EFFICIENCY OF ORGANIC WASTE RECYCLING THROUGH VERMICOMPOSTING PROCESS

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SUMMARY

The agricultural sector and growing food production needs relies on chemical fertilizers. This initially had positive effects on production, but over the last decade the negative impacts of overuse have resulted in low crop productivity, increased pest and disease infestation, soil degradation and consequent adverse effects on environmental parameters. As one of the possibilities in organic farming we found vermicomposting as the more sustainable practice. For the assembly of vermicomposting, mature cattle manure was utilized in three different combinations with organic material and earthworms inoculations (the household waste, the grass clippings and mixture). The experiment was set up by random block design in three replications. Analyzes of qualitative parameters of final product showed a pH reaction neutral to slightly alkaline. The nitrogen compound varied between 2.7-2.9 %, while organic carbon varied between 45.59-47.41% showing a C/N ratio of 16.7-16.67. The potassium content varied between 1.1-1.2% K_2O and phosphorus from 0.3-0.5%. The experiment indicates quite good results of vermicomposting of household waste with manure, showing a neutral pH reaction optimal content of ash and carbon with almost similar and good NPK contents and increased C/N ratio of 16.7 and with satisfying trace elements content and heavy metal contents under the limits. These results indicate that vermicomposting can increase quality of final product.

Key words: *vermicomposting, earthworms, recycling, organic waste*

INTRODUCTION

Vermicomposting may be a mesophilic process (Edwards and Burrows, 1988) that involves a joint action of earthworms (active at 10-32 °C) and mesophilic microbes (Benitez *et al*., 1999) for the conversion of organic wastes into a valuable conclusion called vermicompost. Sinha *et al*. (2010) stated that earthworms restore and improve

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soil fertility and significantly boost crop productivity. It's been found that over the last 20 years, 75% of the agricultural sector relies on chemical fertilizers in agricultural production. This initially had positive effects on production, but over the last decade the negative impacts of overuse have resulted in low crop productivity, increased pest and disease infestation, soil degradation and consequent adverse effects on environmental parameters. This has led to the emergence of the employment of organic agriculture through the varied organic amendments, bio pesticides and bio control measures by researchers and farmers in numerous countries, which has created selective markets for organic products. This can be also supported by the increased use of solid organic waste produced at different levels which mainly includes 46% of organic waste globally, incorporated into soil and water causing various pollutants. Such organic waste is recycled by processes like vermicomposting which may produce organic fertilizers rich in nutrients that are an enriched source of beneficial microbes. Increased public interest and environmental problems associated with the utilization of manure are directing farmers towards alternative solutions, and composting enables a big reduction of environmental problems associated with the employment of assorted manure fertilizers. One of the simplest explanations for vermicomposting is a process that uses earthworms to transform organic residues into a secondary product named vermicompost that can be used as a fertilizer for crop production (Dominguez, 2004). Vermicompost improves the physical, chemical and biological properties of the soil as well contributes to organic enrichment (Chauhan and Singh, 2013). Vermicomposting is the biotechnological method of composting by using different species of earthworms to boost waste conversion mechanism and achieve better product (Devi and Prakash, 2015). The aim of this study is to provide a vermicompost enriched by nutrient and microorganism utilized from mixed bio waste using earthworms.

MATERIALS AND METHODS

For the assembly of vermicompost, partly mature manure was utilized in three different combinations with organic material and earthworms. Mature manure was used as an initial substrate for composting with California earthworms (*Eisenia fetida*, Figure 1).

