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Efficacy of compost made of food wastes with organic amendments for a sustainable and environment friendly agricultural system

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Abstract

Organic amendments in composts are found to be an effective solution for the sustenance of the agriculture system, especially in reducing greenhouse gases. The objective of this research was to develop a compost type made with organic/mineral amendments for environment friendly agriculture. This preliminary study reports the quality of the compost made with different organic/mineral amendments, the performance of different compost types with and without amendments, the potential of organic amendments in reducing greenhouse gas emissions for an environmentally friendly agriculture and the best type of co-compost.

Food waste was co-composted with banana peels, egg shells, onion peels and papaya peels individually with a 1:1 ratio; and the quality of the mature compost was measured using the physicochemical parameters. Six seedlings of *Capsicum annuum* were planted in potting mixtures with a 1:1:1 ratio of co-compost, top soil and sand. The positive control experiment was done with food waste compost and the negative control was with no compost. The performance of the six treatments were evaluated by measuring the plant height, the number of leaves in a plant, number of buds, number of pods and the average weight of pods. CO_2 emission of the six treatments were measured by absorbing it to calcium hydroxide.

The results showed that the co-compost made with banana peels was the best amendment, with better physicochemical characteristics and performance in growth. None of the treatments gave a significant reduction on the emission of carbon dioxide.

Keywords: Compost; Amendments; Greenhouse gas; Physicochemical properties

1 Introduction

Sustainable agriculture is, an integrated system of plant and animal production practices having a site-specific application that will, over the long term, satisfy human needs, enhance environmental quality and natural resource base, make the most efficient use of nonrenewable resources and integrate natural biological processes, sustain economic viability, and enhance quality of life [1]. Due to the limitation of land, the same land is used for agriculture and without replenishment, the land suffers from nutrient depletion and becomes either unusable or suffers from reduced yields. Composting is an effective and a sustainable means of organic matter restoration through carbon restitution to the depleted soils as an organic amendment.

Composting is the controlled conversion of degradable organic products and wastes into stable products with the aid of microorganisms [2]. It is known to influence favorably the physical, chemical and biological properties of the soil. Dalzell

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et al. [3], has reported that composting is the most important and rewarding method for increasing agricultural output by raising the level of soil fertility by improving the long term structural stability, moisture retention of the soil and increasing the supply of plant nutrients. Composting food waste will reduce the food wastes being disposed in land fill and will also help in the food industries in managing their wastes. As an alternative to the waste disposal method, it helps in diverting wastes from land fill, mitigating ground water contamination, reducing air pollution and greenhouse gases.

Composting is a long-used technology, though it has shortcomings that have reduced its extensive usage and efficiency. The shortcomings include pathogen detection, low nutrient status, long duration of composting, long mineralization duration, and odor production [2]. There are also other specific problems related to food waste composting such as the nutrient availability and the presence of impurities which can affect the quality of compost.

However, according to the fourth assessment report of the IPCC, one of the most important issues related to food waste composting is associated with greenhouse gases (GHGs) such as methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O), which can contribute to global warming and stratospheric ozone depletion [4]. This can cause climate change, resulting in desertification, increased melting of snow and ice, sea level rise, stronger storms and extreme events. It thus affects the agricultural system in return with the change of harvesting patterns, changes in plant growth and nutrition levels in soil.

Thus, there is a need to put forward a quality compost type which is sustainable and environmentally friendly, to the agricultural system. According to Barthod et al. [5], the negative aspects of composting can be limited through the addition of organic, inorganic or biological substrates to the composted mixture. Amendments have direct or indirect effects on other composting parameters [6] such as temperature, pH and moisture and thus have an impact on the composting process. They are important in improving nutrient content and availability by reducing mobility of mineral ions in the final product [7, 8]. The effects of inorganic and biological additives have been extensively studied by researchers but the effects of organic amendments on the compost quality have been researched only for a few materials like rice husks [9], wood chips [10], rice straw [11] and saw dust [12].

Several studies also have investigated various types of additives such as coal ash [13], zeolite [14], [15], vermiculite [16], biochar [17], [18] and mature compost [19] to decrease the loss of gases such as greenhouse gases during composting of various organic waste types.

Also numerous studies have investigated the response of carbon and other GHG emissions when applied in the field with and without organic amendments. For example, Zhang et al. [20], evaluated the effect of biochar amendment (three different rates) on yield and CH_4 and N_2O emission from a rice paddy in China. They found 12–14% higher rice yield and 34–41% higher CH_4-C emission as a result of the organic amendment. Álvaro-Fuentes et al. [21] studied the impact of organic amendment and tillage management practices on soil CO_2 flux and found that tillage and fertilization significantly impacted soil CO_2 fluxes. Amos et al. [22] studied fertilizer impact on irrigated maize and documented a 64% CO_2 flux increase compared to the control treatment. Davidson et al. [23] examined differences in soil CO_2 emissions among primary forests, secondary forests, active cattle pastures, and degraded cattle pastures, and found the rates of soil respiration decreased from wet to dry seasons in all land uses. Melling et al. [24], measured monthly soil CO_2 emission from three ecosystems; forest, sago, and oil palm, and found a significant impact of land use on the exchange of CO_2. Abbas and Fares [25] evaluated impact of rates and types of organic amendment on soil organic carbon and CO_2 emissions under a sweet corn and a tropical soil; they found that soil organic carbon content, CO_2 emissions and saturated hydraulic conductivity of the soil significantly increased with addition of organic amendment and/or increase in organic amendment rates, but no significant effect of organic amendment types. Few studies have been conducted to monitor soil organic carbon and CO_2 emission for leafy greens [26, 27]. Ingram et al. [26] investigated the effects of repeated irrigation on total organic carbon on baby spinach. Tavarini et al. [27] studied the effects of green compost on soil biochemical characteristics and nutritive quality of leafy vegetables. On the other hand, limited researches have been conducted on collard greens in the southeast Texas environment [28, 29 and 30]. The effects of organic amendments on soil organic carbon and CO_2 emission have received little attention from researchers.

