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Effect of Different Feeding Materials on the Trace and Nutrient Elements of Vermicompost Using *Eisenia fetida*

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Abstract: The aim of this study was to determine the influences of different feeding materials on the physico-chemical parameters of vermicompost using *Eisenia fetida (Savingy, 1826).* In this study, four treatments, with the same conditions in terms of organic wastes type were prepared to produce vermicompost from hazelnut husk (% 100), tea plant waste (%100), hazelnut husk (A) (% 50) + tea plant waste (B) (50%), hazelnut husk (A) (30%) + tea plant waste (30%) + cow dung (20%) + sawdust (15%) + waste newspaper (%5) using earthworms. The standard laboratory analysis methods were used to determine the physical and chemical parameters in the different produced vermicomposts. The mean N content in the growing medium A, B, C, and D was 1.41%, 2.5%, 1.96%, and 1.47% respectively. The mean phosphorus content in the growing medium A, B, C, and D was 807.69 mg/kg, 1748.25 mg/kg, 1491.25 mg/kg, and 1410.75 mg/kg respectively. The mean potassium in the growing medium A, B, C, and D was 11244.69 mg/kg, 7790 mg/kg, 6884.25 mg/kg, and 8006.25 mg/kg respectively. Compared to the initial vermibed mixture, the N, P, and K content was higher in all the growing mediums. The Pb, Cd and As content was lower in all the growing mediums in the final compost than the initial vermibed mixture. *Eisenia fetida* is very effective in converting some waste materials into a high-quality compost and decreasing the heavy metal content in the final vermicompost more than in the initial vermibed mixture.

Keywords: Hazelnut husk, heavy metal, nutrients, red California worm, tea waste.

Farklı besleme materyallerinin *Eisenia fetida* kullanılarak oluşturulan vermikomposttaki bazı besin elementleri ve ağır metal değişimine etkisi

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Öz: Bu çalışmanın amacı, farklı besleme materyalleri ile *Eisenia fetida (Savingy, 1826)'nın* beslenmesi sonucunda oluşan vermikomposttaki bazı fiziko-kimyasal parametrelerin tespit edilmesidir. Bu amaçla, fındık kabuğu (A) (%100), çay bitkisi atığı (B) (%100), fındık kabuğu (C) (%50) + çay atığı (%50), (D)fındık atığı (%30) +çay atığı (%30) +inek gübresi (%20) +talaş (%15) + atık kağıt (%5) oluşan besi ortamlarında rastgele yönteme göre dört tekrarlı denemeler kurulmuştur. Araştırma sonucunda elde edilen vermikomposttaki bazı fiziko-kimyasal parametreler standart laboratuvar testleri ile tespit edilmiştir. Araştırma sonucunda A, B, C ve D yetiştirme ortamlarından elde edilen ortalama N içeriği sırasıyla %1,41, %2,5, %1,96 ve %1,47 dir. A, B, C ve D yetiştirme ortamındaki ortalama fosfor içeriği sırasıyla 807,69 mg/kg, 1748,25 mg/kg, 1491,25 mg/kg ve 1410,75 mg/kg'dır. Vermikomposttaki Pb, Cd ve As içeriği, tüm yetiştirme ortamlarında başlangıçtaki besi ortamına kıyasla daha düşük seviyede olduğu ortaya konulmuştur. *Eisenia fetida*'nın bazı atık maddelerin yüksek kaliteli kompost haline dönüştürülmesinde ve son vermikomposttaki ağır metal içeriğinin azalmasında etkili olduğu tespit edilmiştir

Anahtar kelimeler: Ağır metal, atık kağıdı, çay atığı, fındık atığı kırmızı Kaliforniya solucanı.