Figure 1. California earthworms (*Eisenia fetida*)

The experiment was organized in line with a random block design in three replications. The initial mature manure was placed in three combinations with household waste, the grass clippings, while the controls were a combination of the previous two combinations. Moistening (if required) was performed in order to maintain the moisture level at 40- 50 %. The composting material was prepared in plastic airtight boxes with a volume of 40 L dimension 36 x 35 x31 cm (L x W x H), at the underside and sidelined wrapped with dark waterproof canvas with small holes. Inoculation composting of epigeic California earthworms was added to every separate box (10 worms per kg material) on an initial mass of 5 kg of manure per treatment. In each box, 1 kg of the mentioned organic materials were added to the surface at weekly intervals. Vermicompost was mixed, finely sieved, sampled, and analyzed after 6 months. The mixtures of used treatments were shown in Figure 2.

Figure 2. Organic materials used for vermicomposting (Household waste, grass clips, and a mixture of the two)

For qualitative analysis, a median mass sample was taken, and also the standard chemical parameters, substitution pH reaction (in 1 mol dm^{-3} KCl) potentiometrically in step with BAS ISO 10390:2009 v/v 1:5) and active pH reaction (in H_2O) was analyzed. Nitrogen contents in vermicomposting mass were determined by the Kjeldahl method (BAS ISO 11261: 2010). Determination of potassium and phosphorus was performed by wet incineration and sample analysis on a phosphorus spectrophotometer and a potassium flame photometer. Values are expressed as P_2O_5 and K_2O in percentage. Total carbon was calculated from the results obtained by the determination of the organic matter. The C/N ratio was calculated using the information of total carbon in dry matter and total nitrogen. The dry matter content was obtained by drying the sample at 105° C to constant mass. Electrical conductivity (EC, mS cm^{-1}, TDS g dm^{-3} and salinity ‰) was analyzed in the ratio of 1:2 (w/v) by a digital portable conductivity meter (HACH semsyion5). Volatile solid content was determined by loss ignition method (dry mass basis) at 550°C for 1 h. The total organic carbon content was calculated from volatile solids (Mohee *et al.*, 2008). Extraction of elements soluble

in aqua regia Ca, Mg, Zn, Cu, Cd, Fe, Pb and Na were done according to ISO 11466:2000 and determination was done by the method of flame and graphite atomic absorption spectrometry: ISO 11047:2000 on the device Perkin Elmer FIAS 800.
Before the inoculation of worms on composting mixture, the manure utilized in the trial was analyzed.
The results were reported as the mean of three replicates with standard error (SE). ANOVA and Tukey's test was used to test the effect of different chemical properties of the vermicompost products due to the earthworm activities. The probability level used for statistical significance was $p < 0.05$ for all measured parameters. For statistical processing the data's GenStat 7 software (Laws Agricultural Trust, Rothamsted Experimental Station) was used.

RESULTS AND DISCUSSION

Results of initial cattle manure used in the trial indicated alkaline pH reaction (8.3) and lower nitrogen and higher carbon content comparing to vermicompost treatment resulting in a C/N ratio of 25.57. Potassium content was low 0.5 % K_2O similar to phosphorus content of 0.8% P_2O_5. Results of this trial with vermicomposting for basic parameters are shown in the table 1 below:

Table 1. The treatment used in the vermicomposting process presented some chemical characteristics

