

CONTRIBUTION OF ORGANIC BULKING MATERIALS ON CHEMICAL QUALITY OF SEWAGE SLUDGE VERMICOMPOST

Efeito de materiais de volume na qualidade química do vermicomposto de lodo de esgoto

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ABSTRACT

Vermicomposting is a suitable method for stabilization and converting of sewage sludge into useful products. To investigate the effects of bulking material on vermicompost quality, an experiment was conducted in a factorial design with three replications. In this experiment, the final dried sludge in lagoons was mixed with bulking materials (woodchips, three leaves, and wheat straw) in four mixing proportions with sewage sludge (0, 15, 30 and 45%, V/V). Chemical properties of bulking materials, sewage sludge, and produced vermicomposts were determined. Vermicomposts had relatively low pH and electrical conductivity (EC). The nutrients content of vermicompost, especially N, P, Fe, and Zn, were high. These properties showed its suitable quality for use in agriculture. Heavy metals concentrations of vermicomposts, except Zn, were lower than recommended values by EPA. Mixing of Bulking materials with sewage sludge decreased pH, N, Pb, Co, and Cd, but increased Ca, Mg, Fe, Cu, Mn, Zn, and Ni content of produced vermicomposts. In most cases, the concentrations of nutrients were higher in 30% mixing proportion. Therefore, 30% (v/v) mixing of bulking material with sewage sludge is recommended for vermicompost production.

Index terms: Vermicompost, sewage sludge, bulking materials, heavy metals, *Eisenia foetid*.

RESUMO

A vermicompostagem é um método adequado para a estabilização e conversão de lodo de esgoto em produtos úteis. Para investigar o efeito de aumentar o volume de material sobre a qualidade do vermicomposto, foi conduzido um experimento em esquema fatorial com três repetições. Neste experimento, o lodo final seco em lagoas foi misturado com materiais de volume (lascas de madeira, três folhas e palha de trigo) em quatro proporções de mistura (0, 15, 30 e 45% V / V) com lodo de esgoto. Propriedades químicas dos materiais de amontoamento, lodo de esgoto e vermicompostos produzidos foram determinados. Vermicomposto apresentaram pH relativamente baixo e CE. O seu teor de nutrientes, especialmente N, P, Fe e Zn foram elevados. Essas propriedades mostraram sua qualidade adequada para utilização na agricultura. Concentrações de metais pesados de vermicompostos, com exceção do zinco, foram menores do que os valores recomendados pela EPA. A mistura de materiais Bulking com lodo de esgoto diminuiu o pH, N, Pb, Co e Cd, mas aumentou a concentração de Ca, Mg, Fe, Mn, Cu, Zn, Ni no vermicomposto produzido. Na maioria dos casos, as concentrações de nutrientes foram maiores na proporção de 30% de mistura. Portanto, recomenda-se a mistura de materiais ao lodo na proporção de 30% para a produção de vermicomposto.

Termos para indexação: Vermicomposto, lodo de esgoto, materiais de volume, metais pesados, *Eisenia foetid*.

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INTRODUCTION

There are a large amount of sewage sludge produced in wastewater treatment plants that caused potential risks for human health and environmental problems (BAZRAFESHAN et al., 2005). Sewage sludge can be used as organic fertilizer and soil amendment, but its odors, heavy metal content, toxic organic compounds, and pathogens show the necessity of treatment and stabilization before application to farm lands (TIQUIA et al., 2002). Stricter regulations governing the discharge of sewage into waters and the escalating costs of alternate disposal procedures and chemical fertilizers have increased interest in using land to dispose of municipal

sewage sludges and effluents (KELLEY et al., 1984). Some of the beneficial effects of land application of sewage sludge are supplying nutrients (N, P, secondary nutrients, and micronutrients), improving of soil physical conditions, and elevating of soil organic matter level. Heavy metals and organic pollutants concentration limits the use of sewage sludge as organic fertilizer (QUATMANE et al., 2000). Biological composting of sewage sludge stabilizes its organic content and decreases the pathogens population (BURGE; ENKIRI, 1978). Although, total concentration of heavy metals increase during composting, the available forms of them decline in this process; probably due to production of insoluble complexes with humic substances (PARÉ et al., 1999).

