Malays. J. Bioeng. Technol. Vol. 2, No. 1, (2025): 1-11
https://doi.org/10.70464/mjbet.v2i1.1473

MALAYSIAN JOURNAL OF BIOENGINEERING AND TECHNOLOGY

Nutrient Analysis of Commercial Compost and Compost Produced from Household Food Waste in Correlation to Soil Physio-chemical Properties

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ARTICLE INFO

Received:12 November 2024
Accepted:1 December 2024
Online:23 March 2025
eISSN: 3036-017X

ABSTRACT

Food waste is one of the concerns that can potentially affect both the environment and humanity. Household food waste was the highest contributor to food waste globally. The main focus of this study is to utilise the food waste from households into compost, assess the physical and chemical properties of compost, and compare the physical and chemical properties with soil and commercial compost. Food waste was collected from households in Pasir Mas, Kelantan area, and left to mature for 2 months. The finished products produced in this research were composted, which is black in colour and odourless or earthy odour in smell. Seven output treatments were prepared: SOIL, O1, O2, O3, P1, P2 and P3 in this research. The results of this study showed that the concentration of physical and chemical parameters in all the samples was in the range of 0.59 g/cm^3 at the lowest to 1.03 g/cm^3 as the highest value for bulk density, and moisture content was 21.12% - 63.88%. The highest concentration value for every experiment except the total potassium (K) experiment is dominated by sample O1, and the lowest was the sample SOIL. In conclusion, the statistical test of significance using ANOVA revealed significant differences ($P<0.05$) between the values of all experiments of bulk density, moisture content, N, P, and K.

Keywords: Food waste; compost; physio-chemical parameters

1. Introduction

The annual rise in food waste has become a major concern for humans and the environment. Nearly one-third of all food provided for human consumption is destroyed or discarded each year, amounting to 1.3 billion tons of food [1]. This becomes a concern when it comes to food waste. Soil erosion, water pollution, deforestation and greenhouse gas emissions that occur in the ways of the production process, transportation, storage and waste management in food production are indirect environmental impacts that occur from food losses and wastes [2]. Furthermore, about 95% of food waste is disposed of in landfills or combustion plants. Furthermore, one of the main sources of greenhouse gas (GHG) emissions comes from food waste disposal, leading to climate change [3]. Methane is a greenhouse gas that is

25 times more potent than carbon dioxide and is produced by the decomposition of food waste [4]. It is possible to reduce pollution by reducing food waste, according to Cattaneo et al. [5].

Malaysia alone wastes 15,000 tons of food daily, 3,000 tons of which are indeed edible and should not be thrown away. When compared to Malaysia, the average Malaysian throws away 1.64 kg of waste every day, while the global average is 1.2 kg. Because of that, the study statistics are worrying, as the daily increase of 65% to 30,000 tons of Malaysian waste production will be by the year 2020 [6]. Food waste produced at the household level is extremely important to the food chain (i.e., waste from residential homes, private and domestic accommodation). Households contribute the highest percentage of food waste produced in Malaysia as compared to developed countries [7].

To overcome these problems, food waste disposal can be reduced by converting it into compost, which is useful for humans. One of the low-cost alternative methods to dispose of this food waste is through composting. Composting is a perfect way to reduce the volume of solid waste that ends up in landfills. Composting is a form of managed decomposition that mimics the natural breakdown mechanism. Composting is the process of converting food waste into biologically stable humid compounds that can be used in a number of soils and plants [8]. Organic fertilizers like compost comprise plants, herbs, poultry, and other raw ingredients. Organic fertilizers are important in the agriculture sector since they benefit the soil while causing no harm to groundwater or plants [8]. Inorganic fertilizer has aided global population development to such an extent that it is estimated that artificial nitrogen fertilizer feeds almost half of the world's population [9]. Inorganic fertilizers have previously been used to cultivate crops in both commercial and subsistence farming [9]. The excessive use of chemical fertilizer caused pollution to the environment. The bulk of heavy metals, including mercury (Hg), cadmium (Cd), arsenic (As), lead (Pb), nickel (Ni), and copper (Cu), as well as natural radionuclides, such as uranium-238, thorium-232, and polonium-210, are found in chemical fertilizers [10]. Due to this, the buildup of heavy metals in soil and plant systems may be impacted by fertilization. Fertilizers can enter the food chain after being absorbed by plants through the soil. As a result, fertilizer pollutes the air, water, and soil [11]. During the peak season, greenhouses and aquaculture use a lot of chemical fertilizers, which makes well water dangerously contaminated. This leads to a decline in crop production quantity and product quality. Problems brought on by excessive fertilizer use [11].

