Preliminary study of a method for obtaining brown-coal and biochar based granular compound fertilizer

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Improving nutrient use efficiency (NUE) and reversing the loss of soil organic matter are major global challenges. Brown coal that is characterized by very low heating value can be used as a component of organo-mineral fertilizers. It contains organic matter in a complex, porous, three-dimensional network, which varies depending on deposit location. Humic acids are very important components of brown coal and can account 10-80% of its organic matter (Allard, 2006). Humic acids contain many functional chemical groups that help to physically modify and improve the chemical properties of the soil and biologically stimulate plant growth. Thus, humic acid products mainly as plant growth enhancers and as ingredients in fertilizer products are widely distributed throughout the world. Brown coal is an alternative material with properties that make it appealing for use as a N fertilizer carrier. Studies found that its incorporation into soil slightly reduced ammonium availability in one soil. Brown coal – urea blended fertilizers show potential for more efficient use of N in the long term and has environmental benefits in retaining more N in the soil. Biochar can contain certain amounts of extractable humic-like and fulvic-like substances (Lin et al., 2012). A number of studies show that biochars can reduce nitrate and ammonium leaching from applied nitrogen fertilizers, but the effectiveness depends on the chemical characteristics of biochars and their rate of application (Manikandan and Subramanian, 2013; Rose et al., 2016; Saha et al., 2017).

The aim of the research is to develop a method for the production of a multi-component granular fertilizer with improved efficiency, easily available humic acids, and urea in the form of an adduct: $CaSO_4 \cdot 4CO(NH_2)_2$ containing brown coal and/or biochar. In the study, the quality of obtained fertilizer products and the possibility of using brown coal and biochar as components of fertilizers is evaluated.

Table 1 shows selected physicochemical properties of brown coal and biochar.

Table 1. Physico-chemical properties of brown coal (Sieniawa, Poland) and biochar (PYREG GmbH, Germany).

Parametr	Unit	Brown coal	Biochar
pH_{H2O}, AR	-	4.3	10.3
Electrical conductivity (EC), AR	($\mu S \cdot cm^{-1}$)	1362	2190
Loss on ignition (LOI), 550°C; 3.5h, DM	(%)	84.45	87.28
Water content, 105°C, 4h, AR	(%)	47.70	45.64
Pb, DM[1]	($mg \cdot kg^{-1}$)	<4.0	<4.0
Cd, DM[1]	($mg \cdot kg^{-1}$)	<1.0	1.58
Total humic acids, DM[2]	(%)	51.02	6.50
Free humic acids, DM[2]	(%)	49.20	4.49
C, DM[3]	(%)	53.46	63.5*)
H, DM[3]	(%)	4.42	0.95*)
N, DM[3]	(%)	0.76	1.80*)
Ratio H/C	-	0.08	0.18*)

Footnotes: [1]determined by ICP-OES; [2]humic acids determined according to BS ISO 5073:2013; [3] determined by combustion using Perkin Elmer 2400 series CHN analyzer; *) results from biochar certificate, DM – dry matter, AR – as received

Pilot scale trials of fertilizer production were conducted at Fertilizer Research Centre of New Chemical Syntheses Institute, Poland using a rapid mixer granulator (IdeaPro MDL-04, Poland), which allows intensive mixing and simultaneous granulation of various raw materials. Table 2 shows consumption of raw materials for brown coal based fertilizer production. The obtained brown coal based fertilizers underwent evaluation of physico-chemical properties (Table 3).

Table 2. Raw material consumption for brown coal based fertilizer production.

No. of	Raw material consumption (% wt.)

trial	brown coal, DM	urea	phosphorite	H_2SO_4, 100%	dolomite	caustic magnesite	H_2O	NH_3(g)
1	50.0	22.8	16.8	10.4	-	-	2.7	-
2	45.5	20.8	15.3	9.4	9.0	-	2.5	-
3	50.0	22.8	16.8	10.4	-	-	2.7	+
4	47.5	21.7	16.0	9.9	-	5.0	2.6	-

Table 3. Selected chemical properties of obtained brown coal based fertilizers.

No. of trial	pH, DM	Ntot. (%)	P_2O_5tot. (%)	NAC+H_2O soluble P_2O_5 (%)	H_2O soluble P_2O_5 (%)	Mg (%)	Ca (%)	Loss on ignition (%)		
								105°C	400°C	1000°C
1	2.62	9.85	4.39	3.72	2.60	-	-	31.32	72.54	81.91
2	3.32	9.83	3.76	3.21	2.33	1.38	5.90	28.70	64.55	73.98
3	4.07	9.58	3.85	3.03	1.77	-	-	31.50	74.53	82.61
4	6.22	8.26	3.67	2.86	0.67	1.88	4.30	30.20	70.67	77.64

Footnotes: NAC+H_2O - neutral ammonium citrate and water soluble

Investigated brown coal is rich in humic acids. Alkaline extraction of humic substances reveals that brown coal and biochar contain 51% and 6.50% of humic-like substances, respectively. Brown coal is acidic while biochar is alkaline.

The initial trials of producing brown coal based granular fertilizers confirm the possibility of obtaining fertilizer granules using a rapid mixer-granulator with quality parameters similar to typical multi-compound fertilizers. The average crush strength range from 19 to 25 N per granule. A substitute diameter of the granules varied from 3.19 to 3.52 mm. To increase the pH value of the fertilizer, dolomite, gaseous ammonia, and caustic magnesite were used. Studied additives had a positive effect on an increase of pH value and were a sources of additional nutrients (Mg, Ca). Brown coal and biochar powder need a binder for the granulation. The developed method allows to obtain the granular fertilizer with a high content of brown coal (at the level of 45-50% by mass).

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