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Determination Of Heavy Metals Concentration In Food Waste Compost On Root Uptake Of Capsicum Annuum L

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Abstract

The increasing amount of food waste in Malaysia in recent years has brought many serious environmental issues to the country where it affects the nation's solid waste management framework. As for now, the Food Waste Management Development Plan for Industry, Commercial and Institution Sector (2016-2026) is taking actions in order to achieve efficient and effective food waste management. One of the strategies listed is by enhancing food waste treatment at source through composting due to its environmental and economic benefits. However, an excessive amount of heavy metals and minerals will pose a harmful effect to the plant and soil by disrupting the microbial biota that is responsible for plant growth. This study was conducted to provide information on heavy metals concentration contained in Food Waste Compost (FWC) and root of Capsicum annuum L. (chilli plant). The study was consist of several stages, starting from the preparation of food waste compost, planting process, treatment application, harvesting, and collecting data followed by laboratory analysis and finalised with analysing data statistically. A total number of 16 experimental units involving four levels of soil treatment (T1 = no FWC, T2 = 31.9 FWC / week, T3 = 81.9 FWC / week, T4 = 11.9 FWC / week) with a set of replications were conducted in the glasshouse. The experimental design was in the form of randomised complete block design (RCBD). The heavy metals in food waste compost, such as lead (Pb), nickel (Ni), chromium (Cr), copper (Cu), zinc (Zn) and cadmium (Cd) were determined using Inductively Coupled Plasma Mass Spectroscopy (ICP- MS). The average concentrations for the heavy metals were Pb (1.0 ± 0.455 ppm), Ni (140.0 ± 9.899 ppm), Cr (446.2 ± 36.770 ppm), Cu (10.9 ± 1.438 ppm) and Zn (19.0 ± 5.940 ppm). However, concentration for Cd was failed to be determined due to its below detectable level readings. From these six metals, Ni and Cr were found higher in a concentration exceeding the heavy metal limits in compost-based on standards from European countries and Canada. The concentration of Cr and Ni were later determined in the root of Capsicum annuum L. with different compost treatment rates using Atomic Absorption Spectroscopy (AAS). Average concentration in root for Ni were (T1: 1.68 ± 0.020 ppm), (T2: 2.25 ± 0.274 ppm), (T3: 2.10 ± 0.390 ppm) and (T4: 2.19 ± 0.274 ppm), meanwhile for Cr were (T1: 1.40 ± 0.04 ppm), (T2: 1.88 ± 0.679 ppm), (T3: 1.90 ± 0.545 ppm) and (T4: 1.88 ± 0.474 ppm). Both metals in all treatments exceeded the permissible limit listed by the World Health Organization (WHO), which for Ni is 1.5 ppm and for Cr is 1.3 ppm with the obtained data being provisionally insignificant ($p > 0.05$). Based on the findings of this study, it can be inferred that the food waste compost contained Ni and Cr exceeding the permissible limit in soil treatment and root of Capsicum annuum L.

Index Terms: *Capsicum annum L., food waste compost, heavy metals, ICP- MS*

Introduction

The increasing amount of food waste in Malaysia in recent years has brought many environmental issues to the country where it affects the nation's solid waste management framework (Lim *et al.*, 2016). According to a study conducted by the National Solid Waste Management Department

(JPSPN) in 2012, food waste is among the highest waste generated in Malaysia approximately about 31 to 45 % of the total volume waste generated every day. As for now, the Food Waste Management Development Plan for Industry, Commercial and Institution Sector (2016-2026) is taking actions in order to achieve efficient and effective food waste management. One of the strategies listed is by enhancing food waste treatment at source through composting due to its environmental and economic benefit (JPSPN, 2012).

According to Gonawala and Jardosh, (2018) composting is one of the low-cost biological decomposition processes that is circuited by microbial activity. It reduces environmental impacts and able to turn organic waste into a useful product as soil amendments (Hernández *et al.*, 2016). Also, supported by (Kadir *et al.*, 2016), where the study mentioned that compost could be used as a soil conditioner, organic fertilizer as it contains high minerals for the soil and plant as such manganese (Mn), zinc (Z), copper (Cu) and boron (B) which are required insufficient amount. Hence, it is considered as an effective solution to recycle biodegradable material, especially food waste into compost. However, the excessive amount of these minerals will pose a harmful effect to the plant and soil by disrupting the microbial biota that is responsible for plant growth (Singh Jiwan & Kalamhad, 2011).

Heavy metal contamination has a harmful effect on biological systems as it does not undergo biodegradation and will accumulate in plants (Hamzah, 2010). According to a study by Dinanmonti *et al.* (1997), the effect of compost use on heavy metal levels in the environment shows an increase of non-essential heavy metals accumulation in plant and soil. These heavy metals are detrimental to human or animal life if they present above specified limits.