Organic material, such as farming waste and manure, on the other hand, enhances the physical and chemical properties of soil, which are essential for plant growth [12]. Compost promotes root growth by optimizing plant root conditions (structure, temperature, and humidity), as well as plant growth by growing the population of microorganisms [12]. This research was conducted focusing on producing compost from household food waste as an alternative way to reduce the amount of food waste to compare the nutrient content of commercial compost with compost produced from household food waste and its correlation to soil physiological and chemical properties.

2. Materials and Methods

2.1 Methodology

The materials used in producing the compost were food waste, sawdust, soil, mesh wire and a weighing balance scale. The food waste was collected using a plastic bag from a household located in Pasir Mas, Kelantan. The analysis of physical and chemical properties of the compost, including colour, texture, odour, moisture content, bulk density and NPK, was conducted at UMK laboratory. The equipment used in the pH measurement of the compost is a pH meter and beaker. Analysis of the chemical characterization of compost such as K was carried out via Atomic Absorption Spectroscopy (AAS) by using the reagent accordingly, and P was determined using a UV spectrophotometer. The N analysis was measured by Kjeldahl digestion. The method in this study includes the process of making the compost until the treatment is produced and the physical and chemical tests of every treatment.

2.1.1 Process of Composting

Before the composting process began, 50 litter compost bins were drilled with a hole in the bottom to remove the extra mousier out of the compost. Inorganic substances like plastic and straw were separated from food waste before being processed further. Then, a layer of food waste of approximately 2 inches was placed in the bin, followed by a layer of sawdust and 1 liter starter culture to a depth of 5 inches; the ratio of the food waste and sawdust is 3:1 [13].

1 liter molasses is added to the mixture, and it works to give energy to the microorganism's culture. This process continued until a thick compost layer formed. Then, the water was regularly sprayed out into the compost pile. The water was added to moisten the layers and maintain the moisture of the pile at around 50%. To ensure the availability of oxygen in the process, the compost was turned from outside to inside and vice versa every seventh day. In aerobic conditions, the compost was allowed to develop for two months. Compost mix output after 2 months of composting. The compost mix is left for 1 week before undergoing analysis in the lab.

SOIL - 100% soil
O1 - 100% food waste compost
O2 - 50% soil + 50% food waste compost
O3 - 75% soil + 25% food waste compost
P1 - 100% commercial compost
P2 - 50% soil + 50% commercial compost
P3 - 75% soil + 25% commercial compost

2.1.2 Moisture Content

Moisture content in this study was measured using the method study by Carneiro et al. [14]. Drying the sample at 105 °C for 24 hours. From each sample, about 10 g of sample was placed in aluminum foil and kept in a dry oven for 24 hours. Then, the moisture content in the compost was calculated by the formula in Eq. (1).

$$\text{Moisture content} = \text{w1} - \frac{\text{w2}}{\text{w1}} \tag{1}$$

Where:
W1 = Initial weight of the sample
W2 = Final weight of the sample

2.1.3 Bulk Density

The bulk density was measured by placing the sample in a petri dish of the same volume. The sample were settled in the petri dish and slightly compacted. Then, the petri dish was weighed, and the bulk density (D) was calculated [15] with the formula in Eq. (2).

$$\text{Bulk density, D} = \frac{(M^{t} - M^{c})}{\text{v}} \tag{2}$$

Where:
M^t =Total mass of the sample and petri dish
M^c= Mass of the petri dish
v =Volume of the petri dish

