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Performance of Effective Microorganism (EM) in Food Waste Composting and Their Association with Seed Germination on Kale Seed

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ABSTRACT

Food waste has an influence throughout the whole food supply chain, from production to consumption. Composting effectively and affordably reduces the need for synthetic fertilizers, water, soil erosion, pesticides, and soil carbon storage. Composting may also improve crop yields and soil fertility, leading to more sustainable farming practices. The potential of efficient microorganisms (EM) for dehydrated food waste decomposition was investigated in this study. The research assessed the temperature and pH profiles during composting, whereas nitrogen, phosphorus, potassium, organic content, and E. coli were measured in mature composts. Therefore, the study revealed that EM greatly hastened the composting process by boosting critical factors such as temperature, pH, nitrogen content (TN : 1.17±0.6%, TP: 0.059±1.92%, K: 0.12±5.3%) organic enrichment (85%), and E-coli (<1 MPN/g). The germination index (GI) of kale seed was then analysed with the study's findings indicating an 80% soil-compost ratio was the best. This research investigates the use of effective microorganisms (EM) to transform food waste into beneficial agricultural resources, with favourable results for soil health and kale seed germination. Researchers and circular economy officials may use the results to promote sustainable agriculture. The research helps to minimize landfill food waste, methane emissions, and synthetic fertilizer consumption, all of which benefit the environment. Farmers and gardeners may use the findings to boost soil fertility and crop yields on a budget. This research indicates that food waste may be transformed into useful resources, encouraging sustainable and eco-friendly agricultural.

Keywords: Food waste; compost; effective microorganisms; germination index

INTRODUCTION

In recent years, food waste has become a complicated topic that has attracted the interest of scientists, consumers, and campaigners' interest. Food waste refers to nutritious food that is discarded or wasted. It occurs throughout the food supply chain, from production and processing to distribution, retail, and consumer consumption. Food waste includes edible and nonperishable foods, like fruits, veggies, cereals, dairy goods, meat, and packed foods. Food waste is a global issue with significant economic, social, and environmental consequences. When food is squandered, is not only the food itself lost but also the water, energy, and land used in its production and processing, distribution, retail, and consumption by consumers. Additionally, as food waste decomposes in landfills, it contributes to greenhouse gas emissions by emitting methane, a potent greenhouse gas. Methane is the second most important greenhouse gas after carbon dioxide in climate change. Research indicates that methane has a significantly higher global warming potential compared to carbon dioxide across various timeframes which have serious consequences for human health (Kang et al. 2022).

Based on findings and studies that have been done on the literature, effective food waste management will help reduce food waste quantities efficiently and implementing the initiatives such as the 3Rs (Reduce, Reuse, Recycle). through education and incentive regulations (Hashim 2021). Composting food waste is also one of the alternatives to counter these issues. According to Abdelfattah et al. (2021), composting is converting food scraps into nutrient-rich compost, which is beneficial as soil fertilizer. Applying decomposition process of the soil will contribute to the reduction of synthetic fertilizer use, including the reduction of total water consumption, the reduction of soil erosion, the reduction of herbicide use, and the improvement of soil carbon storage. Unfortunately, Malaysians' awareness of composting is relatively low (Kasavan et al. 2022).

In addition, several methods for composting food waste with Effective Microorganism (EM), including the bokashi method, have been widely adopted in Malaysia. The bokashi technique is an example of an anaerobic system that uses inoculated cereal to ferment organic matter into compost (Cespedes 2019). An anaerobic process involving organic matter, effective microorganisms (EM), molasses, and water yields bokashi. According to Merta et al. (2021), plants treated with EM Bokashi had the longest stems due to the EM Bokashi's continuous nutrient supply. In the meantime, according to a review by Phooi et al. (2022), bokashi improved the soil's physical, chemical, and biological properties, resulting in increased plant growth and yield. While bokashi composting may have some limitations and difficulties (odour problems due to leachate) in certain circumstances, traditional composting techniques can also have their own drawbacks. Thus, when choosing a decomposition method that works best for individual circumstances and lifestyles, it is crucial to consider a variety of factors and options.

