Development of Synthetic Terra Preta (STP): Characterisation and Initial Research Findings

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Introduction

Amazon Dark Earths (Terra Preta) are a unique soil that have a high soil organic carbon content and are rich in P, Mg, Zn, and Mn. They have a higher water holding capacity than the surrounding soil, higher pH, higher cation exchange capacity (CEC), and thus sustain higher fertility compared to the intensely weathered acidic adjacent soils. Examination of these soils has revealed that they are composed of micro-aggregates that have been formed by the interaction of organic matter, clay particles, residual fired clay, sand, micro-organisms and decomposed/cooked food. There are some controversies as to how these particles are formed. A development program has been initiated at the University of NSW, in collaboration with Cornell University, the New South Wales Dept. of Primary Industries and Western Australia Dept. of Agriculture to develop synthetic high mineral organic micro-aggregates, otherwise known as synthetic Terra Preta (STP) that could be as effective in promoting plant growth and in sequestering carbon as Terra Preta. The principal components of STP are biomass, clay, crushed brick and waste products with high calcium content. It can be manufactured at low temperatures (220-240°C) in an oxidizing environment. Another aim of this project is to assist in the understanding of the formation of the Amazonian Dark Earth micro-agglomerates. This poster outlines the work undertaken to date in terms of its production and characterisation. It will be shown that the particles produced have some similar characteristics and microstructure to Terra Preta

Production of STP

STP was produced using a 50/50 mixture of sawdust and chicken manure, a 50/50 mixture of bentonite and kaolinite clay, crushed brick and waste product from a cement kiln that had a high calcium content. Samples were manufactured at 220°C and 240°C in an oxidizing environment. Samples were also prepared at 1.5 hours, 3 hours and 5 hours at 240°C to determine the effect of time on both composition and microstructure.

Characterisation of STP

Samples of both 220°C and 240°C, which were reacted for 8 hours, were sent to the Western Australian (W.A.) Department of Agriculture (in field tube trials growing wheat at 10 tonnes/hectare), NSW Department of Primary Industries (greenhouse pot trials 240°C sample at 10t/h,50t/h and 100t/h) and Cornell University (greenhouse pot trials).

STP samples which were reacted for 8 hours were analysed for carbon, hydrogen and oxygen content, ash constituent analysis and the agronomic properties (Table 1). All of the samples were initially examined using scanning electron microscopy (SEM). Approximate analysis of the different chemical phases on the surface were carried out using energy dispersive spectroscopy (EDS). Samples were then mounted in resin and polished to undergo further analysis using the SEM to assist in understanding the internal microstructure of the STP as a function of processing conditions.

The samples produced at 8 hours at 220°C and 8 hours at 240°C were sectioned using a focused ion beam instrument and examined using a Philips CM200 transmission electron microscope (TEM) to investigate STP structure at higher resolution. The bulk samples were analyzed using XRD to determine constituent crystal structure. The concentration of radicals in the samples were analysed using electron spin resonance (ESR). The surface chemical composition and functional groups were analysed using x-ray photoelectron spectroscopy (XPS), Raman spectroscopy and FTIR.

Results

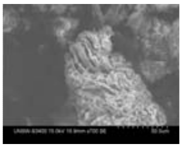
Sample	Units	STP 220°C	STP 240°C
EC	dS/m	1.7	2.3
pH ($CaCl_2$)	pH units	6.5	7.4
Total nitrogen	%	2.1	1.9
Total carbon	%	22	17
Bray phosphorus	mg/kg	340	500
Colwell phosphorus	mg/kg	700	1000
% $CaCO_3$ equivalent	%	4.1	7.6
KCl extractable ammonium	mg/kg	17	32
KCl extractable nitrate	mg/kg	2.3	1.9
CEC	cmol(+) /kg	40	37

Table 1 : Summary of the composition and the agronomic properties

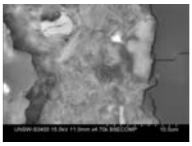
It can be seen from Table 1 that the total carbon and nitrogen content for the lower temperature (220°C) STP is slightly higher than that for the STP produced at 240°C. This is indicative of the small amount of volatiles that are liberated during the oxidation of the surfaces at 240°C. The pH, electrical conductivity, available phosphorous and ammonium content are higher for the STP produced at 240°C. This indicates that there is more mineral matter at the surface of the higher temperature STP that has not reacted with either the organic or clay complexes.

