Biochar in Agriculture
-Perspectives for Germany and Malaysia-

1st Public-Newsletter – July 2013

In this issue:

Editorial

Dear Reader,

Welcome to the first issue of the SAW-Biochar Public-Newsletter. With this newsletter we want to disseminate the approach of our project and give an insight into the progress to the general public. In the first issue we introduce the project, the project partners, the design of the field experiment in Germany, the used biochars as well as some organizational aspects like regular meetings and established communication platforms.

Carbon sequestration potentials in agriculture soils have been discussed in the past mostly as tillage and rotation induced processes, having little economic potential for farmers under the prevailing economic frame conditions.

For some years the application of biochar to agricultural fields has been suggested as an efficient method to simultaneously sequester carbon in the soil, decrease GHG reduction from the soil and improve soil fertility. But holistic scientific research to identify potentials of biochar in the tropics and temperate zones is limited and needs to be improved.

Biochars are produced by thermochemical conversion of biomass. They contain a high concentration of stable carbon, a high adsorption capacity as well as a high surface area improving the nutrient retention capacity, sequestrating carbon and lowering CO_2 and N_2O emissions after application to the soil. However, depending on the biomass material and the conversion technology used, the resulting biochar products differ substantially in their chemical, physical and biological properties.

Project Coordinator

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Project and Goals

The project "Biochar in Agriculture – Perspectives for Germany and Malaysia" started in February 2012 and will be running for 3 years. It is funded by the Leibniz-Gemeinschaft within the context of the Joint Initiative for Research and Innovation (SAW).

This project aims to build a biochar network to provide a better understanding of economic and environmental potentials of biochar by analyzing the impact of biochar on plants, soil, environment, and to the economy in Germany and Malaysia. A special focus is set on the GHG mitigation potential of biochar use and its economic costs.

This holistic challenge is analyzed in an interdisciplinary and international consortium led by the Leibniz-Institute for Agricultural Engineering Potsdam-Bornim e.V. (ATB) in cooperation with the Leibniz Centre for Agricultural Landscape Research (ZALF), the German Institute for Economic Research (DIW), Technische Universität Berlin (TU), Humboldt-Universität zu Berlin (HU) and the University of Putra Malaysia (UPM).

Analyses cover the impact of different biochars from pyrolysis and hydrothermal carbonization (HTC) technology, digestate and fertilizer add-ons on soil fertility in terms of yield potential, water holding capacity, nutrient dynamics and soil biology in laboratory and field experiments (Germany and Malaysia). A three-factorial field experiment near Potsdam builds the center of research in Germany, supplemented by several pot experiments. Some biochars used in the experiment are based on current research of the APECS-Project (Anaerobic Pathways to Renewable Energies and Carbon Sinks).

The potential environmental impacts are estimated together with cost effects at the farm level and welfare effects at national and international levels to provide most efficient concepts for biochar use in the tropics and the temperate zones.

Coordination and dissemination

Andreas Meyer-Aurich, Anja Sänger (Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

ATB coordinates data flows between the partners and initiates joint publications of the partners involved. Regular meetings are organized to assure the project goals. These include annual meetings with all project partners, PhD student meetings (every two month) and a symposium with other working groups as well which is scheduled for 2014/2015

Previous meetings:

May 2012: Kick-off-meeting
July 2012: 1st PhD Student Meeting
February 2013: 2nd PhD Student Meeting
March 2013: 1st Annual Meeting

Future meetings:

July 2013: 3rd PhD Student Meeting at the German Institute for Economic Research (DIW) in Berlin

To ensure an overall intern communication and exchange we set up a sharepoint as well as an intern newsletter. The new website (www.atb-potsdam.de/biochar.htm), our flyer and this public newsletter priority will inform interested stakeholders about the project progress, project partners and publications.

