REFERTIL: reducing mineral fertilizers and chemicals use in agriculture by recycling treated organic waste as compost and bio-char products

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Cite as: E. Someus: REFERTIL: reducing mineral fertilizers and chemicals use in agriculture by recycling treated organic waste as compost and bio-char products, in: Bettendorf, T.; Wendland, C.; Otterpohl, R. 2014. *Terra Preta Sanitation*.

Publisher: Deutsche Bundesstiftung Umwelt

ISBN 978-3-00-046586-4

http://www.terra-preta-sanitation.net

Abstract

The REFERTIL project (FP7 contract no.: 289785) is developing safe and economical biochar quality criteria for EU policy support and proposal for possible inclusion of the biochar case into the EU FERTILIZER REGULATION revision (EC 2003/2003). The objective driven goal of this SME farmer targeted applied science and technology project is to reduce mineral fertilisers and chemicals use in agriculture by recycling treated organic waste as biochar and compost products, with particular attention to the recovery of nutrients, such as Phosphorous and Nitrogen. Input bio waste steams with economical importance are identified in the EU28, qualified and quantified. Available commercial biochar technologies and products detailed accessed, from which 7 biochar technologies selected for best available technology evaluation. 2000 tons of compost and 30 tons of different types of biochar processed between 2012 and 2015. Different types of compost and biochar field tested under different climatic/soil conditions with different food crop plants. Evaluations made for biochar safety, economy, agri-industrial usefulness, EU and Member State legal aspects, environmental and climate impacts, market acceptance and overall benefits. During 2011 through 2013 the REFEERTIL has been significantly improving the application oriented biochar science and technology systems. In this context, sustainable feed materials identified, advanced industrial biochar technologies improved and developed, overall risk and accredited laboratory assessments made, wide range of field tests performed, safe biochar product performances technically and legally determined (including REACH legislation) with recommended maximum allowable limit specifications and user oriented economical application scenarios. Safe compost and biochar quality standards and trading requirements established with clear technical, environmental and safety definition. Two major types of commercial biochar developed, such as the lignocellulose (plant and forestry by-products) based high carbon content biochar soil improver with usual application doses 5 t/ha to 20 t/ha and the food grade animal bone based high P mineral content "ABC" Animal Bone bioChar organic P fertilizer with usual application doses 0.2 t/ha to 0.6 t/ha. Two different biochar mandatory EU law harmonization levels are proposed, such as EU FERTILIZER REGULATION biomass by-product input based biochar with MS mutually recognized quality and MS mandatory determination of the biochar standards made form input waste streams according to the Waste Framework Directive and the End-of-Waste criterion cases. If biomass by-product input based biochar complies with the requirements for soil improver or organic fertilizer, the producer will have the choice to market this product as soil improver or organic fertilizers or both.

Keywords: biochar, phosphorous, pyrolysis, bonechar, fertiliser, carbon, standardisation

INTRODUCTION

Intensive farming practice and human activities have disturbed the natural cycles of Phosphorus and Nitrogen. Industrial agriculture relies on continual inputs of mined and non-renewable Phosphorus and energy-intensive Nitrogen supply. Modern industrial agriculture relies on continual inputs of mined non renewable Phosphorous. Reserves of the phosphate rock used to make such fertilizers are finite, and concerns have been raised that they are in danger of exhaustion. For long term global food security is the sustainable supply of Phosphorus, a key resource for soil fertilisation that cannot be substituted (European Commission 2011a). Therefore, Phosphorous recycling is one of the key priorities of the sustainable agricultural systems. The European Union is almost entirely dependent on imports of phosphate rock (mainly from Morocco). Trends and developments on the global phosphate rock market are putting the EU's security of supply of phosphate rock under increasing pressure. (de Ridder M. *et al.* 2012). The environmental, economic, and social implications of food waste are of increasing public concern worldwide. (European Commission 2011b) In the EU alone, we waste 90 million tonnes of food every year or 180 kg per person. Much of this is food, which is still suitable for human consumption. (European Commission 2011a). According to the Eurostat databases more than 40 million tonnes of animals (bovine, poultries and pigs) slaughtered in the EU 27 countries (Eurostat 2008). Approximately 50 percent of the live weight of cattle, 45 percent of the live weight of pigs, and 40 percent of the live weight of broilers are materials not consumed by humans.