INTRODUCTION

The recycling of waste materials in order to vermicast and vermiwash production is one of the popular methods for sustainable waste management (Yüksek, 2019). Recently, studies on vermicomposting of different types of organic wastes, such as agricultural residues (Lim et al., 2015) and animal wastes (Lalander et al., 2015), plant waste (Abassi et al., 2015) food wastes (Yüksek et al., 2019), municipal solid waste (Singh et al., 2011) through sewage sludge (Sinha et al., 2010; Yadav & Garg, 2011) and industrial wastes, with the help of earthworms, have been increased. Worm-based processing of organic waste is known as vermicomposting, a process developed in the late 1970s (Furlong et al., 2017). Vermicomposting can be defined as the biodegradation process of organic waste materials with the help of specific bacteria and enzymes found in the intestines of worms, which cause the changes in the physico-chemical properties of the waste (Jorge & Edwards, 2011). As a result of the vermicomposting process, the nutrient content of the waste materials increased and converted into a higher quality and valuable soil regulator product (Lim et al., 2014). The vermicomposting process is easy for an inexpensive, natural and environmentally friendly method (Garg et al., 2012) and uses low technology (Ndegwa & Thompson, 2001). In addition, as a result of the vermicompost process, no waste product, which may be a threat to the environment, is formed. The use of the products (e.g. worm, vermiwash tea, vermicast, etc.) obtained as a result of vermicomposting in different areas (e.g. soil improvement, plant nutrition, fish nutrition, health, etc.) is increasing (Orhan, 2019; Orhan vd., 2019; Yüksek et al., 2019; Arıman et al., 206; Arıman et al., 2020).

The Turkish hazelnut and tea industries are growing rapidly, and quickly becoming a significant agriculture-based industries in this country. Turkey has a total of over 702 628 hectares of hazelnut plantations (Anonymous, 2017a) and 76241hectares (Anonymous, 2017b) (The existing tea plantations along with unregistered tea plantations constitute about 100,000 hectares of tea plantations). Tea plant and hazelnut husk wastes are biodegradable wastes that originate from plant sources. In this study, 232 kg of hazelnut husk was obtained from 1 ton of shelled nut production. Turkey's shelled hazelnut production varies between 350 000 and 800 000 tons. Accordingly, the amount of hazelnut husk in Turkey varies between 80500 tons and 184 000 tons. Tea plant wastes and hazelnut husk wastes have been difficult to manage due to the fact that the factories are scattered and spread widely in the northern Black Sea region. There is no planned waste management in hazelnut husk and tea waste. Leaving these wastes decaying indiscriminately outside or in tea gardens and in hazelnut gardens can cause the pollution of soil and water resources and deterioration of ecosystem health. Another important issue is that these wastes are released during the decay and cause unpleasant odors that spread and cause visual pollution. Additionally, all these pollutants may cause human diseases. This clearly shows that with agricultural development, environmental pollution has become an increasingly serious issue in northern Turkey. Although, using earthworms in the recycling of wastes and the production of organic fertilizers has been increasing in Turkey in recent years, as well as in the rest of the world, to date no study has been devoted to the vermicomposting process of biomass residues generated from hazelnut husk and the tea industry.

The aim of this study is to recycle different types of feeding materials (hazelnut husk (% 100), tea plant waste (100%), hazelnut husk (A) (% 50) + tea plant waste (B) (% 50), hazelnut husk (A) (30%) + tea plant waste (30%) + cow dung (20%) + sawdust (15%) + waste newspaper (5%) into compost using *Eisenia fetida*, and to determine the influences of different feeding materials on the physico-chemical parameters and the heavy metal content of vermicompost.

MATERIAL AND METHOD

Earthworm and collection of organic wastes: The earthworms of *Eisenia fetida* used in this study were provided by the Lazutim Organic Agriculture and Livestock Trade Company. The research was carried out in a special room in the Lazutim Trade Company. The tea wastes used in the experiments were supplied from the general directorate of Turkish tea operations, the Hemşin organic tea plant. The hazelnut husk wastes were supplied from a private hazelnut farm located in the Yomra province in Trabzon, Turkey. The cow dung was supplied from animals grazing on the highlands in Ardahan in Turkey. Sawdust waste were supplied from the wood processing plant located in Pazar, in Turkey. Tea waste, hazelnut husk wastes, and sawdust waste was decayed in special cups for three months. In this study, four different combinations of waste mixture, consisting of hazelnut husk (HH), Tea plant waste (TPW), cow dung (CD), sawdust and waste newspaper (Table 1) were prepared in different chemical structures (Table 2).