The significance of this research was to present a quality compost with an organic amendment for the sustainability of the agricultural system and the main aim is to develop a good quality compost by adding different organic amendments to food waste and to improve the sustainability of agricultural systems in an environmentally friendly way while enhancing soil functions and plant growth and reducing emissions.

Thus the objectives of this research were, to report the quality of the compost made with different organic amendments based on physicochemical parameters as a potting mixture, to evaluate the performance of different compost types on growth parameters with and without amendments, to investigate the potential of using organic amendments in reducing GHG emissions from compost for an environment friendly agricultural system and to find out the best type of co-compost as a sustainable product.

2 Material and methods

2.1 Collection of food wastes

Food wastes were collected from kitchen wastes from houses separately as egg shells, onion peels, banana peels, papaya peels and other types together.

2.2 Preparation of compost

The respective food wastes were cut or crushed into smaller pieces 1 – 3 cm in size and were added in a 1:1 (V:V) ratio with other type of food wastes into four separate baskets and a control compost was made with other types of food waste. Mature compost was obtained after 46 days according to Choy et al. [31], where the temperature did not change for 3 consecutive dates. The samples collected were stored in a refrigerator at 4 °C for the determination of the fresh sample [32].

2.2.1 Measurement of physical and chemical parameters of the compost

A homogeneous sample of 200g from each treatment were tested for chemical parameters (organic carbon (OC), organic matter (OM), total nitrogen (TN), total phosphorus (TP), total potassium (TK) and C: N ratio). TN (as N) on dry basis was measured using the SLS 645 Part 1: 2009 method [33], TP (as P_2O_5) on dry basis was measured using the SLS 645 Part 5: 1985 method [34], TK (as K_2O) on dry basis was measured using the SLS 645 Part 4: 1989 method [35], OC and OM was measured using the SLS 1635:2019 [36] and C:N ratio was measured using the SLS 1635:2019 [36]. The moisture content (MC) was measured using the gravimetric moisture content method according to Leege and Thompson [37]. The pH and the Electrical Conductivity (EC) were measured using the saturated paste method [37].

2.3 Selection of seeds

The seeds of KA – 2 variety of *Capsicum annuum* were collected from an agriculture sales outlet in Colombo. Seeds with uniform size, color and weight were chosen for the experimental purpose.

2.4 Preparation of the potting mixture

A potting mixture was made with a 1:1:1 (V: V: V) ratio of compost, sand and top soil. Thus five different potting mixtures were obtained from the different composts. A separate mixture with a ratio of 1:1 (V: V) of sand and top soil was made to compare with the composts.

2.5 Transplanting

A Complete Randomized Block Design was done with six replicates of each six treatments. T_0 – control with no compost, T_1 - control containing compost made of other wastes. T_2 – banana peel co-compost, T_3 – egg shell co-compost, T_4 – onion peel co-compost and T_5 – papaya peel co-compost. Six seedlings were transplanted two in each pot.

2.6 Measurement of plant growth and yield [38]

2.6.1 Average plant height

The height of the plant was measured from the base to the tip of the plant in centimeters and the mean value of the height was obtained for each treatment. This was carried out at 1d, 15d, 30d, 45d, 60d, 75d, 90d and 105d after transplanting.

2.6.2 No. of leaves per plant

The number of leaves per plant were counted manually at 1d, 15d, 30d, 45d, 60d, 75d, 90d and 105d after transplanting. The mean value of the leaves per plant was obtained for each treatment.

2.6.3 No. of buds per plant

The number of buds were counted manually on 1d, 15d, 30d, 45d, 60d, 75d, 90d and 105d after transplanting and the mean of the total number of buds appeared for each treatment until day 105 was calculated.

2.6.4 *No. of pods per plant*

The number of pods were counted manually on 1d, 15d, 30d, 45d, 60d, 75d, 90d and 105d after transplanting and the mean of the total number of pods appeared until day 105 for each treatment was calculated.

2.6.5 *Weight of pods per plant*

The hand plucked pods were weighed and the mean weight of pods for each treatment was obtained.

2.7 Measurement of the emission of carbon dioxide when compost is used as a potting mixture

A randomized complete block design was done with two replications for pots with potting mixture with the six treatments, with a 1:1:1 (V:V:V) ratio of compost, sand and top soil of treatments T_1 (control containing compost made of other wastes), T_2 (banana peel co-compost), T_3 (egg shell co-compost) , T_4 (onion peel co-compost), T_5 (papaya peel co-compost) and with a 1:1 (V:V) ratio of sand and top soil of treatment T_0 (control with no compost). Exactly 2.5 kg of potting mixture was used in 4L sized 12 air tight plastic pots. The plastic pots along with the potting mixture were incubated at the room temperature of 30 ˚C.

The CO_2 emission was measured for 35 days. During the first two weeks, CO_2 emission was measured on days 1, 2, 3, 4, 7, 8, 9, 10, 11, 14 and then once per a week. A CO_2 trap was prepared using a 1M $Ca(OH)_2$ solution and were titrated with 0.1N HCl to determine the quantity of alkali that has not reacted with CO_2. The amount of CO_2 evolved from the soil during exposure to alkali was calculated using the formula: Milligrams of CO_2 = (B-V) N E [39], where B is the volume (ml) of acid needed to titrate $Ca(OH)_2$ in the jars from the control cylinders, V is the volume (ml) of acid needed to titrate the $Ca(OH)_2$ in the beakers exposed to the soil atmosphere, N is the normality of the acid, and E is the equivalent weight. To express the data in terms of CO_2, E = 22. The daily emission of CO_2 was expressed as mg CO_2 - day^{-1} kg^{-1} soil.

