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Possibilities of Coffee Spent Ground Use as a Slow Action Organo-mineral Fertilizer

Tomasz Ciesielczuk, Czesława Rosik-Dulewska**, Elwira Wiśniewska**
**Opole University*
***Institute of Environmental Engineering PAS, Zabrze*

1. Introduction

The purpose of soil fertilization is the provision of nutrients essential to plants in order for them to develop normally, fruit optimally and improve biological and chemical as well as physical characteristics of the soil in a range that is desirable for plants. A shortage of nutrients in soil might lead to the loss of crops. Over-fertilization might also lead to a reduction of crops, a decrease in their value, a rise in production costs and pollution of the environment. In Poland nearly 2,000,000 Mg of mineral fertilizers are used every year, though the most essential for soil fertility is natural fertilization [21].

Due to the fact that natural fertilizers gradually release nutrients to soil solution, they become a valuable source of organic matter and elements important for cultivation. They also improve the structure of the soil. Among the organic fertilizers most commonly used are: manure, slurry, green manure, post-fermentation waste and compost. Biodegradable wastes might be disposed through various methods, though they might be rarely used in an unprocessed form [13]. In case of natural fertilizers/recycled materials exploitation the only threat to cultivation is the possibility of bringing large quantities of heavy metals and organic compounds to the soil, which then might be absorbed by plants [10, 22]. A significant simplification of fertilizers usage in private gardens and potted cultivation is possible through the application of fertilizers in the form of tablets. However, to make fertilization complete, one should also provide easily absorbed elements through the application of organic-mineral fertilizer. "A fertilizer" in which mineral material (A) has been mixed with organic coffee spent grounds (CSG) might make a crucial contribution to a sustainable fertilization, which might be performed even by unqualified individuals. Ashes formed during burning of biomass might be used as a source of mineral elements. Such ashes form not only in biomass power plants, but also in numerous private households. Biomass is becoming more and more popular source of energy, which is connected with the formation of large quantities of ashes. Polish energy policy for the subsequent years assumes a constant rise in renewable energy, which is going to simultaneously cause a rise in the forming of ash, including ash formed as a result of straw burning. The Polish agricultural sector produces approximately 200–300 million Mg of biomass, including 25 million Mg of straw [6, 16]. Around 740 thousand Mg of ash, ready to be used in fertilizer production, might be formed after its incineration. The properties of the ash, if well examined, allow to use it in industry or agriculture.

Similar attempts were made towards furnace ashes [1, 24, 25]. Usage of ash fertilizers has been known for many years, though nowadays ash from the incineration of plants fertilized with sewage sludge should be subject to detailed supervision [4]. The essence of a balanced organic-mineral fertilization is the possibility of usage of multi-component, long-acting fertilizer, which could be applied in the moment of sowing, planting or replanting. Research on the impact of natural waste fertilizers (sewage sludge, food industry wastes) on soil and crops quality has been carried out for years, also in the case of granulated fertilizers, but we wish to emphasize that tests of our unique fertilizer were taken in Poland for the first time [3, 17, 23, 24].

2. The legal basis

Polish law defines fertilizers in the Act of 10 July 2007 about fertilizers and fertilization (Reg. 2007 no. 147 item 1033) as mineral, natural, organic, mineral and organic-mineral fertilizers meant to provide nutrients to plants or increase the fertility of soils and fish ponds. Basic parameters (including content of heavy metals) setting the quality of fertilizers are included in the decree of the Minister of Agriculture and Rural Development of 21 December 2009 about the execution of some regulations of the act regarding fertilizers and fertilization (Reg. 2009 no. 224 item 1804). In case of tablet fertilizers, which are the subject of this paper, containment norms of elements and pollutions for organic fertilizers are to be applied. The definition of a biomass is included in the decree of the Minister of Environment of 20 December 2005 about emission standards (Reg. 2005 no 260 item 2181). According to the decree a biomass is a product entirely or partially consisting of plants, coming from agriculture or forestry, which are burned in order to recover energy within them. The term 'biomass' refers also to agricultural, forestry or food industry plant waste. According to this definition coffee spent grounds (CSG) are considered as a biomass.