Table 1. Type of feeding materials.

Treatment	Feeding materials
A	Hazelnut husk (HH) (%100)
B	Tea plant waste (TPW) (%100)
C	Hazelnut husk (HH) (%50) + Tea plant waste (TPW) (%50)
D	Hazelnut husk (HH) (%30) + Tea plant waste (TPW) (%30) + Cow dung (CD) (%20) + sawdust (%15) + waste newspaper (WN) (%5)

Experimental set up: The study was carried out in four replicates of 40 cm x 40 cm length x 20 cm deep in a plastic box according to the random sampling method. The type of feeding materials is presented in Table 1. About 1000 g of each of the feeding materials (dried to weigh basis) was placed into the experimental box. Thirty earthworms (*Eisenia fetida*) with an average weight of 0,30 ± 0,03 g per worm were introduced into each experimental box. The feedstock was moistened with tap water to obtain an appropriate moisture level for the earthworms to survive. Besides, the moisture content was maintained at 50-55 % by the periodic sprinkling of an adequate quantity of tap water (Table 3) on the feedstock throughout the study. The experimental boxes were kept in the dark at room temperature of 23 ± 2 ˚C. The composting process lasted 84 days (12 weeks), and then the worms were removed from the growing containers. The vermicompost samples were sieved through a two mm sieve after being air dried and sent to the Gumushane University Central Research Laboratory for analysis.

Table 2. Initial physico-chemical characteristics of initial waste mixtures.

Parameters	A	B	C	D
N (%)	0.89 ± 0.08	2.25 ± 0.24	1.59 ± 0.101	1.12 ± 0.06
P_2O_5 (mg/kg)	4031 ± 71.39	1399 ± 9.07	2735 ± 48.21	1876 ± 25.11
K (mg/kg)	7015 ± 51.62	4245 ± 20.88	5640 ± 56.12	4999 ± 12.05
Ca (mg/kg)	1412 ± 41.18	18786 ± 899	10029 ± 204	7936 ± 6.24
Mn (mg/kg)	374 ± 17.69	248 ± 18.90	312 ± 14.04	236 ± 3.05
S (mg/kg)	961 ± 33.60	1898 ± 25.94	1435 ± 32.86	1029 ± 9.00
Al (mg/kg)	3255 ± 90.00	7576 ± 18.71	5455 ± 37.68	4151 ± 5.56
Fe^{2+} (mg/kg)	121 ± 9.29	8626 ± 27.01	4366 ± 9.29	3362 ± 6.03
As (mg/kg)	0.65 ± 0.03	1.91 ± 0.11	1.28 ± 0.01	0.77 ± 0.03
pH (mg/kg)	5.95 ± 0.17	5.67 ± 0.14	5.78 ± 0.07	4.61 ± 0.08
E.C. (µS/cm)	355 ± 6.50	538 ± 18.33	465 ± 17.61	345 ± 5.50
Pb^{2+} (mg/kg)	4.43 ± 0.05	54.09 ± 4.02	28.72 ± 0.72	17,92 ± 0.07
Cd^{2+} (mg/kg)	0.188 ± 0.02	0.117 ± 0.01	0.157 ± 0.01	0.103± 0.01
Cr^{2+} (mg/kg)	6.69 ± 0.14	2.73 ± 0.04	4.70 ± 0.01	3.71 ± 0.10
Cu^{2+} (mg/kg)	6.72 ± 0.03	64 ± 1.01	35.00± 0.32	22.60 ± 0.46
Ni^{2+} (mg/kg)	6.35 ± 0.31	3.88 ± 0.02	5.12 ± 0.01	3.94 ± 0.03

A: Hazelnut husk (%100); B: Tea plant waste (%100); C: Hazelnut husk (%50) + Tea plant waste (%50); D: Hazelnut husk (%30) + Tea plant wast (%30) + Cow dung (%20) + sawdust (%15) + waste newspaper (%5)

Table 3. Some parameters of tap water used for the earthworms to survive (Yüksek vd.,2017).

