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Sustainable Composting of Spent Coffee Grounds & Organic Waste: Enhancing Brazilian Spinach Growth & Soil Fertility

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ABSTRACT

Utilizing spent coffee grounds for compost production presents an avenue to mitigate environmental issues. Converting spent coffee grounds into compost helps improve soil properties, enhancing soil structure stability, reducing compaction, enhancing water retention, and improving soil chemical properties. From the experiments conducted, it was observed that the production of compost from coffee grounds resulting from experiments 1 to 6 can effectively reduce the volume of organic waste, providing a sustainable use for this leftover material. The decomposition process consisted of two stages. The initial stage involved the decomposition by a group of mesophilic bacteria, taking approximately 2-4 days to reach a higher temperature range of 60-70 °C Subsequently, the decomposition of organic matter was facilitated by a group of thermophilic bacteria, with the temperature gradually decreasing to around 25-30 degrees Celsius, which closely approximated the ambient temperature of the compost pile. Overall, the decomposition process took between 80-90 days. Over an 80–90-day composting period, the process achieved optimal conditions, with moisture content ranging between 31.66-34.50%, electrical conductivity values of 0.71-0.79, pH levels between 6.60-7.51, and a carbon to nitrogen ratio of 16.78-18.56%. The compost's nutrient composition included nitrogen (1.43-1.80%), phosphorus (0.54-0.68%), and potassium (0.71-0.80%), adhering to the standards set by the Department of Agriculture, Thailand. Application of this compost significantly improved the growth of Brazilian spinach, evidenced by enhanced canopy width, branch number, plant height, and total weight, with statistical significance ($P<0.05$) compared to control groups. This study not only presents a sustainable approach to managing coffee waste but also provides insights into effective organic fertilizer production for agricultural use. When the compost was tested for its effectiveness on Brazilian Spinach growth, it was found that all experiments had a statistically significant impact ($P<0.05$) on the width of the canopy, number of branches, plant height, and total weight. Notably, the experimental set using 100% coffee grounds (control) resulted in the smallest average measurements for canopy width, number of branches, plant height, and total weight.

Keywords: Composting; spent coffee grounds; organic waste; Brazilian spinach

INTRODUCTION

Coffee is among the most widely consumed beverages in the world, and it is estimated that over two billion cups of coffee are consumed daily coffee intake is highly variable with respect to different countries, ages, and sex, and there appears to be a continuing increase in consumption which parallels, in part, the increasing number of specialty coffee shops in many countries. (Hou *et al*., 2022; Van Dam *et al*., 2020). Coffee is a globally favoured beverage due to its unique flavour and aroma (Campos-Vega *et al*., 2015). Consequently, coffee beans have become a significant economic crop worldwide. Approximately 9 million tons of coffee beans are consumed annually worldwide (Franca and Oliveira, 2022).

During coffee extraction processes in industrial facilities and the preparation of fresh coffee in general coffee shops, residues known as "spent coffee grounds" (SCG) are generated and are underutilized (Cruz *et al*., 2015). SCG comprises various compounds, including caffeine, theobromine, and phenols, as well as several essential plant nutrients such as nitrogen (1.0-2.5%), phosphorus (0.02-0.5%), and potassium (0.35%) (Chrysargyris *et al*., 2021). These residues exhibit potential as a source of nutrients that can enhance soil fertility and crop yields through soil enrichment with organic matter and macro- and micronutrients (Palansooriya *et al*., 2019). Moreover, SCG can be a starting material for compost production (Campos-Vega *et al*., 2015), contributing to environmental sustainability and agricultural efficiency. The increasing popularity of coffee consumption has led to the expansion and heightened competition within the coffee shop industry. Consequently, the generation of SCG has also increased (Mussatto *et al*., 2011), posing environmental challenges. However, SCG can be effectively utilized in compost production and soil enhancement, making it a valuable resource (Campos-Vega *et al*., 2015; Chrysargyris *et al.*, 2021; Cruz *et al*., 2015; Palansooriya *et al*., 2019). Furthermore, reports are indicating that spent coffee grounds contain various micronutrients, such as magnesium, copper, iron, manganese, and zinc, making them a well-rounded source of plant nutrients suitable for agriculture. However, apart from plant nutrients, spent coffee grounds also contain fatty acids, polyphenols, and polysaccharides (Ronga *et al*., 2015).

