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EVALUATION OF THE POSSIBILITY TO USE ORGANIC ACIDS SOLUTIONS FOR PRODUCTION OF FERTILIZERS BASED ON HORTICULTURAL MINERAL WOOL WASTE

OCENA MOŻLIWOŚCI WYKORZYSTANIA ROZTWORÓW KWASÓW ORGANICZNYCH DO OTRZYMYWANIA PREPARATÓW NAWOZOWYCH NA BAZIE ODPADOWEJ OGRODNICZEJ WEŁNY MINERALNEJ

Abstract: The aim of the research was evaluation of the possibility to use organic acids solutions for production of fertilizers based on mineral wool waste. This substrate thanks to inert character and good air-water relationship is commonly used in greenhouse industry. Increased production of vegetable in soilless culture due to world's population growth. However mineral wool after full crop cycle is non-biodegradable – dangerous waste. Possibility of extraction nutrients from this kind of substrate could be solution of that important environmental problem. Before analyses mineral wool waste was grinded on 0.40 mm sieve. Then the extraction process was conducted using 2 % m/m and 10 % m/m citric acid, 2 % m/m and 10 % m/m formic acid, 0.2 % m/m and 2 % m/m acetic acid for 3 and 6 hours at temperature 25 ^{o}C. Solid phase before analyses was mineralized. Iron, phosphorus was analyzed using spectrophotometer methods. Iron analysis is based on formation of a coloured ferric ion complex with 2,2'-bipyridyl. Phosphorus analysis is based on formation of molybdenum blue complex. Calcium and magnesium was examined by complexometric titration with EDTA and using Eriochrome Black T as an indicator, while calcium ions concentration was analyzed using calconcarboxylic acid as an indicator. Content of nutrients after extraction from mineral wool waste allows to conclude that obtained liquid phase can be used as a fertilizer component while solid phase can be used in mixed substrate production.

Keywords: gardening mineral wool, waste, fertilizers, organic acids solutions

Introduction

Global population is constantly increasing. It is likely to achieve 9 billion by 2050. As an effect water consumption will be bigger and agricultural production should be

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doubled in order to provide enough food [1]. Solution of that problem might be hydroponics, which allow to produce crops in greenhouses, private gardens, on the roofs of the buildings or in places where traditional methods cannot be used. Hydroponics cultivation, where plants grow with their roots in an inert medium feed with soluble minerals and nutrients, has many advantages: it requires less water and has shorter harvest time than traditional one [2].

There are many kind of substrates used in hydroponics: organic like coconut fibre, peat and inorganic for example perlite or rock wool. The most commonly used substrate in European Union is mineral wool. It posses qualities like good air-water relationship, high water holding capacity and longevity, which characterize an effective substrate [3].

One of the leading rock wool producer in Poland is Rockwool Group. The first step of rock wool production is melting process in which raw materials (basalt rocks, chalk and coke) are melted at temperatures above 1500 ^{o}C. The melts goes onto the spinning machine, where the fibres are spun. Binding agents are added to make stable fibres. The last step is forming ready product by cutting into slabs, blocks or cubes and packed [4].

Rock wool slabs after full crop cycle turns into non-biodegradability waste. It is serious ecological problem due to big quantity (even 115 thousand tons in Europe), hygroscopic properties and big volume of used substrate. Rock wool slabs are very often accumulated on ‘wild dumps’, which negatively change landscape and can be dangerous for animals and people because of rock wool respirable fibres. Rational methods of reuse of that kind of waste must be found [5, 6].

Rock wool slabs used as a substrate in agriculture contain parts of plants like roots and nutrients from the fertilizers. Therefore extraction of that residues seem to be an interesting opportunity. Phases after extraction can be source of nitrogen, iron, phosphorus, calcium or magnesium, which are important fertilizers components. Mineral substances are essential for appropriate plant growth, they take part in many functions like transport of energy, they regulate enzymes activity and increase immunity from diseases. Production of fertilizers based on extracts containing nutrient for plants can be a solution of the ecological problem such as mineral wool waste [7–10].

Materials and methods

The aim of this research was evaluation of the possibility of nutrients extraction from mineral wool waste using organic acid solutions and reuse liquid and solid phases for fertilizers purposes. For analysis has been taken wool after one year of tomato cultivation, one year of cucumber cultivation and wool after two years of mixed cultivation.