Parameters	Tap water	Apropriate range
Water temperature (ºC)	Appropriate	4-25
Dissolved oxygen (mg/l)	Appropriate	>5
pH	7.81	6.5-9.5
Calcium (mg/l)	4.80	4-160
Magnesium (mg/l)	2.86	0-50
Nitrite nitrogen (mg/l)	0.020	<0,50
Nitrate nitrogen (mg/l)	0.80	0-50
TDS* (mg/l)	92.40	-
E.C** µS/cm	214.6	100-2500

*TDS: Total Dissolved Solids, E.C**: Electrical conductivity

Laboratory Analysis: The analysis of the metals and other elements (Pb, Cd, As, etc.) was conducted according to the NMKL 161, NMKL 186 and NMKL 191 methods using ICP-MS after burning with microwaves (Standart methods 3125). The nitrogen analysis was carried out according to the methods of AOAC 990.03 TS 8337 ISO 11261 based on the method of Kjeldal (TS 8337 ISO 11261). The total content of calcium, magnesium, phosphorus and potassium were measured with the ignition method using an atomic absorption spectrophotometer. The pH and electrical conductivity were measured using a digital pH meter and an electrical conductivity meter, respectively AOAC 981.12 TS EN 159332 (AOAC Official Method). All the analyzes were performed according to standard analysis methods.

Statistical Analysis: The effect of the feeding materials on the physio-chemical content of the vermicompost was analyzed with ANOVA. The differences among treatment averages were compared using the Duncan's test. The significance was set at $p < 0.05$. The SPSS software version 23 was used for the data analysis.

RESULTS

It can be concluded that during the process of the vermicomposting, significant physical and chemical changes occurred in the raw materials of the solid waste due to the biodegradation of the organic matter and the interactions between the earthworms and microorganisms.

Variations in nitrogen (N): The average nitrogen content was the highest for the B growing media at 2.53 % followed by the C growing media. In terms of the nitrogen content, the differences between the growing mediums A and B, and the growing mediums B and D were statistically significant ($p \leq 0.01$) (Table 4). The total nitrogen content was greater in the final vermicomposts than in the initial vermibed mixture in all the growing mediums. Compared to the initial vermibed mixture, the highest increase in the nitrogen content was found in the growing medium A at 36.88 % in the final vermicompost (Table 2, 4).

Table 4. Variation of some nutrients in the vermicompost obtained from different feding materials.

	Vermicompost			
Parameters	A	B	C	D
N (%)	1.41^{b}	2.53^{a}	1.96^{ab}	1.47^{b}
P2O5 (mg/Kg)	807.25^{c}	1748.25^{a}	1491.25^{b}	1410.75^{b}
K (mg/Kg)	11244.69^{a}	7790^{ab}	6884.25^{c}	8006.50^{ab}
Ca (mg/Kg)	9646.19^{b}	12942.75^{a}	14249.50^{a}	11175.75^{ab}
Mn (mg/Kg)	223.09^{d}	1626.50^{a}	1022.15^{b}	600.76^{c}
S (mg/Kg)	677.97^{b}	1478.50^{a}	1366.25^{a}	1117.50^{a}
Al (mg/Kg)	2112.41^{b}	6259.75^{a}	5602^{a}	4367.50^{ab}
pH	7.59^{a}	6.36^{b}	6.36^{b}	7.41^{a}
E.C. (µS/cm)	578^{a}	437.75^{a}	604.25^{a}	636.25^{a}

A: Hazelnut husk (%100); B: Tea plant waste (%100); C: Hazelnut husk (%50) + Tea plant waste (%50); D: Hazelnut husk (%30) + Tea plant waste (%30) + Cow dung (%20) + sawdust (%15) + waste newspaper (%5). Means in the same row followed by the same lowercase letter are not significantly different at $P \leq 0.05$.