Biochar is plant and/or animal biomass by-product based stabile carboniferous substance with well defined and controlled quality that is processed under reductive thermal conditions and applied to improve the soil physical and/or chemical and/or biological properties or the soil activity. Biochar is a thermo chemically modified product, produced from biomass by pyrolysis treatment at 450°C – 550°C (plant biomass) or 550°C – 650°C (animal by-products), obtained from wide range of feed materials by a manufacturing process, which product is having high variation in composition. There are two major types of biochar, such as the lignocelluloses (plant and forestry by-products) based high carbon content biochar soil improver with usual application doses 5 t/ha to 20 t/ha and the food grade animal bone based high mineral content biochar "ABC" Animal Bone bioChar organic P fertilizer with usual application doses 0.2 t/ha to 0.6 t/ha. The plant based biochar does not containing nutrients with economical value, while the ABC is a full value Phosphorous fertilizer with 30 % of P_2O_5. Both types of biochar having a long list of beneficial effects, including water and nutrient holding capacity, therefore improvement of degraded soils and drought tolerant cultivations are important application objectives. Many of the known biochar technologies (designed for traditional energetic charcoal production) are not suitable to fulfil the modern 21st century environmental and climate protection goals, and the EU "End-of-Waste" and Life Cycle Thinking criterions. Therefore significant improvements must be made for these traditional energetic charcoal production technology systems. The environmentally sustainable carbonization improvements are complex and technically demanding challenges.

The irreversibility of biochar incorporation into soil emphasises the urgent need for a full and comprehensive performance and safety characterisation of each biochar type in regard to potential contaminants (mainly heavy metals and PAHs), as influenced by biomass feedstock and pyrolysis conditions. (Verheijen F. et al. 2010).

Contaminants (e.g. PAHs, heavy metals, dioxins) that may be present in biochar may have detrimental effects on soil properties and functions. The controlled use of feedstock and pyrolysis conditions provides necessary benefits to soil functions and reduces threats when applied to fields that have specific soil-environmental-climatic-management conditions. (Verheijen F. et al. 2010). There is no existing uniform EU legislation related the use and quality of biochar. The Community legislation regulates only certain rules and specific aspects of organic waste material treatment. While the amount of organic waste being recycled is increasing, treatment standards are partially exist for recycling. (Commission of the European Communities 2005). At the EU level only inorganic fertilisers are considered in Regulation (EC) No 2003/2003. The other types of fertilisers and fertilising materials are not covered by this European legislation. Therefore, the Commission intends to revise Regulation (EC) No 2003/2003 to extend its scope to other fertilisers and fertilising materials including organic fertilisers, growing media, soil improvers and possibly bio-stimulants. (Spaey D. et all. 2012).

METHODS

Biomass by-product based biochar production is regulated by the REACH legislation, such as chemically modified substance with variable chemical composition. Waste derived biochar is regulated by the Waste Framework Directive End-of-Waste criteria. All biochar production is characterized by biomass origin feed material and reductive thermal processing conditions. Both the lignocelluloses based biochar and the ABC products belong to the class of "UVCB" substance of Unknown or Variable Composition, complex reaction products or Biological material. The biomass origin, the manufacturing process, the variable chemical composition, the product safety requirements and the cascade of application methods and area are the same as for the lignocelluloses based biochar and the ABC. According to the REACH both types of biochar is a product fit for use in soil and recognized for producer's responsibility and manufacturers, distributors, suppliers and retailers product liability performance when manufactured, imported and traded above 1 t/y capacity (from mid 2018). There is an extensively wide range of different biochar input material options, and therefore biochar chemical composition is characterized by:

a) the number of constituents is relatively large and
b) the variability of composition is relatively large or poorly predictable.

In this context the lignocelluloses based biochar is a multi-constituent substance, while the ABC is a mono-constituent well defined substance. However, both are of biomass origin, reductive thermal processing made, 100 % accountability of the substance composition required (chemical composition, chemical identity, molecular and structural information, spectral and analytical data), while the user area and the safety aspects are the same. Beyond the basic biochar product issue itself, it is important to remark, that the efficient application of both biochar types require complex, combined and integrated application strategies and approaches. Therefore, like other ashes and heat treatment products, biochar is subject to REACH if or when it is not considered a waste.