2.1.4 pH Measurement

The pH values for SOIL, P1, P2, P3, O1, O2, and O3 were measured via pH-Meter in the lab. The sample is tested using a Thermos ScientificTM Expert pH tester. Each sample is placed in extraction cups after being weighed to 15 g. After weighing, cups are sealed to prevent moisture loss. Each cup is filled with 30 ml of deionized water using a measuring cylinder, sealed, and shaken briefly. The cap is taken off to give the solution at least half an hour to acclimate to the atmosphere. The standard pH values for the meter are 7 and 4. The electrode is inserted into the slurry while it is being gently swirled. Measurements of pH are made to the closest 0.01. Deionized water is used to rinse the electrode in between samples [16].

2.1.5 Total Nitrogen

To determine the total N content in each treatment, a regular Kjeldahl digestion method was used. To determine N content in all treatments, three stages of the process, which are digestion, distillation, and titration, are required [17]. After the titration process, to obtain the percentage (%) of N for all samples, the following calculation method (Eq. 3) is required:

$$\%\text{Nitrogen} = \frac{(Vs-Vb)\times N}{W\times 10} \quad (3)$$

Where:
Vs = mL of HCl used to titrate a sample
Vb = mL of HCl used to titrate a reagent blank
N = normality of HCl
14.01 = atomic weight of N
W = weight of sample (g)
10 = factor to convert mg/g to %

2.1.6 Total Phosphorus

The total P is determined in all samples using the spectrophotometry method [18]. In this experiment, 5 g of dry sample, 10 mL 6N hydrochloric acid and 5 mL nitric acid were used to digest the material. The sample was heated until it dissolved entirely. The dissolved sample was placed in a 100 mL volumetric flask, and distilled water was used to dilute it until it filled the flask completely. Then, in a 50 mL volumetric flask, 1 mL of diluted sample was combined with 20 mL molybdovanadate reagent. The sample was left for 10 minutes until the colour began to change. The sample was then analysed by UV spectrophotometer at a wavelength of 400 - 450 nm, and the absorbance value was determined. The calibration curve for the determination of phosphate is set as y = 0.1235x - 0.0018 [19].

2.1.7 Total Potassium

In this investigation, atomic adsorption techniques were used to quantify K in all samples. About 2.5 g of the sample was taken from all samples. Then, the sample was placed in a 250 mL volumetric flask and boiled with 150 mL of distilled water for 30 minutes. The distilled water was added up to 250 mL into the mixture and mixed thoroughly [20]. The sample needs to be filtered two times. At first, the mixtures were filtered using Whatman Filter Paper No.2 and were allowed to stand overnight. Then, the mixtures need to be filtered through a 0.45 nm syringe filter before doing serial dilution. The reading was calibrated from an Atomic Absorption Spectrophotometer (AAS), and a wavelength of 404.4 nm was used.

2.1.8 Statistical Analysis

One-way analysis of variance (ANOVA) in SPSS was used to evaluate the physical and chemical parameters of each treatment with the mean separation test using Tukey's HSD test. The sample mean differences were examined using a probability value ($P< 0.05$) according to Andrade [21].

3. Results and Discussion

3.1 Physical Characterization

The 2 months of maturation process has resulted in a change in colour order and texture. The mature compost has very different characteristics from the first day of the composting process. The change of the early composing and mature compost is stated in Table 1.

Compost is a humus that is usually dark in colour, odourless and contains a small particle [22]. Based on the study, we can see that the compost that we produce has the same characteristics as the study done by Mahapatra et al. [22]. Compost is an excellent medium for plant growth because it can improve soil nutrients, help retain soil moisture, promote a good microorganism for plants and help in the development of roots by reducing soil tightness. A study by

eISSN Number: 3036-017X

Ayilara et al. [23] on the same topic discusses that compost has an inoculum that indicates a smaller pore size that is soft and smooth on the surface and has no odour. The results suggest that the produced compost from household food waste has characteristics the same as average mature compost, which is black in colour, has a soft texture, has an earthly smell, and is small in particles; this is also the same characteristic as compost in the study done by Shapiro [24] on the compost from different type of manure state that when compost is mature it will have soft texture earthly smell and easy to crumble. Unpleasant smells like ammonia and big particles of matter indicate that the compost has not fully decomposed or is yet to mature. compost can enhance soil properties in physical properties and chemical properties.