The increasing generation of spent coffee grounds poses environmental challenges, and improper disposal or management may have adverse environmental impacts. Thus, this waste material, which holds potential value, warrants immediate attention for suitable disposal or beneficial utilization (Bomfim *et al*., 2022). Utilizing spent coffee grounds for compost production presents another avenue to mitigate environmental issues. Converting spent coffee grounds into compost helps improve soil properties, enhancing soil structure stability, reducing compaction, enhancing water retention, and improving soil chemical properties (Ribeiro *et al*., 2017). Moreover, as organic waste generation continues to increase annually, leading to environmental concerns, composting spent coffee grounds serves as an effective method to address organic waste issues. This approach promotes sustainable agriculture by providing farmers with a natural alternative to chemical fertilizers, reducing production costs in the process (Ribeiro *et al*., 2017)

The Brazilian spinach (*Alternanthera sessilis*) is a nutritionally valuable vegetable, surpassing other spinach varieties in nutrient content. It is rich in a variety of minerals and vitamins, such as calcium, iron, potassium, vitamin C, vitamin K, beta-carotene, folic acid, and high fiber Commonly consumed as a dip for spicy sauces, its high nutritional value also makes it an excellent choice for animal feed (Anggraeni *et al*., 2023; Ikram *et al*., 2022). The vegetable is typically cultivated using chemical fertilizers and pesticides, leading to potential toxic residue accumulation, posing risks to consumers (Pyakurel *et al*., 2019). The production of compost incorporating spent coffee grounds with local organic materials can enhance the growth and health safety of Brazilian spinach (Miah *et al.*, 2021). Furthermore, this practice serves as a testbed for the effectiveness of coffee ground-based compost, potentially advancing its application as a sustainable planting medium. Therefore, this study aimed to determine if SCG compost can help sustainably improve the growth of Brazilian spinach.

MATERIALS AND METHODS

Research Design

In this study, a Completely Randomized Design (CRD) was employed, comprising six treatment groups. Each treatment was replicated three times, resulting in a total of 18 experimental units. Rectangular plots were utilized to ensure proper air circulation. The treatments were as follows at **Table 1**. These treatments were designed to assess the influence of various organic waste mixtures, including coffee grounds, cow manure, and different types of waste materials, on plant growth. The adoption of CRD and the inclusion of multiple replications enhance the reliability of the experimental outcomes and enable robust statistical analysis.

Table 1: The treatments use in this experimental

Treatment	Ratio
T1	100% Coffee Grounds (Control Group)
T2	Coffee Grounds : Cow Manure (in a 1: 2 ratio)
T3	Coffee Grounds : Cow Manure : Brown Waste (in a 1 : 1 : 1 ratio)
T4	Coffee Grounds : Cow Manure : Brown Waste (in a 2 : 1 : 1 ratio)
T5	Coffee Grounds : Cow Manure : Green Waste (in a 1 : 1 : 1 ratio)
T6	Coffee Grounds : Cow Manure : Green Waste (in a 2 : 1 : 1 ratio)

The composting process involved the following steps 1) Preparation of Organic Waste Materials. In the preparation of compost for this study, the following organic waste materials were collected and used; 1) Brown waste, this refers to fallen leaf litter, which was gathered from Buriram Rajabhat University campus and then reduced in size to a range of 0.5-3 inches using a locally manufactured leaf shredder with a 2-horsepower engine (Diaz *et al*., 1993), 2) Green Waste: Green waste materials, mainly comprising wet waste such as fresh grass clippings, weeds, and green leaves, were collected from the local vegetation and used spent coffee grounds were sourced from coffee shops within Buriram Rajabhat University, Buriram Province. These coffee grounds underwent a sieving process to remove plastic and glass residues. 2) Preparation of bamboo frames rectangular bamboo frames were constructed, each measuring 100 centimetres in width, 100 centimetres in length, and 50 centimetres in height. Plastic mesh netting was used to secure the compost piles in place and prevent any shifting. A total of 12 frames were prepared for this purpose.