2.8 Statistical analysis

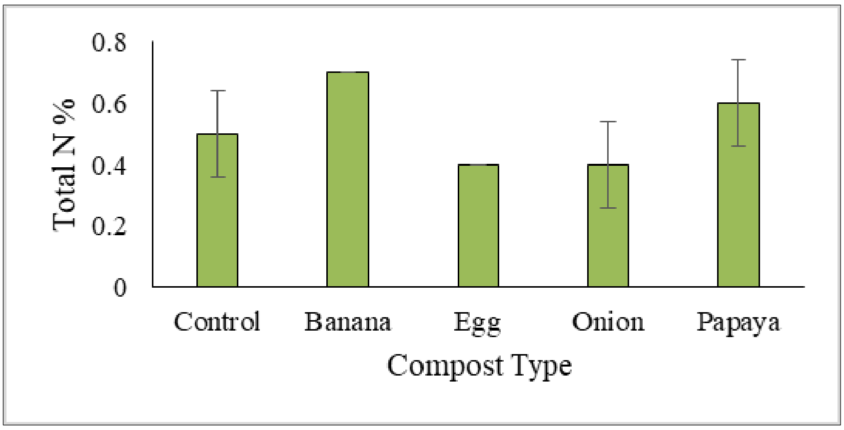
Excel, Microsoft Office 2013 was used for descriptive statistics and graphical data representation. MINITAB version 14.1 was used in statistical analysis.

3 Results and discussion

3.1 Quality of compost based on physicochemical composition

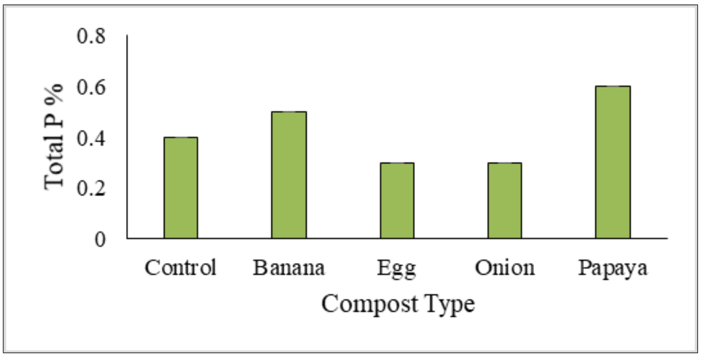
The composition of the compost was measured using the physicochemical parameters such as TN, TP, TK, OC, OM content, C: N ratio, pH, EC and MC to find out the quality of the product.

3.1.1 *Total Nitrogen, Total Phosphorus and Total Potassium in the compost*



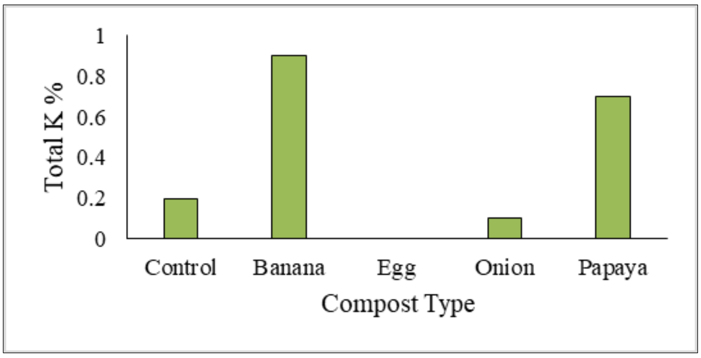
Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 1 Total nitrogen content of different compost mixtures at the end of the composting process.



Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 2 Total phosphorus content of different compost mixtures at the end of the composting process



Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 3 Total potassium content of different compost mixtures at the end of the composting process

Figures 1, 2 and 3 explain the results obtained for the soil quality parameters of composts made with different soil amendments. The composts made with the banana peel amendment and papaya peel amendment showed values higher than the control, while the composts made with the egg shell amendment and onion peel amendment showed values lower than the control in TN, TP and TK.

Composts containing nutrients such as N, P and K play a major role in plant growth. Pramaswari et al. [40], found out that if the initial organic material contained enough N in compost, usually the other nutrients such as P and K will be available in sufficient amounts. Making it true, the compost types other than the compost with egg shell amendment showed sufficient NPK amounts in the current study.

According to the Sri Lankan Standards, TN content as N, percent by dry basis should have a minimum of 5% according to SLS 645: part 1 [33], TP content as P_2O_5, percent by dry basis should have a minimum of 1.0% according to SLS 645: part 5 [34] and TK content as K_2O, percent, by dry basis should have a minimum of 2% according to SLS 645: part 4 [35]. When comparing the NPK nutrient content observed in Figures 1,2 and 3 all the NPK values were very low than the expected amount. But since the control which was food waste compost also had low amounts, comparing with it, the amendments showed considerable NPK values.

But according to Reddy et al. [41], the average value of N, P, K in composts are considered as 0.5%, 0.27% and 0.81%. A research done by Khater [42] for physical and chemical properties of compost types such as, cattle manure, herbal plants residues and sugar cane plants residues, the NPK values were approximately near to the above averages. Even the values obtained by Gharib et al. [43] were similar. Thus we can conclude that although the Sri Lankan Standards are there for NPK, practically they are unable to be achieved. It can also be a reason why the production of composts is done in large scale without following SLS standards.

In the present study, (Figures 1, 2 and 3), in all compost types, TN content appeared higher than the TP and TK contents, which could be due to the breakdown of the amino acids of proteins into nitrates by microorganisms as reported by Robinson and Tartar [44].

