

Changes in the structure of nitrogen-containing compounds of peat-, sapropel-, and brown coal-based organic fertilizers

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Abstract. The three-stage acidic hydrolysis method was used for the degradation of three organic fertilizers prepared on the basis of peat, sapropel and brown coal. This method of hydrolysis may simulate the processes that occur in the natural environment, influenced by chemical and biological factors with a high degree of reliability, by taking substances from fractions depending on stability of compounds in the investigated organic materials. The investigation of changes in the content of nitrogen in the studied fractions allows judging the character and the degree of transformation of nitrogen-containing compounds in kaustobioliths organic substances and prepared fertilizers. In these three organic fertilizers the content of readily (“easy”) hydrolysable nitrogen ranged from 49.1 to 58.4%, the content of hard-to-hydrolyse nitrogen ranged from 4.6 to 19.5%, in unhydrolysable rest, content ranged from 31.6 to 37%. The results showed a significant supply of nitrogen included in amino acid structures in soils. Amino acids represent a form of organic nitrogen, readily hydrolysable by chemicals and enzymes, available for plants and soil microorganisms. The highest supply was observed for the fertilizer prepared on the basis of brown coal. This fertilizer supplied 93.7 % more nitrogen than the reference soil. Two other fertilizers prepared on the basis of peat and sapropel supplied 64.1 % and 56.3 %, respectively more than reference soil. A relationship and good correlation were found between the contents of readily (“easy”) hydrolysable forms of nitrogen and the total amount of amino acids, and also between the contents of readily hydrolysable forms of nitrogen and concentrations of nitrogen in amino acid structures.

Key words: peat, sapropel, brown coal, organic fertilizers, nitrogen products degradation, amino acids

INTRODUCTION

Although a number of countries are characterized by rich deposits of organic resources, the industrial production of organic fertilizers, organomineral mixtures and potting soils based on organic resources (peat, sapropel, and brown coal) is still not sufficient. However, the use of natural organic fertilizers from raw materials such as peat, sapropel and brown coal has increased during the last decades. Peat extraction for the production of growing substrates and gardening is a multi – million dollar industry in North America and Europe. For instance, the Netherlands imports 150 million euro worth of peat every year as a substrate for horticulture.

Knowledge of the ratio between humified and non-humified materials in natural substrates, such as soils, in fertilizers can be considered as very important from agronomical and environmental points of view. The addition of humified materials to the soil is equivalent to the addition of stabilized organic carbon. In contrast, due to biological activities, non-humified materials yield humified compounds and metabolic energy. The actual humification degree in soil depends on the organic materials applied, soil type, and climatic conditions (Ciavatta et al., 1989). Environmental and economic concerns have prompted agricultural producers and researchers to look for improved nutrient management strategies. Environmental and human health concerns about nutrient management are focused on nitrogen, which is not included in crop management, and which might escape from agroecosystems into ground and surface waters (Daniel et al., 1994). Agricultural nutrient management thus aims to balance nutrient inputs with crop demand and to increase the degree of internal nutrient cycling. Management of soils organic matter has emerged as a major strategy to help achieve these goals because of the central role it plays in storing and cycling nutrients (Skoroparov et al., 1987; Seiter & Horwath, 2004).

Understanding the processes and mechanisms of the degradation material added into the soils is a prerequisite for understanding the availability and cycling in nature of nutrients such as derivatives of nitrogen, carbon, sulfur, and phosphorus. Thus, studying the structure and properties of organic substances of native products such as peat, sapropel and brown coal allows the revealing of essential differences predetermined by their genesis and also permits the estimation of their potential agroecological efficiency, and perspective directions for technological processing and use of these valuable organic materials. In this connection the study of changes in the contents of nitrogen forms in native kaustobioliths as well as in those which are technologically treated are of great interest.

The balanced organic fertilizers (BOMF) were worked out by the Institute for Problems of Natural Resources Use and Ecology at National Academy of Sciences of Belarus and were widely investigated in that country. It was revealed that the character of organic substances and the transformation of their nitrogen-containing compounds in kaustobioliths of different origin and properties differ essentially in the process of their composting in mixtures with manure and balanced mineral additives. Appreciably, it is defined on the nature and structure of an initial material's organic matter and also on physical, chemical and biochemical factors when the balanced organic fertilizers are prepared. As a result, an essential increase of readily hydrolysable compounds in nitrogen contents is taking place.

