibniz Institute for Agricultural Engineering Potsdam Bornim, APECS Junior
Research Group

2 Technische Universität Berlin, Institute for Energy Engineering

In this study the biological basics for anaerobic digestion of HTC-liquor were investigated. Hydrothermal carbonization (HTC) produces a solid phase that is discussed as a potential soil amender and a carbon sink. Besides the solid phase, HTC also produces a liquid phase. It usually contains high amounts of soluble organic substances with a chemical oxygen demand (COD) of 20 to 40 g L⁻¹, a total organic carbon (TOC) content of 5 to 15 g L⁻¹, and an acidic pH-value of about 4. Exhibiting such properties makes a subsequent treatment process inevitable. Current state-of-the-art are aerobic water treatment technologies. However, these technologies are associated with a relatively high energy demand for aeration and gaseous losses of carbon and minerals. Therefore, the aim of this experimental study was to analyze the possibility of treating the liquid phase by anaerobic digestion. The focus was placed on the process performance and influence of potential inhibitors contained in the HTC liquid phase.

Anaerobic digestion yields methane, which can be burned, and can therefore be designed with a positive energy balance.

The HTC-liquor for this study was retrieved from an industrial-scale HTC plant processing corn silage. The liquor had a COD of 41 g L⁻¹ and a TOC content of 15 g L⁻¹. The initial pH-value was 3.9 and it contained 230 mg kg⁻¹ ammonia-nitrogen. The experimental set-up consisted of two glass reactors – a completely stirred tank reactor (CSTR) and an anaerobic filter (AF) – each with a hydraulic volume of three liters. Both reactors were operated continuously for 8 weeks at 37 °C. Feeding was conducted manually once per day with an organic load rate of 1 gCOD L⁻¹ d⁻¹. The digestate was removed once a week.

In-line-monitoring was performed with regard to pH, reactor temperature, and gas production rate. The gas was sampled in foil bags and analyzed regularly. Samples of the digestate were analyzed periodically for their COD, TOC and ammonia content as well as their buffer capacity. During operation the gas production rate in each reactor varied between 0.2 and 0.4 L L⁻¹ d⁻¹ with a volumetric methane content of 50 to 68 %. Based on the methane production a COD removal rate of 50 to 80 % was calculated. Relevant inhibition did not occur. With respect to the pH an initial drop was observed. This however was attributed to a lack of trace elements. After the addition of trace elements the pH stabilized at 6.9 and 7.2 in the CSTR and AF, respectively.

It can be concluded that HTC-liquor is a suitable material for anaerobic digestion allowing a waste treatment and integrated methane production that leads to a positive energy balance. Further studies will be important to reveal the specific nutrient requirements of HTC-liquor digestion.

KEYWORDS: hydrothermal carbonization, anaerobic digestion, waste water, biogas

Chemical nature of carbonaceous materials produced by hydrothermal carbonization (HTC) and low temperature conversion (LTC)

C. Koch¹, S. Stengl¹, J. Scheer¹, E.A. Stadlbauer¹, K. Albert², M. P.Bayer³, D. Steffens³

¹Department of Math, Natural Science and Computer Science, University of Applied Sciences Mittelhessen (THM), 35390 Giessen, Germany

²Institute of Organic Chemistry, University Tuebingen, Tuebingen, Germany

³Department of Agricultural Science, Nutritional Science and Environmental Management, Justus Liebig University Giessen, 35390 Giessen, Germany

Thermogravimetry (TG), HTC and LTC investigations were performed with hemicellulose, cellulose and lignin as well as oak saw dust and spent grains. At an atmospheric pressure TG shows a main decomposition of hemicellulose in the range of 280 °C and with cellulose at 340 °C, respectively. Lignin was found to be chemically stable up to 400 °C. Above 200 °C the pressure within the HTC reactor deviates to higher values compared to the corresponding vapor pressure of water as long as hemicellulosic material is present because CO₂ is built up.

This calls for special attention in technical reactors. Carbonaceous materials from HTC and LTC were characterized by elemental analysis and spectroscopic methods. LTC products show a H/C ratio ≤ 0.1 and an O/C ratio ≤ 0.2 . The corresponding values for HTC at 180 °C are

> 1.5 and > 0.4 ; at 250 °C the H/C ratio was > 0.6 and the O/C ratio was > 0.2 . In case of HTC functional groups remain basically intact as seen in FTIR, whereas LTC leads to their disappearance giving rise to an FTIR resembling that of charcoal. Solid state ¹³C NMR of LTC carbonaceous materials resulted to spectra undistinguishable of that from black coal. ¹³C NMR- spectra of HTC products at 250°C showed similar signals as the one of lignite. In conclusion: carbonaceous materials in HTC are preferred products in combustion processes, whereas LTC products fulfill chemical characteristics of biochar.

Tue 27.09.2011 11:50

Production of Biochar in industrial quantities

Dr. Bernd Schottdorf

There is evidence that the fast growing number of hungry people on the globe can not be treated with the use of herbicides, genetically modified plants and fertilizers. The consequence of this strategy is soil degradation and loss of carbon in the soil.

Increasing the carbon content of soil can work against these effects. There is an abundance of scientific results, that the application of Biochar can improve the quality of soil and the productivity of agriculture.