Samples of post-mineral wool waste, before the extraction process were dried at 30 ^{o}C for one day. Dry and brittle material was grinded to a diameter of 0.40 mm.

Extraction process was conducted at 25 ^{o}C for two extraction time: 3 hours and 6 hours. Three kind of acids were used: 2 % m/m and 10 % m/m citric acid, 2 % m/m and

10 % m/m formic acid, 0.2 % m/m and 2 % m/m acetic acid. The mass ratio solid phase to liquid was φ = 1:10. Extraction was performed using Water Bath Shaker Type 357, ELPAN. Phases was separated using centrifuge MPW-360 for 10 minutes and speed 2500r/min. Liquid phase was diluted to volume of 250 cm^3 with distilled water. The solid fracture was mineralized in 2:3 (by volume) mixture of nitric acid and sulphuric acid by heating at temperature of 250 ^oC for 30 minutes. After cooling, small amount of water was added and samples were heated again at temperature of 250 ^oC for 15 minutes. After process samples were diluted to the mark in volumetric flasks (250 cm^3).

The content of phosphorus was determined by spectrophotometric method based on formation of a blue complex phospho-molybdic according to PN-88/C-87015. The absorbance was measured in a quartz cuvette with an absorption layer thickness of 1 cm at a wavelength of 690 nm using an spectrophotometer Jasco V-630 [11].

The content of iron was determined according to PN-85/C-84092. Ions of iron III are reduced to ions of iron II using hydroxylammonium chloride. The coloured complex of iron ions II with 2,2'-bipyridyl is created in solution at pH = 3.1. The absorbance was measured in a quartz cuvette with an absorption layer thickness of 1 cm at a wavelength of 520 nm using an spectrophotometer Jasco V-630 [12].

The content of calcium and magnesium was carried out by titration of samples using EDTA solution at a pH of 10 and Eriochrome Black T as an indicator. The content of calcium was determined using complexometric titration using also EDTA solution but at a pH of 13 and calconcarboxylic acid as an indicator.

Results and discussion

Disposal of mineral wool slabs is very difficult due to its non-biodegradability. However, post-production rockwool contains residues of important nutrients, which can be recovered and reused as a component for new fertilizer product.

Table 1 shows the results of phosphorus, iron, calcium and magnesium content in liquid phase after its extraction form mineral wool waste using for this purpose 2 % m/m and 10 % m/m citric acid, 2 % m/m and 10 % m/m formic acid, 0.2 % m/m and 2 % m/m acetic acid at temperature of 25 ^oC and for two extraction time: 3 and 6 hours.

The highest content of nutrients in liquid phase after extraction was obtained using 10 % (m/m) citric acid and 10 % (m/m) formic acid. Longer time of extraction affected in highest content of examined nutrient. Moreover higher concentration of extractant used in process leads to higher amount of iron, phosphorus, calcium and magnesium in analyzed liquid phase. The biggest amount of phosphorus, iron and calcium was achieved for 6-hour-long extraction using 10 % (m/m) citric acid. Content of mineral substances was the lowest when as an extractant acetic acid was used.

Table 2 shows the results of phosphorus, iron, calcium and magnesium content in solid phase after its extraction form mineral wool waste using for this purpose 2 % m/m and 10 % m/m citric acid, 2 % m/m and 10 % m/m formic acid, 0.2 % m/m and 2 % m/m acetic acid at temperature of 25 ^oC and for two extraction time: 3 and 6 hours.

Table 1

The mineral substances content in the liquid phases obtained by extraction of nutrients from mineral wool waste by using solutions of acetic, citric and formic acid

Extractant	Extractant's concentration [% m/m]	Extraction time [h]	PO_4^{3-} content [% m/m]	Fe^{2+} content [% m/m]	Ca content [% m/m]	Mg content [% m/m]
Acetic acid	0.2	3	0.30	0.06	0.40	0.06
	2	3	0.54	0.02	0.28	0.04
Citric acid	2	3	1.02	0.61	1.40	0.34
	10	3	1.60	2.27	1.92	0.19
Formic acid	2	3	0.01	0.48	1.73	0.02
	10	3	0.31	2.21	2.79	0.14
Acetic acid	0.2	6	0.32	0.02	0.35	0.22
	2	6	0.31	0.03	0.48	0.48
Citric acid	2	6	1.18	0.63	1.46	0.37
	10	6	1.85	2.62	5.22	1.23
Formic acid	2	6	0.02	0.54	1.69	0.77
	10	6	0.15	2.35	3.97	2.43