Despite that, established data or information in regards to heavy metal content in composting products are still inadequate. There is no standard or guidelines on the record provided by the Malaysian Department of Agriculture in the heavy metal limits in compost fertiliser. The closest strategy to engage with heavy metal awareness in plants were through Malaysian Good Agricultural Practice (myGAP) in which vegetable and fruit samples as such chilli, spinach, mango and papayas were tested for heavy metal analysis (Ministry of Agriculture, 2016). However, this strategy is unable to prevent heavy metal contamination to the soil as it is tested on the harvested result. Thus, in order to establish sustainable conservation towards the environment, it is recommended to assess the compost quality which includes analysing the level of heavy metals beforehand for safe use of compost products (Cofie *et al.*, 2016).

Therefore, this study is conducted to identify the concentration of six selected heavy metals listed by the compost-based on Standards from European countries and Canada which are lead (Pb), nickel (Ni) chromium (Cr), copper (Cu), zinc (Zn) and cadmium (Cd) in the food waste compost prepared together with Daya Bersih Sdn Bhd. Further analysis was then conducted in the root of chilli plant (Capsicum annum L.) in order to test for the uptake of selected heavy metals.

This research is beneficial to provide data on the concentration of heavy metals in food waste compost and the plant uptake. At the moment, there is no heavy metal concentration data released in IIUM compound from the compost material. The data analysis can be turned as proof that food waste compost provided is safe to the environment and human through consumption in plant. In general, the data on heavy metal composition will help to achieve sustainable use through the treatment of mounting food waste generation in International Islamic University Malaysia Kuantan Campus into compost materials. Moreover, with the heavy metal data in plant uptake, potential sources of metal contamination can be listed throughout the plantation process to preserve soil resources against heavy metal build up in the long term.

The objective of this study is to determine the concentration of heavy metal content lead (Pb), nickel (Ni) chromium (Cr), copper (Cu), zinc (Zn) and cadmium (Cd)) in the food waste compost using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS); and to determine any exceeding metals concentration in food waste compost on the root of Capsicum annum L. by using Atomic Absorption Spectroscopy (AAS).

Literature Review

Food Waste As Source of Compost

Food waste is a recyclable material in the dominant composition of 40 % to 64 % in municipal solid waste in Malaysia (Lim et al., 2016). Malaysia with a population of more than 30 million in 2014, produced up to 8,000 tonnes of food waste in a day (The Sun Daily, 2014). The reason for the escalating quantity of food waste is due to changes in eating habits due to improved living standards and rapid population expansion and urbanisation (Tarmudi et al., 2009).

In Malaysia, the authority is facing severe challenges in food waste handling and treatment although several efforts have been introduced publicly at national levels such as the National Solid Waste Management (2002-2020), National Recycling Program (2000-2005) and Waste Minimization Master Plan (2005). The lack of success was due to existing waste management practise did not improve significantly (Lim et al., 2016).

Concurrently, however, the food waste management and policy for its treatment is less efficient in Malaysia due to limited budget and restricted periodic analysis. However, it can be done in small scale methods through composting (Tarmudi et al., 2009). According to Cekmecelioglu et al. (2005), composting is a nature-friendly food waste handling methods that offer better management in terms of gas and leachate discharge Moreover, it is considered as one of the low-cost biological decomposition process circuited by microbial activity which is used to recycle recyclable organic materials.

Reducing and managing food waste through composting is suitable as food waste has unique features as raw compost agent, which makes it useful as fertiliser (Risse, 2014). Moreover, food waste contains high energy and is suitable for energy production and waste stabilisation (Okareh et al., 2014). It is considered as a suitable source of compost as it has high moisture content and low physical structure as compared to sewage, sludge and manure (Kadir et al., 2016).

Furthermore, according to Kumar et al. (2010), food waste that is not composted will end up being buried and densely compacted in landfills across the country. The dumping of food waste in the landfill will cause the production and release of greenhouse gases into the atmosphere, mainly carbon dioxide (CO2) and methane (CH4) thus may cause global warming. Poor management of food waste will cause contamination of groundwater and attraction of vermin (Hernández et al., 2016). Hence, converting food waste to fertiliser by composting helps to reduce the amount of food waste generation issue (Stabnikova et al., 2005).

Heavy Metal Contents in Compost

Heavy metal is detrimental elements which cannot be degraded or destroyed making them as the persistent toxic substances in the environment when in excess (Zhuang *et al.*, 2014). This incidence is alarming as they often show harmful effects in plants, animals and humans (Jaishankar *et al.*, 2014).

Table 1 depicts essential heavy metals such as zinc (Zn), boron (B), copper (Cu), iron (Fe), molybdenum (Mo) and manganese (Mn) that plays a beneficial role in plant growth and development. According to Arif *et al.* (2016), optimum levels of some beneficial elements improves the plant's nutritional level and mechanism for growth. However, their excessive amounts in the soil above threshold values can result in toxicity. Thus, it is essential to know the composition of heavy metals in the compost or fertiliser as the application might inhibit the plant growth, and prolonged application will degrade the soil (Nartey *et al.*, 2012).