In the current research, the highest N and K contents were observed in composts with banana peel amendment (Figure 1 and 3). In a study done by Sial et al. [45] on treatment of waste made of banana peels, lower NO_3^--N contents were observed compared to the control. Similar trend too was evaluated by Wang et al. [46] that showed a decrease in the soil NO_3^--N content. But the same study [46] also showed that the N levels decrease mainly due to the increase of pH by banana peels and biochar made from banana. Thus it can be assumed that since the pH was not increased in the compost as observed in Figure 7 and was maintained neutral, there was a chance of containing a higher amount of N in the compost of the current study. Even though many findings indicate that the N content in banana peels is comparatively low [45], the N content in the current research with banana peel amendments was very high. However, Choy et al. [31] reported that banana peels could enhance the release of N from food waste. Therefore, the increased N content in this study could be attributed to a similar impact generated by the banana peels on the food waste.

The TP content of compost with banana peels according to Figure 2 also showed a higher value than the control. It is simultaneous with the study by Sial et al. [45] where available P concentrations of soil showed a statistically significant difference between the waste treatments of banana peel as compared to the control, with values ranging from the 21.1 to 70.6 mg kg^{-1}.

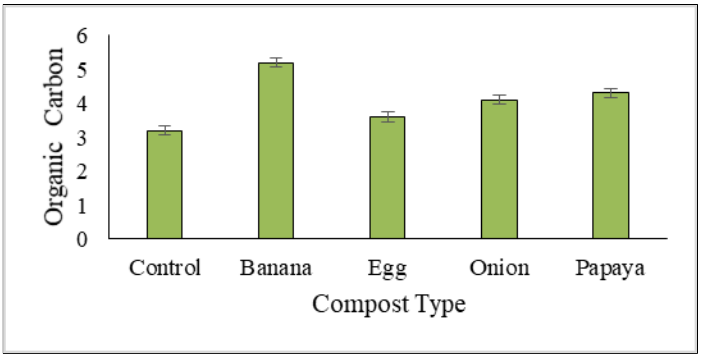
Banana peels are found to be rich in K and it has been suggested by Islam et al. [47] as an alternative source of K for plant productivity in sustainable agriculture. According to a study on nutrient and heavy metal composition of plantains and banana peels by Okorie et al. [48] ripened banana peels contained 9.83mg/100g of K and 0.49 mg/100g of P. However in the present study similar pattern of having higher K value (0.9%) and a lower P value (0.5%) were observed. In Sial et al. [45] biochar made from banana peel increased K concentration 1.9 to 3 times over peel waste. Therefore, banana peel amendments made in the form of biochar can be recommended to achieve better outcome.

Compost with papaya peel amendment had the highest TP content (Figure 2). According to Nasrul and Maimun [49], the P content can be higher by the occurrence of weathering of OM into compost. They further reported that maturation levels of microorganisms will directly improve the content of P in compost.

3.1.2 Organic Carbon and Organic Matter content in the compost

A large body of empirical studies carried out in different agricultural systems has demonstrated that the application of organic amendments in the form of compost, is an effective tool to recover soil organic C stock [50]. So, soil OC too is an important parameter in compost.

The below figure demonstrates the percentage OC where all the compost types had a value higher than the control.

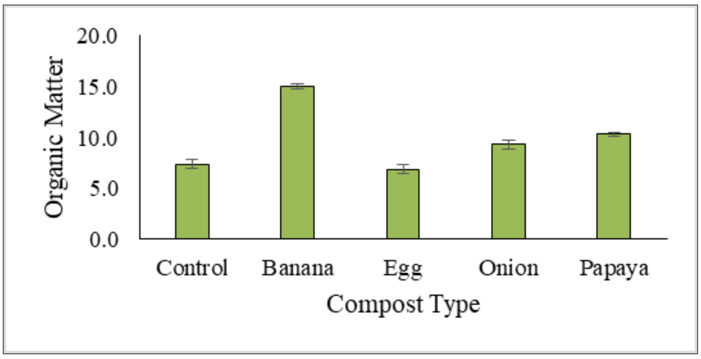


Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 4 Organic carbon content of different compost mixtures at the end of the composting process

In this study, all the co-composts showed higher values than the control which contained only food waste. It can be explained by the research done by Choy et al. [31] where they showed that total C loss was higher for mixtures containing food waste than by fruit peels which indicated that the degree of degradation of compostable part in mixtures with food waste was more than the mixtures with fruit peels.

According to Figure 4, composts made with the amendment of banana peels showed the highest amount of OC. This can be due to the higher C content in them as carbohydrates and fibres. According to Anhawange et al. [51], the percentage concentrations of protein, crude lipid, carbohydrate and crude fibre in banana peels were found to be 0.90%, 1.70%, 59.00% and 31.70% respectively. The total C content of papaya peels was 202.90 g/kg TS according to Dahunsi et al. [52] which is 20.29%. According to Khater [42], OC results in a range from 16.6 to 23.89% in composts.



Values represent means of 2 replications and error bars indicate the standard deviation.

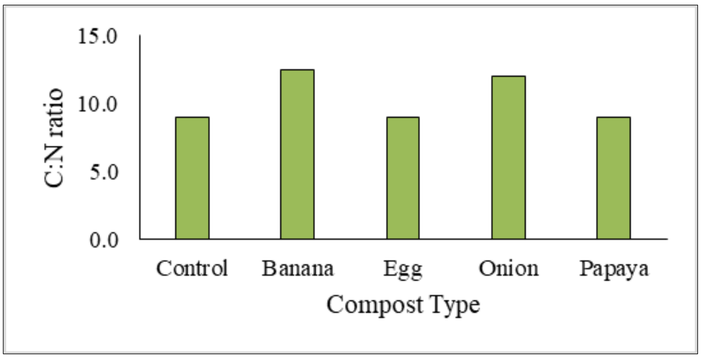
Figure 5 Organic Matter content of different compost mixtures at the end of the composting process

The above figure displays the OM content measured in different co-composts. The OM content in all the amended compost types showed values higher than the control except for composts amended with egg shells. Highest OM content was shown by composts amended with banana peels.