3. Materials and methods

The research was carried out using coffee spent grounds, formed after the preparation of coffee (under pressure of 15 atmospheres), dried in the sun and then dried to a constant mass at a temperature of 105°C. Gelatin, available in the retail trade, was used as a binder. The binding gelatin solution was prepared through the soaking of a weighed amount of gelatin in cold deionized water. Thus the obtained gel was then put into boiling deionized water. The final volume of the binding solution was 180 cm^3, which means that it was 2.8 times more concentrated than a typical food gelatin solution. The mineral supplement was made of ash formed during the incineration of oak's biomass, while magnesium sulfate in a line of an anti-needle-browning fertilizer. The oak wood in the form of woodchips was incinerated with bark. In order to obtain ash the biomass was incinerated at a temperature of 600°C for 3 hours in the muffle furnace and then finished at the same temperature for 1 hour [27]. The ash (A), which had been formed that way, was sieved through a 2 mm sieve and then dried to a constant mass. Capsules were made from cellulose sheets and collagen stick, available in the retail trade in the form of orange-yellow pearls.

3.1. Types of fertilizer tablets

After initial experiments concerning the optimal composition of specific types of fertilizers, the proper mass proportions were set and 3 series of fertilizer tablets were made (Table 1), including: acid organic fertilizer (K0), neutral mineral-organic fertilizer (K10) and acid organic anti-needle-browning fertilizer (K12).

Table 1. Mass proportion of components in fertilizer tablets
Tabela 1. Proporcje masowe składników w tabletkach nawozowych

	Coffee spent grounds (CSG)	Biomass ash (A)	Magnesium sulphate (MS)	Gelatine
K0	10	0	0	1
K10	9	1	0	1
K12	9	0.1	0.9	1

3.2. Method of making fertilizer tablets

CSG dried to a constant mass were mixed with ash A and magnesium sulfate MS. Later hot gelatin solution was added and all ingredients were mixed together. Then the obtained hot substance was put into the plastic matrix. The matrix was cooled and kept at a temperature of 10°C for 6 hours and then dried for 24 hours at a temperature of 105°C. Consequently the obtained tablets were then removed from the matrix and covered with a double sheet of cellulose, dampened and dried at a temperature of 105°C for 2 hours. The tablets were then covered with a hot collagen stick solution and dried at room temperature for 24 hours.

The tablets' density, the content of organic substance by weight method and the content of organic carbon by non-dispersive infrared (NDIR) method, after sample mineralization at a temperature of 1200°C, were determined. The content of phosphorus and Kjeldahl nitrogen was determined after mineralization by sulfuric acid. The content of sodium, potassium and calcium was determined with mineral solutions by FES method with BWB XP apparatus. The content of magnesium and heavy metals like zinc, copper, lead, nickel, chromium and cadmium were determined by atomic absorption spectroscopy (AAS) method with iCE

Thermo 3500 apparatus after microwave mineralization with aqua regia in Mars-X apparatus.

In order to determine the initial release of nutrients, a water extraction was performed, according to the PN-Z-15009 norm. In the extracts pH, EC, content of organic carbon and nitrogen were determined by NDIR method, after sample mineralization at a temperature of 850°C. The content of phosphate and nitrate ions was determined by titration, while phosphate and calcium ions content were determined in mineral solutions by FES method with BWB XP apparatus.

The pot research was carried out during a period of 2 months on the area exposed to the sun, but protected from the wind. The pot's capacity was 2.75 dm^3. They were filled with ready-made garden substrate available in the retail trade. Two fertilizer tablets were put in to each pot, 7.6-8.2 g each. Doses of fertilizer ($N/P_2O_5/K_2O/CaO$) per hectare were: 139/34/24/5, 169/47/62/76 and 168/33/55/28 kg respectively for K0, K10 and K12. In the control group no fertilization was applied. The experiment was repeated three times for every fertilizer serie. The plant chosen for testing was cucumber. Four seeds were planted in every pot. During the experiment an even humidity was ensured through watering with rain water, if needed. After 60 days the above ground parts of the plants were harvested and dried to a constant mass.