Variations in Phosphrous (P): Phosphorus was greater in the final vermicomposts than the initial vermibed mixture in the feeding materials of A and B because of the phosphorus mineralization. The highest amount of phosphorus was obtained from the growing medium B at 1748.25 mg/kg; while the lowest amount of phosphorus was found in the growing medium A at 807.69 mg / kg. In terms of the phosphorus content, the difference between A and B, A and C, A and D, B and C, and B and D mediums was statistically significant ($p \leq 0.001$) (Table 4). Compared to the initial vermibed mixture, the highest decrease in the phosphorus content was found in the growing medium C at 45.48 % in the final vermicompost (Table 2 and 4).

Variations in Potassium (K): The highest amount of potassium was obtained from the growing medium A at 11244.69 mg/kg; while the lowest amount of potassium was found in the growing medium C at 6884.25 mg/kg. In terms of potassium content, the difference between the A and C growing medium was statistically significant ($p \leq 0.05$). The total potassium was greater in the final vermicomposts than the initial vermibed mixture in all the feeding materials because of the potassium mineralization (Table 2 and 4). Compared to the initial vermibed mixture, the highest increase in the potassium content was found in the growing medium B at 45.50 % in the final vermicompost.

Variations in Calcium (Ca): The highest amount of calcium was obtained from the growing medium C at 14249.50 mg/kg; while the lowest amount of calcium was found in the growing medium A at 9646.19 mg/kg. Although the total calcium was increased more in the final vermicomposts than in the initial vermibed mixture in A, C and D growing mediums, the calcium content in the growing medium B was decreased at 45.16 % compared to the initial vermibed mixture. Compared to the initial vermibed mixture, the highest increase in the calcium content was found in the growing medium A at 85.36 % in the final vermicompost. In terms of calcium content, the difference between the A and B, A and C growing mediums was statistically significant ($p \leq 0.05$) (Table 4).

Variations in Manganese (Mn): The highest amount of manganese was obtained from the growing medium B at 1626.50 mg/kg; while the lowest amount of manganese was found in the growing medium A at 223.09 mg/kg. Compared to the initial vermibed mixture, the total manganese was increased in B, C and D growing mediums; while the manganese content in the growing medium A was decreased at 40.35 % in the final vermicompost. In terms of the manganese content, the difference between the A and B, A and C, A and D, B and C, and B and D growing mediums was statistically significant ($p \leq 0.001$) (Table 4).

Variations in Sulfur (S): The highest amount of sulfur was obtained from the growing medium B at 1478.50 mg/kg; while the lowest amount of sulfur was found in the growing medium A at 677.97 mg/kg. Compared to the initial vermibed mixture, the total sulfur was decreased in A, B and C growing mediums while the sulfur content in the growing medium D was decreased (Table 2 and 4). Compared to the initial vermibed mixture, the highest decrease in the sulfur content was determined in the growing medium A at 29.45 %. In terms of the sulfur content, the difference between A and B, A and C, and A and D growing mediums was statistically significant ($p \leq 0.01$) (Table 4).

Variations in Aluminum (Al): The highest amount of aluminum was obtained from the growing medium B at 6259.75 mg/kg; while, the lowest amount of aluminum was found in the growing medium A at 2112.41 mg/kg. Compared to the initial vermibed mixture, the total aluminum was decreased in the A and B growing mediums; while the aluminum content in the growing medium C and D was increased (Table 2 and 4). Compared to the initial vermibed mixture, the highest decrease in aluminum content was determined in the growing medium A at 35.11 %; while the highest increase in aluminum content was determined in the growing medium D at 4.97% in final vermicompost. In terms of the aluminum content, the difference between the A and B, and A and C growing mediums was statistically significant ($p \leq 0.05$) (Table 4).