As per the observations represented in the current study, it is very clear that the amendments are adding an additional OM to the soil medium thus indicating the enhanced OM of compost. Soil Organic Matter (SOM) consists of a continuum of components ranging from labile compounds that mineralize rapidly during the first stage of decomposition to more recalcitrant residues that accumulate during advanced stages of decomposition [53]. The OM content gives a clear idea on the amount of decomposable organic contents rather than the % OC. The % OC is only a fraction of Total OM in soil.

The OM content should be more than 20% according to the Europe Eco-Label Standards Applicable to Composts [54] limits as determined by Test Methods 86/ 278/ EEC. According to Khater [42], the OM content varied in composts ranging from 28.60 to 41.20%. Comparing the values with the present study, the values were found to be very low. It should be enhanced using bulk organic material in future when applying to agricultural fields [55].

3.1.3 C: N ratio as a chemical parameter in compost



Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 6 C: N ratio of different compost mixtures at the end of the composting process

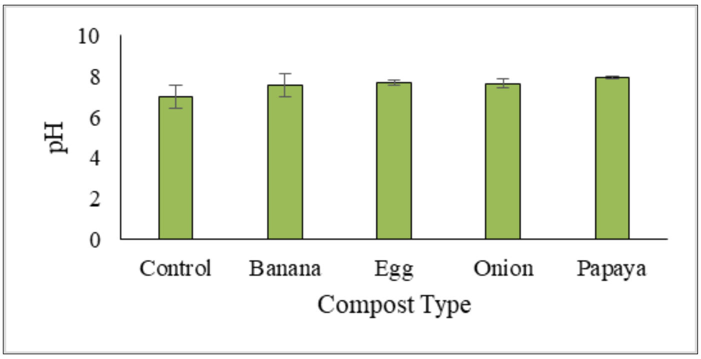
The above figure represents the C: N ratios measured of different types of composts. All types of composts had values greater or similar to the control.

The C: N ratio has been widely mentioned as an index of compost stability and maturity with a value below 20 being suggested as indicative of a mature compost [56]. The C: N ratios of this study are presented in Figure 6. All the mature composts showed values between 9 and 13, indicating an acceptable degree of maturation thus enhancing the quality of compost. According to Lim et al. [57], the final C: N ratio of approximately 10-15 is often taken as an indication of humic material formation and the enhanced stability of treated organic wastes.

Composts with the egg shell amendment showed the lowest C: N ratio. Egg shells contains sufficient protein, glycoprotein, and proteoglycan fibres and due to the high N content than C content, they have a low C: N ratio (≈ 2); as a consequence, egg shell waste as a composting additive can reduce the C: N ratio of raw materials and thus enhance the activities of microorganisms during composting [58].

The C: N in onion peels according to Abdullah and Chin [59] is 60.91. But during composting process, C gets converted to CO_2 and the C: N ratio decreased to the value of 12 as in the study.

3.1.4 *pH as a chemical parameter in compost*

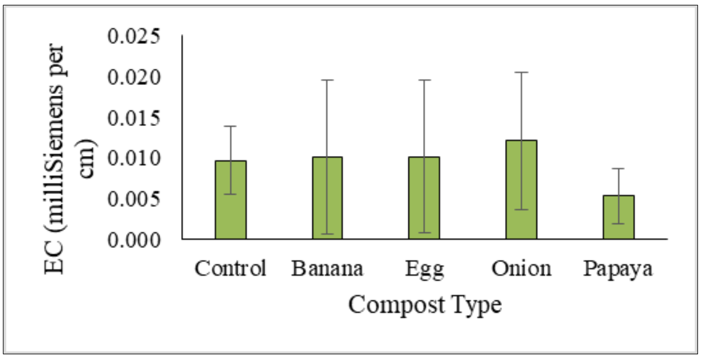


Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 7 pH of different compost mixtures at the end of the composting process

The above figure shows the pH values measured of the different compost types. All the composts showed a higher pH than the control and all of them showed final values of pH close to neutrality and within the range (6.0-8.5) suggested for the agricultural use of compost [60]. According to the Sri Lankan Standards, the pH should be 6.5 – 8.5 according to SLS 1526 [61]. The pH values in the study too were in between 6.5 and 8.5, confirming a pH suitable for agricultural lands. It is obvious that pH played a major role throughout this study in enhancing the performance of compost regardless of their lower NPK values that were reported.

3.1.5 *Electrical conductivity as a chemical parameter of compost*



Values represent means of 2 replications and error bars indicate the standard deviation.

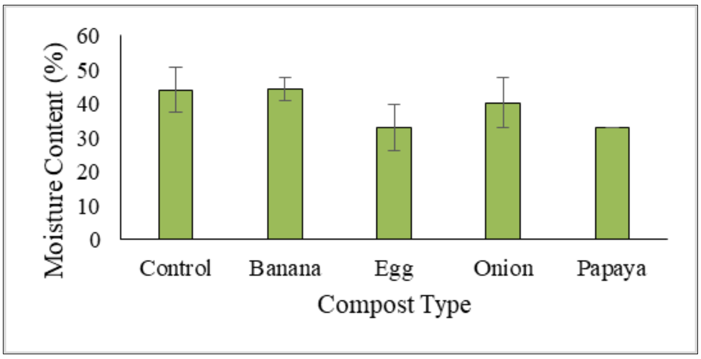
Figure 8 Electrical Conductivity of different compost mixtures at the end of the composting process

Figure 8 represents the EC measured from different compost types. The compost with papaya peel amendment had the lowest EC value while compost with the onion peel amendment had the highest EC value.