To enhance the composting process of dehydrated food waste utilizing Effective Microorganisms (EM), it is essential to consider many critical factors. Dried food waste, referred to as FORBI, possesses a high-calorie biomass and low moisture content, rendering it well-suited for composting and subsequent application as a raw material in compost production (Khalida et al. 2022). Research conducted by Malakahmad et al. (2017) has demonstrated that the addition of effective microorganisms (EM) during the composting of dried food waste improves the decomposition process and increases the quality of the resulting compost. Moreover, EMs have been discovered to expedite the decomposition process, regulate odors, reduce leachate production, and improve the quality of compost products (Filogônio & Korres 2021). In addition, incorporating effective microorganisms (EMs) into compost has been demonstrated to enhance mineralization, leading to an improvement in the quality of the compost (Jusoh et al. 2013). According to Panisson et al. (2021), the use of EM-treated compost has been linked to a decrease in thermotolerant coliforms, which indicates a reduction in pathogens and a potential improvement in seed germination. However, there is lacking study on EM which isolated by the food waste itself especially from the citrus waste. Citrus waste, which contains valuable components with high biological value, can be effectively used for a range of uses, including as the manufacturing of EM. It also can improve the quality and efficacy of EM production especially on the seed germination (Anticona et al. 2020).

The germination test is a method for figuring out whether seeds are good to plant. This is also one of the most common methodologies used to evaluate compost maturity for further agricultural applications is the compost maturity index (Gao et al. 2021). Germination is a qualitative developmental response of seeds that occurs over time (Talská et al. 2020), but different seeds within a given treatment respond at different time intervals. The test consists of depositing a specific number of seedlings in a controlled environment and monitoring their growth over time. The Germination Index is defined as a weighted sum of the daily numbers of germinated seeds (Talská et al. 2020). Moreover, according to Florentine (2018), the germination index (GI), a measure of the germination rate, exhibits a modest variation in response to temperature and light regime for every variety. The decomposition process generates large quantities of plant-toxic substances, and as the compost ages, these substances' concentrations decrease progressively (Hase and Kawamura 2012). When seedlings germinate with a GI greater than 50%, the compost is considered as mature (Shetata et al. 2019). It is important to note that the GI can vary depending on the type of plant species being grown. Additionally, factors such as pH and nutrient content can also affect the maturity of compost.

Therefore, this study was conducted to evaluate the effectiveness of effective microorganisms which isolated from citrus waste in composting dried food waste and further evaluated the compost for plant growth. For this the mini composter was used to dry the food waste and the EM was produced earlier using fruit peels. The effectiveness of compost was measured based on the nutrients contained after the incubation period including nitrogen, phosphorus, potassium, organic content, and *Escherichia coli (E-coli)*. This finding is important as a sustainable approach of food waste management which gives back the benefit to environment.

METHODOLOGY

DESIGN OF THE COMPOST BIN

The selected composting bin is a plastic container with a diameter of 30 cm and a height of 39 cm. The justification for utilizing a plastic container for composting in this study is based on multiple criteria that are in line with the research objectives. The container's size is optimal for conducting controlled, small-scale experiments, enabling accurate monitoring and control of composting variables. This dimension offers sufficient space to view the decomposition process and microbial activity, while also preserving a manageable volume for regular sample and analysis. To avoid compaction of the mixture in the bin and to guarantee that the compost was given oxygen and aeration, holes were pierced on both sides of the container for aeration purposes. In addition, plastic and fabric tape were used to seal the compost container, preventing any sunlight from entering and keeping the compost at a desirable temperature. In addition, it was used to forestall the spread of unpleasant odors and the invasion of any nearby animal species.

FIGURE 1. Composting bin

Furthermore, it is essential to regularly turn the compost to ensure proper aeration and distribution of nutrients. This will also help speed up the decomposition process and produce high-quality compost for gardening or farming. Figure 1 shows the composting bin used in this study.

PREPARATION OF EFFECTIVE MICROORGANISMS

A few ingredients, including fermented soybeans, palm sugar, rice water, orange peels, lemon peels, and pineapple peels, are required to produce an effective microorganism (EM). Two liters of EM was utilized. Therefore, the preparation process involves dissolving palm sugar in a mix of 1 liter of boiling water and 1 liter of rice water. Then, orange peels, lemon peels, and pineapple peels were shredded into tiny pieces measuring between 2 and 5 centimeters, and fermented soybeans were also sliced into small pieces. Then weighed out the ingredients using 200 grams of orange and lemon peel, 200 grams of pineapple peel, and 300 grams of fermented soybeans. After weighing out the ingredients, they were mixed, added to the sugar and water mixture, and placed in a container. The mixture was then left to ferment at room temperature for 3-5 days until it developed a sweet and sour aroma. Finally, the fermented mixture was strained and bottled for consumption.