Possibilities to increase the carbon content of the soil are

--terra preta

--manure management with Biochar

--feeding animals with activated biochar

Quantitative aspects

On the globe agricultural land area of the size of Canada and US combined has undergone degradation and agricultural output is diminished. If we intend to repair these damages, the global need for biochar would be 1 billion tons per year. Biomass to produce this quantity is available. Most of this biomass exists in the form of waste material for which today there is no efficient use. Examples: 1 billion tons of sugar cane, 1 billion tons of cotton straw, 1 billion tons of residues of palm oil production, 500 million tons of tomato straw, plus hundreds of other residues which are not yet utilized.

New method to make biochar

Until recently there was no method available to convert biomass into biochar in industrial quantities as needed. The existing methods had low output or needed specially prepared and homogeneous material. The method which will be described here can solve this problem. It is scalable, it is now proven. The test reactors are running continuously and can be produced in big numbers. They can process any kind of dry (max 40% water) biomass. The principle of the method is similar to the oldest way of charcoal production. Contrary to the original method the pyrolysis zone is stationary on the bottom of the reaction container. The combustion and pyrolysis on the bottom produces a gas with Hydrogen, Methane, CO, CO₂ and hydrocarbons, which gets uplift due to the high temperature of the gas. The biomass is filled automatically into the reactor on the top and is moving downwards. After passing the pyrolysis zone the product is falling through a grid on the bottom and is automatically mixed with water. The gas moves upwards and is filtered while moving through the fresh biomass. The gas can be pumped into a burner.

For one ton of biochar 3 tons of wood chips or an equivalent of other biomass is needed. A daily production of 100 tons of biochar is equivalent to thermal output of 35 megawatt. With our method the output of gas under these conditions is 15 megawatt.

The capacity of our installations can reach from 2 tons to 300 tons of biochar per day.

Tue 27.09.2011 12:10

Hydrothermal Carbonation in a peripheral, agricultural closed installation engineering – from the work of Artec GmbH

Prof. Dr. Eckhard Jedicke & Michael Diestel, Artec GmbH, D-Bad Neustadt/Saale

The company Artec Biotechnologie GmbH is a joint enterprise of the agriculture (farmer's organisation 'Bayerischer Bauernverband', Maschinenring) and of an engineering company (Renergie Systeme GmbH & Co. KG). These companies work primary in the sector of renewable energies. The aim is to develop a technology and to distribute plants of hydrothermal carbonation (HTC) subsequently which can be used peripherally.

A HTC pilot plant 'mole I' has been developed which works actually continuously. Within almost 4,000 operating hours and by using different operating processes this plant provided bio-char made of various educts. The bio-char has been analyzed together with the Karlsruhe Institute of Technology (KIT, ICRT, PD. Dr. A. Kruse) and several other research institutes.

In the aftermath of 'mole I' with a capacity of 180 liter the Artec GmbH plans to realize one of the first research and pilot plant in the following scale: The tabular reactor 'mole II' shall have a capacity of 3,000 liter. The plant will be placed in a container to make it transportable and move it – if necessary – to other places.

Using this concept the Artec GmbH strives for the goal to develop a technology ready for the market to use the hydrothermal carbonation peripherally. Thus, it can be avoided that biomass is transported long distances resource-intensively and entailing high costs. Another advantage of the concept of a peripherally plant is the enablement of material's utilization containing a low dry substance up to 20%.

The Artec Biotechnologie also offers a reaction vessel with a capacity of 2 liter which can be used for research, development and teaching. This reaction vessel makes it possible – in easily modifiable test operations – to perform own HTC-test and thereby to enable an automatic computer-aided recording of important physical parameter of the processes.

Artec Biotechnologie GmbH believes that the HTC has a great capability – especially for the agriculture and forestry – for the utilization of biogenic recycling material and waste products with a multiple profit. This capability can make an important contribution to a regional material flow management. To realize the expected wide applicability it is necessary to run advanced and practical tests especially how the parameters of process can be controlled. With that a defined quality of the coal can be produced. Furthermore it is important to find out the attitude and efficiency of the soil. Therefore the Artec as a small and medium-sized enterprise (SME) would like to offer its collaboration to research institutes.

Tue 27.09.2011 12:30

Hydrothermal Carbonization on the industrial scale

The CS-HTC process

Arne Stark, Robert Maas, Volker Zwing

(CS carbonSolutions Deutschland GmbH)

The process of hydrothermal carbonization (HTC) provides alternative routes towards biomass derived carbon enriched materials. In contrast to the variety of thermal processes generating dry char coal either as main or by-product its energy balance is not inherently inhibited by latent heat components resulting from evaporating the biomasses water content either before or during the process. Instead the conversion of the biomass is taking place over the whole course of the HTC process within liquid water at temperatures around 200°C. While those temperatures are rather mild for a biomass to coal conversion, the condition of liquid water inevitably implies the process taking place under elevated pressures. Without the predicament of preferring dry biomass, the process becomes explicitly suited for treating wet biomass like manure, sewage sludge and many other carbon sources with a high water content generally only rather reluctantly considered for char production. The final product of treating biomass this way is a suspension of fine carbon particles in an organics enriched water phase, which – if desired - can easily be dewatered and dried with minimum effort. The resulting hydrochar turns out to be a valuable product in diverse applications, for example as CO₂ neutral fuel or even as a carbon sink in soil melioration.