Table 1: Essentiality of Heavy Metals to Plant (Arif *et al.*, 2016)

Element	Plants
Lead (Pb)	No
Chromium (Cr)	No

Copper (Cu)	Yes
Cadmium (Cd)	No
Manganese (Mn)	Yes
Molybdenum (Mo)	Yes
Nickel (Ni)	No
Zinc (Zn)	Yes
Boron (B)	Yes

According to Cofie *et al.* (2016), compost quality assessment is crucial as some of the organic materials may contain a substance that is toxic and capable of accumulating in soils and plants. Compost quality assessment includes analysing the level of heavy metals, organic pollutants and impurities. Heavy metals such as manganese (Mn), copper (Cu), nickel (Ni), chromium (Cr) and lead (Pb) may fall into this category as these metals may be immobilised chemically before composting.

Compost may be acceptable for land application when their metal concentrations are consistent with specific threshold values as displayed in Table 2 derived from European countries' standards guidelines (Cofie *et al.*, 2016).

Table 2: The Heavy Metal Limits in compost-based according to the Standards from European Countries (Cofie *et al.*, 2016)

Heavy Metal	Concentration (ppm)			
	UK Standard	Sweden Standard	Austrian Limits A+	EU Eco-Label
Pb	200	100	70	100
Ni	50	50	25	50
Cr	100	100	70	100
Cu	200	100	70	100
Cd	1.5	1	0.7	1
Zn	400	300	200	300

Effects on Plant Growth

Based on the literature, Shah *et al.* (2010) addressed that bioaccumulation of heavy metals in excessive concentrations may replace essential metals in pigments or enzymes disrupting their function and causing oxidative stress to the plants. Furthermore, the heavy metal toxicity hinders the growth process of the underground an aboveground plant parts and the activity of the photosynthetic elements. For instance, chromium (Cr) hinders the availability of nutrients like iron (Fe), manganese (Mn) and copper (Cu) in plant parts like roots, leaves and stem. Likewise, Moral *et al.* (1996) also reported that the nitrogen (N), phosphorus (P), potassium (K) and sodium (Na) contents in stems and branches of tomato plants treated with 50 and 100 mg L-1 of nickel (Ni) and lead (Pb) were significantly reduced. N, P, K and Na are essential for the plant enzymatic processes and growth.

According to Ye *et al.* (1997), Typha latifolia a cattail plant reported having stunting of the shoot, curling and rolling of young leaves, death of leaf tips and chlorosis with the presence of ~80 μM zinc. Effect of heavy metal on growth and development of the plant is also reported by Hanus and Tomas (1993), where Sinapsis alba a white mustard plant at a level of 200 or 400 mg kg-1 of Cr in soil along with fertiliser application showed a significant reduction in its height. Another study by Vernay *et al.*(2008) recorded that Datura innoxia an angel's trumpet plant exhibited toxic symptoms in the form of leaf fall and wilting of leaves at 0.5 ppm of Cr (VI) in soil.

Factors Influencing Heavy Metals Uptake

In order to quantify the heavy metal accumulation in a plant, the understanding of factors that influence the metals uptake in plants must be put into consideration. Heavy metal uptake refers to the process of metal movements from the external environment into a plant, in which these metals can be received through two mediums, which are from the root and foliar uptake (Mccauley *et al.*, 2011). However, in this study, the main focus is through root uptake as compost is applied through the soil. In general, heavy metal uptake is influenced by several factors that include biological and physico-chemical factors.

Biological Factors

Species and Variety: The uptake of heavy metals by plants is species dependent (Tangahu *et al.*, 2011). The metal uptake rate of different species is due to the ability of the plant root to release protons into the rhizosphere in order to increase the solubilization of metals into the root apoplast (DalCorso *et al.*, 2014). Another research stipulates that different species of plant has a different amount of Casparian strip in the root steele. The presence of the strip is responsible for the active uptake of metals and nutrient for the plant (Shahid *et al.* 2017). However, some research suggests that the uptake is related to the plant requirements, which means some plants required more of a specific element compared to others and have a high ability to absorb it.

Age: The age of plants might be responsible for their metals uptake rate and ability (Tangahu *et al.*, 2011). According to Dalcorso *et al.* (2014), as plant mature from seedlings to full-sized plants, the root structure as such its length and hair grows. The root length and hair is accountable in absorbing the metal and water from its source as the greater the length and hair, the greater the amount of Casparian strip present in the root tissue.

Physico-chemical Factors

It is a method of determination of the nature of the interactions between the components of a system through a study of relations between the system's physical properties and composition. Temperature and pH might affect the metal uptake in several ways by altering the metal solubility, root absorption abilities and its physical.