EC is a measure of the soluble salt content which can greatly affect germination and plant growth [31]. All EC levels in the study were less than 5 milli Siemens per centimeter [62], which was an indication that it would not be harmful to the soil. However, the EC values reported in this study were always less than 1 indicating that they do not have any impact on important microbial processes. These results are also in agreement with findings previously reported by [63].

Since EC was very low in all types of composts produced in the current study, we need to balance the measurement by topping up the nutrient solution or by trying a stronger nutrient solution feed before it can serve the purpose of an organic fertilizer.

3.1.6 Moisture Content as a physical parameter of compost



Values represent means of 2 replications and error bars indicate the standard deviation.

Figure 9 Moisture content of different compost mixtures at the end of the composting process

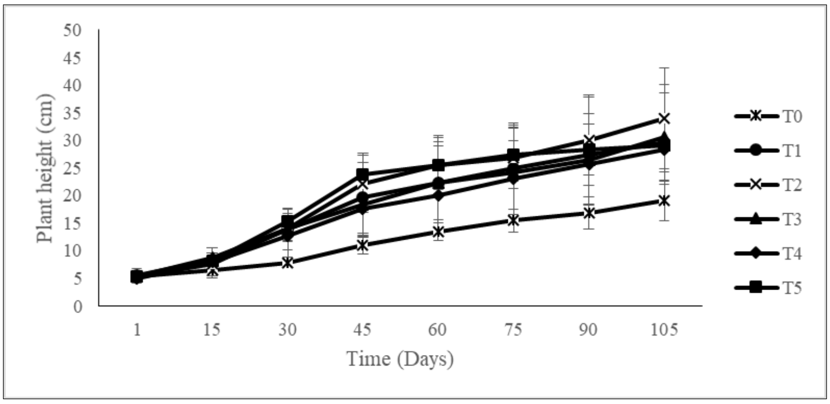
Above figure represents the moisture content in different compost types. Composts made with the banana peel amendment showed higher MC than the control, while the composts made with the egg shell amendment showed values lower than the control.

MC are important in keeping microbial populations active because sufficient moisture is required for microbial nutrition and transport. All composts in the study had a MC between 30% - 45%. But according to Rynk et al. [64] and Jeris and Regan [65] the reasonable range of MC for compost is 40-65%. In the current study, composts made with egg shells and papaya peels had a lower moisture content than the reasonable level. When moisture contents are below 40%, the decomposition process is found to slow down as microbes are unable to carry out their metabolic activities. Thus, egg shells and papaya peels composts have a chance of reducing microbial growth when comparing other composts. When the moisture content is below 15% moisture content, it is found to cease the bacterial activity entirely. All the composts in the study showed values above this and they can be considered as composts of good quality.

3.2 Performance of the compost by growth yield

The performance of the compost types were compared using the growth parameters of *Capsicum annuum*. The growth parameters measured were the plant height, no. of leaves in a plant, no. of flowers in a plant, no. of pods per plant and the average weight of pods in a plant.

3.2.1 Performance of compost in increasing plant height



Values represent means of 2 plants in 3 replications and error bars indicate the standard deviation; T_0 = control with no compost, T_1 = control containing compost made of other wastes, T_2 = banana peel co-compost, T_3 = egg shell co-compost, T_4 = onion peel co-compost and T_5 = papaya peel co-compost.

Figure 10 The changes of mean plant height of *Capsicum annuum* in different treatments of potting mixture during 105 days

Figure 10, displays the heights of plants grown on different potting mixtures with heights represented on days 1, 15, 30, 45, 60, 75, 90 and 105.

The plant heights of *Capsicum annuum* with compost showed a higher growth than on potting mixtures without compost. These results are in agreement with Mercy et al. [66] who stated that height of the fenugreek plant was higher in fruit peel powder applied soil than the control.

According to the statistical analysis, only T_2, which contained banana peels as an amendment showed a significant growth rate ($p<0.05$) compared with the treatment without compost. Other treatments did not show a significant difference in respect to T_0. When comparing treatments with composts with each other, there wasn't any significant difference between the treatments.

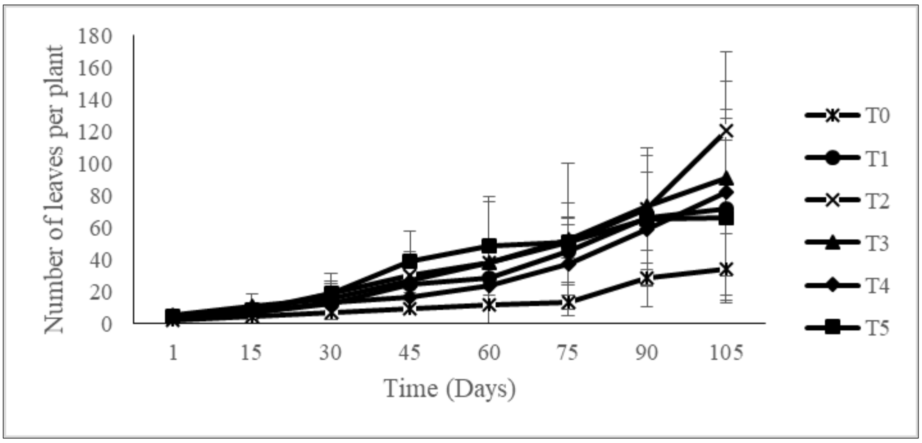
According to Figure 1, composts made with banana fruit peels had more N content than other composts. In a study by Cechin and de Fátima Fumis [67] shoot dry matter production of high N-grown plants was nearly four-fold that of low N-grown plants. Therefore, it can be shown that N straightly induces plant growth.

According to Figure 3, composts made with banana fruit peels as an amendment had more K content too than other composts. K is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism [68]. When comparing other physicochemical values of the composts made with amendments in the current study, banana peels always showed higher values and therefore it was able to enhance physical properties of soil, microbial activity and nutrient availability which was measured by the significant plant height increase.

