Biochar changes in soil based on quantitative and qualitative parameters of humus compounds

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Due to the indisputable significance of humus in many biochemical processes as well as its increasing deficit particularly in light soils, alternative sources of substrates for the production of this constituent should be sought. Considering the physical, chemical and biological stability, the solid product of thermal transformation of biomass called biochar may be such a source (Kwapinski *et al.*, 2010, Allaire *et al.*, 2015).

Biochar is carbon rich solid product obtained from pyrolising biomass under low oxygen conditions (Lehmann, 2007) and is defined by its intentional application to the soil for environmental applications. Biochar contains highly condensed aromatic structures that resist decomposition in soil. For this reason, it can effectively reduce the atmospheric CO_2 concentration, because biochar slows the rate at which fixed carbon is returned to the atmosphere (Xu et al., 2012). As reported by Woolf *et al.* (2010), the use of biochar could mitigate up to 12% of current anthropogenic CO_2 emissions.

The latest literature review brings many doubts regarding the influence of biochar on soil properties, biological activity, or changes of organic compounds, depending on the material used for the production of biochar, temperature of the process, date of application, or dose (Lehmann, 2007; Jha *et al.*, 2010). In consequence, it is difficult to unambiguously show positive and negative aspects of biochar changes, making it impossible to properly assess the effect of its application on physical, chemical and biological properties of soil. Worse still, the question of the extent of biochar's influence on the quantitative and qualitative composition of humic compounds remains unanswered. That is why it is essential to identify potential changes in the quantitative and qualitative composition of humus after application of biochar. This direction of research, particularly with reference to the qualitative composition of humus, provides great potential for progress not only in agricultural sciences, but also in chemistry, biology, or even geoscience. In addition, identification of changes to biochar, taking account of the above aspects may play a key role in detoxification and restoration of soil properties.

The aim of this study was to evaluate the effect of the addition of wheat straw (*Triticum aestivum* L.) and biochar obtained from this biomass on quantitative and qualitative parameters of humus. Wheat straw was dried at ambient temperature, ground in a laboratory mill (mesh size of 4 mm) and mixed to ensure homogeneity. The plant material was pyrolysed in an electric laboratory furnace (equipped with a temperature controller) at 300 °C, for 15 minutes, under a limited supply of air (IBI, 2014). The rate of heating the combustion chamber was 10 °C min^{-1}. The research was carried out under laboratory conditions (after 8 months) with a loamy sand soil. The experiment comprised 10 treatments carried out in 3 replications: control soil without fertilisation (C); soil + NPK (MF); soil + NPK + wheat straw in a dose of 0.2% (WS 0.2%); soil + NPK + wheat straw in a dose of 0.5% (WS 0.5%); soil + NPK + wheat straw in a dose of 1% (WS 1%); soil + NPK + wheat straw in a dose of 2% (WS 2%); soil + NPK+ wheat straw biochar in a dose of 0.2% (WSB 0.2%); soil + NPK + wheat straw biochar in a dose of 0.5% (WSB 0.5%); soil + NPK+ wheat straw biochar in a dose of 1% (WSB 1%), and soil + NPK + wheat straw biochar in a dose of 2% (WSB 2%).

Collected soil samples were dried in the open air and ground in a porcelain mortar. In soil prepared in this way, organic carbon was assessed by oxidative-titrating method. Content of humus compounds was extracted from soil by mixture of 0.1 mol dm^{-3} $Na_4P_2O_7$ solution + 0.1 mol dm^{-3} NaOH. Carbon of humic acids (CHA) was isolated in the extract of sodium pyrophosphate and sodium base, whereas carbon of fulvic acids (CKF) was calculated from the difference between the amount of carbon in the extract (Cext) and the amount of humic acid carbon (Ckh) in the extract. The extraction residue – non-hydrolysing carbon (CNH) – was computed from the difference between organic carbon content (C org.) and the amount of carbon in the extract (Kononova, 1966).

Table 1. The content of soil humus compounds on the first day of the experiment

Treatment	C org. (g kg^{-1})	C ext	CKH	CKF	CNH
		% to Corg			
C	5.10	46.6	9.69	37.0	53.4
MF	5.54	49.0	5.87	43.2	51.0
WS 0.2%	8.15	36.2	6.77	29.4	63.8
WS 0.5%	7.53	68.9	8.36	60.6	31.1
WS 1%	10.1	52.9	6.25	44.2	49.8
WS 2%	12.6	43.1	5.71	37.4	56.9
WSB 0.2%	6.42	26.0	7.46	18.5	74.0
WSB 0.5%	7.96	34.7	6.23	28.5	65.3
WSB 1%	10.9	26.1	4.74	21.3	74.0
WSB 2%	13.3	21.6	4.01	17.6	78.4

Table 2. The content of soil humus compounds after 8 months of the experiment (g kg^{-1}).

Treatment	Corg. (g kg^{-1})	C ext	CKH	CKF	CNH
		% to Corg			
C	5.91	46.9	7.67	39.2	53.2
MF	5.04	57.9	9.08	48.8	42.1
WS 0.2%	5.45	54.2	9.52	44.6	45.8
WS 0.5%	6.63	47.9	9.49	38.4	52.1
WS 1%	7.27	52.5	8.95	43.6	47.5
WS 2%	8.93	43.8	8.77	35.0	56.2
WSB 0.2%	5.91	40.6	9.33	31.2	59.4
WSB 0.5%	7.72	37.8	6.72	31.1	62.2
WSB 1%	11.3	27.2	4.93	22.3	72.8
WSB 2%	15.2	22.0	3.44	18.6	78.0

After 8-month incubation of organic materials, it was found that the content of organic carbon increased relative to the amount of materials used (0.2; 0.5; 1; 2%) (Tab. 2). After the application of thermally unconverted wheat straw (Tab. 1) and biochar obtained from this biomass, the percentage share of humic acid carbon (CKH) in C org. decreased with the increased material dose. A similar trend was noted for carbon of fulvic acids (CKF). The highest share of non-hydrolysing carbon (CNH) in C org., after 8-month incubation, was determined in soil with 1% and 2% additions of thermally converted and unconverted wheat straw. However, the content of CNH after the application of wheat straw biochar was nearly two times higher than after the application of thermally unconverted wheat straw. This means that the application of biochar results in the formation of durable connections of humic substances with mineral portion of soil, which do not undergo hydrolysis during extraction.

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