Soil organic matter represents an equilibrium system which plays a major role in supplying nutrients to plant growth. Transformation of fresh organic matter to stable humic compounds affects the cation and anion exchange capacity. It is known that under the influence of enzymes, secreted by microorganisms, the macromolecules of complex organic compounds are exposed by destruction. The degradation products form the heterocyclic compounds which interact with certain kinds of microorganisms and produce low and high molecular organic substances such as carbohydrates, lignin and peptides (Schnitzer & Khan, 1978; Bambalov et al., 2000; Nieder et al., 2003).

Changes of quality and quantity of soil organic matter due to altered organic fertilizer application occur very slowly. If the changes are in dimensions relevant to practice, it takes more than 10 years until they can be proved. Numerous, long-term

field experiments have shown that with realistic and practically feasible amendments, the soil organic matter, compared with unfertilized plots, can hardly be increased by more than 30 percent over decades. Assuming a practically achievable increase of about 0,3 percent C in the 690 million hectares of arable mineral soils in the temperate climate zone, this overall C sequestration would be on the order of about 6 Pg C within a period of 50 years (Sauerbeck, 1993).

The challenges in determining nutrient availability in cropping systems that are managed to accumulate soil organic matter include assessing the interaction of added nutrients (via organic fertilizers or organic residues) with soil organic matter nutrient pools and the changes of soil organic matter turnover dynamics due to management practices that slow down the depletion of soil organic matter. As organic fertilizer is added and soil organic matter formation proceeds, soil microbial and fauna pools as well as particulate organic matter increase (Hassink et al., 1994; Paul & Clark, 1996). These components of the active soil organic matter are the key to promoting available nutrient supply in agroecosystems. Microbial and faunal biomass mediate the N-containing organic substances mineralization, whereas particulate organic matter contains much of the partially decomposed plant material that fuels mineralization (Hassink, 1995; Wilson et al., 2001).

Among the chemical properties of organic soils, particular attention is paid to nitrogen. Variation in nitrogen gives these soils a specific character. Its content is important, as any quantitative and qualitative conversions as well as transformations in the nitrogen concentrations are distinctly reflected in chemical, and indirectly, in the physical, properties of soil formations that exert a decisive impact on their fertility. From numerous studies on peat soil nitrogen, it appears that organic nitrogen occurs in forms that are both easily decomposed and resistant to decomposition (Maciak et al., 1977; Szajdak & Sokolov, 1997; Bambilov, 2000; Sławiński et al., 2000).

The goal of this study was to investigate the forms of nitrogen in products of three-stage acidic hydrolysis of organic fertilizers prepared on the basis of peat, sapropel and brown coal.

MATERIALS AND METHODS

The investigations were carried out in long-term field experiments at Experimental Station Ducora, 50 km southeast of Minsk. The station belongs to the Institute for Problems of Natural Resources Use and Ecology, National Academy of Sciences of Belarus. The hydrological and meteorological conditions of that area are typical for the central part of Belarus and are well known. The design of experiments was realized on loamy sand podsollic soil. The content of humus was equal to 3% and $H - 3.15 \text{ meq } 100\text{g}^{-1}$ of soil.

The following organic fertilizers called “Balanced Organic-Mineral Fertilizers” (BOMF) were used: BOMF_P - peat, cow manure, NPK; BOMF_S - sapropel, cow manure, NPK; BOMF_{BC} - brown coal, cow manure, NPK. The initial materials were taken from fen sedge peat deposit with the degree of organic matter decomposition of 30 %, siliceous sapropel from Chervonoe Lake, brown coal from Khandinskoe deposit, semi-fluid cattle manure. The mixtures of every kaustobiolith with semi-fluid manure and mineral additives completed preliminary composting within 60 days during the preparation of different kinds of balanced organic-mineral fertilizers.

Different kinds of BOMF were applied for the cultivation of potatoes in equal doses of 60 ton ha⁻¹ to the soils ploughed in April. The potato was planted in May. Soil samples were collected in July from the upper 20 cm layer of soil from 10 sites in every plot. Samples were air dried and crushed to pass through a 1 mm-mesh sieve. These 10 sub-samples were mixed in order to prepare a “mean sample”, which was used for potentiometric determination of pH (in 1-normal KCl), V-sorptive and for the measurements of soil enzyme activity, total nitrogen, P₂O₅, K₂O and humus content as well as amino acids. Nitrogen content in hydrolysates was determined by the Kjeldahl method with hydrogen peroxide (Rowel, 1994). The estimation of weight losses of dry substance in the hydrolysis processing was carried out in parallel (Table 1).