Parameters	Initial cattle manure	Cattle manure and domestic waste	Cattle manure and grass clippings	Mixture (control)
pH H_2O	8.3±0,2	7.2 ± 0.14^{ns}	8.3 ± 0.44^{ns}	7.1 ±0.47^{ns}
pH KCl	7.5±0,1	6.8 ± 0.9^{ns}	7.0 ± 0.37^{ns}	6.7 ± 0.34^{ns}
%N	1.9±0,11	2.7 ± 0.01^{ns}	2.8 ± 0.10^{ns}	2.9 ±0.12^{ns}
%P_2O_5	0.5±0,21	0.3 ± 0.11^{ns}	0.3 ± 0.31^{ns}	0.5 ± 0.15^{ns}
%K_2O	0.8±0,14	1.2 ± 0.08^{ns}	1.1 ± 0.09^{ns}	1.2 ± 0.19^{ns}
% ash	17,4±0,85	21.58 ± 0.99^{ns}	20.20 ± 1.4^{ns}	18.46 ±1.05^{ns}
%C	48.6±3,6	45.59 ± 2.9^{ns}	46.39 ± 5.3^{ns}	47.41 ± 3.8^{ns}
C/N	25.57±2,2	16.7 ± 1.1^{ns}	16.29 ± 2.1^{ns}	16.67 ± 1.3^{ns}
g dm^{-3} TDS	2,01±0,63	2.46 ± 0.32^{ns}	2.81 ± 0.83^{ns}	2.56 ± 0.61^{ns}
‰ Salinity	0,5±0,55	2.53 ± 0.32^{ns}	2.90 ± 0.86^{ns}	2.67 ± 0.61^{ns}
mS/cm EC	1,01±0,3	4.70 ± 0.18^{ns}	5.33 ± 0.45^{ns}	4.92 ± 0.79^{ns}
% Ca	1,98±0,15	2.27 ± 0.50^{ns}	2.45 ± 0.14^{ns}	2.26 ± 0.11^{ns}
% Mg	0,50±0,18	0.67 ± 0.11^{ab}	0.9 ± 0.1^{a}	0.53 ± 0.06^{b}
mg kg^{-1} Cd	0,52±0,03	0.60 ± 0.02^{a}	0.53 ± 0.02^{b}	0.53 ± 0.02^{b}
mg kg^{-1} Pb	4,46±0,52	11.85 ± 0.81^{ns}	10.47 ± 0.79^{ns}	8.13 ± 2.01^{ns}
mg kg^{-1} Cu	38,4±2,34	40.7±4.41^{ns}	43.2±0.51^{ns}	42.8±0.98^{ns}
mg kg^{-1} Zn	119,7±6,32	183.0±10.7^{ns}	161.9±4.6^{ns}	171.6±2.99^{ns}

mg kg^{-1} Fe	3,19±1,2	5.96±0.88^{a}	4.29±0.49^{ab}	3.39±0.79^{b}
mg kg^{-1} Na	100,7±11,2	586±16.46^{a}	338±17.95^{b}	514±47.66^{a}

Values of three different vermicompost are mean ± standard error (n = 3). ns- non significant Means in a row followed by different letters are significantly different at $p < 0.05$ (Tukey test).

The collected data indicate that using organic material together with cattle manure shows a pH reaction neutral to slightly alkaline. In this trial cow manure was used as basis for vermicompost treatments showing lower pH compared to initial one, probably due to presence of various vegetables and fruit home waste and of course earthworms activity. This is in align with Gandhi *et al.* (1997) that stated earthworm activity reduced not only pH but also C/N ratio in manure. According to Dickerson (2001) recommended pH for vermicomposting is around 6-7 as in lower pH the bacterial activity decrease, and worms that do not like it, will migrate or probably die. Brinton (2000) recommended a threshold for vermicomposting A-class range, pH 6.5-8.4. According to organic amendments for pH range it is suggested 6.0 to 8.5 of several legislations (e.g. Italy, Belgium, Spain) to ensure compatibility with most plants (Hogg *et al.*, 2002). We can confirm that in our research all three-vermicomposting mixtures have active and substitution pH neutral, accept alkaline active pH in cattle gun and grass clippings probably due to the grass component, but anyway all fits in suggested range. A larger population of earthworms can significantly contribute to the aeration of the compost mass, which prevents a drastic drop in the pH value, while aerobic condition affects ammonium consumption and prevent pH increment (Rostami, 2011). The nitrogen compound in presented three treatments varied between 2.7%, 2.8% and 2.9 % N while total carbon varied between 45.59%, 46.39%, 47.41% showing a C/N ratio of 16.7, 16.29 and 16.67. C/N compounds in vermicomposting mixtures have decreased up to 34% to 36% from initial cattle gung. Significant decrease of C/N ratio comparing to initial cattle manure was in vermicompost with grass clippings, probably due to uniform mass and earthworms who can easily digest it. A C/N ratio less than 20 confirms organic waste mineralization which indicates compost maturity; however, a C/N ratio less than 12 is also preferred for agricultural purpose (Shak *et al.*, 2014). Rostami (2011) stated that vermicompost process will progress properly by starting the process with a C/N ratio around 25-30 and it will decrease during the process. We have decresment in C/N which is in ailing with previous statement. According to Tchobanoglous *et al.* (1993) carbon reduces because heterotrophic bacteria use organic material as source of electron and carbon is oxidized to CO_2 and releases to atmosphere. Content of carbon (C%) was higher in treatment with the domestic waste and grass clipping probably regarding the complex mixture and it is possible that the complexity of mixtures required longer period for mineralization process. According to Boruah *et al.*(2019) the reduction of organic carbon during vermicomposting is mainly attributed to the respiratory activity of microorganisms and earthworms with a synchronized increase in nitrogen added through the mucus and nitrogenous excretion by the worms. The potassium content varied between 1.1-1.2% K_2O and phosphorus varied within 0.3-0.5% P_2O_5. Slightly different results were obtained by Pukan et al.,

