Treated swine water as amendment for coffee ground composting system

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Abstract. The rise in demand for coffee and pork has led to an increase in spent coffee grounds (SCG) and swine wastewater (SW) by-products. Commercial fertilizers, which harm the environment, need eco-friendly alternatives like compost. However, little research has focused on combining SCG and SW for composting. This study aims to characterize both SCG and SW and determine the optimal ratio for composting them, as well as their effectiveness when mixed with soil. Additionally, it examines the impact of using SW as a nutrient additive in SCG for organic fertilizer. SCG and SW were collected from local sources and characterized. Using the Berkeley Method, composting was conducted in a 1-meter-high and 0.6-meter-diameter cylindrical pile with a PVC net fence. After the mesophilic phase, the compost was mixed with organic soil and used to grow Bok Choy (Brassica rapa Chinensis) to assess its effects. Results showed that the CS 2 mixture (SCG, SW, and vegetable waste) provided optimal NPK nutrient concentrations and improved soil infiltration and porosity. However, further research is needed to confirm its impact on plant growth. In summary, combining SCG and SW offers a promising solution for reducing waste and commercial fertilizer use, supporting sustainable development goals.

1 Introduction

Initially, natural materials like manure and ash were used as fertilizers, later replaced by synthetic ones causing environmental and health issues [1]. Alternatives are crucial; for instance, spent coffee grounds (SCG) and swine wastewater (SW) are being explored. SCG, a by-product of coffee consumption, poses disposal challenges, emitting greenhouse gases [2]. SCG has diverse reuse potential such as biodiesel production and reducing construction carbon footprints [3]. Despite these benefits, SCG's composting potential is underexplored. Pork production, projected to increase, generates significant pollution, notably from SW [4]. SW contributes heavily to greenhouse gas emissions and environmental contamination, necessitating improved management practices [5]. This study will address several information gaps (i) the composition and effectiveness of SCG-SW compost fertilizer on soil health, and (ii) the potential of using SCG combined with treated SW as compost fertilizer for growing food crops.

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2 Composting

2.1 Characterization

Tables 1 and 2 show the methods used to characterize both Spent Coffee Grounds (SCG) and Swine Wastewater (SW) in this investigation.

Table 1. Characterization of pent Coffee Ground (SCG) [6 – 9].

Characterization	**Extraction Method**	**Analysis Method**
Nitrate-Nitrogen (NO_3^-N)	Method 52 from "The Analysis of Agricultural Materials (3rd edition)"	Cadmium Reduction Method (Method 8039)
Phosphate	Mehlich-3 Method	USEPA PhosVer3 (Ascorbic Acid) Method (Method 8048)
Potassium		Tetraphenylborate Method (Method 8049)

Table 2. Characterization of Swine Wastewater (SW) [8 - 9].

Characterization	**Extraction Method**	**Analysis Method**
Phosphate	Mehlich-3 Method	USEPA PhosVer3 (Ascorbic Acid) Method (Method 8048)
Potassium		Tetraphenylborate Method (Method 8049)
Ammonia-Nitrogen ($NH_3 – N$)	-	USEPA Nessler Method (Method 8038)
Chemical Oxygen Demand (COD)	-	USEPA Reactor Digestion Method (Method 8000)

2.2 Composting

2.2.1 Composting Method

The composting method used is the Berkeley Composting Method, developed by Professor Raabe [10]. This hot composting technique accelerates decomposition and reduces pathogens within 14 - 21 days through elevated temperatures. The process involves four stages. Stage 1 involves preparing the composting space and materials. Equal volumes of brown (carbon-rich) materials, which are dried leaves and branches collected and cut to 1.3-3.8 cm in size, in UTAR Kampar Campus, and green (nitrogen-rich) materials included SCGs, SW, and marked down Napa cabbage (*Brassica rapa Pekinensis* Group) and lettuce (*Lactuca sativa*) collected from Econsave Kampar, achieving a C/N ratio of 30:1 by adding same volume of both materials. A PVC fence net forming a 1-meter high, 0.6-meter diameter cylinder that the base was lined with trash bag to prevent leachate leakage were placed under shaded area to maintain optimal temperatures and prevent over-moisturization from rain. Stage 2 involves adding alternate layers of both materials, with periodic additions of water or SW to adjust moisture levels to 50% to ensure efficient decomposition. In stage 3, the compost pile will heat up reaching 30-45°C in the mesophilic phase and 45-70°C in the thermophilic phase for thorough digestion of lipids and proteins, without unpleasant odors. Stage 4 involves daily turning to redistribute the outer and inner compost layers, preventing overheating of microorganisms and ensuring even decomposition.