4. Results and discussion

All the tablets, before being covered with cellulose and collagen, were characterized by a dark brown-black color and despite the identical way of production and same size of matrices, different types of tablets differed in both size and mass (Table 2).

Tablets K10 were the smallest, which was caused by the highest share of ash in their content, which, due to its binding properties, enabled the highest density of CSG. The highest mass was a characteristic for K12 line of tablets due to magnesium sulfate, the lowest – K0, which was a line without any additives. This also caused the highest share of implemented material in reference to the overall mass of a tablet, which was 76.6 and 68.7 respectively for K12 and K0.

Table 2. Basic characteristics of investigated fertilizer tablets and comparison with data obtained for composts and law requirements for organic fertilizers
Tabela 2. Charakterystyka badanych OPK, tabletek nawozowych K0, K10 I K12 oraz porównanie do danych uzyskanych dla kompostów i wymagań prawnych dla nawozów organicznych

	CSG	K0	K10	K12	Composts made of sewage sludge [5]	Composts [7]	Reg. 2009 no.224 item 1804
Dimensions (xyz) [mm]	–	25x25x19	20x20x15	23x23x18	–	–	
Mass of fertilizer [g]	–	5.33(0.13)	5.76(0.15)	6.28(0.54)	–	–	
Mass of tablet [g]	–	7.76(0.12)	7.67(0.25)	8.19(0.17)	–	–	
Organic substances [%]	98.4	98.5	92.3	95.6	–	7.5–67.0	30
TOC [%]	34.1	33.6	32.2	32.5	43.2–72.4[1]	3.1–25.8	
$N_{Kiejd.}$ [%]	0.72	1.75	2.16	2.01	1.16–2.74[1]	0.52–2.90	0.3
C/N	47.4	19.2	14.9	16.2	19.6–42.7		
CaO [g/kg dw]	0.57(0.12)	0.61(0.03)	9.69(0.18)	2.58(0.32)	10.6–58.7	16–92	
MgO [g/kg dw]	4.85(0.59)	5.07(0.43)	6.57(0.02)	156(21.4)	1.8–11.5	–	
Na_2O [g/kg dw]	1.30(0.16)	1.32(0.26)	1.76(0.09)	1.56(0.03)	–	–	
K_2O [g/kg dw]	3.05(0.18)	3.00(0.21)	7.97(0.01)	3.29(0.10)	–	3.2–7.8	2.0
P_2O_5 [g/kg dw]	4.54(0.81)	4.35(1.0)	6.03(0.70)	3.97(1.13)	24.1–55.8	7.6–16.0	2.0

[1] – data concerns TC and TN parameters.
SD value in brackets

The content of organic matter in the examined tablets was high (above 90%), which is particularly crucial in the case of fertilizing sand soils, and have a limited time of holding water. The content of fat in the implemented fertilizer might strengthen water retention in the soil, which was confirmed during the field research using sewage from olive oil mill [3]. Poor substrates used in gardening do not only allow us to lower costs, but also limit the consumption of nonrenewable peat resources. Gelatin, used in the process of tablets creation, plays a crucial role not only as a binder for CSG and A, but also as a source of organic matter and nitrogen in a form that is possible for plants to absorb. It is important that the tablets' covers consist mainly of collagen, which is rich in organic carbon (37.1%) and, while swelling, slowly melts into the soil. The organic substance, being slowly mineralized, simultaneously releases elements into the soil, thus preventing over-fertilization and significantly prolonging the fertilizer's uptime. Due to this fact the assumed fertilizer's uptime exceeds 6 months. Another asset of the examined tablets is also the fact that in a case of drought the collagen covering hardens and consequently does not release the elements from the tablets filling. An important asset is also high (above 30%) content of organic carbon – a value comparable with the one in manure and higher than noted in composts [20].