Table 1. Physicochemical properties of experimental fields.

pH (KCl)	N _{total} , %	P ₂ O ₅ extraction with 0.2 N HCl, mg 100g ⁻¹	V sorptive, %	K ₂ O extraction with 0.2 N HCl, mg 100g ⁻¹	Humus content, %	Activity of catalase	Activity of dehydrogenase cm ³ H ₂ kg ⁻¹ 24h ⁻¹
6.05	0.15	49.6	77.07	20.3	3.0	4.5-6.7	0.47-1.01

The activity of catalase and dehydrogenase was determined by the methods of (Kuprevitch, 1951 and Casida et al., 1964), respectively.

The method of three-stage acidic hydrolysis on our sight may simulate, with a high degree of reliability, the processes that occurred in the natural environment, influenced by chemical and biological factors. This particular mode of hydrolysis allows taking substances from fractions depending on the stability of compounds in the investigated materials. The discharge of readily (“easy”) hydrolysable compounds was carried out in two stages (5 % H₂SO₄ at 97-98° C for 2.5 hours). The precipitation of hard-to-hydrolyse compounds was made by 72 % H₂SO₄ without heating for 2.5 hours and for 5 hours at 97-98° C after 15-multiple water dilution.

The quality and quantity of bound amino acids was evaluated in soils treated using different kinds of organic fertilizers and in reference soils. Within the investigated soils, 19-21 bound amino acids were identified and determined. For the analysis of bound amino acids, soil samples were hydrolyzed with 6 M HCl for 24 h at 105° C. Separation and determination of the bound amino acids were carried out on a T 339 amino acid analyzer (Mikrotechna-Prague) using column Ostion LGFA (0.37 x 20 cm). Lithium-citric buffers of the following pH were used: 2.90, 3.10, 3.35, 4.05 and 4.90 and absorbance of the eluent-ninhydrin complex were monitored at 520 nm. The mobile phase was pumped at the rate of 12 cm³ h⁻¹ and developed a pressure of 2.5 MPa. All experiments were run in triplicate and the results averaged (Szajdak & Österberg, 1996).

RESULTS AND DISCUSSION

The general philosophy on N fertilizer usage is to estimate crop N requirement, determine or estimate N availability from all other sources, and apply sufficient

fertilizer N to meet any deficit that might exist between these two numbers. As it is not possible to determine N availability from all the sources and their potential losses from the soil-plant system, simulation models are used to predict fertilizer N requirements of crops and optimize nutrient allocation from different sources (Bendi & Richter, 2003).

Earlier results have shown that the composting of semi-fluid manure, rich in microflora and its mixtures, with kaustobioliths, caused the essential transformation in group structure of organic substances focused on rising contents of humic substances and a decreasing amount of readily hydrolysable and water-soluble compounds (Sokolov et al., 1995).

The decomposing of readily hydrolysable polysaccharides in the conditions of increased temperature promoted microbiological activity and further development of biochemical processes. The uptake of available compounds by microorganisms, on the one hand, and subsequent replenishment of humic substances stocks after their die-back, on the other, determine the efficiency of the kaustobioliths' modification in their mixtures with manure.

The heterotrophic organisms of the soil, those which must ingest carbohydrates and amino acids to meet their metabolic needs, secrete enzymes into their surroundings to catalyze, usually by hydrolysis, the solution of dead plant matter. Carbohydrates, including cellulose, serve mainly as a source of energy for the metabolism of the microorganisms and for the synthesis of cell substances, including the synthesis of phenolic compounds.

The investigation of the changes in nitrogen content in the studied fractions allows judgment of the character and degree of transformation of nitrogen-containing compounds in the kaustobioliths' organic substances and prepared fertilizers. It should be stressed that total nitrogen content (% to dry mass) in the studied materials was as follows: peat – 2.95; sapropel – 2.70; brown coal – 0.72; BOMF_P – 3.60; BOMF_S – 3.26 and BOMF_{BC} – 1.87.

The obtained results (Fig.) testified to various degrees of liability influence on hydrolytic decomposition of the kaustobioliths in connection with the different origin and metamorphic degree of their organic substance. The portion of readily hydrolysable and hard-to-hydrolyse nitrogen-containing compounds has increased from 1.3 to 1.4 times in comparison with the initial conditions of peat and sapropel in the process of balanced organic fertilizer preparation..