In October 2010 CS carbonSolutions has commissioned a fully continuously working 1:1 prototype plant with an annual capacity of several thousand tons of wet biomass, transferring HTC technology to the next level. An overview over HTC technology, derived materials as well as first impressions and performance data on the CS-HTC process are given.

Yield Performance of Mustard and Barley in Biochar-amended Soils at Different Nitrogen Levels

Gerhard Soja^{1*}, Stefanie Kloss^{1,2}, Jannis Bücken^{1,2,3}, Franziska Rempt¹, Barbara Kitzler⁴, Maximilian Lauer⁵, Sophie Zechmeister-Boltenstern², Franz Zehetner², Andrea Watzinger¹ and Bernhard Wimmer¹

Addresses of the Authors

¹ AIT Austrian Institute of Technology GmbH, Konrad Lorenz-Str. 24, A-3430 Tulln

² Universität für Bodenkultur, Institut für Bodenforschung, Peter Jordan-Str. 82, A-1190 Wien

³ Brandenburgisch Technische Universität Cottbus, Konrad-Wachsmann-Allee, D-03046 Cottbus

⁴ Bundesamt für Wald, Seckendorff-Gudent-Weg 8, A-1130 Wien

⁵ Joanneum Research, Leonhardstr. 59, A-8010 Graz

* Contact person: Doz. Dr. Gerhard SOJA, gerhard.soja@ait.ac.at

Benefits of biochar amendments to agricultural soil depend on local conditions in the soil and on the specific agricultural management. An Austrian research project aims at the determination of the effects of different biochars, different applications rates, different soil characteristics and different nitrogen additions on plant growth and soil characteristics including greenhouse gas emissions and chemistry of seepage water. This study wants to contribute to the basis for decision-making on suspected advantages and disadvantages of a biochar deployment strategy in agriculture.

The results presented here are based on the pot experimental part of the project mentioned before. Using 15 l-pots designed as micro-lysimeters (n=5), a cropping pattern of mustard (*Sinapis alba*) followed by spring barley (*Hordeum vulgare*) was established. The applied nitrogen levels differed from 0-80 kg N.ha⁻¹ for mustard and 0-200 kg N.ha⁻¹ for barley. Three soils representative for Austrian intensive agricultural regions were amended with 0, 1 or 3 % biochar (w/w) and were either cropped or kept bare. Dry matter productivity of mustard was determined after 90 days at autumnal environmental conditions. Subsequently spring barley was grown to full maturity and analysed for above-ground yield parameters.

The biomass origin and processing parameters of the biochars affected yield at the same N-level and in the same soil significantly. Cereal straw biochar increased mustard dry matter by 250 % compared to wood-based biochar in the first crop but only by 25 % in the second crop. Differences induced by pyrolysis temperatures amounted up to 45 % in the first crop and were reduced to 30 % in the second (grapevine pruning pyrolyzed at 525 °C compared to a pyrolysis temperature of 400 °C). Inadequate nitrogen supply decreased yield more when soil was biochar-amended than without biochar: in the first crop, N-deficiency decreased yield by 74 % with biochar but only by 37 % without biochar. In barley, the second crop, these reductions were 62 % and 68 %, resp., indicating the initially high but later on decreasing competition for nitrogen.

Tue 27.08.2011 14:50

Biochar to Reduce Nitrogen Fertiliser Use and N₂O Emissions from On Farm Spring Barley Crops in Scotland

Jim Hammond*¹, Valentini Pappa², Ben Johnson^{1,2}, Simon Shackley¹

¹ UK Biochar research Centre, University of Edinburgh

² Scottish Agriculture College

Much of the previous biochar research focussing on soil gas emissions nitrogen use efficiency has focused on lab or greenhouse scale experiments. We conducted a field trial at an experimental farm in the south of Scotland to assess these and related issues.

Spring barley (*var Optic*) was planted in 10x11m strips, and biochar applied to 3x4m sub plots. Biochar was applied at two rates, 10t/ha and 30t/ha. The biochar used was charcoal fines derived from sycamore and made in traditional ring kilns. Five rates of nitrogen fertiliser were used, expressed as a percentage of the normal application in that area (120kgN/ha): 0%, 60%, 120%, 180%, 240%. Each plot was replicated in triplicate.

Measurements of soil NH₄⁺ and NO₃⁻ were taken on a weekly basis, and total soil N and C, and P and K assessed every three months. In situ gas boxes were used to assess soil emissions of N₂O, CH₄ and CO₂, several times per week. Crop development, yield, total C and N and chlorophyll in leaves were assessed.

Full results will be available by early August 2011. Outcomes will be placed into models used in the already published life cycle assessment [1] and economic evaluations [2] for UK biochar systems; showing the wider significance (or not) of the outcomes from this field trial.

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Tue 27.09.2011 15:10

Soil biochemistry and microbial activity in vineyards after addition of biochar to an acid soil

F. Fornasier¹, S. Baronti², L. Genesio², F. Vaccari² and F. Miglietta^{2,3}

¹Plant/Soil Interactions Research Centre (RPS), Council for Research and Experimentation in Agriculture (CRA), Via Trieste 23, 34170 Gorizia, Italy

²Institute of Biometeorology (IBIMET), National Research Council (CNR), Via Caproni 8, 50145 Firenze, Italy

³FoxLab (Forest and Wood) E. Mach Foundation - Iasma, Via E. Mach 1, 38010 S. Michele all'Adige (TN), Italy

Several studies have shown that biochar application to soil has beneficial effects on several parameters affecting soil fertility: pH, cation exchange capacity as well as physical properties. By contrast few studies investigated soil biological and biochemical properties after biochar application. It is important to know if and how the latter properties are affected, because higher microbiological activity implies better biogeochemical cycling of soil nutrients.