The REFERTIIL biochar reserach and development aiming EU policy support, furthermore providing proposal for possible inclusion of the biochar case into the EC Fertilizer Regulation No. 2003/2003 revision and law harmoniyation. As the current EC Fertilizer Regulation covering mineral fertilizers only, there is an ongoing review on it to adopt draft proposals to fully harmonise the market and extend it to mutually recognized fertilizers, including growing media, soil improvers, organic fertilizers, plant biostimulants, organo-mineral and other fertilizers. In this context, the REFERTIL biochar quality criteria is to meet the objectives of the future legislation. The objective driven goal of this SME farmer targeted project is to reduce mineral fertilisers and chemicals use in agriculture by recycling treated organic waste as biochar and compost products, with particular attention to the recovery of nutrients, such as Phosphorous and Nitrogen. The improved and safe output biochar products enhancing the environmental, ecological and economical sustainability of the food crop production, while reducing the negative footprint and overall contributing to climate change mitigation. The Refertil complex development works covering the fields from the applied biochar science into economical full scale industrialization and commercialization. The accredited analysis of the different samples has been done by the Wessling Laboratories http://de.wessling-group.com . Sampling frequency, procedures and documentation for industrial production of biochar has been determined and EN-12079 used, which for sample pretreatment Method CEN/TC400 - EN 16179:2012 used.

The REFERTIL biochar major work task elements are as following:

1) Input bio-waste identification and quantification: identification, quantification and qualification of the economically important biomass byproduct and organic waste streams according to 21 EWC code systems, set up an input material criterion system and detailed accredited analytical assessment with particular attention to N+P nutrients.
2) Assessment of available biochar technologies and products: environmental, technical, legislative, cost efficiently, benefit and risk evaluation of the available biochar producing technologies; set up a detailed technology and biochar product matrix database; development of detailed biochar policy support draft report submitted to the Commission September 30, 2013 and public consultation made by the end of 2013.
3) Pyrolysis technology improvement towards zero emission thermal processing and different application of specific biochar.

4) Best available technology demonstration for improved and sustainable industrial biochar production and economical applications. 2000 tons of compost and 30 tons of different types of biochar produced and field tested between 2012 and 2015.
5) End user promotion, dissemination and networking with target SME's and farmers.

From legal terminology point of view the new fertilizer regulation may be divided into "soil improver" and "organic fertilizer" product category for biomass byproduct based biochar that could be MS mutually recognized quality. For organic waste based biochar under Waste Framework Directive and End-of-Waste criteria, methodology for biochar product is not established, therefore this might be regulated at Member State level. Member States are able to implement specific national criteria for EoW biochar in order to adapt to local situations, but such national EoW criteria would not have mutual recognition in other Member States. If a product is produced according to locally applicable National End-of-Waste criteria (in the country in which it is manufactured), it cannot then be exported as a product (only as a waste) to other countries (for example, where no national criteria are defined). In this context a clear differences should be done between agricultural, food industrial and forestry by-products based biochar (out of scope WFD) and biochar made form waste material under WFD.

Biochar is a thermo chemically modified product, obtained from wide range of feed materials by a manufacturing process, which product is having high variation in composition, containing several main constituents, impurities and additives. In this context the biochar source is biological, the process is a refinement and new molecules are intentionally generated by pyrolysis process. In this context the lignocelluloses based biochar is a multi-constituent substance, while the ABC Animal Bone bioChar is a mono-constituent well defined substance both are of biomass origin, reductive thermal processing made, 100 % accountability of the substance composition required (chemical composition, chemical identity, molecular and structural information, spectral and analytical data), the user area and the safety aspects are the same. Beyond the basic biochar product issue itself, it is important to remark, that the efficient application of both biochar types require complex, combined and integrated application strategies and approaches.

All biochar potential impact on the environment, ecology and human health need also to be assessed from the content of persistent, bio-accumulative and toxic substance point of view as well.

i. The lignocelluloses based biochar containing more than one main constituent that is present in a concentration between 10% and 80% (w/w).
ii. The ABC Animal Bone bioChar containing one main constituent at least 80% (w/w) and the other constituent substance make up no more than 20% (w/w).