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According to Stover et al., 1967 findings, less than 17 percent of the total amount of Cu, Zn, Pb, and Cd in sludges and approximately 22 percent of Ni are in the sorbed and exchangeable fractions, that is, the forms readily available to plants. The remainder of the metals is present in forms which require conversion to water-soluble, exchangeable, or sorbed forms before uptake by plants. Sommers (SOMMER, 1997) suggest that different chemical forms of a metal may predominate in different sewage sludges. Thus, the behavior of a metal after incorporation into the soil may not be similar for different sludges.

Use of earthworms in sewage sludge composting is a suitable technology for its management. The activity of earthworms helps to remain of aerobic condition and accelerates microbial decomposition. In this process increases the earthworm's biomass and leaves their castings rich from nutrients (BENITEZ et al., 1999). Mixing of bulking material to sewage sludge improves earthworm's activity and the quality of vermicompost (DOMINGUES et al., 1999). Gondek and Filipek-Mazur (GONDEK; FILIPEK-MAZUR, 2001) used from conifers saw dust, shredded cardboard, and wheat straw as bulking agents with the mixing proportion of 15% for vermicompost production from sewage sludge. Arumuga et al. (ARUMUGA et al., 2004), in India, used from the mixture of sewage sludge, rice straw and manure for vermicompost production. Vigueros and Camperos (VIGUEROS; RAMIREZ-CAMPEROS, 2002) used from water hyacinth as bulking material for vermicomposting of sewage sludge. Eastman et al. (EASTMAN et al., 2001) showed that fecal coliforms bacteria and helminthes ova in were significantly lower in vermicompost compare to compost produced from biosolids and vermicomposting is an alternative method for class a compost production.

The aims of this study were: 1) to determine chemical composition of produced vermicomposts from mixing of various bulking material with sewage sludge 2) to investigate their quality and suitability as organic fertilizer

MATERIAL AND METHODS

This study was carried out in glasshouse of University of Mohaghegh Ardabili under natural light condition. The experimental design was factorial with complete random blocks and three replications. The main factor was type of bulking materials and their mixing proportion with sewage sludge was as subordinate factor. Final dried sewage sludge were collected from

Tabriz city sewage treatment plant and mixed with bulking materials (shredded wheat straw, wood chips, and shredded tree leaves) in the proportions of 0, 15, 30, and 45% (V/V) and filled in 4 litter black coloured plastic pots. To determine proper time of earthworm application, 10 mature worms were added in weekly intervals and their survival was investigated. After one month and sure from the residence of earthworms, 100 mature worms from *Eisenia foetida* species were added to the experimental pots. The moisture of materials was controlled close to 70% of saturation based on pot's weight and water sprayed to avoid drying of material's surface. After 5 months of incubation of pots, the colour of materials turned to dark brown black and the activity of worms declined that these conditions indicated the maturity of vermicomposts. At this time, vermicomposts were harvested and analyzed to determine their chemical properties.

The pH and the electrical conductivity of the sludge were measured in a suspension of 1:5 materials and distilled water. For all samples (sludge, bulking materials, and vermicomposts) one gram of grounded samples dried-ash in a muffle furnace at 550° C, extracted with 2 M HCl, and analyzed to yield the total concentrations of important nutrients and other elements (JONES et al., 1991). Organic carbon was measured by Walkley Black method; Total nitrogen with Kjeldahl method using an automated apparatus, Grehardt model 2020 (BOLTS; HOWELL, 1978); total P with ascorbic acid spectroscopic method (BOLTS; HOWELL, 1978); total Na and K by flame photometer; total Ca and Mg by complexometry (SPARKS, 1996). Total concentration of heavy metals include Fe, Mn, Zn, Cu, Pb, Cd, Co, and Ni were determined by atomic absorption instrument, Perkin Elmer model 640 (JONES, 2001).

Data were analyzed by one-way ANOVA in a general linear model, using SAS statistical software (SAS, 1990). LSD Multiple Range Test was applied to compare the means of elemental composition of the samples.

RESULTS AND DISCUSSION

Chemical characteristics of sewage sludge and bulking material that used in the experiment were shown in Table 1. Sewage sludge had neutral pH and low EC that shows suitability for plants growth. The C: N ratio of sludge was lower than suitable values for vermicomposting process. This result showed the necessity of application of bulking materials with high C content. Ndegwa and Thomson (NDEGWA; THOMSON,

Table 1 – Analyses of variance nutrient contents and chemical properties of Type of bulking material (TM), Mixing proportion (MP) and TM×MP used in the experiment.