The content of Kjeldahl nitrogen is similar in all 3 lines of tablets (lowest in K0) and is comparable with good quality compost. Examination of the nitrogen content in the tablets' filling indicated the highest amount of this element in K10 line (1.45% of the filling), with lower amounts in K12 and K0 (respectively 0.84% and 0.74% of the filling). The nitrogen content is high and it fulfills the demands of the Decree of the Minister of Agriculture and Rural Development about the execution of some regulations of the act regarding fertilizers and fertilization (Reg. 2009 no. 224 item 1804). An occurrence of this element in organic form ensures a balanced and slow release of it into the soil, which not only has a positive effect on long-range fertilization by preventing leaf chlorosis, but also prevents the leaching of the element into the groundwater.

The content of calcium (Table 2) is, as planned, highest in the line K10 and lowest in the line K0, intended for acidophilic plants, in case of which an excess of this element could have a negative effect by rising the pH of the substrate. The main calcium source in the fertilizer is the biomass ash, which mixed with CSG and bound with gelatin is relatively resistant to quick leaching, having a positive effect on the pH of the soil and contributing to the reduction of the availability of heavy metals for the plants, as well as the interchangeable aluminum activity [8, 12]. In the K10 line, designed as a neutral fertilizer proper for most plants, the content of calcium is relatively high; lower though than in composts and organic fertilizers (manure). Stabilization of pH is an important element of farming due to the fact of its' limited ability to absorb heavy metals.

The source of magnesium in the analyzed samples is magnesium sulfate (K12 line), as well as both the biomass ash and collagen covering. Content of MgO exceeding over 15% is favorable here, due to the fact of the crucial role of these elements in building chlorophyl, as well as its vulnerability to leaching. In both K0 and K10 lines the magnesium content is much lower and does not exceed 1%. Yet even in the case of fertilizer K12 the complex structure of the tablets ensures its slow release into the soil, which prevents losses caused by leaching.

The content of potassium is high in all types of tablets. Although the highest amount of this element (nearly 8 g K_2O/kg) was found in K10 line, no differences were noted between series K0 and K12. It shows a high share of organic potassium, which is favorable due to its slow release during mineralization of the tablets' organic matter. In all the series the content of potassium fulfills the regulations for organic fertilizers.

The content of phosphorus is interesting. The carried out tests of the tablets filling, as well as the finished product in covering, show that the main source of this element in all three lines is the filling material. Regardless of the line, the content of phosphorus in the finished product is 60.3% (0.45) in relation to the content of this element in the filling. The content of phosphorus is similar in K0 and K12 lines and about 40% higher in K10, which indicates the presence of mineral phosphorus. Phosphorus from the biomass ash is characterized by a limited solubility, which limits its absorption, though the presence of an organic phosphorus shall, to a large extent reduce shortages of this element [9]. The content of phosphorus in the tablets fulfills the regulations of the Decree Reg. 2009 no. 224 item 1804.

The heavy metals content in the examined types of fertilizers is presented in the Table 3. An addition of a biomass ash stabilizes the pH of a given fertilizer and also serves as a source of elements crucial to plants' metabolism [15]. The results show that the ash is a donor of those elements, though designated numbers are low and thus even in the line with the highest share of the biomass ash there is no risk of soil and plant pollution with toxic metals (Pb, Ni, Cr, Cd). It is possible then to use tablets in the farming of vegetables for direct use.

Table 3. Heavy metals content in biomass ash, investigated fertilizer tablets, composts and maximum levels for organic fertilizers [mg/kg dw]
Tabela 3. Zawartość metali ciężkich w popiele z biomasy, badanych tabletkach nawozowych, kompostach oraz dopuszczalne poziomy dla nawozów organicznych [mg/kg sm]

	A	K0	K10	K12	Composts [7]	Reg. 2009 no. 224 item 1804
Zn	609(117)*	25.3(1.79)	53.0(2.86)	25.9(2.65)	277-1756	–
Cu	121(9.6)	7.84(1.05)	14.6(0.71)	7.08(0.03)	36.3-283	–
Ni	19.0(4.4)	0.31(0.11)	1.06(0.07)	0.45(0.24)	11.3-217	60
Pb	23.0(2.3)	<0.03	1.63(0.23)	<0.03	24.6-545	140
Cd	1.72(0.48)	0.07(0.04)	0.15(0.04)	0.04(0.02)	<0.5-4.28	5
Cr	20.5(4.7)	<0.03	<0.03	<0.03	22.4-79.8	100
Mn	2481(403)	11.7(0.31)	281(31.2)	39.4(1.31)	–	
Fe	1217(328)	30.3(0.02)	130(7.3)	40.4(1.02)	–	