There is an extensive opportunity for conversion of organic by-product and/or waste streams into biochar, that feeds originating from the wide range of industrial sectors, but subject to that the output biochar product is proven safe, which information is labeled on the product according to the EU regulations. Potential toxic elements (PTEs) in biochar need to be kept to sufficiently low levels so that they do not cause potential pollution of soil, water and other ecological systems. This is an important element as incorporation of biochar into soil is irrevocable process; therefore only proven safe materials should be put into the soil. Directive 2008/105/EC is listing PAHs, Cadmium and Mercury as identified priority hazardous substances.

The REFERTIL methodology for accredited identification of the PTEs is based on European Committee for Standardization - Project Committee - horizontal and MS mutually recognized standards. If no horizontal methods available, than well recognized accredited methodologies used.

PAH_{16} is one of the identified biochar target contamination. In the soil environment PAH may be leached to surface- and groundwater through various mechanisms, such as erosion or colloid facilitated transport through soil macrospores. Not all biochar adsorbing PAHs same way, while the ageing mechanism and release of PAHs by time is not determined and that is a a significant environmental risk, therefore the precautionary principle to be applied. The applied PAH_{16} limit standardized test method is CEN/TS 16181:2013. Moreover according to the Annex X of the Water Framework Directive (Directive 2000/60/EC as amended by Directive 2008/105/EC) provides a list of priority substances that can present significant risks to the aquatic environment. Discharge or emission of those substances to the aquatic environment is being phased out across the EU. The application of materials to soil can be a route for contamination of surface and ground waters, any pollutant limits set for biochar product should take those substances into account. The recommended maximum allowable PAH_{16} limit value is 6 mg/kg.

Dioxins and furans are not target contaminations in the biochar. Analytical results of the Refertil project showed that there were neither dioxins nor dibenzofurans, nor PCBs present in the biochar samples analyzed in significant concentrations, which – if any – would be a characteristics of the pyrolysis gas vapour phase and not the solid biochar phase. Additionally, for certain waste EoW treatment cases the dioxins, furans and PCBs might be a potential air pollution issue that needs meet the Environmental Protection Authority permit and control specifications (PCDD/F: CEN/TS 16190:2012, PCB_7: EN 16167:2012)

The heavy metal content of the biochar samples are analysed by EPA Method 6010C:2007, the bulk density is by CEN/TS 15401:2006 standard and the percentage of the total carbon content by EN 15407:2011 standards. The nutrient (P, K, Ca and Mg) content of the different biochar samples have been determined by EPA Method 6010C:2007.

Definition of particle size distribution is proposed. Freshly produced lignocelluloses based biochar use to be moistened (usually <40% w/w) for transport and storage, all in order to minimize any health and environmental hazard (i.e. self ignitions, dust explosion, note: although the biochar product is sold on dry basis, but the transport is certainly made on total weight basis, product + water, which will be an additional economical challenge for the lignocelluloses based biochar). However, the complex biochar field application challenges starts at handling and soil incorporation, how to evenly spread and which machines to be used, that highly variating farm level practical factors are influencing the biochar application conditions. Farmers need simple, robust and high efficient solutions for competitive price that fit into their existing practice and machinery use. Biochar is also a form of black carbon which is extremely fine powder that can accumulate in the lungs as a result of prolonged inhalation. Black carbon has been declared as possibly carcinogenic to humans by the International Agency for Research on Cancer. Breathing in very small biochar dust particles is known to pose various health risks including respiratory diseases and even cancer. Under industrial conditions factory moisten the biochar may reduce health and environmental hazard but does not remove the risk. Biochar is bulky and low cost material, which under commercial conditions in many cases cannot afford much additional cost for transport of water and store inert. The light “dust” fraction of the biochar can be suspended in the air and easily moved by light winds, and losses can occur during transport from storage heaps, as well as during loading and in-field application when using machinery such as spinning disc spreaders. Especially during warm summer days, the low volume weight and light dust fraction of biochar is rapidly and easily dry out, resulting that small fraction particles will fly and may result air pollution. In practice and in industrial scale this potential emission risk should be avoided and minimized.

The quality parameters and agronomic value of all type of biochar products that characterize the usefulness of biochar in agricultural applications (such as the nutrient content) should be declared as total and requiring that information concerning nutrient content be communicated with the product. In all and any cases the nutrient specification should be considered according to the characteristics and to the application performance of the product. Lignocelluloses based biochar does not contain economically interesting nutrient add-on inputs to soil, and therefore this type of biochar is not a fertilizer but rather a soil improver. Therefore from the end-user point of view the nutrient add-on soil input content for this type of biochar is not of much interest. However, it is having a nutrient and water retention beneficial performance. In the case of organic fertilizer a criteria for the minimum P_2O_5 content should be set up. ABC Animal Bone bioChar is a full value organic P fertilizer with its high 30% P_2O_5 and complex mineral content.