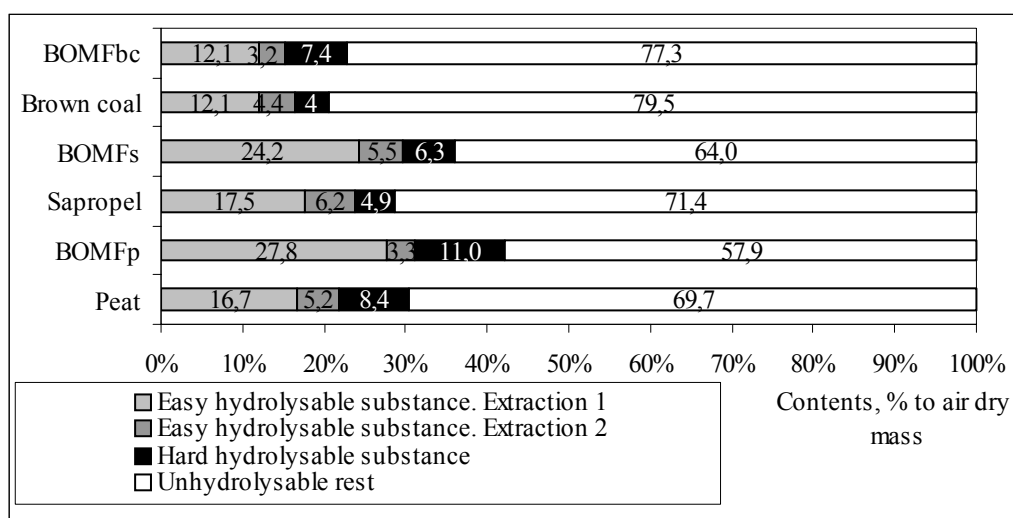


Fig. Weight losses of dry substances based on peat, sapropel, brown coal and BOMF in the course of hydrolysis processing.

Note: BOMF_P - peat, cow manure, NPK; BOMF_S - sapropel, cow manure, NPK; BOMF_{BC} - brown coal, cow manure, NPK

Since the contents of nitrogen in kaustobiolith-based fertilizers are essentially different, the qualitative estimation of hydrolysis fractions of nitrogen and their part of the total nitrogen content seems sensible for exposition of the degree of nitrogen transformation as a potential for nutrients for plants.

The analysis of nitrogen contents in hydrolysates testifies to the large distinctions in stability of its fixation with an organic substance in different kinds of kaustobioliths and BOMF. Thus, on the portion of nitrogen in the amount of readily hydrolysable substances is degraded in variant with peat account for the one third from its quantity. In BOMF_P (peat-based) it achieves half of its total contents. At the same time, the portion of hard-to-hydrolyse substances has changed only slightly and was equal to 17-19 % (Table 2).

The obtained results pointed out the balance dislocation in favor of hydrolysable nitrogen being most preferable for biological objects and available for cultivated plants and soil microorganisms.

The organic substances of sapropel in contrast with peat are rich in readily and hard-to-hydrolyse substances and are appreciably poor in humic content. The distinctions in structure of organic substances were reflected in the content of nitrogen in hydrolysates. If the absolute content of nitrogen in different fractions of sapropel and BOMF_S hydrolysates were diverse, the part of it that has remained as before testifies to insignificant destructive changes in chemical compounds and low transformation of nitrogen in compost processing. Some increasing in the share of nitrogen in unhydrolysed rest (from 31.6 to 33.5 %) and reduction in the share of hard-to-hydrolyse nitrogen (from 25.6 to 17.39 %) can be explained by the results that were carried out previously and showed the maximal microbiological activity in this variant and consumption of hydrolysable forms of nitrogen by microbe mass.

Table 2. Fractional structure of nitrogen in native kaustobioliths and fertilizers prepared on their basis.

Object	Total nitrogen, %	Nitrogen in fractional structure of organic substances, % to total		
		Readily/Easy hydrolysable	Hard-to-hydrolyse	Unhydrolysable rest
Peat	100	33.6	19.5	46.9
BOMF _P	100	51.4	17.0	31.6
Change to initial, ±		+ 17.8	- 2.5	- 15.3
Sapropel	100	45.3	25.6	29.1
BOMF _S	100	49.1	17.4	33.5
Change to initial, ±		+ 3.8	- 8.2	+ 4.4
Brown coal	100	12.5	1.4	86.1
BOMF _{BC}	100	58.4	4.6	37.0
Change to initial, ±		+ 45.9	+ 3.2	- 49.1

The most essential changes in structure of nitrogen-containing compounds occurred in the process of brown coal composting. The fraction of readily hydrolysable nitrogen has reached 58.4 % in composition of BOMF_{BC} or has grown 4.7 times in comparison with native brown coal; the part of nitrogen in the structure of hard- to-hydrolyse substance has grown 3.3 times and the quantity of unhydrolysable rest decreased 2.3 times accordingly. Thus, as a result of composting treatment the total content of all fractions of hydrolysable nitrogen has increased from 13.9 % in brown coal to 63.01 % in the balanced organic fertilizers on their basis.