Properties	Mean square			
	Replication	Type of bulking material (TM)	Mixing proportion (MP)	TM×MP
PH	0.298**	31.298**	32.42**	<0.0001**
EC	0.009**	1.3**	1.17**	0.000**
OC	33.02**	3.302**	10.43**	45.83**
N	0.075**	0.224**	0.367**	<0.001**
P	0.187 ^{ns}	0.31 ^{ns}	0.22 ^{ns}	0.00 ^{ns}
K	0.0001 ^{ns}	0.0004 ^{ns}	0.00036 ^{ns}	0.00056 ^{ns}
Ca	1.25**	1.707**	3.84**	0.57**
Mg	0.0559**	0.136**	0.185**	0.0139**
Fe	1474223**	206584.6**	517042**	271378**
Cu	1197.8**	814.7**	1457.4**	338.7**
Mn	6493.3**	21679.8**	20268.1**	0.000**
Zn	81.03**	8720.37**	274.81**	8965.19**
Pb	2.06**	72928.5**	36744.3**	7923.8**
Ni	3.89**	48.19**	26.46**	55.57**
Co	2.43**	2.37**	26.27**	19.91**
Cd	4.14**	9.51**	7.25**	2.61**

** , * and ns, significant in 1%, 5% and not significant, respectively.

2000) reported that the C:N ratio of 25:1 for starting materials in vermicomposting process of sewage sludge resulted in maximum stability, highest fertilizer value, and minimum potential environmental pollution. Total concentration of P was high, probably due to carbon involvement and reduction of sludge volume in decomposition stages in treatment steps. Atieh et al. 2000 suggested that rapid break down of C compounds and CO₂ evolution from the manure could lead to a decrease of biomass and consequent increase of vermicompost nutrients content.

Chemical composition of bulking materials used for vermicompost production was also represented in Table 1. C: N ratio of wood chips and wheat straw were lower than reported values for these wastes (80:1, and 500:1, respectively) (GUPTA et al., 1977). Partial decomposition of materials might cause to decrease of their C: N ratio. Wood chips had higher C, and C/N content and lower content of other nutrients compare to other bulking materials. A comparable data was reported by Hashemimajd, 2010.

It seems that since sewage sludge had much higher P content than bulking material and in decomposition process much of bulking material's carbon was lost, therefore, the P content of vermicomposts did not

significantly different. On the other hand, losses of potassium during vermicomposting process caused to hinder the effect of bulking materials in potassium concentration of sewage sludge vermicompost. Wortmann et al. 2007 confirmed the loss of potassium during composting of different organic wastes.

The effects of type and mixing proportion of bulking materials on chemical composition of produced vermicompost were shown in figures 1-3. Addition of bulking materials decreased the pH of vermicompost compare to control, proportional to mixing percentage with sewage sludge. The amount of pH reduction was greater when woodchips was used as bulking material. Reduction of pH during vermicomposting process might due to production of organic acids and insertion of Ca to earthworm's body. There was contradictory data in literature about the change of pH in vermicomposting process. Hashemimajd et al., 2006 reported the increment of pH in vermicomposting process for mixture of sewage sludge and wood chips, while Atiyeh et al. 2000 showed the pH of manure was decreased in vermicomposting. The higher reduction of pH in wood chips might due to higher CO₂ Production in this

treatment that caused to produced more organic acids including H_2CO_3 . Sundberg et al., 2004 reported organic acids are produced during initial phases of composting. Electrical conductivity (EC) of vermicomposts were higher than initial sewage and might due to mineralization of organic compounds during vermicomposting process. Hashemimajd et al., 2006 confirm EC enhancement during vermicomposting of saw dust. Organic carbon (OC) content of vermicomposts was higher than original sewage sludge But there was no distinct trend among the effect of type and mixing proportion of bulking material on vermicomposts OC (Figure 1). Application of bulking materials also reduced N content of vermicompost compare to initial sewage sludge and its effect was proportional to the bulking material mixing percentage. These results might due to higher C and lower N content of bulking material compare to sewage sludge. Nitrogen concentration of vermicomposts in 30 mixing proportion was higher than that of 45% treatment.

It probably showed the higher stability of 30% treatment (Figure 2). Arumuga et al. 2004 pointed out that the C content of materials was decreased while the N content was increased and there were no significantly differences, in this respect, between kinds and mixing proportion of bulking material. Nakashi et al. 2001 found that saw dust is the most effective material for avoiding N loss as NH_3 from compost piles and its effect is proportional with mixing proportion. Wortmann et al. 2007 declared that bulking material decrease C:N ratio of wastes and reduce the N losses during the process.