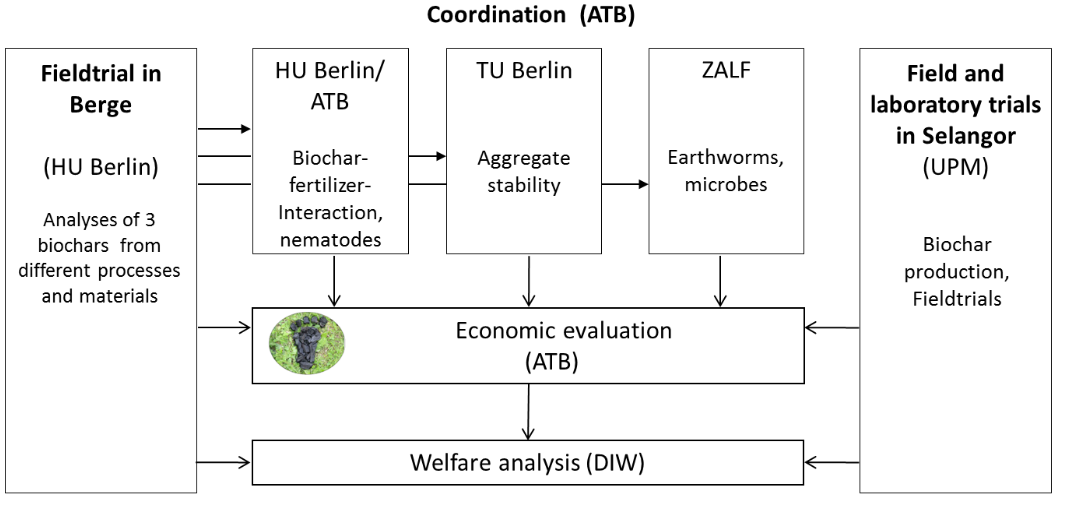


Figure 1: Structure of the biochar research network

Field experiment at the research station Berge

Andreas Muskolus (Institute of Agricultural and Urban Ecological Projects)

The field experiment in Berge is aimed to provide empirical data of a wide range, collected under real-life conditions. A three factorial experimental design is providing the basis for investigating effects of biochar application on soil physical and chemical properties, soil ecology, crop growth, and gaseous emissions. Experimental factors include the type of biochar (origin of material and processing), digestate incorporation before application and the fertilization intensity (Table 1). Research objectives are the determination of the (I) impact of different non-treated and treated (digestate incorporation) biochar, (II) interaction of N-fertilization and biochar and (III) interaction of N-fertilization, digestate incorporation and biochar.

Site characteristics:

Location:	Brandenburg
Elevation:	45 m AMSL
Mean annual temp.:	8.7 °C
Mean annual precip.:	503 mm
Soil type:	Loamy sand Sl3D
Soil evaluation points:	35
pH-value:	5.5
C_t:	0.6 %
N_t:	0.06 %
P_{dl}:	8.9 mg per 100 g soil
K_{dl}:	11.8 mg per 100 g soil

In Summer 2012 we chose the most suitable area for the field experiment having regard to topography and electrical conductivity (EM38 scanning). The trial area was divided in 4 blocks (replications) consisting of 16 plots (treatments), respectively. Treatments were randomized in each block. In September 2012 biochar and HTC-char was applied to the plots following by tillage and sowing of winter wheat.

Table 1: Experimental factors of the field experiment

Factor A:	Chars
a1	Control
a2	Pyro
a3	HTC
a4	Pyreg
Factor B:	**Incorporation of digestate**
b1	No incorporation
b2	Incorporation
Factor C	**N-fertilization**
c1	0%
c2	50%
c3	100%
c4	130%

Figure 2: Timetable

Figure 3: Research area in Berge a) biochar application (09/2012) b) directly after char application c) winter wheat (05/2013)

Char materials

Jan Mumme, Mamadou Diakité (Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

1. HTC char from maize silage (HTC-char)

For HTC char ensiled whole crop maize was used as feedstock harvested in autumn 2011. The maize silage was processed by batch-wise HTC at 210°C and 23 bar for 8h. Afterwards the resulting HTC slurry was separated by means of a chamber filter press. The solid phase (the HTC char) was filled in flexible intermediate bulk container (FIBCs) and transported to ATB Potsdam for further treatment.