Variations in Iron (Fe^{2+}): The highest iron value was found in the growing medium C at 3699.25 mg/kg; while the lowest iron was found in the growing medium B at 2336.25 mg/kg. Compared to the initial vermibed mixture, the iron content was lower in the growing mediums B, C, and D; while it was higher in the growing medium A in the final vermicompost. The highest decrease in iron content was found in the growing medium B at 72.91 %. In terms of iron content, the difference between growing mediums was not statistically significant ($p \leq 0.05$) (Table 5).

Table 5. Heavy metals concentration in the vermicompost obtained from different feeding materials (as mg/kg).

Parameters	Vermicompost			
	A	B	C	D
Pb	2.40^{a}	1.35^{b}	2.31^{a}	1.62^{b}
Cd	0.087	0.095	0.070	0.097
Cr	2.77^{b}	4.36^{a}	3.41^{ab}	3.68^{ab}
Cu	7.91^{b}	13.07^{a}	12.72^{a}	9.17^{b}
Ni	2.77^{b}	4.63^{a}	4.06^{a}	3.66^{ab}
Fe	2768.60^{b}	2336.25^{c}	3699.25^{a}	2989.25b
As	0.42	0.27	0.76	0.64

A: Hazelnut husk (%100); B: Tea plant waste (%100); C: Hazelnut husk (%50) + Tea plant waste (%50); D: Hazelnut husk (%30) + Tea plant waste (%30) + Cow dung (%20) + sawdust (%15) + waste newspaper (%5). Means in the same row followed by the same lowercase letter are not significant.

Variations in pH: The highest pH was found in the growing medium A at 7.59; while the lowest pH value was found in the growing media B and C at 6.36. Compared to the initial vermibed mixture, the pH increased in all the growing mediums. The highest increase was found in the growing medium D at 37.79%; while the lowest increase was determined in the growing medium C at 9.12%. In terms of the pH content, the difference between A and B, A and C, B and D, and C and D growing mediums was statistically significant ($p \leq 0.01$) (Table 4).

Variations in electrical conductivity (E.C): The highest E.C. was found in the growing medium D at 636.25 μS/cm; while the lowest E.C was found in the growing medium B at 437.75 μS/cm. Compared to the initial vermibed mixture, the E.C content was greater in the growing mediums A, C, and D; while it was lower in the growing medium B. The highest increase in the E.C was determined in the growing medium D at 45.77%; while it was decreased in the growing medium B at 18.63%. However, in terms of the E.C content, the difference between A, B, C, and D, the growing mediums was not statistically significant (Table 4).

Heavy metals concentrations

Lead (Pb^{2+}): The highest lead value was found in the growing medium A at 2.40 mg/kg; while the lowest lead was found in the growing medium B at 1.35 mg/kg. Compared to the initial vermibed mixture, the lead content was lower in all the growing mediums A, B, C, and D. The highest decrease in lead content was found in the growing medium B at 97.50 %. In terms of lead content, the difference between A and B, A and D, and C and D growing mediums was statistically significant ($p \leq 0.05$) (Table 5).

Cadmium (Cd^{2+}): The highest cadmium value was found in the growing medium D at 0.097 mg/kg; while the lowest cadmium was found in the growing medium C at 0.070 mg/kg. Compared to the initial vermibed mixture, the cadmium content was lower in all the growing mediums A, B, C, and D. The highest decrease in the cadmium content was found in the growing medium C at 55.41 %. In terms of the cadmium content, the difference between the A, B, C, and D growing mediums was not statistically significant (Table 5).