Biochar was applied at two rates (20 t ha⁻¹ at the first years and 20 t ha⁻¹ at the second years) in a vineyard (Tuscany, Italy). Soil had a pH (water) of 5.8 which increased by about one unit after biochar application. Soil samples, taken in September 2010, were assayed using a rapid method based on enzyme desorption and fluorescent substrates. Six enzymatic activities (arylsulfatase, beta-glucosidase, chitinase, esterase, leucine-aminopeptidase, alkaline phosphatase) were quantified in order to have a global evaluation of microbial activities. We detected a big increase (up to four times) of soil alkaline phosphatase (an enzyme produced exclusively by soil microorganisms), leucine-aminopeptidase and chitinase. The other enzymes were affected to a lower extent. These results showed that biochar, besides affecting positively chemical and physical properties, can increase to a great extent biochemical activity of soil, thus improving biogeochemical cycling of soil nutrients.

Tue 27.09.2011 15:30

Effect of bone during fixed bed pyrolysis of biomass

Mohammed Alhassan* and John Andresen

Energy and Sustainability Research Division

Department of Chemical and Environmental Engineering

University of Nottingham

University Park, NG7 2RD, U.K.

mohammed.alhassan@nottingham.ac.uk*; john.andresen@nottingham.ac.uk

Bio-char from biomass pyrolysis offers a geotechnical solution to the major global issues of climate change, soil degradation and food shortage. The focus of this study is to generate stable and nitrogen enriched bio-char and high quality oils produced from co-pyrolysis of biomass with bone at low temperatures. The char can act as fertiliser while at the same time optimises the chemical stability of the char to act as a Carbon Capture and Storage system (CCS). By improving the use of bio-char, it may be possible to also utilise the bio-oil for renewable generation. To achieve this, the present study has focused on the influence of bone (BM) addition from 0wt% to 25wt% during pyrolysis of Pistachio (PS), Wood (WD), and wheat straw (ST) in a fixed bed pyrolysis reactor at 300°C. The analysis of the char products shows that the addition of bone to the biomass increased their char yields from 0wt% to 10wt%, but higher addition of bone was found to reduced the overall char yield from the biomass. At 10wt% bone addition, the carbon, hydrogen, and nitrogen content, and the gross calorific value of the chars were increased by 7wt%, 29wt%, 163wt% and 19Mj/kg, for wheat straw, 62wt%, 46wt%, 135wt%, 110Mj/kg for wood and 7wt%, 76wt%, 42wt% and 33Mj/kg for pistachio. The oxygen content of the wheat straw, pistachio and wood mixed with 10wt% bone decreased by 28wt%, 21wt%, and 93wt%, respectively. The bio-oil yield increased for the bone addition up to 5wt% for all the samples. Gas production was minimized at 10wt%. Especially, the addition of bone to PS alters the concentration of important chemicals in the bio-oil generated while the kinetic study shows that bone addition alters the reaction rate for the conversion of the biomass to products. The major hydrocarbons components of the gas produced from pistachio were of C1 to C4 with CH₄ constituting up to 42wt% of the total evolved gas. Comparison between the elemental components of the chars produced showed similar pattern of change for all the biomass investigated. Hence it can be concluded that at 10wt% addition of bone to the biomass, bio-chars and oil yield could be optimised for soil amendment, energy production, while retaining carbon for sequestration.

Poster presentations

Growth of maize in acid soil amended with biochar, derived from gasifier reactor and gasifier stove, with or without organic fertilizer (biodigester effluent)

Huy Sokchea and T R Preston*

*Center for Livestock and Agriculture Development (CelAgrid)
PO box 2423, Phnom Penh , Cambodia
huysokchea@yahoo.com*

** Finca Ecológica, TOSOLY, UTA (Colombia)
AA #48, Socorro, Santander, Colombia*

A biotest with maize as indicator plant was used to measure the value as an amender of acid soil (pH 4.6) of biochar derived from gasification of rice husks. The experiment was designed as a 5*2*2 factorial in a completely randomized design (CRD) with 3 replicates. The factors were: source of biochar (from a downdraft gasifier reactor or an updraft gasifier stove). level of biochar (0, 2, 4, 6 or 8% added to the soil); and application of biodigester effluent (0 or 10 g N/m²).

The biochar from the stove contained more ash (less organic matter) and the pH was higher compared with biochar from the gasifier. The yield of the aerial fraction and of total biomass of maize was 30% higher when the soil (pH 4.6) was amended (at 6 to 8% of the soil) with biochar from an updraft gasifier stove than from a downdraft gasifier reactor. There was no effect of the level of biochar on maize growth in the absence of biodigester effluent but growth was increased 90% when biochar was incorporated at 6% of the soil and biodigester effluent was applied at 10g N/m² over 30 days. Soil pH was raised from 4.6 to 4.9 and water holding capacity by 50% when 6-8% biochar was added to the soil.