Table 1: The differences between early composing processes, mature compost and commercial compost

Changes of physical properties	Day 1	After 2 months	Commercial
Appearance			
Colour	The yellow colour is from the sawdust, and the variety of brown, black, and green colours are from the food waste.	Dark in colour with a little bit of yellow colour from sawdust.	Dark in colour
Odour	Woody-like smells from sawdust and unpleasant smells from the food waste. It also has a sweet and sour smell from the starter culture and molasses added.	Odourless with a little bit of earthy smell.	Odourless with a little bit of earthy smell.
Texture	Large size of food waste and sawdust particles.	Very soft, friable texture and moist particle	Very soft, friable texture and moist particle

3.1.1 Bulk Density

The experiment measured the bulk density of various compost treatments, which ranged from 0.59 g/cm³ (for food waste compost O1) to 1.03 g/cm³ (for O3). For commercial compost, the bulk densities were 0.75 g/cm³ (P1), 0.83 g/cm³ (P2), and 0.93 g/cm³ (P3). The soil used had a bulk density of 0.98 g/cm³, similar to previous studies done by Abua et al. [25]. Bulk density reflects the amount of pore space in a medium, and a lower bulk density indicates more organic matter, as seen in food waste compost, which has the lowest bulk density [26]. When combined with topsoil, both types of compost had similar bulk densities, with food waste compost having a slightly higher value. In the physical properties study, we can see that the highest bulk density of soil in the SOIL sample can be lower by mixing it with compost, as in the case of samples O2 and P2. The low compost bulk density is due to its organic matter, which creates more pore space in the medium [23]; this makes the compost structure more friable. The bulk density of 0.59 g/cm³ is the same as the bulk density in the study done by Khater [27], where in his experiment, using cattle manure and sugar cane plant residues (50:50), herbal plants residues (100:0) and sugar cane plants residues (100:0) had a bulk density of 0.573 g/cm³, 0.582 g/cm³ and 0.420 which not so different to household food waste bulk density.

An ANOVA test (Fig. 1) confirmed that the differences in bulk density among the samples were statistically significant. Bulk density is crucial for soil functions such as water movement, aeration, and microbial activity. Ideally, bulk density should not be too high or too low, as extremes can affect soil structure and plant growth. The optimal bulk density varies depending on the type of plant and its growth requirements. So, from the study, we can see that compost will influence the bulk density of soil by lowering its bulk density.

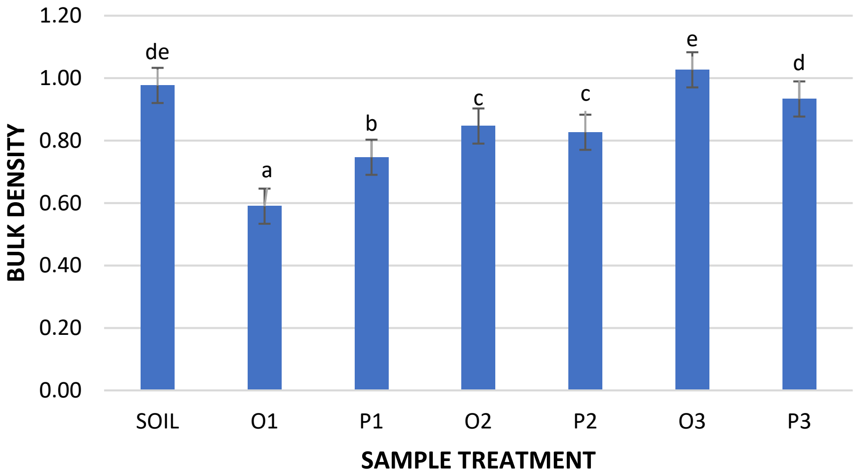

Fig. 1: The differences in bulk density (g/cm^3) for every sample treatment using simple volume method

3.1.2 Moisture Content

The experiment measured the moisture content of different compost treatments. The moisture content of the soil was 21.12%, while the food waste compost treatments (O1, O2, O3) had higher moisture content: 63.88%, 53.66%, and 32.81%, respectively. The commercial compost treatments (P1, P2, P3) had moisture contents ranging from 50.77% to 51.33%. In the study, soil has the lowest moisture content, 21.13%, and compost from household food waste has the highest, 63.88%. The combination of soil and compost shows that compost can increase the moisture content of the soil, as in samples O2, O3, and P2, P3. The moisture content from the chicken manure compost also has a range of moisture content of (45-61%) [28].