3.2.2 Performance of compost in increasing number of leaves per plant

The figure below represents the number of leaves per plant, in different treatments, measured on days 1, 15, 30, 45, 60, 75, 90 and 105 during the growing period.

The number of leaves per plants were very low in treatment T_0 where no compost was added while the other treatments had a higher number of leaves. Treatment T_2 where composts with the banana peel amendment was added, showed the highest increase. All the treatments showed an increase with a high gradient while the gradient in T_5 slowed after day 45.



Values represent means of 2 plants in 3 replications and error bars indicate the standard deviation; T_0 = control with no compost, T_1 = control containing compost made of other wastes, T_2 = banana peel co-compost, T_3 = egg shell co-compost, T_4 = onion peel co-compost and T_5 = papaya peel co-compost.

Figure 11 The changes of no. of leaves per plant of *Capsicum annuum* in different treatments of potting mixture during 105 days

According to the statistical analysis, all the treatments did not have a significant difference in their increase in the number of leaves when compared with each other treatments. When comparing both Figures 10 and 11, all the treatments fluctuated during the 105 days of the growing period in a similar pattern.

A study done by Fender et al. [69] identified that with favourable MC and N supply, the plants produce more than 30% additional leaves compared with the low MC and low N treatments, in particular when growing in a moist and warm atmosphere. In regard to this literature, we can prove that the high number of leaves that were present in treatment T_2

in the current study was due to the high amounts of N that was present (Figure 1) in the compost made with the banana peel amendment. According to Figure 9, the co-compost made with banana peels also had the highest MC and according to Fender et al. [69], it too could have had an impact on the higher number of leaves.

3.2.3 Performance of compost in yielding buds and pods

Table 1 The no. of flowers per plant, no. of pods per plant and the weight of pods per plant of *Capsicum annuum* in different treatments of potting mixture after 105 days

	No. of flowers per plant	**No. of pods per plant**	**Average weight of pods (g)**
T_0	0.00 (0.00)	0.00 (0.00)	0.00
T_1	3.67 (5.54)	1.33 (2.80)	1.63
T_2	9.83 (9.56)	0.50 (1.22)	2.00
T_3	10.67 (16.16)	2.00 (4.43)	1.75
T_4	2.83 (5.60)	0.00 (0.00)	0.00
T_5	8.00 (9.81)	1.83 (2.04)	1.50

Values represent means of 2 plants in 3 replications (standard deviation); T_0 = control with no compost, T_1 = control containing compost made of other wastes, T_2 = banana peel co-compost, T_3 = egg shell co-compost, T_4 = onion peel co-compost and T_5 = papaya peel co-compost.

Above table represents the no. of flowers per plant, no. of pods per plant and the weight of pods per plant in different treatments of potting mixture after 105 days. Treatment T_0 did not yield any buds or pods but all the other treatments had an effect on the yield. When considering the yield of the plants, treatment T_3 showed the highest number of buds per plant and number of pods per plant, while highest average weight of pods were shown by plants with treatment T_2.

T_3 treatment consisted of composts made with egg shell amendment and this compost performed well by giving a good yield with a high number of buds, pods and also weight of pods. It is because egg shell contained Ca as a nutrient which neither of the other types of composts did. According to White [70], Ca play and important role in blossoming and fruiting in plants and therefore we experienced a good performance from composts made with egg shell amendment.

Also, it has been reported that pepper likes OM [71] and P and K content in mixture elements have been suggested to promote fruit set of crops such as pepper [72]. In the current study, composts made with banana peel amendment showed higher amounts of P (Figure 2), K (Figure 3) and OM (Figure 5). Thus treatment T_2 with the same compost performed well by having high number of buds and pods with a high weight.

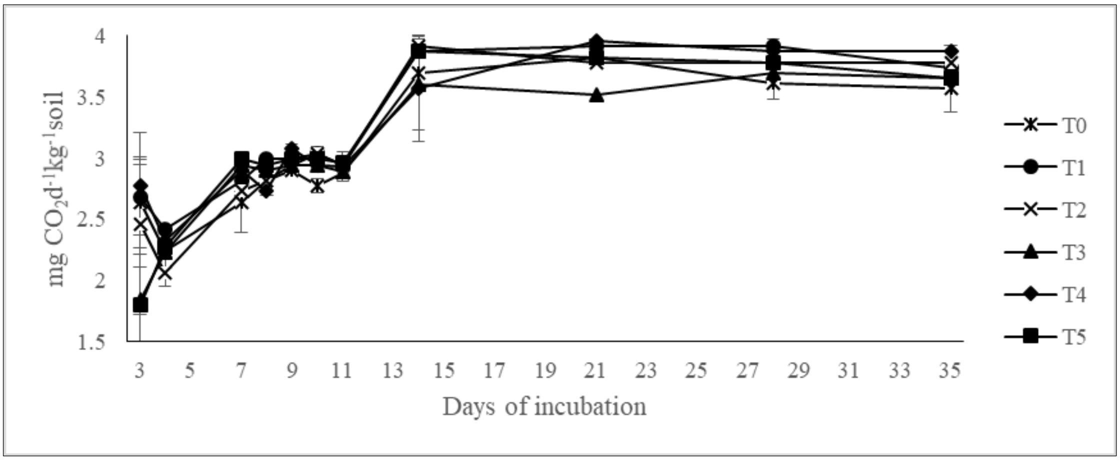
3.3 Carbon dioxide as a greenhouse gas emission

Generally, the rate of soil CO_2 emission varies for different organic amendments as the figure below (Figure 12). From the trend of CO_2 emission, it was observed in all treatments, that emission was stabilized after 2 weeks of incubation. The CO_2 emission was high in the first 3 days and there was a sudden drop and then again it had a rise in the first 2 weeks. All the emissions showed an emission of 3.50 mg – 4.00 mg of CO_2 d^{-1} kg^{-1} soil after 2 weeks of incubation. This behavior was similar to the observation in Ray et al. [73] where CO_2 emission spiked following the organic amendment regardless of organic amendment types and their application rates, and then gradually decreased; it reached the lowest levels in three months after the start of the experiment.