SEM and TEM results

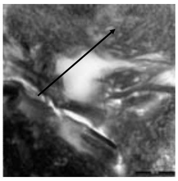
240°C

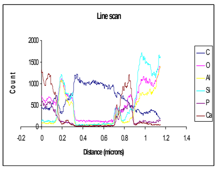


Wood particle covered with clay (SEM)



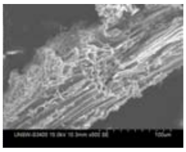
Cross-section of a wood/clay complex (SEM)



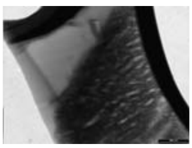


A elemental analysis line scan performed along the arrow shown on the adacent TEM image. Total length of the line scan is 1.15µm.

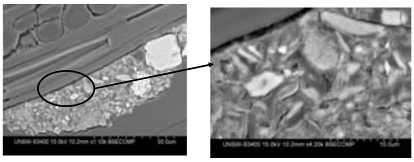
220°C



Less coverage of clay compared to 240°C



TEM image showing a clear boundary between carbon and clay

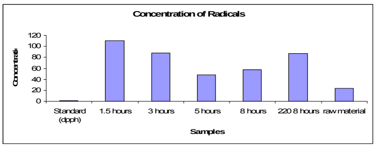


SEM image showing a clear boundary between carbon and clay-based regions

SEM and TEM discussion

It can be seen from the images that in the 240°C samples the wood particle is covered with more clay compared to the equivalent particle in the 220°C sample. There is also a clear boundary between the clay and wood particle in the 220°C sample. The TEM image of the 240°C sample shows a complex mixture of compounds, including aluminium silicates and calcium phosphate, which can be seen from the line scan.

EPR results



The concentration of radicals in the raw material is the lowest, which is expected. A trend can be observed when the concentration of radicals dropped as the time spent in the oven increase. However, the concentration of the 8 hour sample was found to be slightly higher compared to the 5 hour sample. The 220°C sample was found to have a higher radical concentration compared to the 240°C sample. This supports the result that radical plays an important part in plant growth as shown in the pot trials result below.

Pot trial results

Wheat Trials Geraldton: All Application rates at 10t/h in Red Sandy Loan

Type	Fertilizer	Mean Plant weight /g
Control	N	2.35
Control	Y	7.95
Wood Biochar	N	2.28
Wood Biochar	Y	7.28
LTSTP	N	6.65
LTSTP	Y	9.53
HTSTP	N	5.1
HTSTP	Y	6.45

Wheat Trials Wollongba (Red Chromosol): 240°C STP at different rates

Char (T/Ha)	Fertilizer	Mean Plant height (mm)
0	N	123.38
0	Y	154.75
10	N	137.66
10	Y	200.50
50	N	145.75
50	Y	207.625
100	N	164.5
100	Y	202.625

Initial in field tube trials carried out with sandy soils indicate that 220°C STP can have improved growth rates for wheat both with and without fertiliser. Due to the high least significant difference in results it is not possible to determine whether 240°C STP had a significant improvement in growth over the control without fertiliser.

Initial results from Wollongba show that 240°C STP results in significant increases in height at an application rate of 50t/ha with and without fertiliser.

Discussion

The microstructure observed in STP is broadly similar to Amazonion Terra Preta. The pot trial results have also shown that STP has the abilities to promote plant growth.

The 240°C sample has a higher similarity to Terra Preta's microstructure as there are no clear boundaries between the phases. This shows that the different components in STP have reacted with each other. However, the pot trial results shows that the 220°C sample is better in promoting plant growth. Further trials are ongoing to optimise conditions to generate microstructures which best promote plant growth

Conclusion & Future work

1. We have successfully synthesised STP which closely resembles Terra Preta with a process that only takes 8 hours.
2. Benefits of STP includes promoting plant growth, higher CEC compared to surrounding soils and a higher organic mineral content.
3. Future work include trials to monitor greenhouse gas emissions

STP is a low cost, easy and rapid to produce and most importantly it resembles Terra Preta!