2. Pyrolysis char from maize silage (Pyro-char)

For this pyrolysis char ensiled whole crop maize was used as feedstock harvested in autumn 2011. The maize silage was processed by continuous pyrolysis at 600°C for 30 min. Afterwards the hot char was quenched by means of water sprinkling, filled in FIBCs and transported to Potsdam for further treatment.

3. Pyrolysis char from wood (Pyreg-char)

For this pyrolysis char screenings from wood chip production were processed by continuous pyrolysis at 850°C for 30 min. Afterwards the hot char was quenched with water, filled in Big Bags and transported to Potsdam for further treatment.

4. Digestate from maize silage (Digestate)

As feedstock for the biogas process (activation) and soil application ensiled whole crop maize was used harvested in autumn 2011. The maize silage was digested by a batch-wise solid-state process at mesophilic temperatures (approx. 35°C). Afterwards the resulting digestate was transported by truck as bulk material to ATB Potsdam.

Digestate incorporation to chars:

The incorporation of digestate to the Pyro- and HTC-chars was realized by methanogenic fermentation. In order to obtain suitable conditions for methanogenic fermentation each char was mixed with inoculum (the digestate) and water. For this, a carbon-based inoculum to substrate ratio of 1:2 was aspired. By means of water addition each mixture was intended to reach a dry matter (DM) content of 25-30%. Afterwards the mixtures were filled in FIBCs. In order to establish anaerobic conditions the FIBCs were wrapped in silage plastic. To ensure mesophilic conditions all FIBCs were placed on a water-heated concrete plate and covered with an additional plastic sheet. After 29 days the fermentation was stopped and the FIBCs were removed from the heated concrete plate and transported to the field testing site in Berge.

Pyreg-char was not fermented but mixed with digestate before application.

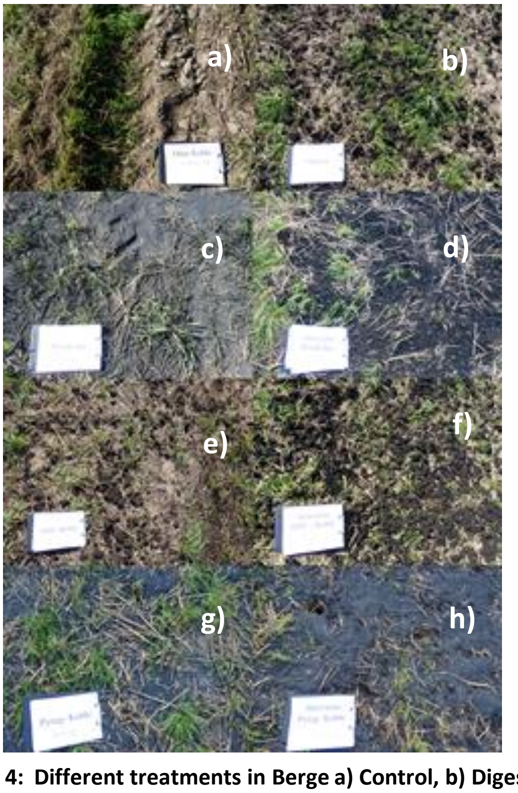


Figure 4: Different treatments in Berge a) Control, b) Digestate, c) Pyro-char, d) Pyro-char + digestate, e) HTC-char, f) HTC + digestate, g) Pyreg-char, h) Pyreg-char + digestate

Table 2: Material characteristics

Material	DM [%FM]	Ash [%DM]	C [%DM]	N [%DM]	pH	Electrical conductivity
HTC-Char	47.39	3.19	64.55	2.09	5.25	0.30
Pyro-Char	92.85	18.42	75.16	1.65	9.89	3.08
Pyreg-Char	55.09	16.64	77.62	0.72	9.35	1.71
Digestate	23.60	20.89	40.06	3.66	8.26	2.38
HTC-Char + Digestate	32.80	25.24	54.86	2.88	7.03	1.24
Pyro-Char + Digestate	30.03	27.57	55.77	2.58	9.52	2.25

Effects of biochar on the Soil-Plant-System

Frank Ellmer, Heiko Vogel, Katharina Reibe (Humboldt-Universität zu Berlin)

To quantify the influence of Pyreg-char and the addition of digestate and/or nitrogen fertilizer on the yield of different crops we conducted two 3-factorial pot experiments. The three factors biochar, digestate and nitrogen fertilizer were included with two levels ("with" and "without") and 6 replications. In the first pot experiment three crops were planted in sequence: white mustard – oat – corn. In the second experiment the sequence was: oat – white mustard – corn. While significant differences between the treatments were observed in both experiments, treatments with Pyreg-char and without any addition showed no yield increase. A further pot experiment has been set up to compare the effect of different types of biochars (Pyreg, Pyro, HTC, treated HTC, treated Pyro and Pyreg mixed with digestate) on the yield and the quality of wheat.