** SD value in brackets*

Regulations of the Decree of the Minister of Agriculture and Rural Development regarding the execution of some regulations of the act regarding fertilizers and fertilization (Reg. 2009 no. 224 item 1804) set a maximum content of nickel, cadmium, chromium, lead and mercury in organic fertilizers. The noted concentrations are 33–85 times lower than the norms in the Decree. Organic fertilizers (e.g. manure) might contain higher amounts of those elements, which is potentially dangerous for cultivated plants [26]. It confirms the validity of the usage of fertilizer tablets analyzed herein, which are based on materials nearly entirely free of metal pollutions. It is assumed that a number of bio-available metals in the examined fertilizers will not exceed 40–50% of their overall content, which in future should be confirmed or negated through specialist research [22, 24]. From the perspective of plants metabolism content of iron is particularly important. Its shortage (besides lack of magnesium and nitrogen) is the main reason for chlorosis.

The results of the leaching test provide only initial information about the number of elements released to the aqueous solution during the first 24 hours (Table 4). The shaking caused a partial disintegration of K0 line tablets and, to a smaller extent, K12 line of tablets. It depicts a strong binding of K10 tablets' filling, including ash with CaO. It was indicated that although the supplementation of the biomass ash provides water-soluble elements, they are released gradually into the soil due to the slow decomposition of the fertilizer tablet observed during the experiment. The final content of elements released into the soil (in the moment of making an extraction) will depend also on the precision of the covering creation, as well as on the time required for the mineralization of organic compounds in the examined tablets; in the case of gardening fertilizer tablets, both mineral and organic.

Table 4. Characteristic of water extract of investigated fertilizer tablets
Tabela 4. Charakterystyka wyciągu wodnego z badanych tabletek nawozowych

	K0	K10	K12
Reaction (pH)	5.39	6.91	5.65
EC [mS/cm]	1.21	1.20	3.29
N_{Kiejd} [mg/dm^3]	874.0	615.2	617.7
NO_3^- [mg/dm^3]	24.9	8.55	22.9
PO_4^{-3} [mg/dm^3]	54.3	20.7	36.0
K^+ [mg/dm^3]	230	378	252
Ca^{2+} [mg/dm^3]	44.1	63.2	113.5
Na^+ [mg/dm^3]	192	116	132
TOC [g/dm^3]	4.408	2.970	2.985

Crucial parameters (applied also to rare and valuable plants) are: pH and electrolytic conductivity. The series of initial experiments enabled to optimize an amount of biomass ash, which opened the possibility of producing tablets of adequately low pH (proper for acidophilic plants) in case of K0 line, as well as of neutral pH in case of K10 line (a universal fertilizer for most plants). K12 line has acidic pH and the supplement of magnesium sulfate fills in the lack of magnesium ions, thus preventing needle chlorosis (Table 1). According to Arvidsson, Lundkvist [2], Park et all [19] a tree ash alkalizes a soil, enlarges cation-exchange capacity and maximum level of alkaline cations, although a significant rise of pH might cause iron to move to its +3 form, which might cause a lack of this element [2, 19].