Composting process

Each experimental treatment involved the mixing of composting materials in specific proportions. These mixtures were thoroughly blended to ensure homogeneity. Adequate moisture was provided by watering the mixture to achieve appropriate moisture levels (**Figure 1**). Moisture content was periodically checked using the Fist probe method (Bachert *et al*., 2008). Once the composting materials were well-mixed and reached the desired moisture content, they were placed into the prepared bamboo frames. Composting piles were formed, and each pile was of uniform size and shape. The composting piles were rectangular in shape, measuring 1.0 × 1.0 × 0.50 meters (width × length × height) (**Figure 2**). Care was taken to ensure that each pile was of the same dimension. The compost piles were maintained by periodically monitoring moisture levels, moisture checks were conducted once a week, and water was added to the compost piles as needed to maintain optimal moisture content. The composting process continued for a duration of 60 days. Upon completion of the composting period, the quality of the compost produced in each experimental trial was assessed according to the organic fertilizer standards set by the Department of Agricultural Research.

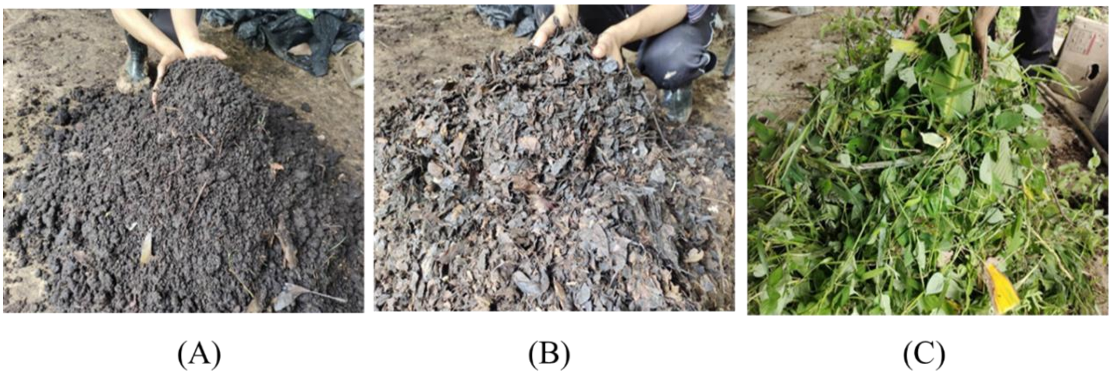

Figure 1: Materials used in the production of coffee ground compost mixed with organic waste. (A) Coffee grounds, (B) Brown waste, (C) Green waste

Figure 2: Preparation of rectangular framework for the coffee grounds composting process mixed with organic waste.

Research site

This experiment was conducted at a research plot located at coordinates 14.976799° latitude and 103.003828° longitude, with the address 99, Moo 10, Krasang Subdistrict, Mueang District, Buri Ram Province, Thailand.

Sample collection for chemical and physical analysis

Sample collection was performed weekly throughout the experiment. Sampling was carried out by randomly collecting samples from the central, top, and all four sides of each compost pile at a total of 10 points, each with a sample weight of 200 grams. The collected samples were then used to determine the bulk density. Subsequently, the compost was divided into four portions using the quartering method until approximately 250 grams of representative samples were obtained for each compost pile (Campos-M & Campos-C, 2017). Each parameter was measured twice, including moisture content. The temperature within the compost pile was monitored daily at the same locations where samples were randomly collected. Laboratory analysis included the following parameters: 1) pH value, 2) carbon-to-nitrogen ratio, 3) electrical conductivity (ds/m), 4) nitrogen content (%N), 5) phosphorus content (%P), and 6) potassium content (%K).

Testing the efficiency of compost

Seedlings of Brazilian Spinach (*Alternanthera sessilis*), also known as Sissoo Spinach or Samba lettuce were prepared for the experiment. Sixty-day old seedlings exhibiting robust growth were selected. They were carefully washed to remove any contaminants and trimmed to a length of 5 inches using pruning shears. Subsequently, these seedlings were planted in plastic bags containing compost derived from coffee grounds. Each treatment group consisted of 12 seedlings, resulting in a total of 72 seedlings. The experiment was designed following a Completely Randomized Design (CRD) and was positioned to receive natural sunlight. Daily watering was carried out to maintain soil moisture levels consistently.

Statistical data analysis

The collected data were subjected to statistical analysis using Analysis of Variance (ANOVA) based on the Completely Randomized Design (CRD). Differences in means were compared using Duncan's Multiple Range Test (DMRT). Additionally, a descriptive analysis was conducted to elucidate the results, explaining the composting process as observed in the experiment. Furthermore, the quality of the compost was assessed in comparison to the organic fertilizer standard of the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand, established in the year 2005 (2548 BE).