To investigate the effects of different biochars on root growth of wheat 12 rhizoboxes with the variants "without biochar", "Pyreg", "Pyro" and "HTC" were set up on 3 June 2013. To analyse the effects of different biochar types (Pyro, Pyreg, HTC, treated HTC) on the collembolan Protaphorura fimata we exposed 150 individuals for 5 weeks to 2.5 kg defaunated soil mixed with the different biochars. The experiment is currently being repeated. Finally, we are conducting measurements in a field trial to quantify the response of winter wheat development to biochar.

Figure 5: Mitscherlich pot experiment

Gas flux measurements at the research station Berge

Jürgen Kern, Christiane Dicke, Giacomo Lanza (Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

The aims of the work package are to assess the stability of the biochars and to test if biochar can reduce the nitrous oxide (N_2O) emissions after application in the field.
Every week, gas flux measurements with closed chambers have been performed. Gas samples are taken and the concentrations of carbon dioxide (CO_2), methane (CH_4) and N_2O are determined, together with the isotopic signature of carbon in the carbon dioxide ($\delta^{13}CO_2$). Once a month, soil samples for the determination of the available, mineral nitrogen (N) are taken. The amount of CO_2, N_2O and CH_4 emissions depend on the season. After the spring fertilization, a short-time increase in N_2O emissions was observed. So far, no differences between the treatments could be detected. The isotopic signature of the emitted gas shows values very close to the ones of C_3 organic matter, suggesting that the CO_2 emission from biochar is negligible in comparison to the one from other soil components in the present conditions.

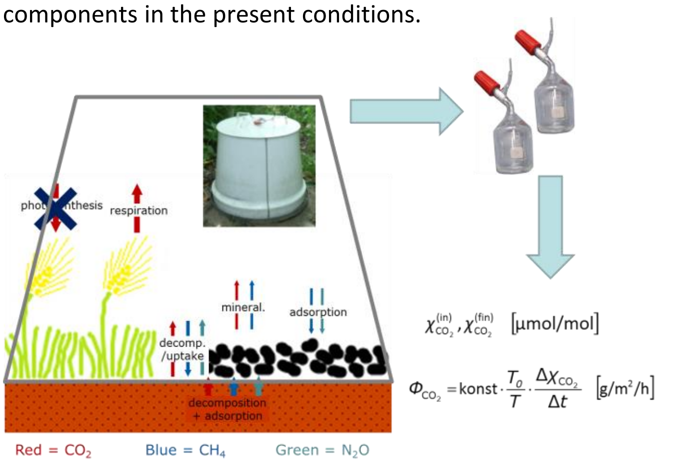


Figure 6: Gas measurement principle

Effects of biochar on the dynamics of soil aggregation

Martin Kaupenjohann, Frederick Büks (Technische Universität Berlin

Currently our group is researching the dynamics of microaggregate formation depending on biofilm formation and biochar application in soils with low sorption capacity. On the basis of a soil column experiment we hope to identify the influence of both parameters on the size, amount, geometry and stability of aggregates. The aggregate stability is determined by means of ultrasonication with and without foregoing selective biofilm detachment. An adequate method for gentle biofilm detachment is currently quested by experimental setups with enzymes, nematodes, amoebas and predatory bacteria.
The second part of the project will be used to determine and characterize the binding forces of variable and permanent surface charges on dilative and non-dilative minerals.
The developed methods will be applied to the field experiment in Berge (Germany) and tested for representativeness for sandy soils with low sorption capacity. Our aim is to get information about biological and chemical effects of biochar application and its consequences for aggregate stability in sandy soils.