Addition of bulking material elevated the Ca, Mg, Fe, Cu, Mn, and Zn contents of produced vermicomposts than that of control. Silva et al. 2002 showed that Ca and Mg concentration were increased in vermicomposts. In most cases the concentration of these elements was higher again in 30% mixing proportion. The concentration of Mg was greater in pots containing wood chips (Figure 1), probably

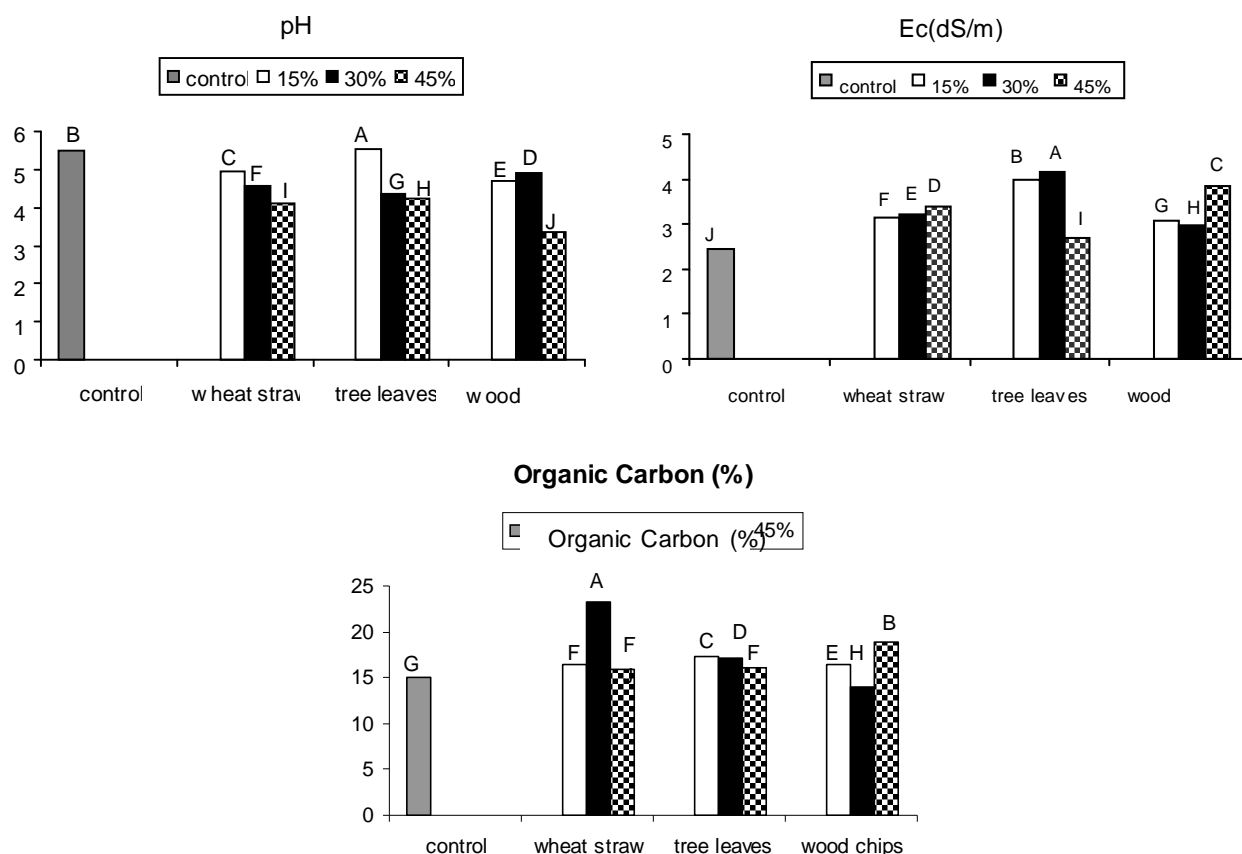


Figure 1 – pH, EC, and percentage of organic carbon of vermicomposts in different treatments, columns showed with similar capital letters have not significantly difference at 5% level (Duncan multiple range test).