Soil salinity caused by an overdose of mineral fertilizers results in deteriorated growth and even in the death of plants [18]. The essence of the proposed "fertilizer" is then a slow release of minerals within it, in order to limit leaching of elements and enable plants to absorb them. Electrolytic conductivity of K0 and K10 fertilizer lines is similar, although probably it is a result of a lack of decomposition of the tablets. It is supposed that after decomposition of K10 tablets, the amount of ions released to the solution should rise. The test confirmed the stability of the examined tablets. In case of K12 line, as an effect of magnesium sulfate supplement, the electrolytic conductivity is too high, i.e. 3,29 mS/cm, which, in the case of an overdose, might cause harmful soil salinity. It is especially important in the case of plants of limited demand for fertilizers and it also happens while applying commercial, long-lasting fertilizers [11]. A strong rise of conductivity was noted also after modifying ash-sewage sludge granules (coal ash + municipal sewage sediments) with potassium salts (KCl and K_2SO_4). The noted conductivity was 44 mS/cm [23]. the small amount of nitrate ions released into the solution is particularly important in the analyzed fertilizers. NO_3^- ion is not subject to exchangeable sorption in the soil and thus it is vulnerable to leaching [28]. Nitrogen in the analyzed fertilizer tablets is almost entirely organic, which limits its losses and positively influences its slow release, replacing the partition of a basic dose of a traditional fertilizer (manure, slurry) on a few portions, which always makes additional courses of a spreader necessary. Such courses are not always possible due to environmental conditions, e.g. ground humidity or a rise of production costs [14]. An additional asset is the possibility to apply the fertilizer in the moment of planting, because of the delayed release of compounds, which enables the regeneration of the root system.

The high content of calcium in the solution of K12 line tablets is interesting. Despite the lower content of this element in the tablets concentration of Ca^{2+} ions, in the solution was nearly two times higher. This can be explained by the higher stability of K10 tablets and, in consequence, lower release of calcium during shaking. The content of calcium might also have an influence on the relatively high crops in the pot experiment.

The initial pot research showed the stability of the fertilizer tablets during the period of two months. While analyzing roots, many healthy, small roots were noted to overgrow the fertilizer tablets. The applied fertilization on the level of the maximum allowed dose of nitrogen (170 kg N/ha) did not show an ecotoxic influence [28]. The obtained biomass of cucumber shoots was higher than in the control group: 1.6, 2.6 i 2.4x respectively for the lines K0, K10 and K12. Although in the case of K10 line crop mass was the highest (an average 5.4 g dw/shoot), the more balanced results were attained due to the slightly lower mass of the K12 line. Standard deviation value was 0.61 for K12 and 1.74 for K10. It shows a cucumber's invulnerability to low pH and salinity higher than in K0 and K10, characteristic for K12 fertilizer.

5. Conclusion

1. Fertilizer tablets, very popular in both professional and amateur gardening, are usually products of a big gardening company, characterized by a relatively high price. An important alternative for them would be the possibility of producing them on one's own or in small, family companies operating in a local market.
2. In the process of tablet production the main component of the fertilizer might be cumbersome and easily rotting coffee spent ground. Production of fertilizer tablets from CSG, biomass ash and magnesium sulfate not only allows it to lower the mass of produced wastes, but might also contribute to improving the productivity of soils.
3. These fertilizers, rich in nitrogen, potassium, calcium and organic substance, decompose slowly, which is essential from the point of view of nutrients' availability (usually in the organic form).
4. Slow decomposition of tablets prolongs the time of the fertilizer's influence, which gradually releases elements, according to the rules of constant and balanced development.
5. The low content of heavy metals proves the high quality of the analyzed fertilizers, which enables them to be used in the cultivation of edible plants. These fertilizers used in professional or amateur gardening, might significantly lower cultivation costs, due to the possibility

of fertilization only once a season - in the moment of planting or sowing. It is particularly important in the case of plants cultivated in containers, in which fertilization is time-consuming and the possibility of using a poor mineral substrate might contribute to lowering production costs and minimizing the environmental pressure through limitation of peat exploitation - the material which is now commonly used in the production of gardening subtracts.