Impact of biochar on soil biota and microbial activities

Peter Lentzsch, Monika Joschko, Stephan Wirth, Philip Rebensburg (The Leibniz Centre for Agricultural Landscape Research)

The project includes the analysis of the impact of different biochars and digestates from biofuel production on a) the soil microbial community structure with parameters like microbial biomass, soil respiration, decomposition rates and 16S and 18S rDNA fingerprinting and b) earthworm population dynamics (abundance and species composition). For pre-treatment site characterization of the experimental field in Berge, Germany, soil samples of 8 selected plots were taken before the soil amendments were applied to the plots. Earthworm monitoring was carried out (hand-sorting from 50 x 50cm soil patches) in September 2012. Earthworm abundance ranged from 20-75 (mean: 47) worms/m², mean worm biomass/m² was 28g. Microbial biomass ranged from 93-410 µg/g soil. DNA-fingerprint analysis of soil microbial population structure reveals a highly heterogeneous microbial initial state of the test site, every plot is specifically colonized and furthermore two are extremely distinct from the rest. From the given data it can be concluded that the site is heterogeneous.
Based on these basic results, further characterization regarding treatment impact will take place under consideration of plot specific conditions.

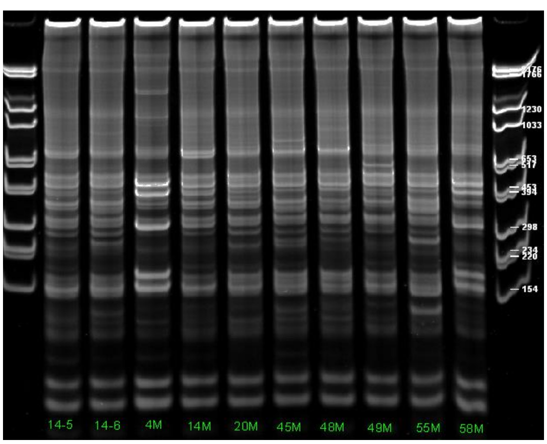


Figure 7: 18S-fingerprint (fungal population)

Life cycle assessment and farm economic evaluation of biochar

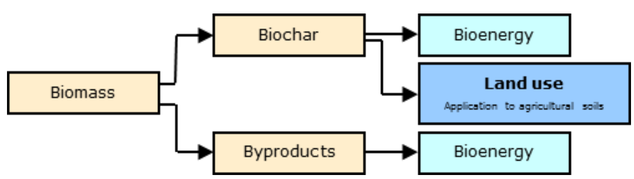
Andreas Meyer-Aurich, Anja Sänger (Leibniz-Institut for Agricultural Engineering Potsdam-Bornim.)

Aim of this life cycle assessment is to compare the environmental impacts of different biochars, such as resource consumption, impacts on soil functions and emissions from the raw material acquisition to several years after field application. Beside a comparative evaluation of different types of charred biomass with and without digestate incorporation, a control will be considered additionally as well as the interaction between biochar use and mineral N fertilization. The farm's economic budgeting will allocate additional revenues due to higher yields and cost estimations of biochar production and application to the production systems. Since we expect fertilizer/biochar interactions, we will integrate the potential fertilizer saving effect in the economic analysis.

Welfare analysis

Claudia Kemfert, Isabel Teichmann (German Institute for Economic Research)

This work analyzes the economics of greenhouse gas mitigation with biochar in Germany and Malaysia for the case when biochar is incorporated in agricultural soils and the liquid and gaseous by-products are used for energy production. For both countries, we calculate marginal abatement cost curves for feedstock-specific biochar options to study the contribution of biochar for greenhouse-gas mitigation and the associated abatement costs. Regarding both the mitigation potential and its costs, we have a special focus on the agricultural co-benefits of biochar deployment in soils. The analysis for Germany will be completed soon. Afterwards, we start with the research on biochar in Malaysia.