REFERTIL RESULTS AND DISCUSSION

Table 1 is showing the Polycyclic Hydrocarbons (PAHs) and Polychlorinated biphenils (PCBs) content of the different biochar and wood charcoal samples. The amount of PCB 28, PCB 52, PCB 101, PCB 118, PCB 138, PCB 153, PCB 180 compounds were below 0.01 mg/kg dm both in the all animal bone char and plant based biochar samples. The result shows that five plant based biochar samples PAH_{16} limit value over the recommended maximum allowable limit 6 mg/kg. The characteristics of the different biochar samples clearly reflecting the biochar production thermal conditions, most importantly the heat transfer efficiency, whereas clearly demonstrated that several "biochar" processing technologies are fault performance with low efficient carbon processing efficiency. In industrial biochar production scale the key indicator for high quality biochar production is not the high enough temperature or the residence time, but rather the carbon processing construction design performance for high heat transfer efficiency. Concerning the environmental zero emission pyrolysis performance only the ABC processing qualified.

Table 1. Dry matter content, bulk density, pH, total carbon content and the organic contaminants of the different biochar products.

	Dry matter % dm. w/w	Bulk density kg/m^3	pH	Total C % dm. w/w	Sum of PAH_{16} (mg/kg)	Sum of PCB_7 (mg/kg)
Food grade animal bone based biochar						
ABC-bc/7 (C3 pig bone, Sweden)	94.49	510	8.75	11.2	0.12	n.d
ABC-bc/10 (C3 poultry bone, Sweden)	99.95	310	7.58	9.9	0.37	n.d
ABC-bc/11 (C3 pig bone, Sweden)	99.14	500	7.63	12.3	1.43	n.d
Plant biomass byproduct based biochar						
DK-bc/1 (wood biochar, Denmark)	63.55	250	7.28	54.1	1.29	n.d
DK-bc/2 (wood biochar, Denmark)	79.86	210	4.04	80.2	0.74	n.d
DK-bc/3 (wood biochar, Denmark)	75.85	240	4.33	82.7	0.91	n.d
D-bc/1 (wood chips, Germany)	89.09	220	9.74	56.1	2.62	n.d
D-bc-2 (wood chips, Germany)	74.71	260	9.35	81.0	0.71	n.d
FR-bc/1 (plant extraction, France)	97.27	190	9.39	69.4	**47.5**	n.d
FR-bc/2 (oak chips, France)	94.91	180	9.51	81.1	**10.33**	n.d
FR-bc/3 (thuja, France)	98.45	300	**11.1**	30.7	**48.95**	n.d
E-bc/1 (wood biochar, Spain)	61.46	440	9.41	75.8	0.47	n.d
IT-bc/1 (wood biochar, Italy)	91.48	160	**10.8**	92.9	**10.12**	n.d
UK-bc/1 (wood biochar, UK)	98.31	420	9.94	98.2	**10.55**	n.d
H1 (hard woodchar, Hungary)	93.87	360	8.32	79.8	4.82	n.d

Table 2 is showing the P, K, Mg, Ca nutrient value of the different biochar products. Comparing the different plant- and animal bone based biochar samples large differences have been observed especially in the Phosphorus (P) and Calcium (Ca) content. The ABC biochar samples having high amount of P, ranging from 110000 to 133000 mg/kg dry matter which is equal with 25-30 percent Phosphor pentoxid (P2O5) equivalent. The P content of the different plant based biochar samples are ranging between only 46-4400 mg/kg dry matter, this equal to only 0.01-1.01 % P2O5 equivalent. This result is clearly indicating that the low P nutrient value of the plant based biochar is economically not interesting and not suitable for providing adequate cost efficient nutrient for plants. The results of the analytical characterisation is indicating that the average carbon content of the plant based biochar ranging from 54.1 % to 98.2 %. In some cases the pH is above pH10 value which is not reccomended for soil application.

Table 2. The nutrient value of the different biochar products.