COMPOST PREPARATION

The food waste (vegetables, eggshells, and onion peel) was obtained from the cafeteria at the MARA University of Technology (UiTM) campus in Shah Alam, At the same time, bulking agents (sawdust and dry leaves) were taken from the materials laboratory (UiTM). Both materials were used as compost beds. Then, the scrap food and the bulking agent were shredded into tiny particles ranging from 2 to 5 centimeters. After that, the vegetable scraps and the compost bed were mixed in a mini composter (Figure 2), for drying purposes. The mixture in a mini composter was heated up to 80°C, and for eight hours.

FIGURE 2. Machine to heat and dry the food waste

After removing the mixture from the machine and allowing it to cool to room temperature, 1 liter of the EM that was prepared earlier was added to the mixture. This will help activate the composting process by introducing beneficial microorganisms. The mixture was transferred to a compost bin and regularly turned to ensure proper aeration. The compost bin can hold up to 3 kg of compost (2 kg of food waste, 600 g of sawdust, and 400 kg of dry leaves). Over time, the mixture will break down into nutrient-rich compost that can be used to fertilize plants and improve soil health.

DETERMINATION OF THE GERMINATION INDEX OF SEED

The number of germinated seeds for fertilizer-treated seeds and the average root length of fertilizer-treated seeds were determined to compute the germination rate index. Therefore, the seed germination rate was prepared in a petri dish with a different ratio of soil and compost soil by a water extract of a sample that been mixed and filtered with a different ratio which is 0%, 10%, 20%, 50%, 80% and 100% (by w/w). Apart from that, germination parameters, the Germination Index (GI), and the Root Length Index (RLI) were assessed. Water extracts of compost samples were generated to test these characteristics; mulch was suspended in water in a 1:9 (wet weight/volume) ratio and stirred for 10-15 minutes (Bhave & Kulkarni 2019). Following mixing, a 3-hour contact time was established. Once the solids settled to the bottom of the flask, the extract was separated from the solids. The Germination Index (GI) was calculated by placing ten kale seeds in a 9-cm diameter petri dish coated with filter paper and adding a 10 ml aliquot of extract at different dilutions. The seeds were germinated in 10 ml of distilled water as a control. The Petri dishes were incubated in the dark at 25 °C for 72 hours. After three days, the percentage of germinated seeds and the length of the sprouts and roots were measured. The effectiveness of fertilizer was determined by counting the number of germinated seeds and measuring the root length.

Equation 1 and Equation 2 were used to determine the Germination Index (GI) and Root Length Index (RLI) (Bhave & Kulkarni, 2019; Stabnikova et al. 2005):

$$GT = A/B \times 100\% \quad (1)$$

Where A is the number of germinated seeds for seeds treated by compost and B is the number of germinated seeds in distilled water.

$$RL = C/D \times 100\% \quad (2)$$

Where C is the average root length of seeds treated by compost (cm) and D is the average root length of seeds in distilled water (cm).

The Germination Index (GI) was calculated using the following formula as shown in Equation 3 (Stabnikova et al. 2005; Bhave & Kulkarni 2019).

$$GI = (A \times C)/ (B \times D) \times 100\% \quad (3)$$

EXPERIMENTAL SET-UP

The experimental setup for the technique incorporates a thorough approach to monitoring critical factors in the composting process. Temperature was measured using a high-precision thermometer, with measurements recorded at numerous sites inside the compost to guarantee a representative evaluation. pH levels were tested by first collecting a 30 mg compost sample, diluting it in 300 ml of distilled water, and then filtrating the mixture. The pH of the filtrate was measured using a portable meter built for pH/EC/TSD/C. Nitrogen content is tested by the Persulfate Digestion Method, whereas Phosphorus is determined employing the PhosVer 3 (Ascorbic Acid) Method, and Potassium is quantified through the Tetraphenylborate Method. The VSS (Volatile Suspended Solids) technique is applied for measuring organic content, comprising sample filtering and subsequent drying to quantify weight loss. The Most Probable Number (MPN) approach is extensively applied in labs to identify and quantify *E. coli* in samples following the standard method (Standard Method 9223B). After incubation, the presence or lack of growth in each dilution is recorded, and the MPN is computed using statistical tables provided. Each measuring technique follows established guidelines, and devices such as spectrophotometers are utilized for reliable results. Regular monitoring and recording of data during the composting process were crucial to noticing trends and fluctuations in the parameters (pH an temperature), enabling a thorough knowledge of the composting dynamics. Strict attention to calibration methods (nutrient and organic content) and established operating protocols were maintained to assure the trustworthiness of the produced findings.