Source: I. Teichmann based on Lehmann (2007)

Figure 8: Major material flows involving biochar

Impact of biochar application on soil nematodes

Stefanie Menzel (Humboldt-Universität zu Berlin)

This work aims to analyze the effect of differently treated biochars on the soil nematode *Caenorhabditis elegans*. Thereby, conclusions on bioavailable pollutants and it's effect on the reproduction, growth, stress tolerence and the age as well as on gene expression and the maturity index of the nematodes will be drawn. Predominantly, tests are carried out in a liquid medium in 12-well plates in accordance with ISO 10872. Later, the biochars are going to mixed with standard soil. Additional, the composition of nematodes in samples from the field experiment in Berge will be determined.

Field experiment with biochar in Selangor, Malaysia

Azni Idris, Rosenani Abu Bakar, Tinia Idaty Mohd. Ghazi, Mohd Amran Mohd Salleh, Sherwin Lee Chan Kit (University of Putra Malaysia)

There is limited information concerning the mechanisms of empty fruit bunch (EFB) biochar to retain the nitrogen (N) fertilizer or reduce N leaching, especially the nitrate (NO_3^-) based fertilizer, since it is negatively charged. Further, there is great lack of information of its effect on the N_2O emission on the upland soil. It is uncertain that the biochar may reduce the N_2O flux, whether or not through the sorption of the greenhouse gases (GHG) or just decelerate the GHG production process. Hence, this study is currently carried out to investigate the effects of EFB biochar on fertilizer-N recovery and N_2O emission by using maize as a test crop of an upland cropping system. The study is divided into three sections (I) lab incubation study on N sorption (NH_4^+ and NO_3^-), (II) pot experiment on N-fertilizer leaching and maize crop uptake, and (III) field trial to study the effects of EFB biochar on crop performance, GHG emission, soil carbon dynamics, and soil properties. Initially, characterization of the EFB biochar was carried out, with the reference of the International Biochar Initiative (IBI) guidelines (Table 3).

Currently, the lab incubation (Study I) is carried out to elucidate the mechanisms of how EFB biochar would prevent the N_2O emissions, whether EFB biochar is sorbing the ammonium (NH_4^+) during nitrification or the nitrate (NO_3^-) during denitrification. Hence, the objective of the study is to investigate the effects of EFB biochar on N_2O emission using different application rates of EFB biochar (0, 5, 10, & 20 t/ha, with three replications, and eight sub-replicates for destructive sampling) in clayey soil. Two types of fertilizer are used; ammonium sulphate ($[NH_4]_2SO_4$) and potassium nitrate (KNO_3). First, about 100 g of oven-dried clayey soil will be incubated for seven days, wetted with deionized water (is maintained at 60% water-filled pore space or WFPS). Then, $(NH_4)_2SO_4$ fertilizer (150 kg N /ha rate) is added into the jar and incubated for eight weeks or 56 days to simulate silking stage of maize in the pot experiment. Another jar of soil for second treatment, KNO_3 fertilizer, is to be done simultaneously. A destructive sampling is carried out weekly to analyse the NH_4^+ and NO_3^- concentration in the soil. This is done by having the soil samples in the air-tight closed jars to collect the N_2O gas and its cumulative concentration is obtained at every end of the week.

Table 3: EFB biochar characteristics

Characteristics	Results		
Moisture (ASTM D 1762-84, 1990)	12.76 %		
Volatile Matter (ASTM D 1762-84, 1990)	66.75 %		
Total Ash (ASTM D 1762-84, 1990)	16.41 %		
pH (H_2O) (Rajkovich et al, 2011)	8.93		
Electrical Conductivity (Rajkovich et al, 2011)	2.95 mS/m		
Particle Size Distribution	mm	g	%
(ASTM D 1762-84, 1990)	>8.00	8.60	1.7
	>4.75	4.38	0.9
	>2.80	5.68	1.1
	>2.00	8.80	1.8
	>1.00	31.72	6.3
	>0.50	102.16	20.4
	>0.30	140.83	28.2
	<0.30	194.39	38.9
Total C (Air-dried biochar; by LECO Carbon Analyzer)	202.6 mg/g		
Total N (Kjeldahl Method)	9.6 mg/g		
*P	263.0 mg/kg		
*K	7202.6 mg/kg		
*Ca	6038.8 mg/kg		
*Mg	456.0 mg/kg		
*Fe	648.4 mg/kg		
*Zn	52.4 mg/kg		
*Cu	18.9 mg/kg		
*Mn	63.9 mg/kg		
C:N	21.1		

* P, K, Ca, Mg, Fe, Zn, Cu, and Mn were analysed by using dry ashing method.