RESULTS AND DISCUSSION

The constituent components and initial physical properties of composting materials

During the preparation of coffee grounds and organic waste compost mixtures, consistent initial average values were maintained for the compost mix materials, as presented in **Table 2**. Additionally, the initial volume of compost heaps in all test plots remained uniform, with controlled sizes to ensure equality. Moisture content ranged from 52.30% to 62.00%, density ranged between 186.53 kg/m^3 and 204.42 kg/m^3, electrical conductivity exhibited variations from 0.45 ds/m to 0.56 ds/m, initial pH levels fell within the range of 5.50 to 6.00, and the carbon-to-nitrogen ratio spanned from 28.25/1 to 32.45/1. These values were deemed suitable for the composting process, aligning with previous research findings. (Azim, 2018) observed that the optimal ratio for decomposition in compost production lies within the range of 25-35/1, a conclusion supported by (Diaz *et al*., 1993), who proposed suitable ratios for composting in the range of 20-35:1 and 30:1. Therefore, each experiment utilized an appropriate ratio for the composting process, ensuring efficient and high-quality compost production, consistent with the standards established by the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand, for organic fertilizers in 2005.

Table 2: Initial parameters for various experimental treatments investigating compost mixtures effects on Brazilian spinach growth.

	Treatments					
Parameters	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
Volume (m^3)	0.50	0.50	0.50	0.50	0.50	0.50
Moisture (%ww)	52.30	62.00	54.53	56.20	60.45	58.55
Density (kg/m^3)	198.56	201.50	186.53	210.42	204.42	198.56
EC (ds/m)	0.45	0.56	0.48	0.52	0.48	0.54
pH	5.50	5.50	6.00	6.00	5.50	6.00
C/N ratio	28.25/1	28.12/1	31.50/1	32.45/1	30.22/1	31.54/1

The composting process occurring during the experiment

The compost obtained from the composting process relies on the activity of microorganisms to decompose and maintain suitable environmental conditions for these microorganisms. Various strains, such as fungi, bacteria, and protozoa, play a crucial role in breaking down organic compounds like lignocellulose and cellulose (Grgas *et al*., 2023; Palaniveloo *et al*., 2020).

The temperature change data showed that the average temperature for all experiments ranged from 26 to 30 degrees Celsius. There was a consistent pattern of temperature variation, where during the initial 2-5 days, mesophilic microorganisms, including bacteria and protozoa (Kiely, 1998), rapidly decomposed sugars and organic compounds, leading to a temperature increase of approximately 40 degrees Celsius. This rise in temperature resulted in the highest organic matter decomposition rate (Haug, 1993). Subsequently, the compost temperature ranged from 40 to 70 degrees Celsius, indicating the dominance of thermophilic microorganisms. These microorganisms thrive at high temperatures and decompose complex organic compounds that are difficult to break down. To maintain a uniform heat distribution, the compost heap needed to be turned to enhance aeration. This phase, characterized by thermophilic activity, was the longest in the composting process. However, if the temperature exceeded this range, some microorganisms ceased to grow and decomposition stalled. Afterward, as the available food source for microorganisms diminished, overall microbial activity decreased once more. When the temperature stabilized between 25-28 degrees Celsius, further organic matter decomposition continued.

The average temperature of the compost heap gradually decreased as it approached the surrounding air temperature, eventually leading to the formation of humus. On average, the composting process took approximately 80-90 days, resulting in high-quality compost suitable for plant growth (Bomfim *et al*., 2023). Nevertheless, when using this compost, it is advisable to adjust the pH level to suit specific plant requirements.

Regarding changes in moisture content, the experimental results indicated a rapid decrease in moisture levels in all experiments. Adjustment of moisture levels was necessary to maintain suitability throughout the composting process. Moisture content varied significantly during the initial 21 days of composting, correlating with the optimal temperature range for the activity of thermophilic microorganisms. Subsequently, moisture content gradually decreased until the end of composting. Each treatment exhibited statistically significant differences ($P<0.05$) in the final moisture content. The average moisture content at the end of the experiments ranged from 31.66% to 34.50%, which remained below the organic fertilizer standard set by the Department of Agriculture at a threshold of less than 35%. Regarding changes in pH levels, there were statistically significant differences ($P<0.05$) in the pH values of the compost. The pH values tended to approach neutrality more closely by the end of the composting process. The average pH levels at the conclusion of the experiments ranged from 6.80 to 7.51, which fell within the organic fertilizer standard set by the Department of Agriculture at a range of 5.5 to 8.5 (**Table 3**). Generally, plants have specific pH requirements for optimal growth, typically in the range of 6.0 to 7.0 (Hassin *et al*., 2022).