STATISTICAL ANALYSIS

In this study, the percentage of nitrogen (N) was determined using the Persulfate Digestion Method. This involved oxidizing organic matter to release nitrogen, which was then quantified using appropriate analytical techniques. The equation for calculating the percentage of nitrogen (%N) was expressed as in Equation 4:

$$\%N = \left(\frac{N \times 14.01}{Sample\ weight}\right) x\ 100 \quad (4)$$

N is the amount of nitrogen obtained from the Persulfate Digestion Method. For the analysis of phosphorus (P), the PhosVer 3 (Ascorbic Acid) Method was employed. This method utilizes colorimetric determination to measure phosphorus content. The equation for calculating the percentage of phosphorus (%P) was formulated as in Equation 5:

$$\%P = \left(\frac{N \times 31.0}{Sample\ weight}\right) x\ 100 \quad (5)$$

where *P* denotes the amount of phosphorus obtained through the PhosVer 3 Method. Potassium (K) content was quantified using the Tetraphenylborate Method. The Tetraphenylborate Method involves specific chemical reactions for potassium determination. The equation for calculating the percentage of potassium (% K) was represented as in Equation 6:

$$\%K = \left(\frac{K \times 39.10}{Sample\ weight}\right) x\ 100 \quad (6)$$

K signifies the amount of potassium obtained through the Tetraphenylborate Method. Additionally, the analysis of organic matter was conducted using the VSS (Volatile Suspended Solids) technique. This method measures the volatile fraction of organic matter. The equation for determining the percentage of organic matter was expressed as in Equation 7:

$$\%OM = \left(\frac{w1 - w2}{w1}\right) x\ 100 \quad (7)$$

Where w1 is the initial weight and w2 final weight.

In the statistical analysis, data were regarded to represent individual samples. Nevertheless, the samples were acquired from well-established composting operations. Additional data were acquired for several operations, such as continuous temperature readings. The study of these parts of the samples seeks to offer a complete grasp of the composting processes. The continual temperature monitoring permitted a complete examination of the temperature fluctuations during the maturation period, offering significant insights into the dynamics of the composting process.

RESULTS AND DISCUSSION

TEMPERATURE ANALYSIS

The temperature changes that occurred in the compost pile during the process of composting are shown in Figure 3. Daily, temperature measurements were taken until the compost reached maturity, which was signified by a change in color from light brown to dark brown. When the composting process started, the temperature was in the mesophilic range (40 degrees Celsius); however, on day 2, the temperature quickly rose to 41 degrees Celsius because of the buildup of heat due to the respiration of microorganisms. On the other hand, the temperature of the compost was progressively brought down to the atmospheric level.

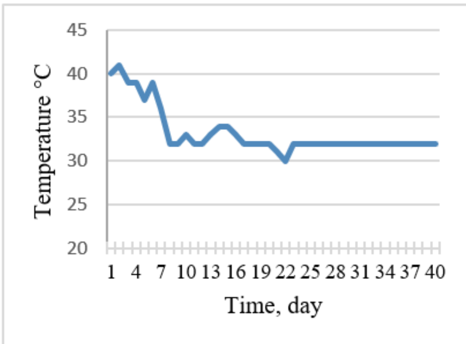

FIGURE 3. Temperature Profile of Composting Process

According to Wichuk and McCartney (2010), compost is in a stable state when the temperature of the compost is equivalent to the temperature of the surrounding environment. This stable state indicates that the composting process is complete, and the compost is ready for use. Achieving this temperature equilibrium is important for ensuring the successful decomposition of organic matter and the production of nutrient-rich compost. Microorganisms can break down organic material more effectively when the temperature is kept steady, which is why it is essential to maintain a consistent temperature.