References

1. **Antonkiewicz J.:** *Wykorzystanie popiołów paleniskowych do wiązania metali ciężkich występujących w glebie*. Ochrona Środowiska i Zasobów Naturalnych, 41, 398–405 (2009).
2. **Arvidsson H., Lundkvist H.:** *Effects of crushed wood ash on soil chemistry in young Norway spruce stands.* For. Ecol. Manage., 176, 121–132, (2003).
3. **Barbera A.C., Maucieria C., Cavallarob V., Ioppoloa A., Spagna G.:** *Effects of spreading olive mill wastewater on soil properties and crops, a review.* Agricultural Water Management, 119 43–53, (2013) http://dx.doi.org/10.1016/j.agwat.2012.12.009.
4. **Bielicka A., Bojanowska I., Krupa A., Schuetz P., Leszczyński J.:** Biomasa – produkt II stopnia oczyszczania ścieków jako źródło energii odnawialnej. Ochrona Środowiska i Zasobów Naturalnych, 31, 296-301, (2007).
5. **Boruszko D.:** *Badania i ocena wartości nawozowej kompostów i wermikompostów*. Rocznik Ochrona Środowiska (Annual Set the Environment Protection), 13, 1417–1428 (2011).
6. **Bzdawka-Piątkowska K.:** *Stan obecny i perspektywy rozwoju energetyki odnawialnej w Polsce.* Ochrona Środowiska i Zasobów Naturalnych, 33, 20–26, (2007).
7. **Ciesielczuk T., Rosik-Dulewska Cz., Karwaczyńska U.:** *Komposty z odpadów jako potencjalne źródło substancji organicznej i biogenów w produkcji roślinnej.* (w) Kompostowanie i mechaniczno-biologiczne przetwarzanie odpadów (red.) G. Siemiątkowski, 108–116, Opole (2011).
8. **Ciba J., Skwira M., Zołotajkin M.:** *Wpływ wybranych substancji chemicznych na zawartość glinu wymiennego i pH gleb leśnych – przegląd literaturowy*. Ochrona Środowiska i Zasobów Naturalnych, 31, 63–67, (2007).
9. **Demeyer A., Voundi Nkana J.C., Verloo M.G.:** *Characteristics of wood ash and influence on soil properties and nutrient uptake: on overview*. Bioresource Technol., 77, 287–295 (2001).

10. **Fekri M., Kaveh S.:** *Heavy metal accumulation in soil after application of organic wastes*. Arab J Geosci 6, 463–467, 2013DOI 10.1007/s12517-011-0328-1
11. **Golcz A., Komosa A.:** *Uwalnianie się azotu, fosforu i potasu z nawozu wolnodziałającego osmocote plus w uprawie papryki (Capsicum annuum L.)* Acta Agrophysica, 7(3), 567–576 (2006).
12. **Hermann J., Harasimowicz-Hermann G.:** *Przydatność popiołów ze spalania biomasy do stosowania w rolnictwie i rekultywacji gruntów*. Inżynieria Ekologiczna, 12, 195–196 (2005).
13. **Kazimierowicz J.:** *Organic waste used in agricultural biogas plants***.** Journal of Ecological Engineering Volume 15, No. 2, April 2014, pp. 88–92. DOI: 10.12911/22998993.1094983
14. **Krawczyk W., Walczak J., Paraponiak P., Dąbrowska-Wieczorek M., Herbut E.:** *Determining the burden of organic fertilizers on the soil and water environment*. Rocz. Nauk. Zoot., 40, 2 209–226 (2013).
15. **Kucharski J., Jastrzębska E.:** *Liczebność drobnoustrojów i właściwości fizyko-chemiczne gleby zanieczyszczonej popiołem drzewnym*. J. Elementol., 10(3), 513–525 (2005).
16. **Kwaśniewski D.:** *Ocena produkcji i potencjalnych możliwości wykorzystania słomy do celów grzewczych na przykładzie powiatu żywieckiego*. Inżynieria Rolnicza, 6, 113–119 (2008).
17. **Ociepa-Kubicka A., Pachura P.:** *Wykorzystanie osadów ściekowych i kompostu w nawożeniu roślin energetycznych na przykładzie miskanta i ślazowca.* Rocznik Ochrona Środowiska, 15, 2267–2278 (2013).
18. **Mazur Z., Radziemska M., Tomaszewska Z., Świątkowski Ł.:** *Effect of sodium chloride salinization on the seed germination of selected vegetable plants*. Scientific Review – Engineering and Environmental Sciences, 62, 444–453 (2013).
19. **Park B.B., Ruth D.Y., James M.S, Don K.L., Lawrence P.A.:** *Wood ash effects on plant and soil in a willow bioenergy plantation*. Biomass Bioenerg., 28(4), 355–365 (2005).
20. **Poulsen P.H.B., Magid J., Luxhøi J., de Neergaard A.:** *Effects of fertilization with urban and agricultural organic wastes in a field trial - Waste imprint on soil microbial activity*. Soil Biology & biochemistry 57 794e802 doi:10.1016/j.soilbio.2012.02.031.
21. Rocznik Statystyczny Rolnictwa 2011. Główny Urząd Statystyczny, 165, Warszawa 2012.