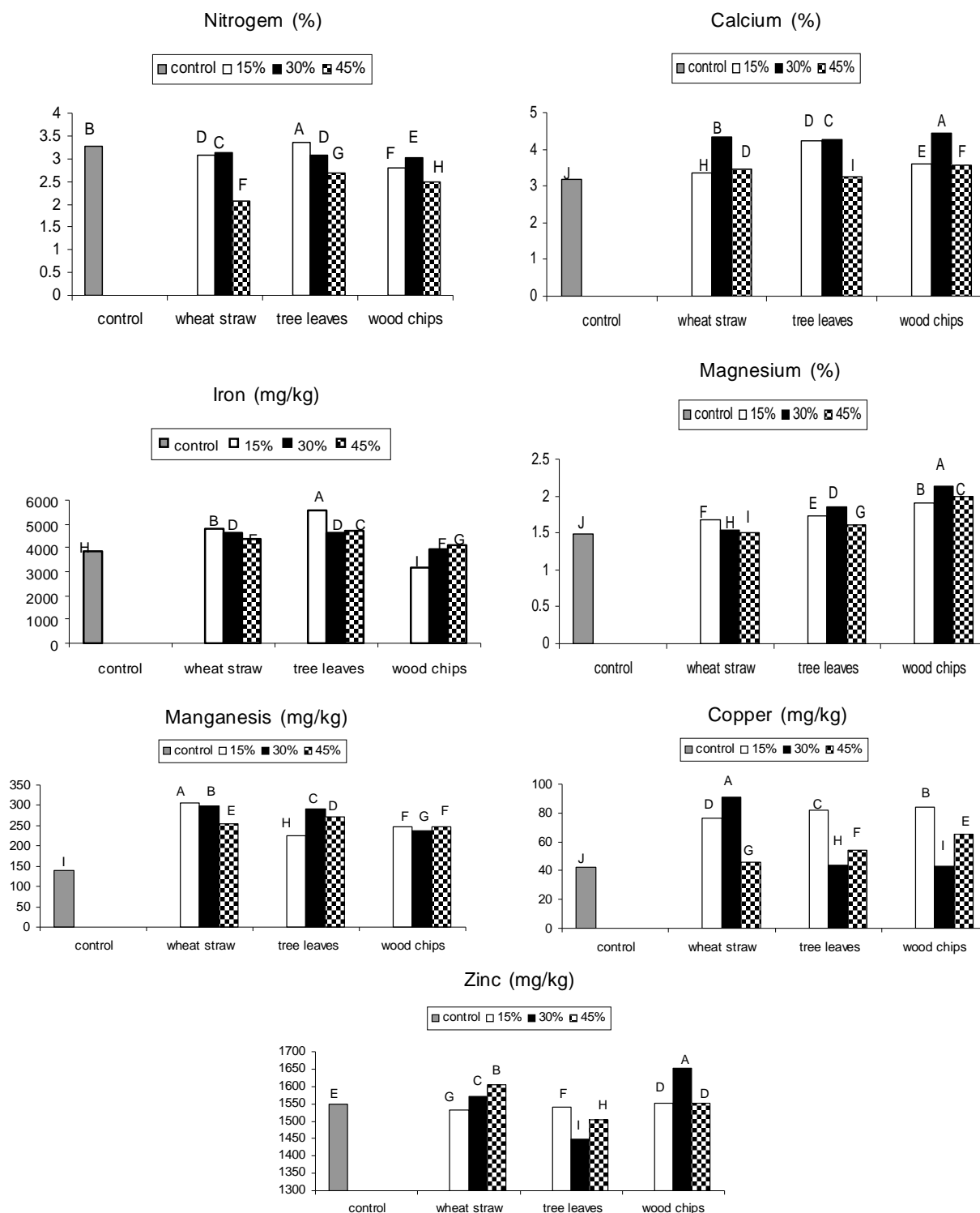


Figure 2 – Percentage of nitrogen, calcium, magnesium and concentration of iron, manganese, copper and zinc in produced vermicomposts, columns showed with similar capital letters have not significantly difference at 5% level (Duncan multiple range test).

reflected the higher concentration of this element in initial wood chips (Table 1). The iron content was higher of vermicompost in tree leaves and sludge mixture but lower in wood chips containing treatments. There was no distinct trend in the concentration of Cu in different treatments. Sommers, 1997 confirmed that the Cu content of sewage sludge is very variable. Wheat straw and wood chips added treatments had highest and lowest Mn conten, respectively. The concentration of Zn was lower in the tree leaves incorporated treatments. Increasing of nutrient concentration of final vermicompost in bulking material added might due to evolvement of CO₂ and increase the concentration of other nutrients (ATIYEH et al., 2000).