An ANOVA test revealed significant differences in the moisture content between the treatments (Fig. 2). The results showed that food waste compost (O1) had the highest moisture content, while the soil had the lowest. Mixing compost with soil increased the moisture content significantly. Food waste compost generally had a slightly higher moisture content than commercial compost in 50% treatments, but in the 25% compost treatment, commercial compost had a slightly higher moisture content. Commercial compost's fine particle size may have contributed to its efficiency in keeping the moisture when mixing with soil. In contrast, food waste compost, with larger particles, may have been less effective at increasing soil moisture. Optimal moisture content for compost (50% - 70%), as compost with too high moisture content can restrict gas exchange and microbial activity [29]. The experiment concluded that compost, as a natural fertilizer, enhances soil moisture retention, with food waste compost having a higher capacity for moisture retention than commercial compost.

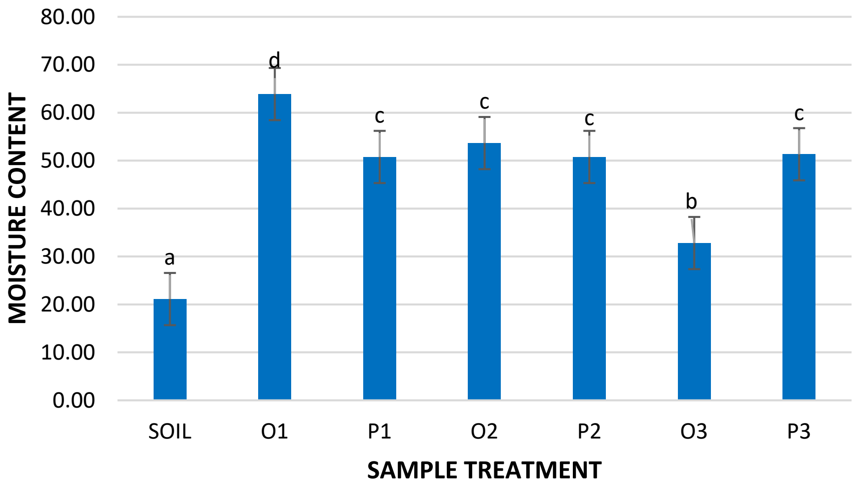

Fig. 2: The different Percentages of moisture content (%) of every sample treatment using oven drying method. Tested values are significantly different at p≤0.05 (one-way ANOVA)

3.1.3 pH Determination

The pH measurements for each sample in the experiment ranged from 5.87 to 7.35. The lowest pH was observed in the P3 commercial compost treatment (pH 5.87, slightly acidic), while the highest was in the O1 food waste compost sample (pH 7.65), close to neutral. Food waste compost treatments (O1, O2, O3) maintained a pH of around 7, similar to plain soil, indicating no significant impact on soil pH [23]. In contrast, commercial compost treatments (P1, P2, P3) slightly acidified the soil, with pH levels between 5 and 6. In chemical properties, although commercial compost had lowered the soil pH from 7.35 neutral to slightly acidic, which is pH 6 and 5.87. The household food waste compost maintains the soil's neutral pH, as seen in treatment O2 and O3 (7.56 and 7.44). The pH of compost is influenced by the material used in the composting process, and the average pH of compost can be between 6 and 8 [30].

ANOVA analysis showed significant differences in pH values across treatments. The pH of O1 aligns with the recommended compost pH range (6.9 – 8.3). This study indicates that compost has contributed to a change in the pH of the soil. However, compost from household food waste does not change the soil pH when the pH range between soil and the mix between the soil and food waste compost is still at pH 7.