2.2.2 Composting Materials

Table 3 showed the combination that will be determine the optimum composition of compost made. All the combination were based on our preliminary study to observe the differences compared to C1 based on [10].

Table 3. Different combinations of compost pile portions.

Label No.	Brown Material (wt% of compost)	Spent Coffee Ground (wt% of compost	Swine Wastewater (wt% of compost, wt% of water usage)	Other Green Material (wt% of compost)
C1	50.0	25.0	25.0, 50.0	0.00
C2	50.0	12.5	12.5, 25.0	25.0
C3	50.0	0.00	0.00, 0.00	50.0

2.3 Growing Plants

The selected plant is Bok Choy (*Brassica rapa Chinensis*), which requires around 30 days from seeding to harvest. According to recommendations, seeds are sown directly at a depth of 1.5 cm with 7 to 10 cm spacing [11]. Bok Choy thrives in soil with a slightly acidic to neutral pH range (5.5 - 7.0). The soil used was Green Lover 4in1 organic soil included coconut peat, burnt clay, rice husk biochar, dolomite, purchased from Baba Gardening with the nutrition composition recorded in Table 4.

Table 4. Composition of Green Lover 4in1 organic soil.

	pH	Total Nitrogen (%w/w)	Total Phosphorus (%w/w)	Total Potassium (%w/w)	C/N ratio
[12]	8.6	0.4	0.6	0.1	54.4

Each pot contains 3 seeds, and each experimental condition was replicated three times. Prior to application, the soil needs to be mixed with compost. The compost was collected and sifted through a KIENCO sieve with a 200 mm pore size (series number: 5722245) to remove undigested materials. The extraction and analysis of the soil are conducted in the same manner as described for SCG in Table 1. Table 5 outlines the recommended compositions for soil and compost mixtures based on soil weight [13]. Plant growth measurements, including plant height and root length, are taken using a ruler. Additionally, the number of roots and leaves is counted manually and recorded.

Table 5. Different combination of portion of soil and compost.

Label No.	Description
S	Fully using Green Lover 4in1 organic soil, as a control set
CS 1	65% of Green Lover 4in1 organic soil; 35% of Compost No.1
CS 2	65% of Green Lover 4in1 organic soil; 35% of Compost No.2
CS 3	65% of Green Lover 4in1 organic soil; 35% of Compost No.3

3 Results and discussion

3.1 Characterization

3.1.1 Spent Coffee Ground (SCG)

In this experiment, SCG showed significantly lower levels of nitrogen (7.5 ppm compared to an average of 21750 ppm), phosphate (57.40 ppm compared to 1137.50 ppm), and moderately lower levels of potassium (1016.20 ppm compared to 3097.5 ppm) in Table 6 [14]. These differences of the results obtained were due to the SCG was a stable compound that hardly to extract its nutrients without decomposing [15].

Table 6. Results of characterization of SCG.

pH	Nitrate-Nitrogen (ppm)	Phosphate (ppm)	Potassium (ppm)
6.5	7.50	57.40	1016.20

3.1.2 Swine Wastewater (SW)

In Table 7, SW in this experiment showed lower levels of COD (226.17 ppm compared to an average of 1109.53 ppm), total nitrogen (506.48 ppm compared to 1239.38 ppm), phosphate (49.78 ppm compared to 116.45 ppm), and slightly lower levels of potassium (632.07 ppm compared to 868.63 ppm) [16 -17]. These differences are attributed to the sample undergoing biological treatment and filtration before passing through carbon and sand filters for discharge, resulting in reduced nutrient content.

Table 7. Results of characterization of SW.

pH	COD	Ammonium Nitrogen (ppm)	Phosphate (ppm)	Potassium (ppm)
7.8	226.17	506.48	49.78	632.07

3.2 Composting

3.2.1 Characterization

Figure 1(a)–(c) shows the characterization results for each compost-soil mixture, labeled as CS 1, CS 2, and CS 3. The nutrients indicated include nitrate-nitrogen, phosphate, and potassium.

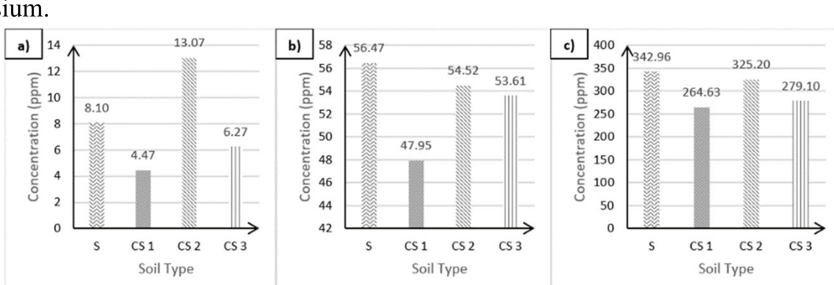

Fig. 1. (a) Nitrate-Nitrogen concentration of each soil type; **(b)** Phosphate Concentration of each soil type ; **(c)** Potassium concentration of each soil type.