Table 2

The mineral substances content in the solid phases obtained by extraction of nutrients from mineral wool waste by using solutions of acetic, citric, formic acids

Extractant	Extractant's concentration [% m/m]	Extraction time [h]	PO_4^{3-} content [% m/m]	Fe^{2+} content [% m/m]	Ca content [% m/m]	Mg content [% m/m]
Acetic acid	0.2	3	2.58	1.89	9.74	0.18
	2	3	1.82	1.79	6.99	0.85
Citric acid	2	3	1.22	0.42	7.18	2.00
	10	3	1.02	0.51	5.82	1.55
Formic acid	2	3	2.19	1.70	5.37	2.00
	10	3	1.79	1.86	6.43	0.94
Acetic acid	0.2	6	2.77	2.39	13.52	0.05
	2	6	1.95	1.78	9.34	0.31
Citric acid	2	6	1.22	1.49	11.80	0.39
	10	6	0.97	0.04	6.64	1.04
Formic acid	2	6	2.18	0.69	6.40	0.26
	10	6	2.26	0.17	7.10	1.49

The highest content of phosphorus, iron, calcium and magnesium was obtained for extraction using acetic acid solutions. Magnesium content in solid phase after extraction was the lowest. Most of process using extractant of lower concentration and for longer time of extraction affected in biggest amount of examined mineral substances.

The highest content of nutrients was obtained for 6-hour-long extraction using 10 % (m/m) citric acid. The results are presented in Fig. 1. Citric acid is recommended in

Regulation (EC) No 2003/2003 of the European Parliament and of the Council of 13 October 2003 relating to fertilizers as an effective extractant of phosphorus, which is very important nutrient. Global consumption of phosphates which are main phosphorus source is rising. The result of that is phosphates price increase. Therefore recovery of phosphorus from mineral wool slabs is very important.

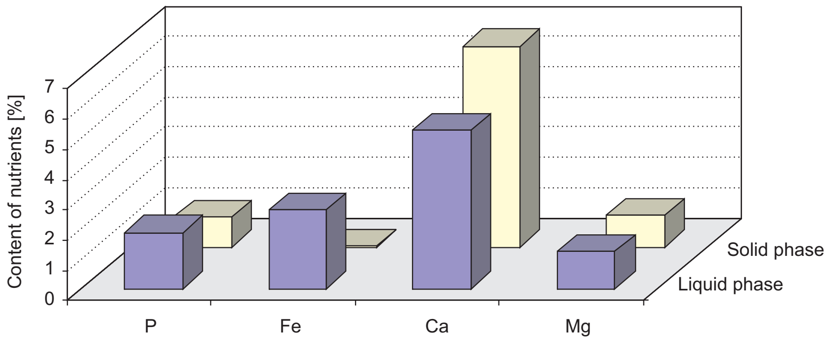

Fig. 1. Mineral substances content in the liquid and solid phases obtained from mineral wool by using 10 % (m/m) citric acid during 6 hours extraction

Figure 2 presents block diagram of receiving exemplary hydroponic solution for tomato cultivation. Liquid phase obtained from extraction process using 10 % (m/m)