(2013) using slurry method (non-enriched and enriched) and conventional method that found total K_2O content varied from 0.69, 0.73 and 0.65% while for P_2O_5 content varied 1.1, 1.51 and 0.82%. Results of Bhat *et al.* (2013) indicated a range of potassium and phosphorus 2.47% P_2O_5 and 2.37% K_2O for final vermicompost. But diversity in nutrient compound probably could be due to the domestic waste and its nutritional value and of course initial material and favorable condition that can speed up by earthworm activity. Higher potassium content is expected in organic compounds, and we recorded 37 to 50% higher content of potassium comparing to initial cattle manure. Suhane (2007) asserts that vermicompost has a minimum of 4 times more nutritive than cattle manure compost. Based on the presented results, the experiment indicates quite good results of vermicomposting of household waste with cattle manure, showing a neutral pH reaction and showing the best content of ash and carbon with good NPK contents and with slightly increased C/N ratio of 16.7. It's to be noted that a decline within the C/N ratio to < 20 indicates a sophisticated degree of organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes (Senesi, 1989). It's believed that a C/N ratio below 20 is indicative of acceptable maturity, while a ratio of 15 or lower is preferable (Morais and Queda 2003). As we can see (Table 1) ash content was increased in vermicomposting materials compering to initial cattle manure as Gupta and Garg (2008) confirm that the increase in the ash content illustrates faster rate consuming the wastes by the earthworms and the microbial assimilation is also performing the degradation process rapidly.