Key words: Biotest, CEC, downdraft, pH, updraft, WHC

“Terra Preta do Índio – Recovering the Past, Regaining the Future of Amazonian Dark Earths”

Paiva, P.M.*; Silva, F.W.R.; Rittl, T.F.; Azevedo, A.M.; Junqueira, A.B.; Torres, C.; Peña-Venegas, C.P.; Quintero-Vallejo, E.; Melo, I.; Sagrilo, E.; Peña-Claros, M.; Kuyper, T.W.

The Wageningen University interdisciplinary programme on Amazonian Dark Earths

Department of Soil Quality, Wageningen University, P.O. Box 47, 6700 AA Wageningen, the Netherlands

*corresponding author: paulo.paiva@wur.nl

“Terra Preta do Índio – Recovering the Past, Regaining the Future of Amazonian Dark Earths” is an international and interdisciplinary programme started in 2010 at Wageningen University. The general objective of the programme is to contribute to the improvement of the livelihoods of the smallholders living in the Amazon basin, via information on the sustainable use and conservation of Amazonian Dark Earths (ADE) and creation of similar soils. The central questions are: (1) Under what historical ecological conditions was ADE formed?; (2) What are the present uses and soil fertility dynamics of ADE in their agro-ecological and socio-economic context?; and (3) Which constraints and options can be recognised (and subsequently removed), both in the institutional domains and in the technical dimensions for (rapidly) creating similar soils in order to contribute to sustainable (soil, agro-ecosystem, forest, landscape) management, enhanced food security and livelihood? The current partnership includes about 40 researchers from 11 institutions in the Netherlands, Bolivia, Brazil and Colombia. This framework provides support for a post-doc, and 10 South American PhD students (listed authors) who will carry out their research in Bolivia, Brazil and Colombia. The PhD students are responsible for developing one of the following research topics: (1) Institutional and policy aspects of Terra Preta (Nova) production, use and management; (2) The economic origin of Terra Preta Soils in the Amazon Region; (3) Reconstructing the origin of Terra Preta – BC at interaction with calcium and phosphate and its leaching; (4) Soil biota in Terra Preta; (5) Local perceptions, practices and implications for livelihoods and agrobiodiversity in traditional use of ADE; (6) Drivers and implications of the diversity of traditional use and management of ADE; (7) Effect of ADE on the composition, structure and dynamics of an Amazon forest in Bolivia; (8) The creation of Terra Preta Nova; (9) Crop yield and soil quality as affected by biochar, green manure and mineral fertilizer; and (10) Assessing the impact of Terra Preta Nova on carbon budgets. The post-doc is responsible for both daily programme coordination and for synthesizing the results obtained in the abovementioned research topics.

Effect of Palaterra[™] and its components on maize biomass under water stress

Kurtz M¹, Bach M¹, Breuer L¹, Frede H-G¹

¹ Justus-Liebig-University Giessen, Institute for Landscape Ecology and Resources Management, Heinrich-Buff-Ring 26, 35392 Giessen

Biochar application to agricultural soils is currently discussed as a promising tool to improve soil fertility and water use efficiency. Beside biochars produced by pyrolysis and by hydrothermal carbonization, Palaterra® is a third class of biochar. Palaterra® is a mixture of charcoal, compost from various biomass and/or organic waste material, and specific microorganism cultivars, fermented together to form a "Terra Preta similar product". The effect of Palaterra® and its parent materials on maize yield under water stress was tested in a greenhouse pot experiment. Soil from an Ortic Luvisol Ap horizon (Loess Parabraunerde, site Rauschholzhausen) was added and mixed homogeneously with 10% and 20% parent material or Palaterra® to form 5 kg composite per pot. Additions included (1) charcoal, (2) charcoal + compost, (3) charcoal + compost + active microorganism, (4) "ready to use" Palaterra and (5) soil with no addition (control). A 'sufficient' vs. a 'reduced' watering strategy adjusted the mean soil water content to nearly 80% and 40% of the maximum water holding capacity of the soil-substrate composite, respectively. Maize plants (one per pot) were harvested 77 days after sowing and dry weight of biomass was measured. Biomass production under the reduced watering strategy was similar among all composites with slightly higher production at the 20% addition level as compared to the 10% addition level. The sufficient watering strategy more than doubled biomass production. Based on a paired t-test (8 replications per variant), significant yield differences were found between the wet and the dry variants, but not between the different composites and the control. Possible explanations for these unexpected results are (i) the good soil quality of the parent material that provided a sufficient nutrient status no matter whether nutrient rich substrates are added, and (ii) that maize as C4 plant which is adapted to dry environmental conditions is able to compensate for differences in nutrient statuses under both dryer and wetter conditions.

COCONUT PEEL FIBER'S BIOCHAR vs. EUCALYPTUS SAWDUST'S BIOCHAR

Edivaltrys Inayve P. de Rezende¹ (PG), Antonio S. Mangrich¹ (PQ), Marcelle Guth de F. Batista² (IC), Jéssica Marina Signorelli Toledo² (IC).