From 90-95% of the nitrogen in the surface layer of most soils occurs in organic forms. The main identifiable organic compounds of nitrogen (30-45%) in soil hydrolysates are the amino acids. Amino acids enter into soil from root exudes and also are created in the process of decomposition of post-harvest residues; they can also be a result of transformation by means of transamination of appropriate keto acids. These compounds represent food for plants and other soil organisms. Amino acids occur in soil in free and bound fractions. Free forms are very unstable, quickly migrating and present in very low content (Życzyńska-Bałoniak & Szajdak, 1992). A considerable quantity of amino acids occurs in soil in the protein fraction bound to humus, mostly to humic acids (Sörensen, 1967; Flaig, 1986; Szajdak & Österberg, 1996). Humus has a protective effect on complex protein, preventing its further decomposition (Trojanowski, 1973). Soil peptides have denatured structure to various degrees (Trojanowski, 1973; Turski et al., 1974). The protein fraction of humus is included in organic soil colloids. The colloidal character of peat soils is stronger than in most mineral soils. The specific surface area of organic colloids is from 2-4 times greater than that of montmorillonite minerals (Buckman & Brady, 1971; Kwak et al., 1986). A characteristic feature of protein represents a high content of various functional groups (-NH₂, =NH, -SH, -COOH) as a result of which these proteins possess ion-exchange and complexing properties. Therefore they transport complexes of heavy metals and biologically active substances for plants and soil organisms (Schnitzer & Khan, 1978).

The total amount of bound amino acids in the reference soil was equal to 519 mg kg⁻¹ (Table 3). All used fertilizers increased the total amount of bound amino acids in soils. The highest increase characterizes BOMF_{BC} fertilizer: it increased the total

amount of bound amino acids by 97.7%. BOMF_S revealed the lowest impact on the total amount of amino acids, at 57.5%. BOMF_P showed the median increase between BOMF_{BC} and BOMF_S, at 69.5% of the total amount of amino acids in soil. When considering amino acids as acidic, neutral, basic and sulphuric, it was shown that in all soil samples amino acids with neutral net charge revealed the highest concentrations. The highest impact of fertilizers in increasing the quantity of amino acids was characterized with basic amino acids. The increase of basic amino acids ranged from 105.1 to 184.4 % compared with the reference soil. Acidic amino acids represent the lowest fraction of amino acids in soils.

The contents of bound amino acids in soils showed that glutamic acids predominated among acidic amino acids; glycine and leucine represented the highest concentrations among neutral amino acids.

In addition, the investigation revealed a higher quantity of β -alanine in soils treated with different organic fertilizers than in the reference soil. BOMF_P and BOMF_S increase compared with reference soil the concentration of β -alanine 67.1% and 20.2%, respectively. This indicated a higher microbial biomass in soils treated with organic fertilizers, since β -alanine is a typical constituent of bacterial cell walls (Stevenson, 1972; Durska & Kaszubiak, 1980). A similar phenomenon of accumulation of β -alanine was noticed in a previous study under continuous cropping of rye and crop rotation as well as under conventional and no-tillage management (Życzyńska & Szajdak, 1993; Szajdak & Österberg, 1996; Szajdak et al., 2003).

Our study showed higher concentrations of lysine in fertilized soils. Soils treated with the fertilizers were characterized by on average 34% higher concentration of lysine than reference soils. The high concentration of lysine may indicate a higher microbial biomass in soils treated with the organic fertilizers in comparison with the reference soil. Lysine is converted in soils from α,ϵ -diamiopimelinic acid (Durska & Kaszubiak, 1980). The highest content of lysine was measured in soils treated with BOMF_{BC} and was equal to 52.60 mg kg⁻¹ of soil. This quantity was 40.9 higher than in the reference soil (Nieder et al., 2003).

The study showed that the concentrations of proline were, on average, 79.6% lower in fertilized soils than in the reference soil. The smallest amount of proline was determined in soils treated with BOMF_{BC} and was equal to 2.37 mg kg⁻¹. This amount was 89.9% lower than in the reference soil. Smaller amounts of proline in fertilized soils than in reference soil is positive, because proline is a secondary amine, which in the presence of nitrate ions may form N-nitrosamines (under acidic conditions) which are potent toxins with carcinogenic, mutagenic and teratogenic effect (Kofod et al., 1981; Von Hofe et al., 1987; Larsson et al., 1990).