	P (mg/kg)	P_2O_5 (%)	K (mg/kg)	K_2O (%)	Ca (mg/kg)	CaO (%)	Mg (mg/kg)	MgO (%)
Food grade animal bone based biochar								
ABC-bc/7	127000	29.1	3000	0.36	272000	38.1	6000	1,00
ABC-bc/10	133000	30.5	2000	0.24	300000	42.0	6000	1,00
ABC-bc/11	111000	25.4	1000	0.12	157000	22.0	5000	0,83
Plant biomass byproduct based biochar								
DK-bc/1	46	0.01	572	0.07	3450	0.48	140	0,02
DK-bc/2	98	0.02	1100	0.13	1300	0.18	100	0,02
DK-bc/3	69	0.02	800	0.10	1400	0.20	200	0,03
D-bc/1	828	0.19	6720	0.81	4270	0.60	306	0,05
D-bc-2	1600	0.37	7000	0.84	17000	2.38	3000	0,50
FR-bc/1	4400	1.01	12200	1.47	4700	0.66	857	0,14
FR-bc/2	425	0.10	3040	0.37	1440	0.20	138	0,02
FR-bc/3	2800	0.64	14000	1.69	20000	2.80	909	0,15
E-bc/1	1300	0.30	9000	1.08	43000	6.02	3000	0,50
IT-bc/1	273	0.06	5020	0.60	4670	0.65	364	0,06
UK-bc/1	309	0.07	2900	0.35	2000	0.28	300	0,05
H1	780	0.18	4450	0.54	30200	4.22	1200	0,20

The ABC can also be considered as a unique Ca source as its Ca content is ranging from 157000 -300000 mg Ca/kg dry matter, which is equivalent with 22-42% Calcium oxide (CaO) form. The different plant based biochar containing only 0,18-6 % CaO form expressed nutrient. The heavy metal content of all ABC samples are well below the existing limit values in the EU and national legislations. Same results have been received for the different plant based biochar products expect one sample (FR-bc/) where the Ni content is exactly equal with the setted limit value. On the contrary the Zn content of the FR-bc/3 sample is 1480 mg/kg dry matter which is almost more than two fold compared to the limit value. The limit values for heavy metals in organic fertilising material based on the existing EU and national legislations are the following: Cd: 3 mg/kg dm, Cr: 100 mg/kg dm, Cu: 100 mg/kg dm, Hg: 1 mg/kg dm, Ni: 50 mg/kg dm, Pb: 180 mg/kg dm, Zn: 600 mg/kg dm (Spaey D. et all. 2012).

Screening of antagonistic bacteria derived from different soils, showed that most of these bacteria (60%) were able to dissolve Phosphorus (P) from ABC and that some of them had also the potential to inhibit plant pathogen. The strategy of combining ABC with beneficial soil microorganisms will enhance sustainability of crop production system by re-using P from waste of the food chain and reducing pesticide applications with biological control agent (J. Postma et al 2010.). Growth of the microorganisms at the bone char dissolved some of the phosphates as visualized by electron micrographs. This means the microorganisms must have incorporated inorganic P into organic P of their metabolites. (Leinweber et al. 2007.). ABC is a P fertilizer of solubility intermediate between Gafsa phosphate rock and triple superphosphate fertilizer. (Warren et al.).

The REFERTIL is not recommending H/Corg labelling for biochar product quality and stability specification. In the H/Corg discussion the term “stability” is not defined from legal point of view, while this issue is rather an important item for the manufacturer’s production record. In this context the H/Corg, such as suggest by other researchers <0.7 value, will not be universally relevant safe product quality indicator for all different types of biochar produced from wide range of different feeds. The H content of the H/Corg indicator does not provide sufficient information about the biochar quality status, such as whether it is a structural bonded H or adsorbed on surface, for ex. PAHs or other remaining VOC/SVOC compounds.