¹Chemistry Department / UFPR

²Chemistry Engineering Department/ UFPR

mangrich@ufpr.br

The consumption of coconut water from Bahia (*Cocos nucifera*), fresh or processed, is generating major environmental problem due to the final destination of the peels of these fruits, because these materials are highly resistant to the action of microorganisms. The same concerns also can be addressed for sawdust, wood industry waste. This study aimed to prepare the soil conditioner biochar (BC) from the low-temperature pyrolysis of eucalyptus sawdust and coconut peels fiber. The obtained product will have a stable and organized internal structure that is able to resist to the attack of microorganisms and also acts as negative carbon trap. In addition, this material has a functionalized periphery able to perform the functions of natural organic matter soil. The samples of biomass used in this study were ground in a willye-type knife mill in two particle sizes (0.5 mm and 1.0 mm), and then taken to a computer-controlled EDG FT-40 furnace inside a tubular glass reactor. A factorial planning was performed, with the control of the following parameters: rate of heating (V, 5 and 10 °C·min⁻¹), final temperature reached (T, 300 and 350 °C) and levels of stay (P, 30 and 60 min). The obtained solids (BC) and the precursor samples were analyzed by EPR spectroscopy, which provided the g-factor value, spin density and maximum microwave power supported for each sample. For all pyrolysed samples the obtained g-factor was lower than the value found for the precursor material, indicating the movement of organic free radicals (OFR) from near to the oxygen atoms to near to the carbon atoms to the sawdust biochar. For the biochar from coconut shell the OFR appeared intermediately between the atoms of carbon and oxygen. In all the pyrolysed samples the spin density was higher than the starting material, suggesting that more carbon condensed aromatic structures are present in the product (BC) than in the original biomass. The pyrolysed samples of coconut support greater power of saturation than the eucalyptus sawdust pyrolyzed product, indicating that in the coconut biochar spins relaxed in a shorter time in consequence of a more efficient dissipation of the stored energy in the excited state to return to the ground state. This phenomenon suggests carbon structures with conjugated double bonds in the prepared biochar.

NOVOTNY, E. H.; HAYES, M. H. B.; MADARI, B. E.; BONAGAMBA, T. J.; AZEVEDO, E. R. de; SOUZA, A. A. de; SONG, G.; NOGUEIRA, C. M.; MANGRICH, A. S. Lessons from the Terra Preta de Índios of the Amazon Region for the utilisation of charcoal for soil amendment. *J. Br. Chem. Soc.* **2009**, *20* (6), 1003-1010.
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Influence of charcoal residuals on enzyme activities in a *Tuber magnatum* truffle ground

Gilberto Bragato, Chiara Della Torre, Erica Tomat, [Flavio Fornasier](mailto:flavio.fornasier@entecra.it)

*Agriculture Research Council-Centre for Soil-Plant Relationships, Gorizia, Italy.
e-mail: flavio.fornasier@entecra.it*

Tuber magnatum is an ectomycorrhizal fungus that produces renowned and highly valued white truffles. In Central Italy best quality truffles are gathered in forested valley bottoms characterized by soft and moist soils. In our decades-long investigations, we recorded the presence of *T. magnatum* truffles in areas formerly involved in charcoal production and, since we observed a significant increase of enzyme activities in the presence of other truffle species and an increase in quality of white truffles from charcoal areas, we planned an investigation to assess if and how soil enzyme activities are influenced by charcoal residues in natural *T. magnatum* production areas. We focused our attention on a truffle ground where the following sequence of productive surfaces was present: terrace with charcoal residues in the first 12-15 cm, terrace riser with charcoal residues accumulated by mass movement, valley bottom. Five samples per area were collected at 0-10 cm. Five more samples were collected on the charcoal terrace at a depth of 20-30 cm and used as a reference term for soils that are both unproductive and without charcoal residues. In the laboratory, samples were analysed for soil organic matter, pH, CaCO₃ and 5 enzyme activities - alkaline phosphatase, arylsulfatase, b-glucosidase, chitinase and leucine esterase - determined in soil extracts with fluorogenic substrates. Results showed that: i) truffle producing soils showed enzyme activity values that on average were 3-5 times higher than those not involved in white truffle production; ii) soil strata with charcoal residues (truffle-producing) displayed enzyme activities even higher than those recorded in the "traditional" production area of the valley bottom.

Effects of biochar on leachate characteristics in a micro-lysimeter experiment with a sandy soil (planosol)

Jannis Bücken^{1,2,3}, Stefanie Kloss^{1,2}, Franziska Rempt¹, Bernhard Wimmer¹, Franz Zehetner², Barbara Kitzler⁴, Maximilian Lauer⁵, Sophie Zechmeister-Boltenstern², Andrea Watzinger¹ and Gerhard Soja^{1*}

Addresses of the Authors

¹ AIT Austrian Institute of Technology GmbH, Konrad Lorenz-Str. 24, A-3430 Tulln

² Universität für Bodenkultur, Institut für Bodenforschung, Peter Jordan-Str. 82, A-1190 Wien

³ Brandenburgisch Technische Universität Cottbus, Konrad-Wachsmann-Allee, D-03046 Cottbus

⁴ BFW, Seckendorff-Gudent-Weg 8, A-1130 Wien

⁵ Joanneum Research, Leonhardstr. 59, A-8010 Graz

* Contact person: Doz. Dr. Gerhard SOJA, gerhard.soja@ait.ac.at

The use of biochar as soil-amendment for agriculture and as a tool to sequester CO₂ from the atmosphere is of increasing interest. Depending on pyrolysis temperature, an intensive pore system develops and specific surface area of the biochars increase which may enhance nutrient adsorption. Hence, differences in nutrient dynamics between biochar-amended and unamended soils are expected. Biochar, in this case, acts as a linkage between the solid phase, the gaseous phase, the liquid phase, and the microbial community within the soil-water-plant system.