Regarding changes in density, the experiments revealed that the composting process led to the decomposition of the compost materials into compost, resulting in a reduction in size and a subsequent increase in average density values. There were statistically significant differences ($P<0.05$) in density values among the experiments, with average values ranging from 265.32 to 282.00 kg/m^3 (**Table 3**). Changes in the carbon-to-nitrogen (C/N) ratio occurred as the decomposition process transformed organic matter into humus. With the conversion of organic matter to humus, the quantity of humic acids increased, resulting in a decrease in the C:N ratio of the entire treatments. Statistically significant differences ($P<0.05$) were observed in the C:N ratio, with values ranging from 16.78 to 17.66/1. These values approached the standards set by the Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand, at the level of 20:1. Successful composting processes are crucial as they are a significant source of carbon and nitrogen in the soil, with more than 90% of nitrogen present in the form of organic compounds (Yan *et al*., 2022). Changes in nitrogen (N), phosphorus (P), and potassium (K) elements were observed to approach standard values, with statistically significant differences ($P<0.05$). Specifically, nitrogen had an average ranging from 1.43% to 1.76%, phosphorus ranged from 0.54% to 0.68%, and potassium averaged between 0.71% and 0.80%. These values complied with the standards set by the Department of Agriculture, Ministry of Agriculture and Cooperatives, which specify nitrogen content greater than 1.00%, phosphorus content of 0.5%, and potassium content of 0.5% for organic fertilizers. These elements are essential for plant growth and yield (Wang *et al.*, 2021). Notably, plants have a higher demand for nitrogen compared to phosphorus and potassium (Jiaying *et al*., 2022).

Table 3: Comparative analysis of compost parameters against the standard from Department of Agriculture, Thailand.

Parameters	Treatments						Std[1]
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	
Volume (m^3)	0.43a	0.44a	0.38ab	0.38ab	0.35c	0.33c	-
Moisture (%ww)	34.50a	32.66ab	31.66b	32.66ab	33.00ab	32.33b	<35
Density (kg/m^3)	276.33b	274.33b	265.33c	266.33c	276.66b	282.00a	-
EC (ds/m)	0.73	0.75	0.71	0.78	0.78	0.79	<6
pH	6.83	6.66	7.51	6.80	7.00	7.16	5.5-8.5
C/N ratio	16.94c	16.84c	17.66b	18.56a	16.78c	17.56b	<20
%N	1.55b	1.48bc	1.43c	1.50b	1.76a	1.80a	1.00
%P	0.54bc	0.54c	0.65a	0.68a	0.59b	0.56bc	0.50
%K	0.71c	0.78ab	0.80a	0.76ab	0.75b	0.80a	0.50

Std[1]: Signifies the standard guidelines established by the Department of Agriculture in Thailand.

Testing the efficiency of coffee ground compost

An experiment was conducted to compare the growth of Brazilian spinach after 30 days of planting at a rate of 2.5% of soil volume. In **Table 4**, the average canopy width exhibited statistically significant differences, with values ranging from 5.66 to 15.33 centimeters. The number of branches per plant also displayed statistically significant differences, with averages ranging from 6.00 to 8.33 branches. Plant height showed statistically significant variations, with average values ranging from 10.00 to 20.00 centimeters. The total weight exhibited statistically significant differences, with average values ranging from 24.00 to 85.00 grams per bag. These findings suggest that compost made from coffee grounds, undergoing microbial decomposition, meets the standard criteria set by the Department of Agriculture for essential nutrients such as nitrogen, phosphorus, and potassium. This facilitates the growth of Brazilian spinach. However, it is advisable not to apply an excessive amount, aligning with the research of (Cervera-Mata *et al*., 2018), which found that trace elements (Zn, Cu, and Fe) can be beneficial for aromatic herbs after the addition of coffee grounds in low proportions. Similar observations were made by (Chrysargyris *et al*., 2021), where an increase in the number of leaves and fresh weight of cabbage and cauliflower was noted. Notably, an excess of coffee grounds (10%) led to a decrease in the number of leaves and fresh weight of these vegetables, which is consistent with the impact observed when coffee grounds were combined with other high-rate amendments (Ribeiro *et al*., 2017).

Figure 3: Growth of Brazilian spinach after 30 days of stem cutting when cultivated with various treatments of coffee grounds compost mixed with organic waste.