In our trial regarding a different organic waste EC as most important factor of vermicompost phytotoxicity varied between 4.7-5.33 mS cm^{-1} and these results are in accordance with Majlessi *et al.* (2012) who reached value of 4.9 mS cm^{-1} in the final product. Increase in EC caused by ions discharge some researchers explained that happened due to the breakdown of organic substrates, ammonium, phosphate, potassium, nitrate, and calcium (Gong *et al.*, 2019; Yuvaraj *et al.*, 2019; Paul 2020). Mitchell (1997) states that electrical conductivity of vermicompost from cattle manure in his research was 2.5-3.1 mS cm^{-1}, while Tiquia and Tam (1998) found that compost with an EC of 3.5-4.7 mS cm^{-1} did not reduce germination in their research on seeds and root elongation of cabbage and spinach. Some biological test with vermicompost on excessive salinity could be good confirmation of phytotoxicity. Salinity can be also developed from nitrogen mineralization and production of organic acids, even these factors indicate the compost stability and not its maturity. Iannotti *et al.*, (1994) found 32% of analyzed samples shown EC values greater than 4 dS m^{-1} (6.1 to 15 dS m^{-1}), probably due to the raw material used (i.e. food waste). Heavy metals, like Pb, Cd, Cu, Zn contents in vermicompost regardless of different materials of vermicomposting were found to be below permissible limit. Different materials used in all three treatment in trial result in calcium content that varied between 2.53% - 2.9%, and that was in align with findings of Suthar (2009) in vermicompost (2.0–2.57% Ca). It was reported by Srimathi *et al.* (2019) that significant increment of magnesium in vermicompost elevates initial Mg content from 0.37-0.41% to 0.35-0.65% wich is in aligmant with our results. From our trial it is important to emphasize the significant higher content of magnesium in vermicompost with grass clippings probably regarding the rich chlorophyll content in grass. The magnesium is the central atom of the chlorophyll molecule, with each molecule containing 6.7% magnesium. For the total concentrations of Cd, Fe and Na it was found significant difference among the treatments. All three values (Cd, Fe and Na) were significantly higher in first treatment with cattle manure and home waste which probably refers to some residues applied with waste and these values were lower in initial material. Measured heavy metal contents in the final vermicompost were under the US EPA standard limits (US EPA, 1993). In accordance with applied organic material within the treatments, these results show that vermicompost could rises the speed of organic matter and increase the capacity of carbon sequestration.

CONCLUSION

An appropriate pH environment, N and C contents, which are reflected in a favorable C/N ratio, create an environment in which earthworms can reproduce, recycle and efficiently process organic substances and ultimately result in quality vermicompost. Through vermicomposting, the nutrient content could be elevated resulting in good and adequate fertilization manure that could be widely applied. But when it comes to pH and EC regarding the obtained vermicompost's the most suitable soil for application would be the one with lower pH reaction, especially the combination of cattle manure and grass clippings. The recycle of organic material trough the vermicomposting could be definitely positive ecofriendly way of reducing of waste and producing organic fertilizer amendments.

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UČINKOVITOST RECIKLIRANJA ORGANSKOG OTPADA KROZ POSTUPAK VERMIKOMPOSTIRANJA

Rezime

Poljoprivredni sektor i rastuće potrebe za proizvodnjom hrane uvelike se oslanjaju na kemijska gnojiva. To je u početku imalo pozitivne učinke na proizvodnju, no tijekom posljednjeg desetljeća negativni učinci pretjerane uporabe rezultirali su niskom produktivnošću usjeva, povećanom zarazom štetočinama i bolestima, degradacijom tla i posljedičnim štetnim učincima na parametre okoliša. Kao jednu od mogućnosti u organskom uzgoju pronašli smo vermikompostiranje kao održiviju praksu. Za pripravljanje vermikompostne smjese korišten je zreli stajski gnoj u tri različite kombinacije s organskim otpadom i uz inokulaciju glista (kućni otpad, pokošena trava i mješavina-kontrola). Eksperiment je postavljen slučajnim bloknim rasporedom u tri ponavljanja. Analize kvalitativnih parametara konačnog proizvoda pokazale su neutralnu do blago alkalnu pH reakciju. Dušik je varirao između 2,7-2,9 %, dok je organski ugljik varirao između 45,59-47,41 % pokazujući omjer C/N od 16,7-16,67. Sadržaj kalija varirao je između 1,1-1,2% K_2O i fosfora od 0,3-0,5%. Eksperiment pokazuje dosta dobre rezultate vermikompostiranja kućnog otpada sa stajskim gnojem, pokazujući neutralnu pH reakciju, optimalan sadržaj pepela i ugljika s gotovo sličnim i dobrim sadržajem NPK i povećanim C/N omjerom od 16,7 te sa zadovoljavajućim sadržajem elemenata u tragovima i sadržajem teških metala ispod granica. Ovi rezultati pokazuju da vermikompostiranje može povećati kvalitetu konačnog proizvoda.

Ključne riječi: *vermikompostiranje, gliste, recikliranje, organski otpad*