Temperature: High temperature is one of the most important environmental factors limiting the growth and productivity of plant species from temperate climates (Rachmilevitch *et al.*, 2008). A soil temperature of 23°C or above is detrimental to root growth and other activities (Pote and Wang, 2006). Literature review reported that root growth is crucial for metal absorption in a plant; inhibition of growth will limit the metal uptake (Tercek *et al.*, 2003). According to Fritioff *et al.* (2005), the release of heavy metal is greater at a higher temperature than lower temperature. As metal exists in soil stably, the soluble speciation of metal could be released into water or through a chemical reaction. With increasing temperature, the reaction could be accelerated and dissolved oxygen in the water, and the dissolution of the carbonates and hydroxide increased. Therefore, the metal release rate of water-soluble fraction, carbonate fraction and exchangeable fraction from soil increased. Changes in temperature also further change the composition of the plasma membrane lipids (Lynch and Steponkus, 1987). The scenario, alters the plant membrane fluidity, resulting in lower membrane permeability at low temperatures and lower metal uptake (Hänsch and Mendel, 2009). In conclusion, lower temperature enhances heavy metal absorption by plants as it promotes root growth, contains more dissolved oxygen for metal to bound in soil and water and lowers membrane permeability of plant cells.

pH: It has been widely documented that heavy metal uptake by plants is strongly pH-dependent (Wang *et al.*, 2006). Based on a previous study by Adanczyk-Szabela *et al.* (2015), increasing the soil pH to 10, resulted in a significant decrease in the metal content of all plants investigated. The result is consistent with literature data, which indicate that at high soil alkalinity, most plants are not prone to metal uptake. However, there is a general understanding that low pH prompts high metal mobility (Violante *et al.* 2010). When the pH value is high, the ions exist by insoluble oxide and hydroxide which the plants hardly absorb heavy metals. When the pH value is low, organic acids and H+ competition will lead to ions replaced by H3O+, which mobilise heavy metals ions from sediment and increase the possibility of root to absorb heavy metals (Li *et al.*, 2015).

Capsicum annum L. (Red Chilli Var. Bara)

Capsicum annum L. belongs to the family Solanaceae which is one of the most important vegetables as spice crop around the world (Basu *et al.*, 2003). The genus name Capsicum derived from the Latin word ‘Capsa’ meaning chest or box because of the shape of fruit which encloses seeds very neatly, as in the box (Sanati *et al.*, 2018).

Genus Capsicum represents a diverse plant group which contains approximately 30 species, 5 of which C. baccatum, C. annum, C. chinense, C. frutescens and C. pubescens are domesticated and cultivated in different parts of the world. Among the five species of Capsicum cultivated, C. annum is one of the most common cultivated crops worldwide followed by C. Frutescens (Baral & Bosland, 2002).

According to Fudholi *et al.* (2013), for Malaysian red chilli, it was found to have high in vitamin C (175 mg/100 g), calcium (15 mg/100 g), fiber (4.8 %), protein (2.8 %), iron (1.8 mg/100 g), ash (0.9 mg/100 g), and lipids (0.7 mg/100 g). Furthermore, red chilli is a good source of antioxidants as it is rich in vitamins A and C, minerals, and other phytochemicals, which are an important source of nutrients in the human diet.

Chilli is grown for their food value, health-promoting properties and also the source of capsaicinoids that have a variety of medicinal uses (Sanati *et al.*, 2018). However, the accumulation of heavy metals by medicinal plants grown in composted soil can be a severe problem that requires continuous monitoring (Antonius, 2016). Furthermore, previous research found that heavy metal concentration in chilli parts in neighbouring country Thailand were high exceeding the permissible limit (Limmatrapirat *et al.*2011).

Another prior research by Abdrahim *et al.*(2012), also found that chilli planted in ultra-basic soil, Negeri Sembilan accumulated concerning the amount of nickel, zinc, iron and manganese in roots, fruits, leaves and stem with availability percentage of 8 to 10 %. Thus, it can be concluded that chilli plant is suitable for this study as it is capable to absorb and accumulate heavy metals and at the same time valuable to be preserved as it is useful in medicinal uses.

Methodology

Preparation of Compost

The preparation of food compost followed by the standard operational guidelines for composting enlisted by Daya Bersih Sdn Bhd. Food waste leftover such as rice, chicken and vegetables remain generated at Mahallah Talhah were collected in a mobile garbage bin within three days until it reached 300kg. Once it reached the required weight, bins were transported to the composting centre at Daya Bersih Composting Unit. Food waste was mixed thoroughly in a steel container to promote homogeneity. The microbial spray was applied for fast growth rates of the microorganism to decompose. Next, the food waste was meshed in a blender to smaller pieces. The pieces were then placed in a heated automated spinning barrel until it dried and became ash. The end product was kept in a sealed plastic bag for usage.

Experimental Design

A total number of 16 experimental units involving 4 levels of treatment with a set of replications were conducted in the glasshouse. The experimental design was in the form of randomised complete block design (RCBD) as shown in Figure 1. It is used to control variation in an experiment by varying the location of the same treatment randomly to ensure uniformity in the exposure of sunlight and humidity of the crops.