Chromium (Cr^{2+}): The highest chromium value was found in the growing medium B at 4.36 mg/kg; while the lowest chromium was found in the growing medium A at 2.77 mg/kg. Compared to the initial vermibed mixture, the chromium content was lower in the growing mediums A, C, and D; while it was higher in the growing medium B in the final vermicompost. The highest decrease in the chromium content was found in the growing medium A at 58.59 %. In terms of the chromium content, the difference between the A and B growing mediums was statistically significant ($p \leq 0.05$) (Table 5).

Copper (Cu^{2+}): The highest copper value was found in the growing medium B at 13.07 mg/kg; while the lowest copper was found in the growing medium A at 7.91 mg/kg. Compared to the initial vermibed mixture, the copper content was lower in the growing mediums B, C, and D; while it was higher in the growing medium A in the final vermicompost. The highest decrease in the copper content was found in the growing medium B at 79.58 %. In terms of the copper content, the difference between the A and B, A and C, B and D, and C and D growing mediums was statistically significant ($p \leq 0.05$) (Table 5).

Nickel (Ni^{2+}): The highest nickel value was found in the growing medium B at 4.63 mg/kg; while the lowest nickel was found in the growing medium A at 2.77 mg/kg. Compared to the initial vermibed mixture, the nickel content was lower in the growing mediums A, C, and D; while it was higher in the growing medium B in final vermicompost. The highest decrease in the nickel content was found in the growing medium A at 56.38%. In terms of the nickel content, the difference between the A and B, A and C growing mediums was statistically significant ($p \leq 0.05$) (Table 5).

Arsenic (As): The highest arsenic value was found in the growing medium C at 0.76 mg/kg; while the lowest arsenic was found in the growing medium B at 0.7 mg/kg. Compared to the initial vermibed mixture, the arsenic content was lower in all the growing mediums in the final vermicompost. The highest decrease in arsenic content was found in the growing medium B at 85.86 %. In terms of the arsenic content, the difference between the growing mediums A and B, C and D was not statistically significant ($p \leq 0.05$) (Table 5).

DISCUSSION

Earthworms infiltrate organic wastes through the digestive tract, causing physical, chemical and biological changes (Suthar, 2010). Earthworms can boost the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid, enzymes, and even the decaying dead tissues of worms in vermicomposting subsystem (Suthar, 2007). The structure, the amount of nitrogen content and mineralization of the organic waste is effective on the nitrogen output in the final vermicompost. In previous studies it was reported that, the enhancement of N content in vermicompost was probably due to mineralization of the organic matter (Bansal & Kapoor, 2000; Kaushi & Garg, 2003; Malafaia et al., 2015; Amouei et al., 2017). In addition, the increasing nitrogen content value could be due to nitrogenous metabolic products of earthworms, which were returned to the vermicompost as casts and urine (Muthukumaravel et al., 2008). The results are in accordance with previous studies (Garg et al., 2006; Adi & Noor, 2009; Amouei et al., 2017; Mousavi et al., 2017).

The phosphate content is attributed to the mineralization and mobilization of phosphorous due to the earthworm activity. It is thought that the content and quality of the raw materials consumed by worms and the vermicomposting process are effective in changing the amount of phosphorus in the growing media. Earthworms play an important role in the release of phosphates in organic matter (Ansari & Rajpersaud, 2012).

The increase in K of the vermicompost in relation to that of the simple compost and substrate was probably because of the physical decomposition of organic waste matter due to the biological grinding during passage through the gut, coupled with enzymatic activity in the worm's gut, which may have caused its increase (Rao et al., 1996). The microorganisms present in the worm's gut probably converted insoluble K into the soluble form by producing microbial enzymes (Kaviraj & Sharma, 2003).