22. **Rosik-Dulewska Cz., Karwaczyńska U., Głowala K., Robak J.:** *Elution of heavy metals from granulates produced from municipal sevage deposits and fly-ash of hard and brown in the aspect of recycling for fertilization purposes*. Archives of Environment Protection, 34(2), 63–71 (2008).
23. **Rosik-Dulewska Cz., Karwaczyńska U., Ciesielczuk T., Głowala K.:** *Possibilities of non industrial re-usage of waste according to rules in of environment protection*. Rocznik Ochrona Środowiska (Annual Set the Environment Protection), 11, 863–874 (2009).
24. **Rosik-Dulewska Cz., Karwaczyńska U., Ciesielczuk T.:** *Metale ciężkie w granulatach popiołowo-osadowych wykorzystywanych do celów nawozowych*. Przemysł Chemiczny 92/8 :1520–1524 (2013).
25. **Roszyk J., Nowosielski O., Komosa A.:** *Przydatność ekstraktów z popiołu węgla brunatnego do nawożenia dolistnego kalafiora.* Roczniki Akademii Rolniczej w Poznaniu – CCCLVI, 189–197 (2004).
26. **Tella M., Doelsch E., Letourmy P., Chataing S., Cuoq F., Bravin M.N., Saint Macary H.:** *Investigation of potentially toxic heavy metals in different organic wastes used to fertilize market garden crops*. Waste Management, 33, 184–192, (2013) http://dx.doi.org/10.1016/j.wasman.2012.07.021
27. **Xiao R., Chen X., Wang F., Yu G.:** *The physicochemical properties of different biomass ashes at different ashing temperature*. Renewable Energy, 36, 244–249 (2011).
28. **Wójcik P., Dyśko J., Kaniszewski S., Kowalczyk W., Nowak J.:** *Zrównoważone nawożenie roślin ogrodniczych*. Skierniewice (2014).

Możliwości zastosowania odpadów poekstrakcyjnych kawy jako wolno działającego nawozu organiczno-mineralnego

Streszczenie

Biodegradowalna frakcja odpadów po wydzieleniu jej ze strumienia odpadów komunalnych może stanowić ważne źródło materii organicznej, która zawracana do użytkowania mogłaby stanowić cenny nawóz rolniczy. W szczególności materia organiczna zawarta w odpadach przemysłu spożywczego oraz powstająca w gospodarstwach domowych może służyć do wytwarzania nawozu. W niniejszej pracy przedstawiono wyniki badań zastosowania nawozu wykonanego z odpadów poekstrakcyjnych kawy (CSG) modyfikowanych dodatkiem popiołu z termicznego przekształcania biomasy (A) lub siarczanem magnezu (MS), jako wolnodziałającego nawozu organicznego (organiczno-mineralnego) konfekcjonowanego w postaci tabletek. Nawóz taki może być zastosowany w momencie sadzenia roślin, ponieważ uwalnianie składników w nim zawartych następuje dopiero po pełnym uwilgotnieniu tabletki nawozowej. Dzięki otoczce kolagenowej, uwalnianie składników pokarmowych do gleby następuje powoli, co zmniejsza ryzyko przenawożenia lub utraty składników w drodze wymywania ich w głąb profilu gleby. Tabletkowane nawozy wykonane z mieszaniny CSG oraz A wpisują się w realizację zasad dobrej praktyki rolniczej oraz zrównoważonego rozwoju, a tematyka tak unikalnie skonstruowanego nawozu jest podejmowana po raz pierwszy.

Słowa kluczowe:
nawóz, odpady poekstrakcyjne kawy, popiół z biomasy

Keywords:
fertilizer, coffee spent ground, biomass ash