The study was conducted in Glasshouse Complex (GHC), International Islamic University Malaysia in Kuantan Campus. A total of 32 chilli seeds was grown in the germination tray by using peat moss. After one month of the sowing process, the grown chilli plants were transplanted into polybags with one plant each.

There were four levels of treatments consisting of four different rates of food waste compost with control, as shown in Table 3. Treatments applied were spread uniformly in each polybag for four weeks. The calculation was made by referring to the Department of Agriculture Malaysia, specifically for chilli plant.

Figure 1: Arrangement of the crops following RCBD design.

Table 3: Treatment rates

Treatment	Rates per week (g)
T1 (Control)	Soil without application of food compost
T2 (Optimum)	31.9
T3 (Excessive)	81.9
T4 (Insufficient)	11.9

Laboratory Analysis

In General, all digestion procedures conducted employed by 65% of Nitric acid (HNO_3) (Merck GmbH, Germany). Meanwhile, 27% of hydrochloric acid (HCl) (R&M Chemicals, United Kingdom) was used to employ the digestion of soil and food compost. As for 30% of hydrogen peroxide (H_2O_2) (R&M Chemicals, United Kingdom) was used in the digestion of root samples. Finally, 40% of hydrofluoric acid (Merck GmbH, Germany) was utilised for soil digestion.

Soil pH

Soil pH was determined before plantation and after plantation. It was analysed followed by the standard water method. 25mL of distilled water was added to 10g of air-dried soil in a falcon tube at a ratio of 1: 2.5. Next, samples were shaken for 15 minutes at 180rpm using a centrifuge and left to stand overnight to separate the sediment with the water. The pH was taken by using a calibrated pH meter with two buffer solutions: pH 4.0 and pH 7.0.

Sample Digestion Using Teflon Bomb Method

This digestion is closed in order to avoid atmospheric contamination due to the minimal amount of samples. After respective acids for each sample were added into the Teflon bomb, all samples were heated in the oven 150°C for three hours. After heating, the Teflon bomb was cooled down at room temperature. Samples were then ready to be detected for its heavy metal content using Inductively

Coupled-Plasma Mass Spectrometry (ELAN 9000 system, PerkinElmer Inc., USA) for food waste compost and Atomic Absorption Spectroscopy (PerkinElmer Inc., USA) for soil.

Food waste compost: In this study, the method used to digest the samples was modified from Environmental Protection Agency (EPA) Standard Method 6020a (EPA, 2011), which is specifically for organic samples. Triplicate samples were weighed 0.05g before being placed in the Teflon vessel. The weight of the samples were recorded. 1 ml of hydrochloric acid (HCl) and 3 mL of nitric acid (HNO_3) were added subsequently into each sample. HNO_3 and HCl are strong mineral acids that can stabilise numerous elements in solution. According to Müller *et al.* (2014), HNO_3 is the primary acid used in most digestion procedures as since most nitrates are soluble and it is an excellent oxidising agent at high temperature. Meanwhile, HCl provides the complexing properties where it complexes a number of ions, stabilises them in solution and ensures they do not adsorb onto particulate matter or vessel walls.

Soil: Method used to digest soil samples was modified from the Environmental Protection Agency (EPA) Standard Method 3052 (EPA, 2010), which is specifically for siliceous and organically based matrices. Dried and grinded samples were weighed 0.05g before placing it in Teflon bomb vessel. 1ml of hydrofluoric acid (HF), 3ml of nitric acid (HNO_3) and 1ml of hydrochloric acid (HCl) were added subsequently into the Teflon bomb. Addition of HF was included for digesting silicates in soil samples (Dean, 2005).

Sample Digestion Using Open Digestion Method

Open digestion is suitable for large batch samples as it is simple to be conducted in basic apparatus such as a conical flask or beaker on a hot plate in the fume hood. The common application of this method is for agricultural and environmental sample analysis. This method leaves no pressure built up to the system as reaction gas can escape throughout the process. In this study, digested samples in open digestion method were then ready to be detected for its heavy metal content using Atomic Absorption Spectroscopy (PerkinElmer Inc., USA) for the root of chilli and water.

The root of Capsicum annum L.: The samples were digested followed the published methods (Uddin *et al.*, 2016) with some modifications. In this method, 0.05g of grinded root samples were weighed and placed into conical flasks. Three mL of trace metal grade nitric acid (HNO_3) was added, and the conical flasks were placed on a heating plate up to 90°C. The heating process was conducted in the fume hood to ensure no acid fumes escaped to open air. After 30 minutes of heating, 1ml of hydrogen peroxide (H_2O_2) were added to the conical flasks. The heating process continued for another 2 hours. After cooling to room temperature, the solution was transferred into 15ml falcon tube and diluted with deionised water until marked to 10ml.