The biochar results of the accredited validation and permit trials executed by Government Office for Fejer Country in Hungary (biochar application permit number: 02.5/67/7/2009; issued on March 31, 2009, valid March 31, 2019; for application areas: open soil and green/glass house organic, low input and conventional cultivations) of the ABC natural product are supporting to get higher plant yields with better quality and safer food products. The test results indicated, that already in the seedling period was realized >20 mm size differences benefit for the ABC products (600 kg/ha dosages) applied in the root tone in greenhouse nursery with sweet pepper. Stronger plant at nursery stage provides life time positive effect for plant growth. The ABC treatments resulted earliness concerning yield results (>300%) at the first harvests, compared with the untreated control under greenhouse sweet pepper vegetable cultivation. Compared to the control the plant yields and quality is increased by >50% after 600 kg/ha dosages ABC treatment in tomato and green pepper greenhouse vegetables cultivation. The extra surplus yields are 2.5-5 tonnes/hectare. The application of ABC biochar is significantly increased the plant yield and quality after the ABC treatment in open field cultivation with several vegetables test plant, such as tomato, green pepper, broccoli and Chinese cabbage. The mineral and nutrient content of the tomato fruit is increased by >10% resulted highly improved fruit quality, better taste and extended fruit storage performance. On the basis of extended soil analysis ABC treatment influenced favourable the soil structure and increased plant available soluble macro and micro nutrient content of soil (FP6 PROTECTOR, EU contract no.: 514082, 2005-2008 and CIP Eco-Innovation, EU contract no.: ECO/08/238984/SI2.532247-PROTECTOR, 2009-2012).

Table 3. REFERTIL recommended biomass by-product based biochar safe quality standards and trading requirements with maximum allowable limits of potential toxic elements.

	ABC ORGANIC P-FERTILISER biochar (mg/kg d.m.)	**SOIL IMPROVER** biochar (mg/kg d.m.)
Potential Toxic Elements		
As	10	10
Cd	1.0	1.0
Cr	100	100
Cr (VI)	0.5	0.5
Cu	200	200
Pb	120	120
Hg	0.5	0.5
Ni	50	50
Zn	600	600
Organic pollutants		
PAH_{16}	6	6
PCB_7	0.2	0.2
PCDD/F5 (ng/kg)	20	20
Toxicology		
Plant response	no inhibition	no inhibition
Quality parameters		
Particle size distribution	1 mm-5 mm 90%	1-20 mm 90%
Bulk density	declaration	declaration
Dry matter content	declaration	declaration
pH	6-10	6-10
Total Organic C	no minimum organic C content	>50%
Nutrient content		
Total N	declaration	declaration
Total P (P_2O_5)	>25 %	declaration
Total K	declaration	declaration
Ca	declaration	declaration
Mg	declaration	declaration
Agronomic efficiency	proved and declared	proved and declared

CONCLUSIONS

Farmers expect increased economical and ecological benefits, including soil fertility improvements, higher yields, higher fruit quality, better soil structure and water retention, furthermore better utility of natural nutrients from biochar at lower cost than other competitive soil improvers, and primarily interested in short-term profitability, usually within three years. Therefore, the biochar production and application strategies must be well designed and meet the user's soil, climatic, environmental and economical conditions where the number of biochar benefits most efficiently can be utilized.

The low nutrient content of the plant based biochar have limited capacity to provide adequate and economical nutrient supply for reduction of mineral fertiliser use into agriculture. However, the water and nutrient holding capacity of the biochar, and other beneficial combined effects, makes the product highly interesting for many soil applications. Biomass by-product plant based biochar samples having high >50% w/w stabile carbon content and determined as soil improvers with high doses (approx. 5-20 t/ha), while Animal Bone bioChar is full value organic P fertilizer with 30% P_2O_5 with low doses (approx. 0.2-0.6 t/ha).

PAHs, Cadmium and Mercury identified as priority hazardous substances. Based on the achieved results, the REFERTIL set up recommended biomass by-product based biochar safe quality standards and trading requirements with maximum allowable limits of potential toxic elements. Two different biochar mandatory EU law harmonization levels are proposed, such as EU FERTILIZER REGULATION biomass by-product input based biochar with MS mutually recognized quality and MS mandatory determination of the biochar standards made form input waste streams according to the Waste Framework Directive and the End-of-Waste criterion cases. If biomass by-product input based safe biochar complies with the requirements for soil improver or organic fertilizer, the producer will have the choice to market this product as soil improver or organic fertilizers or both. The low quality and not eligible biochar is remaining subject to waste legislation.

ACKNOWLEDGEMENT

The REFERTIL (289785) Collaborative project is co-funded by the European Commission, Directorate General for Research, within the 7th Framework Programme of RTD, Theme 2 - Food, Agriculture and Fisheries, and Biotechnology. The authors are solely responsible for the content of this information. The European Community is not responsible for any use that might be made of data appearing therein.

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