A significant increase of 1-methylhistidine and 3-methylhistidine was observed in soils treated with all organic fertilizers. All fertilizers influenced the content of 1-methylhistidine, and ranged from 9.7 to 16.4 times higher than in the reference soil.

The highest increase of these amino acids was observed in soil fertilized with BOMF_{BC} and was equal to 188.55 and 138.20 mg kg⁻¹, respectively. The lowest increase was estimated in soils fertilized by BOMF_S.

Table 3. Bound amino acids quantities in soils treated with different kinds of fertilizers in mg kg⁻¹ of soils.

Amino acids	Reference soil	Soil treated		
		BOMF _{BC}	BOMF _P	BOMF _S
<i>Acidic</i>				
Taurine	1.13±0.03	1.25±0.04	1.45±0.05	4.33±0.15
Cysteic acids	9.28±0.32	11.16±0.50	14.20±0.49	12.37±0.43
Phosphoethanolamine	5.31±0.19	0.54±0.02	6.72±6.72	2.51±0.09
Glutamic acids	37.14±1.29	41.27±1.44	67.31±2.34	57.74±2.01
α-aminoadipic acid	26.16±0.92	44.00±1.53	28.31±0.98	37.42±1.31
<i>neutral</i>				
Proline	23.69±0.83	2.37±0.08	5.96±0.20	6.13±0.20
Glycine	71.14±2.48	97.13±3.36	103.4±13.61	99.18±3.46
Alanine	29.46±2.48	45.42±1.59	50.28±1.75	39.46±1.38
α-aminobutyric acid	-	0.27±0.01	8.95±0.31	5.92±0.21
Valine	33.02±1.15	138.12±4.82	47.54±1.67	53.78±1.87
Methionine	26.14±0.91	32.32±1.13	40.74±1.42	28.49±0.96
Cystathionine	2.18±0.08	6.51±0.22	6.04±0.21	4.37±0.15
Leucine	71.45±2.49	104.74±3.65	119.6±14.17	96.76±3.38
Tyrosine	7.17±0.25	21.34±0.75	13.02±0.45	11.24±0.39
β-alanine	32.71±1.14	32.11±1.12	54.83±1.91	39.33±1.36
β-aminoisobutyric acid	0.92±0.03	0.29±0.01	1.02±0.03	1.38±0.05
γ-aminobutyric acid	10.34±0.36	19.40±0.67	6.18±0.21	7.61±0.27
<i>basic</i>				
Ornithine	5.44±0.19	6.98±0.24	8.12±0.28	6.60±0.23
Lysine	37.34±1.30	52.60±1.83	52.24±1.89	44.86±1.57
Histidine	13.82±0.48	20.65±0.72	22.08±0.77	14.46±0.51
1-methylhistidine	11.53±0.40	188.55±6.51	111.47±3.89	129.02±4.50
3-methylhistidine	70.64±2.46	138.20±4.81	88.92±3.10	96.94±3.38
Arginine	13.38±0.46	22.68±0.74	22.24±0.77	18.33±0.64
Total amount of amino acids	519.39±22.8	1027.90±45.02	880.51±38.30	818.23±36.2
Total amount of nitrogen in amino acids	64.40±2.80	124.75±5.42	105.66±4.60	100.64±5.64

In this soil the content of 1-methylhistidine was equal to 129.02 mg kg⁻¹ and 3-methylhistidine was equal to 96.94 mg kg⁻¹. The lowest contents of these amino acids were determined in soils fertilized by BOMF_P. Both 1-methylhistidine and 3-methylhistidine are products of the decomposition of lower (thallophytic) plants such as mosses, lichens and algae (Parsons & Tinsley, 1975). Hence increased total amounts of these compounds in the tested samples indicate higher biomass of these plants in the studied soils.

The results showed a significant supply of nitrogen included in amino acids structures in soils. Amino acids represent a readily hydrolysable form of organic nitrogen by chemicals and enzymes, which is available for plants and soil microorganisms. The highest supply was observed for BOMF_{BC}, supplying 93.7% more nitrogen than the reference soil. Two other fertilizers - BOMF_P and BOMF_S - supplied 64.1% and 56.3%, respectively more than the reference soil.