Water: Water samples were retrieved from the main water source in the Glasshouse Complex (GHC). The method to digest water followed the Environmental Protection Agency (EPA) standard method 3005A (EPA,1992) which specifically acid digestion for water samples. 5 mL of trace metal grade nitric acid (HNO_3) was added into 50 mL of water sample. The mixture was then heated in a heating plate at 80°C - 85°C until the volume has been reduced to 15-20ml. After cooling to room temperature, the solution was transferred into 100ml volumetric flask and diluted with deionised watermarked until 100ml.

Statistical Analysis

Single-factor analysis of variance (ANOVA) was used at 0.05 level of significance on heavy metal data obtained from the root of 32 chilli plants using Microsoft Excel Data Analysis software.

Results And Discussion

This chapter focuses on the results of the heavy metal analysis on food waste compost and root uptake of Capsicum annum L. plant that had been done in this study. This chapter emphasises on the findings on the heavy metals concentration in respective samples and treatments.

Heavy Metal Concentration in Food Waste Compost

Based on Table 4, the concentration of Cd was found to be below the detectable level. The reason for this occurrence was due to the calibration range was much higher than the analysed sample. Low concentration sample was read off the curve as negative concentrations or below the detectable level. In addition, the blank sample might contribute to the low reading, in which the blank subtraction sample might be digested in a contaminated Teflon vessel resulting in greater reading compared to other samples.

Table 4 Average concentrations of heavy metals in food waste compost

Heavy Metals	Average Concentration (ppm)
Pb	1.0 ± 0.455
Ni	140.0 ± 9.899
Cr	446.2 ± 36.770
Cu	10.9 ± 1.438
Cd	BDL
Zn	19.0 ± 5.940

BDL: Below Detectable Level

Regardless, other heavy metals tested do not exceed the permissible limit compost based on standards from European Countries shown in Table 2 except for Cr and Ni concentration in food waste.

The exceeding concentration of Cr and Ni were probably due to compost production stage such as mixing or grinding stage and from sources of food waste. Based on previous research, Cr is highly used in metallic uses. In stainless steel, average Cr content is about 17 % mostly from kitchenware and other small items (Holm *et al.*, 2002). Thus, there are probability sources of food waste during the composting batch to have been contaminated by Cr. Furthermore, Cr is mainly used in layers of approximately 0.2-1.2µm for decorative coating on steel, coppers alloys and plastic. Hence, it may have higher chances during the composting stage, peels, dust and plastics ware coats from working utensils may end up in the mixture of compost.

As for Ni, according to Bożym *et al.* (2015) , from their previous research, it has been found that Ni highest concentration was reported in the peels of potatoes and carrots. It was denoted that during the composting batch, food waste was mainly sourcing from peels of both vegetables. Furthermore, both vegetables were used in dishes provided by the cafeteria from various stalls. The accumulation of the peels mounted to increase the concentration of Ni. Besides, according to Kamerud *et al* .(2013), Ni is also used in metallic uses similar to Cr. Ni was mainly found in the stainless steel uses for kitchen utensils due to its good thermal conductivity and resistance to corrosion. Research conducted by Kamerud *et al.* (2013), found that Ni was responsible for the high metal concentration in food which leached from low-grade stainless steel kitchen utensils. From the research, Ni was found to leach in tomato sauce cooked for six hours as 6.60 % from the steel pan.

Physico-Chemical Characteristics of Soil

pH

Soil pH for chilli plant to grow is between 5.8 and 6.8 (Fudholi *et al.*, 2013). Based on Table 5, the soil was found slightly acidic post plantation for all treatments significantly with ($p < 0.05$). According to Sundberg (2003), the decrease in pH in compost was influenced by organic acids formed during fermentation of organic matter by anaerobic microorganisms. The main product is acetic acid, butyric or propionic and lactic acid which lowers the soil pH over time. In order to fix this problem, pH can be increased by the addition of calcium carbonate in ground fine, forming carbonic acid which then will dissociate into carbon dioxide.

Table 5 Average soil pH before and after plantation

Treatments	Average Soil pH	
	Before plantation	After plantation
T1	5.9	5.8 ± 0.177
T2	6.0	5.0 ± 0.272
T3	5.8	5.4 ± 0.232
T4	5.9	5.3 ± 0.158

Heavy Metal Concentration (Ni And Cr) in Water, Soil And Root Uptake Of Capsicum Annum L. Plant

Water and Soil

In order to determine whether food waste compost affects the root uptake of Ni and Cr in chilli plant, the concentration of water and soil were taken to eliminate any possibility that the metal uptake was from these two sources.

Based on Table 6, the metal concentration determined in the soil does not exceed the permissible limit. The permissible limit for Ni in the soil is 35ppm, meanwhile for Cr is 100 ppm as recommended by the World Health Organisation (WHO, 1996).