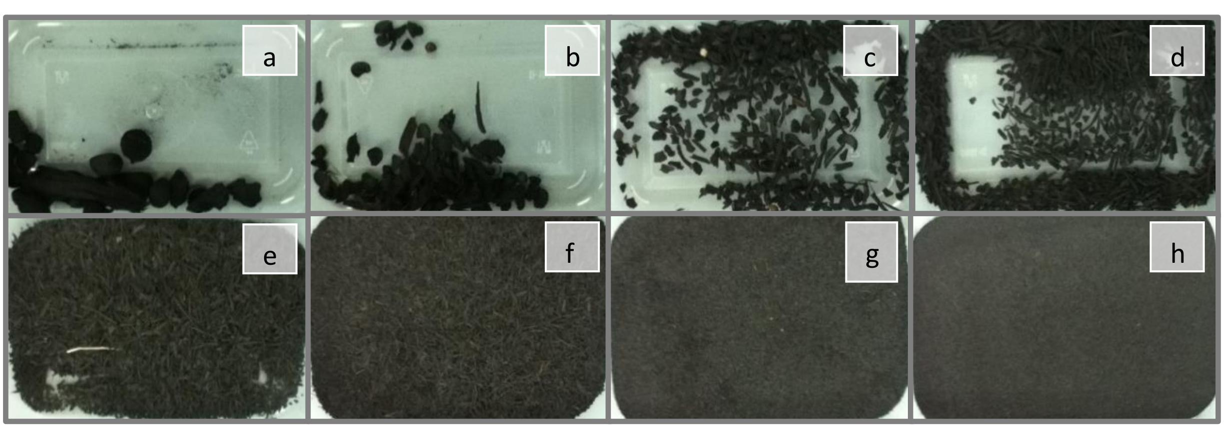


Figure 9: Sieved EFB biochar according to different particle sizes:
a) > 8.00 mm, b) > 4.75 mm, c) > 2.80 mm, d) > 2.00 mm, e) > 1.00 mm, f) > 0.5 mm, g) > 0.30 mm, and h) < 0.30 mm.

Biochar network

Coordination and dissemination; Life cycle assessment and farm economic evaluation of biochar
Dr. Andreas Meyer-Aurich
Dr. Anja Sänger
(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Research station Berge
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Welfare analysis
Prof. Dr. Claudia Kemfert,
Isabel Teichmann – PhD Student
(German Institute for Economic Research)

Char materials (Pyro- and HTC char)
Dr. Jan Mumme
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(Leibniz-Institut for Agricultural Engineering Potsdam-Bornim)

Impact of biochar application on soil nematodes
Stefanie Menzel – PhD Student
(Humboldt-Universität zu Berlin)

Contributions

Participation in conferences:
Summerschool „Bio:char crossroads“ 9.-12.9. (Teilnehmer u.a. Christiane Dicke, Giacomo Lanza, Sherwin Lee)

Publications:
Soni S Harsono, Philipp Grundmann, Andreas Meyer-Aurich, Anja Hansen, Lek H Lau, Mohammad Amran M Salleh, Azni Idris, Tinia I Mohd Ghazi 2013. Energy balances, greenhouse gas emissions and economics of biochar production from palm oil empty fruit bunches. Resources, Conservation & Recycling. Accepted.

Presentation:
Project presentation to the senate of the BMELV (28.11.2012)

Teichmann Isabel 2013. Marginal Abatement Cost Curves for Biochar Options in Germany. Kiel Institute Summer School on Economic Policy - Challenges of Climate Engineering - 9-15 June 2013, Kiel Institute for the World Economy, Germany

Media reports:
- http://www.biochar-international.org/profile/ATB_Germany
- http://www.dw.de/biokohle-f%C3%BCr-malaysia/a-16100553-1

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