These bacteria, which flourish at certain temperatures, are essential to the process of composting since they are responsible for the process. Compost has the potential to kill out these microorganisms if it is heated to an excessive degree, which would result in the process of decomposition coming to a stop. On the other hand, if the compost is allowed to reach an excessively low temperature, the microorganisms may go dormant, which will slow down the process of decomposition. For this reason, attaining temperature equilibrium is very necessary to guarantee the creation of compost of a consistently high quality.

During the process of composting, the presence of ample moisture leads to significant microbial activity, resulting in temperatures that can reach up to 60 degrees Celsius. Nevertheless, the highest recorded temperature in this investigation was 40 degrees Celsius, which might be attributed to the utilization of dried food waste instead of wet food waste. Dried food waste possesses a markedly reduced amount of moisture, which is essential for facilitating microbial activity and generating heat during the composting process (Filogônio & Korres, 2021). Decreased moisture levels restrict the growth of microorganisms and decelerate breakdown processes, leading to a decrease in overall production of metabolic heat. In addition, the thermal characteristics of the composting mixture containing dried food waste hinder its ability to achieve elevated temperatures (Vico et al. 2018). The observed lower maximum temperature of 40 degrees Celsius can be attributed to these parameters, which emphasize the influence of moisture content on composting dynamics and microbial effectiveness. This discovery offers significant knowledge regarding the process of composting and the distinctions between utilizing dehydrated and moist food waste.

PH

The neutral pH level found in the last stages of composting is a consequence of a balanced equilibrium of moisture, oxygen, and temperature. This equilibrium is vital for the action of compost microbes, which break down complex organic materials into needed nutrients for plant development. The careful orchestration of composting conditions, as indicated by Shilev et al. (2007) and Islam et al. (2021), not only shows the effectiveness of the composting process but also sets the scene for the formation of nutrient-rich compost. This nutrient-rich compost is a wonderful resource for promoting plant health and soil fertility.

These scientific discoveries extend beyond the immediate advantages of successful organic matter decomposition, revealing the larger consequences of obtaining a neutral pH in compost. Achieving a neutral pH minimizes the probability of generating an environment that invites pests or illnesses. The resultant compost is a safer and healthier solution for soil enrichment, matching with sustainable farming methods. In conclusion, the effectiveness of composting is predicated on rigorous considerations of composting conditions, as indicated by Shilev et al. (2007) and Islam et al. (2021). This information give useful insights into the ideal pH range, stressing its potential advantages for both the environment and agricultural output.

TOTAL NITROGEN, N

According to Table 1, the total nitrogen value was 1.17% which compared to previous researchers, the final compost's nitrogen value was within the required range. This indicates that the composting procedure was effective in preserving the required nitrogen levels. These findings are consistent with earlier study findings, bolstering the efficiency of composting approaches in regulating nitrogen levels. Furthermore, compost used for agriculture must have more than 1% of total N to exert fertilizing capabilities (Fan et al. 2018).

The successful maintenance of desired nitrogen levels in the compost is important, as nitrogen is a crucial nutrient for plant growth. This indicates that the compost produced can be used as a valuable soil amendment to enhance plant productivity and nutrient availability. Additionally, the consistent results across different studies highlight the reliability and reproducibility of composting techniques in managing nitrogen content, making it a sustainable and environmentally friendly method for waste management.

TABLE 1. Nitrogen content of the final composting process

Total Nitrogen, N (%)	Reference
1.17 ± 0.6	This study
> 0.6	Hamid et al. 2019
> 1.0	Fan et al. 2016
> 1.5	Keng et al. 2020
2.6 ± 0.3	Syuhadah Aji et al. 2021

PHOSPHORUS, P

Phosphorus, according to Fan et al. (2018), is a necessary nutrient for root development and plays a significant role in plant metabolic activities. According to Table 2, the quantity of phosphorus recovered from the compost was 0.059 %, which is not significantly higher than the average value based on prior research. It is crucial to remember that the phosphorus availability in compost varies based on variables such as composting processes and feedstock type.

However, the proportion is insufficient to make a meaningful contribution to root development and metabolic activities. This low phosphorus percentage in the compost may suggest the need for further phosphorus supplementation or alternate phosphorus sources for optimum plant development. More study is required to establish the best course of action for dealing with this problem. A variety of factors, including pH levels (Zhu et al. 2018), soil texture (Khoshnaw and Eismail, 2021), and microbial activity (Mise et al. 2018), may influence phosphorus availability in soil. As a result, additional study is needed to determine the true impact that the phosphorus concentration of the compost created has on plant growth and metabolism. More research is required to identify the components that contribute to the phosphorus concentration of compost. Understanding how these components interact with one another might also give useful insights into improving compost production for plant growth and general plant health.