Table 6 Average concentrations of Heavy metals in soil and water

Heavy Metals	Average concentration (ppm)	
	Soil	Water
Ni	0.60 ± 0.555	0.00
Cr	2.93 ± 0.329	BDL

BDL: Below Detectable Level

As for water, the concentration for Ni in water was below the permissible limit suggested by WHO which is 0.2 ppm. However, the concentration of Cr was below the detectable level. The concentration for Cr was too low and did not exceed the permissible limit listed by WHO which is 0.1 ppm. Thus, it can be concluded that water supply for the plantation might not contribute to the root uptake Ni and Cr due to low in concentration.

Root of Capsicum annum L. Plant

Based on Table 7, the application of food waste compost was varied into four treatment rates, which were (T1) control with no addition of food compost, (T2) optimum, (T3) excessive and (T4) insufficient application of food compost.

Table 7 Average concentration of Nickel and Chromium in the root of Capsicum annum L. plant

Treatments	Average concentration (ppm)	
	Ni	Cr
T1	1.68 ± 0.020	1.40 ± 0.043
T2	2.25 ± 0.274	1.88 ± 0.679
T3	2.10 ± 0.390	1.90 ± 0.545
T4	2.19 ± 0.274	1.88 ± 0.474

Statistically, the average concentration treatments for Ni and Cr were provisionally insignificant with ($p > 0.05$). The reason was probably due to the small sample size in this study which makes it harder to find a significant difference. Total samples in this research were 32 samples with eight samples per each treatment. By calculating the effect size followed by published calculation in Sullivan and Feinn (2012), this study sample size was considered very small with (d = 0.12).

Nickel: Based on Table 7, all treatments exceeded the Ni permissible limit for uptake in the medicinal plant as recommended by WHO which is 1.5 ppm. Comparing of all treatments, average concentration for treatment (T2) has the highest concentration which was 2.25 ± 0.274 ppm while treatment (T1) has the lowest concentration which was 1.68 ± 0.020 ppm with the application of the food compost.

The highest concentration of Ni in treatment (T2) was probably due to the optimum application of food compost to the chilli plant. Generally, root acquires sufficient nutrient elements, as stated in Table 2.1 from the soil to crops in the form of fertiliser to enhance growth performance of the plant (Arif *et al.*, 2016). As mentioned in chapter 3.3.3, in treatment (T2), the amount of food compost applied was based on calculation referring to Department of Agriculture Malaysia specifically for chilli which provides necessary comprehensive nutrients for growth. Thus, with sufficient quantity of nutrients, root can function and develop appropriately for greater absorption. Hence, this explains the reason in treatment (T2) in which it is assumed that the root received sufficient essential of nutrients supply for growth along with Ni concentration in the compost.

Furthermore, based on literature, soil pH value below 5.6 favours the absorption of Ni due to higher exchangeable Ni content in soil with increasing soil acidity (Sengar *et al.*, 2008). Comparing the soil pH of all treatments in Table 4.2, treatment (T2) has the lowest pH favouring the Ni uptake in the root. Furthermore, at low pH condition, Ni is highly mobile in soil and water (ATSDR, 2005). The reason for this circumstance is mentioned in 2.3.2 (2) that low pH enhances metal mobility for root absorption, which H3O+ ion promotes mobilisation of metal from soil (Li *et al.*, 2015). Thus, this makes root absorption of Ni more efficient in treatment (T2).

Apart from that, low Ni concentration with the application of food compost was found in treatment (T3) with 2.10 ± 0.390 ppm was due to excessive application of food compost which inhibits the absorption of nutrients due to root damage. Based on previous research by Miksen (2018), it was reported that excessive use of soil amendments caused root burns. Root burn is a condition in which roots suffer damage from overabundance of soluble salts in the soil. The salts from amendments essentially burn the roots and foliage thus inhibiting plants to uptake any source of nutrients for growth.

Furthermore, Ni is a mobile metal that can be accumulated in other parts of the plant (Meindl *et al.*, 2014). Based on previous research, it was shown that Ni is highly accumulated in the leaves (Singh *et al.*, 2016). Another research by Yusuf *et al.* (2011) found that Ni has been found to accumulate in the leaf epidermis of Hybanthus floribundas, Alyssum bertolonii and Senecio coronative of hyperaccumulator species. This evidence strengthens the understanding that Ni might be transported to other parts of the plant besides accumulating in the root, which explained the low concentration of Ni in root for treatment (T3). Thus, as for treatment (T3), there were two possibilities for the low concentration of Ni in root which are may due to root burns or due to the mobility of Ni to other parts of the plant.

However, slight availability of Ni in control treatment (T1) with 1.68 ± 0.020 ppm was probably contributed from the soil. It was found that the soil contained 0.6 ppm of Ni. Ni availability in soil is common as it occurs naturally in the weathering process as such soils and rocks. Apart from that, the potential source of Ni might be leached from rainwater due to its open area location. According to Milik and Pasela (2018), the concentration of Ni presence in vehicle fuel emanating in rainwater through diffusion of gas is prominent in leaving a runoff effect to the soil. Thus, there is a possibility Ni to be sourcing from rainwater due to its open area location.