Table 4: Average growth parameters of Brazilian spinach at 30 days after stem cutting.

Treatment	Canopy Width (cm)	Number of Branches	Plant Height (cm)	Total Weight (grams)
T_1	5.66b	6.00b	10.00b	24.00c
T_2	14.66a	7.66a	17.16a	81.00b
T_3	15.00a	8.00a	18.00a	82.66ab
T_4	15.33a	8.00a	20.00a	84.00a
T_5	15.00a	8.33a	19.00a	83.66a
T_6	15.33a	8.33a	19.33a	85.00a

*Significantly different at the $p < 0.05$ level.

CONCLUSION

From the experiments conducted, it was observed that the production of compost from coffee grounds resulting from experiments 1 to 6 can effectively reduce the volume of organic waste, providing a sustainable use for this leftover material. The decomposition process consisted of two stages. The initial stage involved the decomposition by a group of mesophilic bacteria, taking approximately 2-4 days to reach a higher temperature range of 60-70 °*C*. Subsequently, the decomposition of organic matter was facilitated by a group of thermophilic bacteria, with the temperature gradually decreasing to around 25-30 °*C*, which closely approximated the ambient temperature of the compost pile. Overall, the decomposition process took between 80-90 days. The planting material has physical and chemical properties suitable for the Brazilian Spinach. All these values were within the standards set by the Department of Agriculture. When the compost was tested for its effectiveness on Brazilian Spinach growth, it was found that all experiments had a statistically significant impact ($P<0.05$) on the width of the canopy, number of branches, plant height, and total weight. Notably, the experimental set using 100% coffee grounds (control) resulted in the smallest average measurements for canopy width, number of branches, plant height, and total weight.

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REFERENCES

Anggraeni, L., Robi'In, R., Latifah, E., Rahmawati, D., Baswarsiati., Khamidah, A. and Zubaidi, T. 2023. Plant architectural arrangements to improve production and quality of Brazilian Spinach. *3rd International Conference on Smart and Innovative Agriculture (ICoSIA 2022)* 29: 635–645.

Azim, K. 2018. Composting parameters and compost quality: a literature review. *Organic Agriculture* 8: 1-18.

Bachert, C., Bllingmaier, W. and Wattanachira, S. 2008. *Open Window Composting Manual*. Weimar.

Bomfim, A. S., de Oliveira, D. M., Walling, E., Babin, A., Hersant, G., Vaneeckhaute, C. and Rodrigue, D. 2023. Spent coffee grounds characterization and reuse in composting and soil amendment. *Waste* 1(1): 2-20.

Bomfim, A.S.C., Oliveira, D.M., Voorwald, H.J.C., Benini, K., Dumont, M.J. and Rodrigue, D. 2022. Valorization of spent coffee grounds as precursors for biopolymers and composite production. *Polymers(Basel)* 14(3): 437.

Campos-Vega, R., Loarca-Piña, G., Vergara-Castañeda, H. A. and Oomah, B. D. 2015. Spent coffee grounds: A review on current research and future prospects. *Trends Food Sci. Technol* 45: 24–36.

Campos-M, M. and Campos-C, R. 2017. Applications of quartering method in soils and foods. *International Journal of Engineering Research and Applications*, 7: 35-39.

Campos-Vega, R., Loarca-Piña, G., Vergara-Castañeda, H. A. and Oomah, B.D. 2015. Spent coffee grounds: A review on current research and future prospects. *Trends in Food Science & Technology* 45(1): 24-36.

Cervera-Mata, A., Pastoriza, S., Rufián-Henares, J.Á., Párraga, J., Martín-García, J.M. and Delgado, G. (2018). Impact of spent coffee grounds as organic amendment on soil fertility and lettuce growth in two Mediterranean agricultural soils. *Archives of Agronomy and Soil Science* 64(6): 790-804.

Chrysargyris, A., Antoniou, O., Xylia, P., Petropoulos, S., and Tzortzakis, N. 2021. The use of spent coffee grounds in growing media for the production of *Brassica* seedlings in nurseries. *Environ Sci Pollut Res Int* 28(19): 24279-24290.

Cruz, R., Mendes, E., Torrinha, Á., Morais, S., Pereira, J. A., Baptista, P. and Casal, S. 2015. Revalorization of spent coffee residues by a direct agronomic approach. *Food Research International* :190-196.