TABLE 2. Phosphorus content of the final composting process

Total Phosphorus, P (%)	Reference
0.059 ± 1.92	This study
> 0.22	Hamid et al. 2019
0.6 > 1.7	Fan et al. 2016
Not Available	Keng et al. 2020;
1.1 ± 0.6	Syuhadah Aji et al. 2021

POTASSIUM, K

Potassium is a nutrient that is necessary for the growth of plants and the presence of potassium in compost can contribute to the overall nutritional content of the compost that is produced. Potassium, in the meantime, is an essential component in the process of facilitating the growth of roots, the development of plants, and the transfer of energy within plants. The value of potassium in this study was found to be 0.12% as shown in Table 3 which is lower than other studies. This suggests that the original composition of the compost materials, which includes food waste, can influence the potassium levels in the result. Noted that the composition of food waste used in this study consist of mixed of fruit, vegetable, eggshell and leftover food. Thus, the potassium content was differed from the previous study. In addition, the research conducted by Lalremruati et al. (2022) emphasizes that vegetable waste compost had the highest concentration of potassium, which facilitated optimal development of plant roots and increased biomass production.

This implies that the origin of organic substances, such as leftover food, might impact the nutrient makeup of the compost, especially the quantities of potassium. Therefore, based on the value obtained it was determined that the compost produced in this study would have a sufficient and beneficial impact on plant growth and development. Ofei-Quartey et al. (2022) carried out research indicating that the optimal potassium levels in compost should fall within the range of 0.013395% to 0.06862%. Within this range, a potassium content of 0.12% is falls within the ideal range, suggesting that it may be enough for promoting plant growth.

TABLE 3. Potassium content of the final composting process

Total Potassium, K (%)	Reference
0.12 ± 5.3	This Study
> 0.25	Hamid et al. 2019
0.4 > 1.1	Fan et al. 2016
Not Available	Keng et al. 2020
0.8 ± 0.2	Syuhadah Aji et al. 2021

ORGANIC CONTENT

The importance of discovering organic content in compost, particularly organic matter obtained from food waste, is underscored by the many advantages it provides for soil health and environmental sustainability. The organic content in mature compost in this study was found to be 85%. This finding was far higher than study made by Ajaweed et al. (2022) which found that the organic matter of food waste composting for agricultural waste was 38.23%. Smith et al. (2018) discovered that the organic content of compost considerably improves soil structure, increases nutrient availability, and improves water retention capacity. Furthermore, it has been shown that adding compost to soil reduces the demand for synthetic fertilizers and pesticides, boosting sustainable agriculture methods.

Furthermore, the mature compost satisfies the criteria for the EU guidelines (>15), and the CCQC recommends a minimum organic matter content of 25% (Ajaweed et al. 2022). This shows that the compost generated by food waste composting is of good quality and has the potential to improve soil health and agricultural output. Furthermore, the compost's high organic matter content may contribute to carbon sequestration, which can help minimize the effects of climate change. Thus, the compost formed from food waste composting is of excellent quality and has the potential to increase soil health and agricultural productivity. The organic matter content was determined to be substantially more than the specified values, suggesting its success in following EU rules and CCQC recommendations. Additionally, the high organic matter content may help to carbon sequestration, giving a possible strategy for minimizing the consequences of climate change.

PATHOGEN (*E-COLI*)

The presence of a pathogen in compost must be considered because applying compost containing pathogens to the crop soil will impact the environment and then pose a threat to humans. This study will focus on the presence of *E-coli* in the composting of food waste. Understanding the factors that contribute to the presence of *E. coli* in compost will help develop effective strategies to mitigate its spread and protect both the environment and human health.