As a result of the research, it was determined that the pH value increased in all the feeding materials in the final vermicompost. The highest increase (37.78 %) in the pH value occurred in the D growing medium with a different mixture composition. This research showed that *Eisenia fetida* and microorganisms are effective in changing the pH in the waste materials, and the differences in the pH of the final vermicompost are directly dependent on the type and content of the raw materials used for vermicomposting. Suthar et al., (2015) reported that during the vermicomposting process, the microbial activity and decomposition of organic matter resulted in the formation of ammonium and increased the pH. Compared to the initial values, the E.C content values increased in the feeding materials A, C, and D, while it decreased in the feeding material B in the final vermicompost. The biggest change in the E.C values occurred in the D feeding materials, which had 4 different feeding material mixes. It can be concluded that the differences in the growing mediums, earthworm activity in different growing mediums, and the decomposion of organic waste materials are effective in the changing of electrical content. Amouei et al., (2017) reported that some minerals can accumulate in the earthworms' bodies, and consequently, reduce amount of minerals in the vermicompost.

As a result of the vermicomposting process, the Pb, Cd and As content in all the feeding materials was decreased. The highest decrease in the Pb content was determined in the feeding material B (97.5 %), while the lowest decrease was determined in the feeding material A (45.82 %). The highest decrease in the Cd content was determined in the feeding material C (55.41%), while the lowest decrease was determined in the feeding material D (5.82 %). The highest decrease in the As content was determined in the feeding material B (85.86 %); while the lowest decrease was determined in the feeding material D (16.88 %). The change of Cr, Cu and Ni content in the vermicompost obtained from the different feeding materials was irregular. The mean Cr content decreased by 58.59 %, 27.45 % and 0.8 % in the feeding materials' A, C and D respectively; while the Cr content increased by 57.71 % in the feeding material B. The mean Cu content decreased by 79.58 %, 63.65 %, and 59.42 % in the feeding materials' B, C, and D; while it increased by 7.71 % in the feeding material A. The mean Ni content decreased by 56.58 %, 20.70 %, and 7.10 % in the feeding materials' A, C, and D; while it increased by 19.33 % in the feeding material B. Our research showed that *Eisenia fetida* can accumulate a significant amount of metals in their tissues during vermicomposting. In many studies, it has been found that earthworms can accumulate heavy metals in their tissues during the process of vermicomposting (Hopkin, 1989; Hopkin & Spurgeona, 1999; Malley et al., 2006; Nahmani et al., 2007; Singh et al., 2014; Kızılkaya & Türkay, 2014; Tang et al., 2017). The type and content of the feeding materials is also thought to have an effect on the heavy metal's accumulation in the earthworm tissues. However, during the vermicomposting process, a group of heavy metals in the feeding materials leached to vermiwash. In a study conducted by Yüksek et al., (2017) *Eisenia fetida* were fed with fermented cow dung for 60 days, and vermiwash was harvested in day 60. As a result of their study, compared to initial feeding material (cow dung), the mean Cd, Pb, and As content increased by 96,84 %, 79,37%, and 75,08% in the vermiwash; while the Cu and Ni content decreased by 64%, and 22% in the vermiwash when compared to the initial feeding material.

CONCLUSION AND RECOMMENDATION

This research has clearly shown that *Eisenia fetida* is very effective in the recovery of organic wastes and increasing the N, K, and pH content in the final vermicompost. Moreover, *Eisenia fetida* was very effective for the reduction of the bioavailability of the heavy metals (especially, Pb, Cd, and As) during the vermicomposting of the husk material, husk and tea waste materials, and husk material mixed with tea waste, cow dung, sawdust and waste paper materials.

The agricultural wastes in the northeastern Black Sea, located in the Trans- Caucasus corridor, can be converted into vermicomposts in small enterprises. In this way, while the conservation of both soil and water resources is ensured rural development and women's employment might be increased. We believe that, it may be very beneficial for the environment to conduct other research to show how to maximize the level of macro nutrients in organic wastes, how to reduce heavy metals in organic wastes to the lowest level, and what quantities of the heavy metals are trapped in the worm tissues.

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