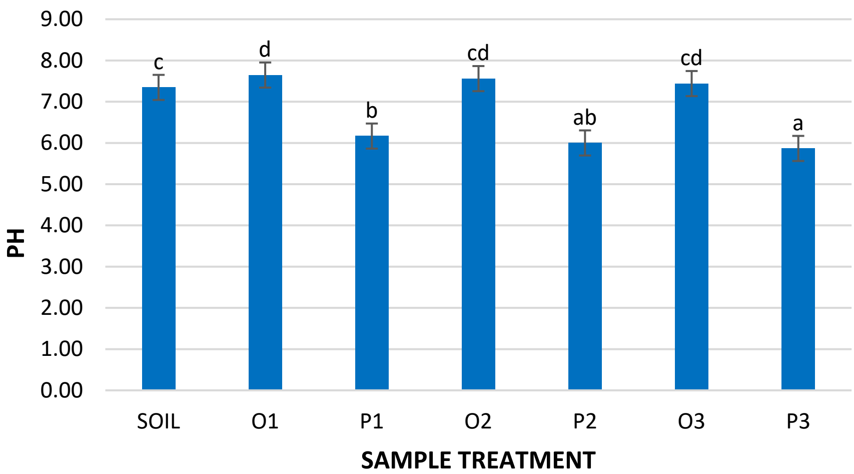

Fig. 3: The difference pH for every sample using Thermos Scientific^{TM} Expert pH tester. Tested values are significantly different at p≤0.05 (one-way ANOVA)

3.1.4 Total Nitrogen (N)

Mineral N, P, and K are essential nutrients for plant growth, especially during the early stages of sprouting. However, nutrient loss can occur due to leaching, affecting plant development. Adding organic compost to the soil can help replenish nutrient levels without causing issues often associated with synthetic fertilizers. In the N analysis done by Sharma et al. [31], the average total N is in the range of 1.667% for compost from goat dung, whereas compost from buffalo manure had the lowest at 0.665%. This indicates that household food waste with a total N of 2.1% had the highest concentration of N compared to manure compost [27].

ANOVA analysis showed significant differences in N content across treatments (Fig. 4). The food waste compost sample O1 had the highest N level at 2.1%, while plain soil had the lowest at 0.11%. Food waste compost generally contains more N than commercial compost, making it an effective soil enhancer. In only one case (25% compost), commercial compost (P3) had a higher N level (1%) than food waste compost (O3, 0.85%). Overall, food waste compost proved to be an excellent nutrient source, aligning with findings by Hamid et al. [8], which noted that food waste compost generally exceeds 0.6% N. This study has shown that compost from household food waste contains a high amount of N. This indicates that household food waste is N rich material that can help supply plant nutrients.

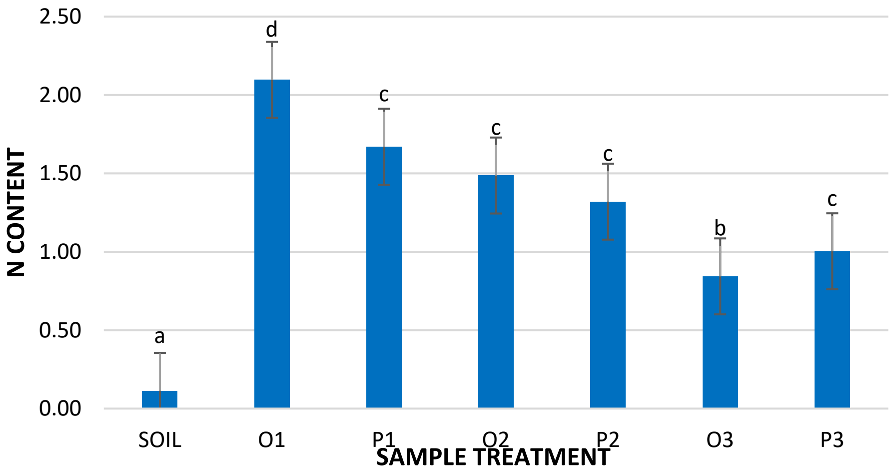

Fig. 4: The differences in N content in every sample treatment using the regular Kjeldahl digestion method. Tested values are significantly different at p≤0.05 (one-way ANOVA)