We studied six treatments (n=5) with two different biochars (wheat straw and woodchip-mixture). Five treatments were planted with mustard (*Sinapis alba* cv. Serval) and one was an unplanted control. The amended treatments were established with 3% w/w biochar produced from either wheat straw or woodchip-mixture. N-fertiliser application rates (0-80 kg N.ha⁻¹) varied for treatments both with and without biochar. The control (unplanted and unamended) received the standard fertilizer rate of 40 kg N.ha⁻¹. Water contents in the pots were continuously monitored. Leachates of each pot were collected in regular intervals of four weeks and subsequently analyzed for pH, EC, NH₄⁺, NO₃⁻, PO₄³⁻, and DOC concentrations. Anion concentrations were measured with ion-chromatography and the elemental composition of the leachates with ICP-MS.

The cation exchange capacity (CEC) of the soils slightly increased after the addition of biochar but still remained in a rather low range of 75.1±0.4 mmol_c kg⁻¹ (soil without biochar), 84.1±1.1 mmol_c kg⁻¹ (soil + 3% wheat straw biochar), and 92.2±0.8 mmol_c kg⁻¹ (soil + 3% woodchip-mixture biochar). In the short term, biochar application caused a significant reduction of nitrate load in the leachate by 40-80 % and a minor reduction of DOC-load by 20-30 % at a fertilizer rate of 40 kg N.ha⁻¹, but over time nutrients were increasingly released. This behavior has to be further investigated to supply reliable information for the use of biochar as a soil amendment. The most important factor seems to be the type of biochar feedstock. Various biomass types resulted in significantly different biochar characteristics and, thus, in a wide range of effects on water holding capacity, nutrient leaching, and crop yields.

Short Term Effects of Biochars from Hydrothermal and Pyrolytic Carbonisation on Important Functions in Soils: Worm Activity and Plant Growth

Dr. Carola Holweg¹, Andrea Kruse², Markus Mokry³

Nachhaltigkeits-Projekt Carbonsolum¹, Institut für Katalyseforschung und Technologie (IKFT)², KIT
Landwirtschaftliches Technologiezentrum Augustenberg (LTZ)³

The CarboSolum project follows questions upon biochars for purposes of soil melioration. Effects of biochars from hydrothermally (HTC) as well as pyrolysis-techniques shall be investigated based on their practical, economical and ecological implications. Their usefulness will be also considered in face of agricultural practices and the present techniques of biochar production in Central Europe. The substrates for carbonisation include digestate, draff or material from landscape management.

Apart from the cultivation of crops on open fields and under greenhouse conditions, we test biochars for possible biological implications. In this respect, we present first results obtained both from standardized biotests with earth worms and the in situ-response in the field. In standard tests using biochars at 1, 5 and 10 % it became obvious that wet products from HTC caused avoidance by worms even at low concentrations (1 %). However, pre-drying prior to the mixture with standard soil diminished this effect or, if derived from digestate, even turned it. Interestingly, worms were attracted by pyrolytic biochars at concentrations of 1 %, whereas concentrations of 5 % caused avoidance similar to wet HTC-biochar at 1 %. In the open field, the frequency of excreta on the soil surface was used as a measure for the activity of local earth worms. Three months after the application of wet biochar from HTC (draff) or biochar from pyrolysis (digestate), worm activity decreased by nearly 50 % on HTC-fields compared to pyrolysis or control fields. In a first small-pot analysis applying biochars at 7 %, we followed plant germination of *Brassica hirta*. Negative short term effects such as inhibition of germination were absent in case of biochars from pyrolysis. Interestingly, negative effects in case of HTC-biochars were less severe if they were mixed with soil several weeks before sowing. Comparing the results from biotests with the content of organic matter in the different biochars, one might suppose that interferences of HTC-biochars with biological functions are due to these compounds, maybe specifically relating to the volatile and unstable portion. Due to the high charge with organic matter in the liquid phase of hydrothermally produced biochars, pre-drying might be recommended prior to any further investigation and practice in a biological system, if not more appropriate means or pretreatments will be found.

Hydrothermal Carbonisation – New Ways to use Municipal Biomass

Falko Kietzmann

Hallesche Wasser und Satdtwirtschaft GmbH

The Hallesche Wasser und Stadtwirtschaft GmbH (Municipal Water Management and Waste Disposal Company of Halle) – subsidiary of the Stadtwerke Halle (Municipal Utilities of Halle) – and the Deutsches BiomasseForschungsZentrum Leipzig (German Biomass Research Centre) work together on a research project concerning climate-friendly and economically advantageous recycling of biogenic residual materials. In particular it deals with the hydrothermal carbonisation (HTC) as an innovative conversion process to transform municipal biomass into high-quality solid fuels. The joint project “Integrated utilisation plant an strategy for municipal biomass – HTC Hallesche Wasser und Stadtwirtschaft“ is part of the FRG’s “national climate protection initiative” subsidised by the BMU (Federal Environmental Ministry). The evaluation of the process’ potential of reducing greenhouse gasses is part of the project, which started in December 2010 and runs until May 2013.