Observed was the relationship between the contents of the readily hydrolysable fraction of nitrogen in three-stage acidic hydrolysis and the total amount of amino acids as well as the contents of the readily hydrolysable fraction of nitrogen in three-stage acidic hydrolysis and in amino acids. These relationships reflect well agreement between these results, representing macro and micro scale of processes, and mechanisms in soils treated with organic fertilizers. For both relationships the correlation coefficients were 0.998 and 0.999. These high values of correlation coefficients suggest significant participation of amino acids in the readily hydrolysable form of nitrogen.

CONCLUSIONS

It was estimated by the method of three-stage acidic hydrolysis that the character of transformation of nitrogen-containing compounds of peat, spropel, brown coal, in the process of their composting in mixtures with manure and balanced mineral additives, differs essentially and is predetermined by the origin and structure of organic matter of these native materials. Physico-chemical and biochemical factors of their processing play an important role and lead to an increase of readily (“easy”) hydrolysable nitrogen-containing compounds, which participate in the process of preparing balanced organic fertilizer. The relationship and high correlation between amounts of readily hydrolysable forms of nitrogen and amino acids was found. These substances represent a sub-fraction of readily hydrolysable forms of nitrogen and significantly reveal processes in soils treated with organic fertilizers.

REFERENCES

- Bambalov, N. 2000. Organic substances and classification of the meliorated soils forming as a result of peat layer destruction. *Acta Agroph.* **26**, 109–119.
- Bambalov, N. Smychnik, T. Maryganova, V., Strigutsky, V. & Dite, M. 2000. Peculiarities of chemical composition and the molecular structure of peat humic substances. *Ibid.* **26**, 149–177.
- Benbi, D.K. & Richter, J. 2003. Nitrogen Dynamics. In Benbi, D.K. & Nieder, R. (eds): *Handbook of Processes and Modeling in the Soil-Plant System*. Food Products Press, the Haworth Reference Press Imprints of the Haworth Press, Inc. New York, pp. 409–482.
- Buckman, H. & Brady, N. N. 1971. Soil and its properties. PWRiL, Warszawa, pp. 328–333. (In Polish).
- Casida, L.E. Jr., Klein, D. A. & Santorio, T. 1964. Sequential products of anaerobic denitrification in Norfolk soil material. *Soil Sci.* **98**, 371–376.
- Ciavatta, C., Antisari, L.V. & Sequi P. 1989. Humification parameters of organic materials applied to soil. In Bhattacharji, S., Friedman, M., Neugebauer, H.J. & Seelacher, A. (eds): *Humic Substances in the Aquatic and Terrestrial Environment*. Springer-Verlag, Berlin, pp. 177–185.
- Daniel, T.C., Sharpley, A.N., Edwards, D.R., Wedepoh, L.R. & Lenmunyon, J.L. 1994. Minimizing surface water eutrophication from agriculture by phosphorus management. *J. Water Soil Conserv.* **49**, 30–38.
- Durska, G. & Kaszubiak, H. 1980. Occurrence of α,ϵ -diaminopimelic acid in soil. III. α,ϵ -diaminopimelic acid as the nutritional component of soil microorganisms. *Pol. ecol.Stud.* **6**(2), 201–206.