3.1.5 Total Phosphorus

The experiment measured P content across treatments (SOIL, O1, O2, O3, P1, P2, and P3). The plain soil sample had the lowest P level at 48.29 mg/L, while the O1 food waste compost treatment had the highest at 76.97 mg/L. Food waste compost samples generally showed higher P content than commercial compost, with O1, O2, and O3 values at 76.97 mg/L, 70.74 mg/L, and 59.6 mg/L, respectively. In commercial compost samples, P levels were 76.03 mg/L for P1, 67.51 mg/L for P2, and 57.7 mg/L for P3. These results indicate that compost effectively boosts soil P levels, with food waste compost providing a slightly higher concentration than commercial compost. The P and K values of compost from sugar cane plant residues (100:0) are 11.3 mg/L for total P and 21.1mg/L which is so much lower than compost produced from household food waste when the total value of P of O1 is 76.97 mg/L and total K is 49.33 mg/L [27].

ANOVA testing confirmed significant differences in P content across treatments (Fig. 5). P is crucial for plant growth, but excess amounts can lead to overgrowth in some plants. The recommended P concentration for soil is 40–100 mg/L [32], which aligns well with the levels found in this experiment's compost-enriched samples. This study concludes that compost can enhance total P in soil, as shown in samples O2, O3 and P2, P3. In total P, the recommended P concentration for soil is 40–100 mg/L [23]. When mixing soil with compost, the value of total P increases, such as in O2, O3, P2, and P3, where household compost is slightly better in total P than commercial compost.

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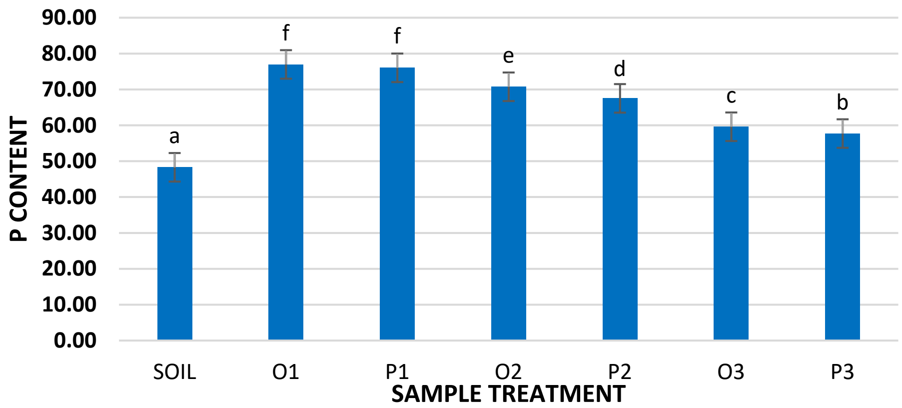

Fig. 5: The difference concentration of P (mg/L) for all sample treatments using spectrophotometry method in the presence of molybdovanadate reagent and tested in UV spectrophotometer at a wavelength of 400 - 450 nm. Tested values are significantly different at p≤0.05 (one-way ANOVA)

3.1.6 Total Potassium

In this experiment, K levels were measured across treatments (SOIL, O1, O2, O3, P1, P2, and P3). The lowest K concentration was in the plain soil sample (0.88 mg/L), while the highest was in the commercial compost sample P3 (60.82 mg/L). Among other treatments, food waste compost samples had K values of 49.33 mg/L for O1, 13.03 mg/L for O2, and 8.54 mg/L for O3. The results indicate that mixing soil with compost increases K levels, confirming compost's effectiveness in enhancing soil K content. The difference between soil total nutrients and compost is high in total K when the commercial compost and house household compost had a total K value of 60.82 mg/L and 49.33 mg/L. The mixture of soil and compost created a variety of total K values, the highest of which was 19.59 mg/L for P2 treatment and 8.54 mg/L for P3 treatment.