Impact of hydro-char and pyro-char on soil respiration

Saadatullah Malghani^{*1,2}, Susan E. Trumbore¹, Gerd Gleixner¹

1) Max-Planck institute for Biogeochemistry Jena, Germany 2) Friedrich Schiller university Jena, Germany

*E-mail address: smalgh@bgc-jena.mpg.de

Two thermal degradation processes, in the presence and absence of water, are most common in practice to carbonize the biomass. Chars made from slow pyrolysis and hydro thermal carbonizations (HTC) are not only different in physical appearance but also vary in their chemical properties. We evaluated the impacts of corn chars, hydrothermally produced hydro-char (total carbon=44.5%) and slow pyrolysis pyro-char (total carbon=77.78%) on net soil respiration. Soil laboratory incubation was carried out at constant temperature (20°C) and moisture (70% WHC) with continuous flow of CO₂ free synthetic air. Respiration of two different forest soils, hainich forest soil (silty clay, total organic matter=3.42%, pH = 6.26) and ölkinitz forest soil (sandy loam, total organic carbon = 3.87%, pH = 4.7), amended with or without char was monitored continuously by LI-COR-6262. As expected, bio-chars addition resulted in higher CO₂ emissions than control. The variations in $\delta^{13}\text{C}$ signatures among treatments, hydro-char, pyro-char and control, showed that hydrochar contributed to soil respiration to a larger quantity. Char production technique play an important role in carbon sequestration.

Key words: dry and wet pyrolysis; $\delta^{13}\text{C}$; soil respiration; laboratory incubation

BIOCHAR FROM GASIFICATION PROCESS: PHYSICO-CHEMICAL PROPERTIES, POLYCYCLIC AROMATIC AND HEAVY HYDROCARBONS BURDEN, BIOASSAY.

Massimo Valagussa – MAC Minoprio Analisi e Certificazioni,

Viale Raimondi 54, I-22070 Vertemate con Minoprio (CO)

Alessandro Pozzi - AGT Advanced Gasification Technology, Via Trieste 2, I-22060 Arosio (CO)

Charcoal can be made from different feedstock under different conditions (process), obtaining products with a wide variety of characteristics, not always suitable for soil application, mainly due to toxic compounds content affected by biomass source and/or by technology process.

The present study reports about different biochar characterization obtained from an industrial thermo-chemical processes (gasification for energy production) and the effects on plants growing when this kind of char is applied on soil.

Charcoal, obtained from conifer wood, poplar wood, wheat straw, marc and olive residues, was analyzed with Standard European methods for its main physical and chemical properties (bulk density, pH, salinity, humidity, total carbon and nitrogen, ash) and for polycyclic aromatic (PAHs) and heavy hydrocarbons burden.

Finally chars have been tested with bioassay (using lettuce) and germination test (using cress) in order to investigate the growing effects at different rates.

The work reports in detail the results of these laboratory activities, confirming that different feedstock gives different charcoal with reference to the main physical and chemical properties.

The content of PAHs and heavy hydrocarbons was always low and, with regard to the first, well below the threshold of danger to human health.

Concerning bioassay and germination tests, the data generally showed positive effects on plant growing, but dynamics and consequently optimum rates were different changing the starting feedstock; marc showed instead negative effects on germination test.

Biochar addition to Sorghum-sudangrass: effect on productivity and nitrogen uptake after two years from the application

Zavalloni Costanza^{1*}, Pirelli Tiziana¹, Fornasier Flavio², Delle Vedove Gemini¹, Alberti Giorgio¹, Peressotti Alessandro¹

¹Department of Agricultural and Environmental Sciences, University of Udine, Italy

² C.R.A. Consiglio per la Ricerca e Sperimentazione in Agricoltura - Istituto Sperimentale per la Nutrizione delle Piante, Sezione di Gorizia, Gorizia, Italy

* Corresponding author: costanza.zavalloni@uniud.it

Biochar increases soil nutrients adsorption capacity due to the negative charges on its surface and this could explain the higher crop productivity observed mainly on tropical soils. To explore the potential of biochar additions to nutrient-rich agricultural soils in temperate regions a pot experiment was established with different soil soluble nitrogen (N) levels and biochar. Sorghum-sudangrass was sown on a silty-loam agricultural soil with pH of 7.8 and optimal plant available P and K. In order to create a range of soil soluble N content, the following four N levels were compared: a control (untreated soil), addition of crop residues (R, at a rate of 3 mg residues g⁻¹ soil), addition of N-fertilizer (F, at a rate of 0.0503 mg N g⁻¹ soil as ammonium sulphate), and the combination of both. These treatments were combined with two biochar levels (no biochar and biochar at a rate of 10 mg g⁻¹soil). The biochar was obtained from pyrolysis at 500°C of fruit trees pruning residues. In summary, the following eight treatments, replicated six times, were compared: untreated soil, biochar (B), crop residues only (R) and with biochar (RB), fertilizer only (F) and with biochar (FB) and the combination of both factors (FR and FRB). Treatments were evaluated in terms of germination, soil soluble N, plant growth rate and productivity, N uptake and soil microbial biomass. During the first growing season after the soil treatments application plant growth, above-ground N content and biomass of sorghum-sudangrass were positively affected only by the soil available N and biochar had no appreciable effects. Results from the second growing season will be presented.