Addition of bulking materials were decreased the concentrations of Pb, Co, and Cd but increased Ni

contents of them. (Figure 3). Some researchers declared that changes of heavy metal concentration in vermicomposting process depend on the elemental composition and chemical properties of sludge. Manios; Stenifored, 2006 reported that Zn concentration of vermicompost produced from 1:1 mixing of sewage sludge and olive leaves (V/V) was more than 1:2 mixing proportion and Pb concentration was higher in 1:2 mixture but Ni concentration was similar in both treatment. Concentration of heavy metals except Zn was lower that standard limit recommended by US EPA (RENNER, 2000). Concentration of Zn was slightly higher than acceptable level (1500 mg/kg). Numerous reports confirmed that the concentration of heavy metals in sewage sludge vermicompost as in acceptable limits (EASTMAN et al., 2001; PARVARESH et al., 2004; SILVA et al., 2002; VIGUEROS; RANIREZ-CAMPEROS, 2002).

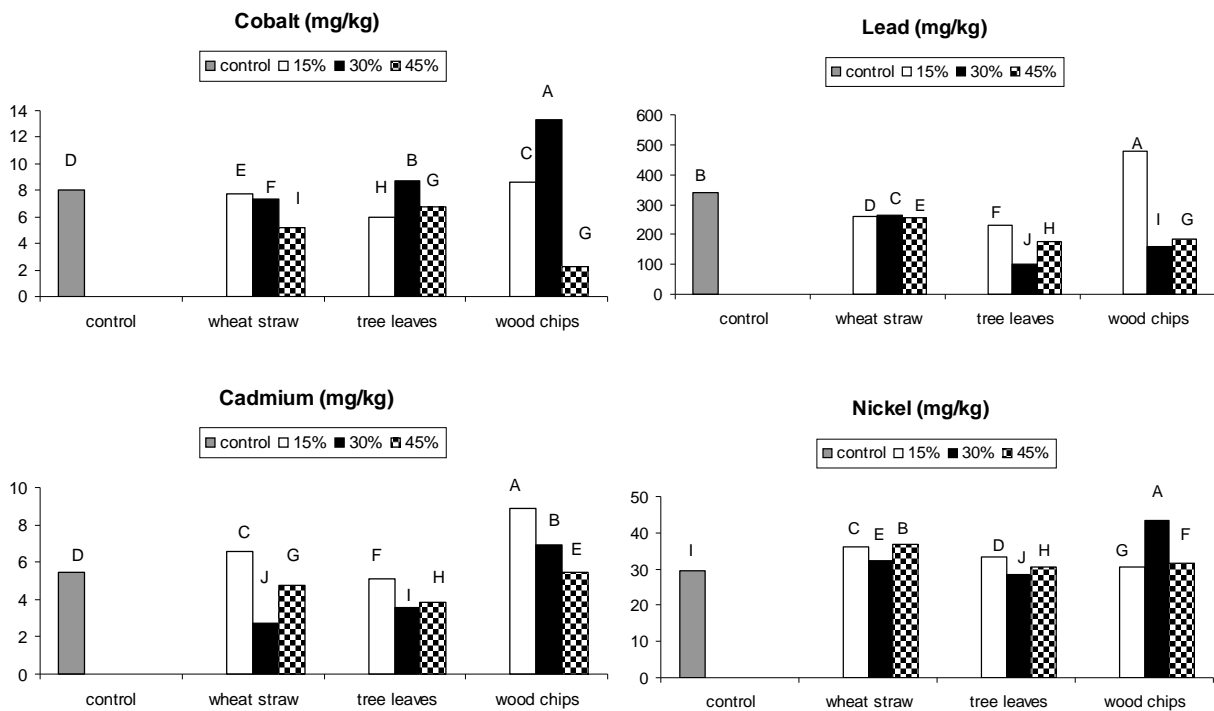


Figure 3 – Concentration of cobalt, lead, cadmium and nickl in vermicompost, columns showed with similar capital letters have not significantly difference at 5% level (Duncan multiple range test).

CONCLUSION

Sewage sludge vermicomposts have low pH, low salinity, and high nutrients content. Mixing of bulking materials with sewage sludge reduced pH, N, Pb, Co, and Cd concentration while increased Ca, Mg, Fe, Cu, Mn, Zn, and Ni content of vermicompost. The heavy metals concentration in vermicompost is in EPA recommended ranges. The concentrations of nutrient were higher in 30% of mixing proportion. Further researches about the effect of vermicomposts produced from different type of bulking materials and sewage sludge on soil properties and plants growth is recommended.

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