According to Forster et al. [74] 0.9 to 1.5 g / kg /3rd day of CO_2 evolves from OM while Iannotti et al. [75] 1.3 g C-CO_2 /kg DM in 3days of CO_2 evolves from OM in mature compost. In the current study, the CO_2 emission was low compared to research studies.

In general, after incorporation of composts to soils, it takes time for the microbial activities to start. The study was conducted in the laboratory condition; therefore, data might not correlate with the field conditions because of environmental diversity and heterogeneity. Therefore in the first two weeks we could observe a large variation in CO_2 emission in all the treatments. This is correlated with the observations in Ray et al. [73].

CO_2 can be released when OM in soil is broken down through microbial degradation and through root and faunal respiration. They are influenced by many factors like soil conditions, temperature, alternate wetting and drying, composition of organic residues and soil microflora. Soil microflora have been found to contribute 99 % of the CO_2 arising as a result of decomposition of OM [76].



Values represent means of 2 replications and error bars indicate the standard deviation; T_0 = control with no compost, T_1 = control containing compost made of other wastes, T_2 = banana peel co-compost, T_3 = egg shell co-compost, T_4 = onion peel co-compost and T_5 = papaya peel co-compost.

Figure 12 Carbon dioxide emission from different organic amendments

The evaluation of composts by Wang et al. [77], found that composts with respiration rate less than 2 g CO_2 g^{-1} compost day^{-1} were not phytotoxic to seedlings and would be considered stable. Since the CO_2 emission in the current study, is less than 2000 mg CO_2 g^{-1} compost day^{-1}, all the composts are safe for the use in agricultural systems. Ray et al. [73] states that spatio-temporal variations of soil CO_2 emission can be influenced by climatic parameters such as temperature and rain and hydrologic parameters like soil moisture. Since the research was carried out under laboratory conditions, there wasn't any effect from climatic parameters.

According to Figure 12, T_0 had the least CO_2 emission and that is mainly due to the absence of an organic amendment to the soil. This is in correlation with Ray et al. [73] where cumulative soil CO_2 emissions from all of the amended plots were higher than those from respective un-amended (controls) plots. According to Ray et al. [73] increasing soil moisture can indicate an increase in microbiological activities resulting in an increase of the soil OC and also CO_2 emission because soil CO_2 is mainly produced as a result of the soil microbial respiration and vegetation root respiration.

According to Figure 12, CO_2 emission was relatively high in treatment T_1 which was the control. Treatment T_2 showed the highest amount of CO_2 emission. It was due to the presence of higher OC and OM content as in Figure 4 and 5, in composts amended with banana peels. According to Figure 9, the highest moisture contents are observed in the control compost and compost made with banana peels which are used as T_1 and T_2. So according to the explanation of Ray et al. [73], it can be concluded that the higher CO_2 emission in both the treatments were due to the high moisture content that increased the microbial activities that helped in more decomposition of OM, which was also high in their amendments.

In a research on contrasting effects of banana peels waste and its biochar on greenhouse gas emissions and soil biochemical properties by Sial et al. [45], showed that the cumulative CO_2 emissions for biochar 1 and biochar 2 made with banana peel treatments decreases 20.0% and 24.0% in comparison to the banana peel amendment, respectively. Thus biochar made with banana peel seems to be a more efficient reducer of greenhouse gases than the normal peel.

According to Figure 12, treatments T_3 and T_5 which contained amendments egg shells and papaya peels showed a reduced level of CO_2 emission. Composts made with added egg shells had low levels of OC (Figure 4) and low level of OM content (Figure 5). This caused the reduction in CO_2 emission from T_3 treatment. According to Figure 9 composts made with egg shells and papaya peels showed lower values compared with the other composts. This value was below 40% which was the optimum MC that should be present in composts. So due to it, the microbial activities have been limited and therefore the decomposition rate has slowed down causing a reduction in the CO_2 emission in treatments T_3 and T_5. In Figure 6, compost types egg and papaya showed lower C: N ratio that is an indication of reduced soil OC. It too is a cause for reduced CO_2 emission in treatments T_3 and T_5.

However, it is very clear that a substantial amount of CO_2 is being released from different treatments with organic amendments thus indicating possible contributions towards global climate change, which is an important topic, being discussed by the environmental experts [78], [79], [80]. Therefore, this small set of data could be an eye opening for further research.

Bernal et al. [81] has suggested that stable OM that are applied to soil emit less C than an instable one. This stability is related to compost's chemical composition [82]. To improve C stabilization in the organic amendments, the addition of minerals, such as goethite, montmorillonite or industrial wastes such as red mud can be used. Some authors have observed that the presence of these minerals during composting allowed to increase the half-life of organic amendment C and thus increase soil C stocks without altering soil properties [83, 84].

4 Conclusion

Composts made with the banana peel amendment was identified as a high quality soil amendment which can be used as an organic fertilizer in agricultural systems.

When considering the different compost types, plants treated with the compost made of banana peel amendment showed a significantly higher growth rate than others while the composts made with the eggshell amendment showed a higher yield. Thus we can conclude that composts with an amendment with banana peels and eggshells perform well compared to other amendments.

All the amended compost types had a higher emission of CO_2 than the soil without compost.

Thus we can recommend composts made with banana peels and egg shells as an additive as a soil conditioner and potting media for sustainable use.

Compliance with ethical standards

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Disclosure of conflict of interest

No potential conflict of interest was reported by the authors.

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