Comparing food waste and commercial composts, commercial compost generally contained more K, except in the 25% compost mix (O3), where food waste compost had a slightly higher K concentration. ANOVA testing showed statistically significant differences in K content across treatments, with a significance value above 0.05 (Fig. 6). In total, the nutrient properties of crucial plants need minerals, which are N, P, and K. The lowest amount in every mineral is the soil, where the values of 0.11%, 48.29 mg/L and 0.88 mg/l for N, P and K. From this study, the compost can increase the total nutrient content in soil and household food waste contribute an increase in most of the nutrient like N and P and only in K nutrient is dominating by commercial compost.

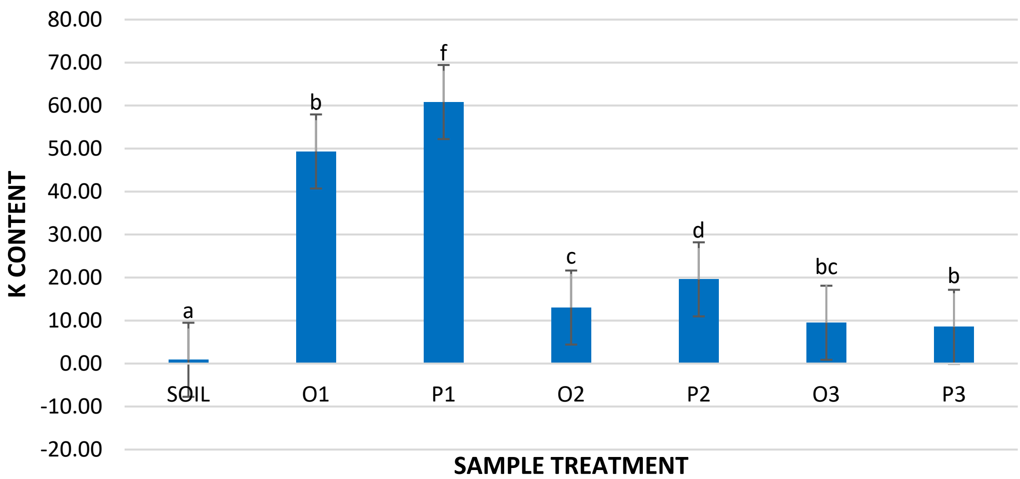

Fig. 6: The difference concentration of K (mg/L) in all sample treatments using simple boiling and serial dilution methods tested with Atomic Absorption Spectrophotometer (AAS). Tested values are significantly different at p≤0.05 (one-way ANOVA)

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4. Conclusion

The composting method has a high potential to overcome the food waste problem. Products produced from the composting process, which is food waste compost, have characteristics similar to commercial compost in appearance, odour and texture. Household food waste compost improves soil physical properties, notably by reducing bulk density due to its organic matter content, which increases pore space. The recorded bulk density (0.59 g/cm^3) aligns closely with values from compost produced from agricultural residues, supporting its suitability as a soil amendment. Additionally, the compost enhances soil moisture content significantly, ranging from 63.88% in pure compost to improved values in compost-soil mixtures. In terms of chemical properties, household food waste compost maintains a neutral pH (7.44–7.56), which benefits soil health compared to the slightly acidic pH observed with commercial compost. Nutrient analyses reveal that compost from household food waste significantly enhances essential macronutrient levels in soil, particularly N (2.1%), P (76.97 mg/L), and K (49.33 mg/L). These values surpass those of several manure-based composts and commercial compost for N and P. Overall, household food waste compost is an effective soil amendment, improving both physical and chemical soil properties. It not only supports better soil structure and moisture retention but also enriches the soil with essential nutrients, offering an eco-friendly alternative to commercial and manure-based composts.

Acknowledgement

The authors wish to acknowledge the financial support of the Malaysian Ministry of Finance (MoF) and Universiti Malaysia Kelantan (UMK) (InsPek-KPS-00). Special thanks are also dedicated to colleagues and technical staff for the encouragement and hard work done.

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eISSN Number: 3036-017X