Diaz, L. F., Savage, G. M., L., E. L. and Golueke, C. G. 1993. *Composting and Recycling Municipall Solid Waste*. Lewis Publishers.

Franca, A.S. and Oliveira, L.S. 2022. Potential uses of spent coffee grounds in the food industry. *Food* 11(14): 2064.

Grgas, D., Rukavina, M., Bešlo, D., Štefanac, T., Crnek, V., Šikić, T. and Landeka, D.T. 2023. The Bacterial Degradation of Lignin: A Review. *Water* 15(7): 1272.

Hassin, A.L.M., Hassan Abd El-mawla, M., Gomoa, L.A. and Muftah, A.E. 2022. Integrated effect of fertilizers on soil pH, EC and organic matter content. *Journal of Pure & Applied Sciences* 21(4): 323-328.

Haug, R. 1993. *The Practical Handbook of Compost Engineering* . Routledge.

Hou, C., Zeng, Y., Chen, W., Han, X., Yang, H., Ying, Z., Hu, Y., Sun, Y., Qu, Y. and Fang, F. 2022. Medical conditions associated with coffee consumption: Disease-trajectory and comorbidity network analyses of a prospective cohort study in UK Biobank. *Am. J. Clin. Nutr 116*, 730–740.

Ikram, E.H.K., Nasir, W.D.N.M. and Ikram, N.K.K. 2022. Antioxidant activity and total phenolics content of Brazilian Spinach (*Alternanthera sissoo*) and spinach cultivar in Malaysia. *Mal J Med Health Sci 18(SUPP8)* 221-229.

Jiaying, M., Tingting, C., Jie, L., Weimeng, F., Baohua, F., Guangyan, L. and Guanfu, F. 2022. Functions of nitrogen, phosphorus and potassium in energy status and their influences on rice growth and development. *Rice Science 29*(2): 166-178.

Kiely, G. 1998. *Environmental Engineering*. McGraw-Hill.

Miah, M., Mandal, P., Mousomi, K.N. and Jahan, I. 2021. Response of spinach to organic and inorganic fertilizer sources with liming in acidic Soil. *Journal of Pharmacognosy and Phytochemistry* 10(5): 247-251.

Mussatto, S.I., Machado, E.M.S., Martins, S. and Teixeira, J.A. 2011. Production, composition, and application of coffee and its industrial residues. *Food and Bioprocess Technology 4*(5): 661-672.

Palaniveloo, K., Amran, M. A., Norhashim, N.A., Mohamad-Fauzi, N., Peng-Hui, F., Hui-Wen, L. and Razak, S.A. 2020. Food waste composting and microbial community structure profiling. 8(6): 723.

Palansooriya, K.N., Ok, Y.S., Awad, Y.M., Lee, S.S., Sung, J.K., Koutsospyros, A. and Moon, D.H. 2019. Impacts of biochar application on upland agriculture: A review. *J Environ Manage* 234: 52-64.

Pyakurel, A., Dahal, B. and Rijal, S. 2019. Effect of molasses and organic fertilizer in soil fertility and yield of spinach in Khotang, Nepal. *International Journal of Applied Sciences and Biotechnology* 7: 49-53.

Ribeiro, J.P., Vicente, E.D., Gomes, A.P., Nunes, M.I., Alves, C. and Tarelho, L.A.C.2017. Effect of industrial and domestic ash from biomass combustion, and spent coffee grounds, on soil fertility and plant growth: experiments at field conditions. *Environ Sci Pollut Res Int* 24(18): 15270-15277.

Ronga, D., Pane, C., Zaccardelli, M. and Pecchioni, N. 2015. Use of spent coffee ground compost in peat-based growing media for the production of basil and tomato potting plants. *Communications in Soil Science and Plant Analysis*, 47(3):356-368.

Van Dam, R.M., Hu, F.B. and Willett, W.C. 2020. Coffee, caffeine, and health. *N. Engl. J. Med* 383(4):369-378

Wang, Y., Chen, Y.F. and Wu, W.H. 2021. Potassium and phosphorus transport and signaling in plants. *J Integr Plant Biol* 63(1), 34-52.

Yan, S., Ren, T., Wan Mahari, W. A., Feng, H., Xu, C., Yun, F. and Liu, G. 2022. Soil carbon supplementation: Improvement of root-surrounding soil bacterial communities, sugar and starch content in tobacco (*N. tabacum*). *Science of The Total Environment* 802:149835.