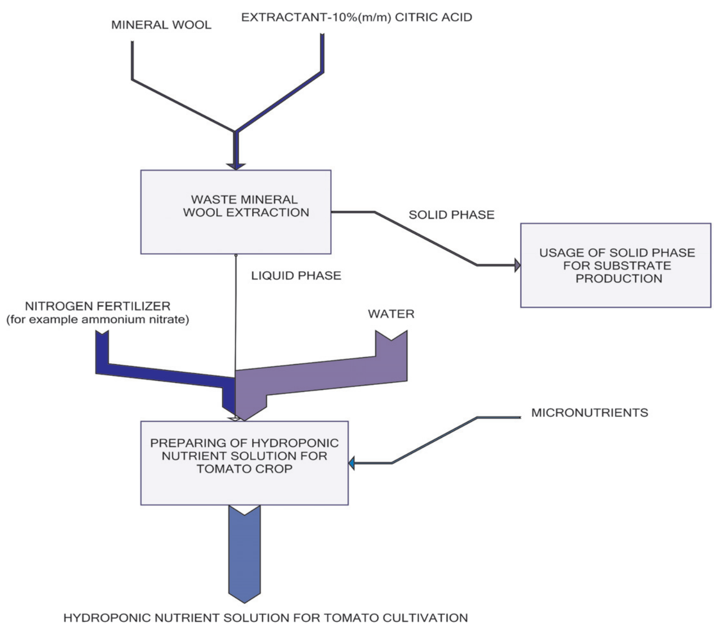

Fig. 2. Block diagram of receiving the hydroponic solution for tomato cultivation based on horticultural mineral wool waste

citric acid after dilution and necessary microelements supplementation can be used to create fertilizers. Nitrogen fertilizer for example ammonium nitrate is added to provide nitrogen in hydroponic solusion. It is possible to use also solid phase obtained after extraction using citric acid for substrate production in order to improve their air-water properties. Nutrients contained in solid phase is another advantage of this proposition of miner wool waste reuse.

Conclusions

Rockwool is commonly used substrate in horticulture. Big amount of mineral wool slabs after crop production negatively affects environment, therefore a rational method of reuse must be found. Extraction of nutrients residue from mineral wool waste may solve this problem. The extraction process was conducted using organic acid solutions as a extractant. The content of mineral substance in liquid and solid phase after extraction was determined by type of extractant and extraction time. The highest results was obtained for 6-hour-long extraction process using 10 % (m/m) citric acid. The results show that organic acid solution can be used to extract essential nutrients from horticultural mineral wool waste. Liquid phase which was obtained during extraction can be used to receive fertilizer products and solid phase for example as a supplement in substrates production in order to improve their air-water properties.

Acknowledgments

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[12] Polska Norma PN-85/C-84092 Surowce fosforowe. Metody badań. Oznaczanie składników podstawowych.

OCENA MOŻLIWOŚCI WYKORZYSTANIA ROZTWORÓW KWASÓW ORGANICZNYCH DO OTRZYMYWANIA PREPARATÓW NAWOZOWYCH NA BAZIE ODPADOWEJ OGRODNICZEJ WEŁNY MINERALNEJ

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Abstrakt: Ciągle wzrastająca liczba ludności naświecie jest przyczyną zwiększonego zapotrzebowania na żywność, a tym samym konieczne jest zwiększenie poziomu produkcji rolnej. Można osiągnąć większą wydajność zbiorów dzięki zastosowaniu upraw hydroponicznych, które są popularne w hodowli kwiatów ciętych oraz warzyw. Dominującym podłożem w tego typu uprawach jest wełna mineralna, która charakteryzuje się korzystnymi właściwościami powietrzno-wodnymi. Podłoże po uprawie stanowi uciążliwy, nieulegający biodegradacji odpad. Podejmowane są działania mające na celu rozwiązanie tego ekologicznego problemu. Jednym z nich jest wykorzystanie składników mineralnych, takich jak żelazo, fosfor, wapń i magnez, pozostałych po uprawie w podłożu. Przeprowadzono badania mające na celu określić możliwość wykorzystania do ekstrakcji tych składników roztworów kwasów organicznych. Oznaczenie w poekstrakcyjnych fazach (ciekłej i stałej) zawartości badanych pierwiastków pozwoli na ustalenie optymalnych warunków pozwalających wykorzystać je do uzyskiwania preparatów nawozowych. W otrzymanych próbkach po procesie ekstrakcji trwającej 3 i 6 godzin przy użyciu roztworów kwasów octowego, cytrynowego i mrówkowego zbadano zawartość fosforu, żelaza, wapnia i magnezu. Próbki stałe poddano mineralizacji przed przeprowadzeniem analiz. Oznaczanie fosforu i żelaza wykonano, używając metod spektroskopowych. Badanie zawartości wapnia i magnezu wykonano za pomocą miareczkowania, używając jako titranta roztworu EDTA. Na podstawie uzyskanych wyników można stwierdzić, że poekstrakcyjne fazy ciekłe mogą być wykorzystane przy produkcji preparatów nawozowych, natomiast faza stała może stanowić dodatek poprawiający właściwości podłoży ogrodniczych.

Słowa kluczowe: wełna mineralna, odpad, preparaty nawozowe, roztwory kwasów organicznych