As for treatment (T4), Ni was found to be 2.19 ± 0.274 ppm with the insufficient application of food waste compost which differs significantly with the control treatment (T1). Thus, from here, it can be postulated that the food compost contributed to the Ni absorption in root of chilli as Ni was sourcing from the food compost, soil and possible rainwater leaches.

Chromium: As illustrated in Table 7, all treatments exceeded the Cr permissible limit for uptake in the medicinal plant as recommended by WHO which is 1.3 ppm. The maximum concentration of Cr was found in treatment (T3) with 1.90 ± 0.545 ppm which vary slightly from treatment (T2) and (T4) with 1.88 ± 0.679 ppm and 1.88 ± 0.474 ppm respectively. The minimum was found in treatment (T1) with 1.40 ± 0.043 ppm.

The high concentration of Cr in treatment (T2), (T3) and (T4) was probably due to the application of food compost applied in the treatment. Most studies have demonstrated excessive accumulation of Cr in roots and the immobilisation of this metal in the vacuoles of plant root cells (Nematashi *et al.*, 2012). Based on the literature, the plasma membrane of the roots is the first functional structure to come in contact with metals (Hayat *et al.*, 2012). Furthermore, in roots, Cr6+ occurs actively, while Cr3+ absorption occurs by osmosis (Barros *et al.*, 2006). According to Mccauley *et al.* (2011), active transport or root interception is the rapid uptake by root cells of ions or molecules against concentration gradient that requires energy to move through the root membrane while osmosis is the passive movement of molecules through the root membrane without transport protein or energy needed.

With these two transportation mediums, Cr can easily be absorbed by root. Thus, it can be postulated that Cr concentration in all treatments increased to an extent as Cr in root tissues were immobile, leading to accumulation of the metal over time. Generally, Cr was absorbed by root efficiently through active transport and osmosis. From the concentration in the three treatments, it can be presupposed that the maximum capacity for Cr accumulation in root is between 1.8-1.9 ppm for chilli at the rootage of two months.

Based on Table 4.3, treatment (T2), (T3) and (T4) with soil pH of 5.0, 5.4 and 5.3 respectively has acidic soil pH value as the acidic condition for chilli is below 5.8 (Fudholi *et al.*, 2013). As mentioned in 2.3.2 (2), low soil pH favours the absorption of metals in the root tissue. According to Zayed and Terry (2003), Cr most predominant state is Cr3+, however, in low pH condition, Cr6+ will be reduced to Cr3+ by redox reaction increasing the absorption of Cr through active transport. The movement of molecules is transported faster with active transportation compared to osmosis.

Besides, Cr can come from the naturally occurring element which can be found in soil and gases (Chatterjee, 2015). Based on literature, Sharma *et al.*, (2005) found that the metallic elements emitted from vehicle exhaust emission from two-stroke engines included Cr. The reason for this occurrence might be in relation as the crop location was in an open area and close to road. Rainwater runoff and leaches may contribute as according to Milik and Pasela (2018), Cr was found in the rainwater as a result of metal leaching in a study of four urban locations. Hence, this explains the slight availability of Cr in treatment (T1) which potentially sourcing from rainwater leaches due to the open crop location. Furthermore, based on Table 4.3, soil contained 2.93 ± 0.329 ppm of Cr. Thus, it can be presupposed that Cr availability in treatment (T1) was from rainwater leaches and soil used as supported by the literature.

Conclusion

From this study, the result shows that the food waste compost contained Ni and Cr exceeding the permissible limit with Ni (140.0 ± 9.899 ppm) and Cr (446.2 ± 36.770 ppm). The accumulation of the elements was potentially attributed from the food source during composting batch and work utensils during the process. Furthermore, it was found that Ni and Cr were found to accumulate in the root of chilli exceeding the permissible recommended by the World Health Organisation (WHO) varying with their treatment rates. Average concentration in root for Ni were (T1: 1.68 ± 0.020 ppm), (T2: 2.25 ± 0.274 ppm), (T3: 2.10 ± 0.390 ppm) and (T4: 2.19 ± 0.274 ppm), meanwhile for Cr were (T1: 1.40 ± 0.04 ppm), (T2: 1.88 ± 0.679 ppm), (T3: 1.90 ± 0.545 ppm) and (T4: 1.88 ± 0.474 ppm).

Varying the application of food compost ranging from optimum, excessive and insufficient supplies gave patterns to the accumulation of both metals. As for Ni, the optimum application of food compost accumulated higher in root meanwhile for Cr, the addition of food compost regardless of its rate gave a near similar concentration of Cr uptake. Thus, it can be concluded that Cr is more efficient to be absorbed and immobile in root compared to Ni. Hence, the food waste compost has exceeding Ni and Cr concentration for the root uptake of Capsicum annum L.

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