- Flaig, W. 1986. Some basic principles of water management in peat. In Fuchsman, C.H. (ed.): *Peat and Water. Aspects of Water Retention and Dewatering in Peat*. Elsevier Applied Sciences Publishers. pp. 119–132.
- Hassink, J. 1995. Decomposition rate constant of size and density fractions of soil organic matter. *Soil Sci. Am. Soc. Am. J.* **59**, 1631–1635.
- Hassink, J., Neutel, A.M. & De Ruiter, P.C. 1994. C and N mineralization in sandy and loamy grassland soils: the role of microbes and microfauna. *Soil Biol. Biochem.* **26**, 1565–1571.
- Kofoed, D., Nemming, O., Brunfeldt, K., Nebelin, E. & Thomsen, J. 1981. Investigations on the occurrence of nitrosamines in some agricultural products. *Acta Agric. Scand.* **31**, 40–48.
- Kuprevich, V.F. 1951. The biological activity of soils and methods for its determination. *Dokl. Akad. Nauki SSSR*, **79**, 863–866. (in Russian).
- Kwak, J. C., Ayub, A. L. & Shepard, J. D. 1986. The role of colloid science in peat dewatering: principles and dewatering studies. In Fuchsman, S.H. (ed.): *Peat and Water Aspects of Water Retention and Dewatering in Peat*. Elsevier Applied Science Publishers, London, pp. 95–118.
- Larsson, B. K., Esterdahl, B. G. & Regner, S. 1990. Polycyclic aromatic hydrocarbons and volatile N-nitrosamines in some dried agricultural products. *Swedish J. Agric. Res.* **20**, 49–56.
- Maciak, F., Söchtig, H. & Flaig, W. 1977. Composition of amino acids in peat-forming plants and in peats. In *Soil Organic Matter Studies*. Vol. II. Proceedings of a Symposium Braunschweig, 6-10 September 1976. International Atomic Energy Agency, Vienna, pp. 343–357.
- Nieder, R., Benbi, D.K. & Isermann, K. 2003. Soil organic matter. In Bendi, D.K. & R. Nieder, R. (eds): *Handbook of Processes and Modeling in the Soil-Plant System*. Food Products Press, The Haworth Reference Press Imprints of the Haworth Press, Inc. New York, pp. 345–408.
- Parsons, J. W. & Tinsley J. 1975. Nitrogenous substances. In Gieseking, J. (ed.): *Soil Components*. Springer Verlag, Berlin, Vol 1, pp. 263–304.
- Paul, E.A. & Clark, F.E. 1996. *Soil Microbiology and Biochemistry*. Academic Press, San Diego, CA, 275 pp.
- Rowell, D.L. 1994. *Soil Science, Methods and Applications*. Addison Wesley Longman Limited. Edinburgh Gate Harlow, pp. 152.
- Sauerbeck, D. 1993. CO₂ – emissions from agriculture: Sources and mitigation potentials. *Water, Air, and Soil Pollution*. **70**, 381–388.
- Schnitzer, M. & Khan, S. U. 1978. Soil organic matter. Elsevier Scientific Publishing Company, Amsterdam. p. 261–262.
- Seiter, S. & Horwath, W.R. 2004. Strategies for management soil organic matter to supply plant nutrients. In Magdoff, F. & R.R. Weil, R.R. (eds): *Soil Organic Matter in Sustainable Agriculture*. CRC Press. p. 269–293.
- Skoropanov, S.G., Brezgunov, V.S. & Okulik, N.V. 1987. The extended fertility reproduction of peat soils. Minsk, Nauka and Tekhnika, pp. 248 (in Russian).
- Sławiński, C., Sokołowska, Z. & Walczak, R. 2000. Effects of secondary transformation of peat-moorsh soils on their physical properties. *Acta Agroph.* **26**, 85–93.
- Sörensen, J. H. 1967. Duration of amino acids metabolites formed in soil during decomposition reactions. *Soil Sci.* **104**: 204–241.
- Sokolov G.A., Tishkovich A.V., Shatikhina T.A. et al. 1995. Physico-chemical and biochemical transformation of kaustobioliths as the basis for producing efficient fertilizers. Proceed. of Int. Peat Society Symposium: Peat Organic Matter. Minsk. p. 101–102 (in Russian).
- Stevenson, G. 1972. *The Biology of Fungi, Bacteria and Viruses* (in Polish), PWRiL, Warszawa (in Polish).
- Szajdak, L. & Österberg, R. 1996. Amino acids present in humic acids from soils under different cultivations. *Environ. Int.* **22/3**, 331–334.

- Szajdak, L. & Sokolov, G. 1997. Impact of different fertilizers on the bound amino acids content in soils. *Int. Peat J.* **7**, 29–32.
- Szajdak, L., Jezierski, A. & Cabrera, M.T. 2003. Impact of conventional and no-tillage management on soil amino acids, stable and transient radicals and properties of humic and fulvic acids. *Org. Geochem.* **34**, 693–700.
- Trojanowski, J. 1973. The conversions of organic substances in soils. PWRiL. Warszawa, 67–70 (in Polish).
- Turski, R., Domżał, H. & Słowińska-Jurkiewicz, A. 1974. Impact of the colloidal fraction of humus on the hygroscopicity, the limit of the consisting and swelling of loessial soils. *Rocz. Glebozn.* **25**(3), 85–99.
- Von Hofe, E., Schmerold, I., Lijiński, W., Jeltsch, W. & Kleihus, P. 1987. DNA methylation in rat tissues by series of homologous aliphatic nitrosamines ranging from N-nitrosodimethylamine to N-nitrosomethyldodecylamine. *Carcinog.* **8**(9), 133–1341.
- Wilson, T., Paul, E.A. & Harwood, R.R. 2001. Biologically active soil organic matter fractions in sustainable cropping systems. *App. Soil Ecol.* **16**, 63–76.
- Życzyńska-Bałoniak, I. & Szajdak, L. 1993. The content of bound amino acids in the soil under rye monoculture and Norfolk crop rotation in different periods of plants development. *Pol J. Soil Sci.* **26**(2), 111–117.