TABLE 4. The comparison value on the microbial standards for the pathogen of Escherichia coli

Escherichia coli	Reference
< 1MPN/g	This Study
51 MPN/g	Nur Aqeela et. al.,2021
NA	US EPA 503 (Gurtler et al. 2018)
< 1000 CFU/g	UK Composting Standard (Sunar et al. 2014)

Many studies have employed *E. coli* as an indication to identify the presence of a pathogen in compost. *E. coli* was not found in this experiment as shown in Table 4. This suggests that the composting process efficiently removed the presence of *E. coli* due to proper temperature and time duration, which are key factors in killing pathogens. However, it is important to note that the effectiveness of the composting process in eliminating *E. coli* may vary depending on various factors, such as the initial contamination level and the composition of the compost materials. Therefore, further research is needed to determine optimal composting conditions for consistently eliminating *E. coli* and ensuring safe compost usage. As a result, compost may be regarded as safe for use in a variety of applications.

In conclusion, the proper temperature and time duration in the composting process efficiently removes the presence of *E. coli*, making the compost safe for use. However, it is important to consider factors such as initial contamination level and compost composition, as they may affect the effectiveness of eliminating *E. coli*. Further research is needed to determine optimal composting conditions for consistently ensuring safe compost usage in various applications.

GERMINATION RATE INDEX

The germination index, comprising both the speed and uniformity of seed germination, serves as an important indicator in measuring seed vigor and early seedling establishment. Our research focused on analyzing the germination index under varied ratios of soil and compost, hoping to untangle the complex interactions between these components and their impact on the germination process. Additionally, we evaluated the influence of composting with EM on the germination index to understand how unique nutrient compositions may affect seedling growth. Therefore, the Germination Index with a different ratio of soil and compost was shown in Table 5.

Based on Table 5, the effect of compost concentrations on seed root length demonstrates a dynamic link between compost application and root growth. Gradual increases in compost content result in increased root length up to 50%, demonstrating a favorable association (Wang et al. 2023). However, beyond this threshold, there is a slight decrease in root length, indicating a possible saturation or imbalance in nutrient supply. The ideal compost content for root growth has been determined to be 50%, highlighting the need for exact calibration in optimizing favorable benefits. These results are consistent with recent research (Smith & Brown, 2020) demonstrating the importance of compost in delivering necessary nutrients and promoting microbial activity.

TABLE 5. Germination Index with a different ratio of soil and compost

Compost + soil (% by weight)	0%	10%	20%	50%	80%	100%
Number of germinated seed treated with compost	10	8	6	6	7	5
Number of germinated treated with distilled water	7	7	7	7	7	7
Average root length of seeds treated with compost (cm)	1.83	1.78	1.77	2.58	2.29	2.48
Average root length of seeds treated with distilled water (cm)	1.72	1.72	1.72	1.72	1.72	1.72
Germination Index (%)	152	118	88	128	133	103

The study reveals significant patterns in seed germination index related to compost and soil concentrations, peaking at 0% and 80% compost. This emphasizes the critical role of compost-to-soil ratios in seed germination. The optimal germination index at 80% compost suggests a balanced ratio, while a decline at higher compost percentages underscores the importance of equilibrium in soil composition. The index acts as a quality control tool, ensuring composted soil satisfies criteria for enabling seed germination.

Additionally, an average germination rate of 90% or above is regarded as an outstanding or excellent result, but for other species with smaller or numerous seeds, a rate of 70% to 80% is rated entirely acceptable. The research advocates for a holistic approach to compost and soil management in agriculture, stressing the need to optimize ratios for enhanced seed germination and adjust them based on crop requirements. The study concludes by recommending further investigation into the underlying mechanisms influencing germination responses to diverse compost and soil ratios, offering valuable insights for future research.

CONCLUSION

This research focuses on examining the performance of Effective Microorganisms (EM) in food waste composting and its effects on seed germination, especially with kale seeds. The study revealed that EM greatly hastened the composting process by boosting critical factors such as temperature, pH, nitrogen content, organic enrichment, and pathogen suppression. The use of EM resulted in a shorter composting duration of less than two months, a matured compost look, and enhanced odor reduction. Moreover, nutritional content, notably nitrogen and potassium, suggesting sufficient amount for plant growth but yet required additional phosphorus as supplement. The germination index studies indicated the potential of EM-treated compost as a vigorous growing medium for kale seeds, highlighting the significance of exact compost-to-soil ratios for optimum seed germination and root length. The research emphasized the dynamic interaction between compost treatment and seed germination indices, underlining the importance for nuanced compost and soil management in agriculture. Overall, the study supports individualized methods depending on crop needs to enhance the efficacy of agricultural operations.

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DECLARATION OF COMPETING INTEREST

None.

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