The nitrate-nitrogen concentration was highest in CS 2 (13.07 ppm), followed by S (8.10 ppm), CS 3 (6.27 ppm), and CS 1 (4.47 ppm). Mixing CS 2 with soil increased nitrate-nitrogen concentration by 61.35%, benefiting plant uptake. However, CS 1 and CS 3 reduced the original soil's nitrate-nitrogen because the nitrogen was used to decompose organic matter in the compost if not fully decomposed [18]. CS 3 could have had higher nitrate-nitrogen if it entered the thermophilic phase, unlike CS 1, which lacked decomposable vegetables. Thus, complete mesophilic decomposition increases nitrate-nitrogen availability. Phosphate concentrations were highest in S (56.47 ppm), followed by CS 2 (54.52 ppm), CS 3 (53.61 ppm), and CS 1 (47.95 ppm). CS 1 showed a decrease in phosphate due to the soil-to-compost mixing ratio. CS 2 and CS 3, having undergone mesophilic stages, provided more phosphate for plant uptake, mirroring the nitrate-nitrogen results with CS 2 having the highest phosphate. Potassium concentrations were highest in S (342.96 ppm), followed by CS 2 (325.20 ppm), CS 3 (279.10 ppm), and CS 1 (264.63 ppm). CS 2 provided sufficient potassium without significantly reducing soil levels, unlike CS 1 and CS 3. In summary, CS 2 supplied sufficient nutrients, surpassing ordinary organic soil in nitrate-nitrogen concentration, demonstrating its potential as an effective fertilizer.

3.2.2 Physical Characteristics

Ideal planting soil should manage water efficiently, preventing plant submersion while avoiding excessive permeability that can cause nutrient loss. Table 8 shows the porosity in terms of water storage and infiltration rate for the samples. The results indicate that CS 2 has the lowest porosity and the highest infiltration rate, meaning it stores less water but allows it to pass through quickly. This is consistent with sandy soil, which has smaller particles and higher infiltration rates. The other samples have similar porosity and infiltration rates, with CS 1 having the lowest infiltration rate. While high infiltration rates are generally not ideal for plants, soil with low infiltration rates takes longer to reach field capacity, which can affect water intake [19]. Proper porosity, allowing for both water retention and air circulation, is crucial. Therefore, CS 2's higher infiltration rate may be advantageous for planting as it balances water and air content effectively.

Table 8. Porosity and infiltration rate of samples.

Properties \ Sample	S	CS 1	CS 2	CS 3
Porosity (water storage, mL)	215	210	183	217
Infiltration rate (cm/seconds)	4.25	3.72	6.80	4.44

3.2.3 Plant Growth

The germination percentage was calculated by applying Equation 1 [20]. Based on Table 9, the germination percentages for soils S, CS 1, and CS 2 are similar, with CS 3 showing a slightly higher percentage, but not significantly enough to indicate greater planting potential. Measurements of plant height, root length, number of roots, and leaves showed no significant differences across soil types, indicating that plant growth was not substantially better in any soil. During this experiment, the sunlight was a limiting factor, with the greenhouse receiving only 1-2 hours of sunlight between 1200 and 1400. The light intensity in the greenhouse was much lower compared to outdoor sunlight, resulting in insufficient light for optimal plant growth.

$$Germination\ Percentage\ (\%) = \frac{Number\ of\ successfully\ germinated\ seeds}{Number\ of\ seeds\ planted}\ x\ 100\% \quad (1)$$

Table 9. Germination and growing result of planting Bok Choy.

Parameters	S	CS 1	CS 2	CS 3
Germination Rate (%)	33.33	33.33	33.33	55.56
Plants' height (cm)	2.40	2.60	3.70	2.70
Roots Length (cm)	2.30	3.90	3.80	2.20
Number of Roots	4	4	4	4
Number of Leaves	3	3	3	3

4 Conclusion

In summary, the study aimed to characterize SCG and SW and determine the optimal composition for soil amendment. The compost mix (CS 2) with a ratio of brown material, SCG, SW, and markdown vegetables (50:12.5:12.5:25) provided the highest levels of nitrate-nitrogen, phosphate, and potassium. CS 2 also significantly improved soil infiltration rate and porosity. Although CS 2 resulted in the tallest plants, the difference was not significant due to insufficient light. The reduction of waste supports Sustainable Development Goals (SDGs) 12 and 15 by converting waste into valuable resources. The Berkeley Composting Method requires substantial space and may not be practical for household use; thus, simpler composting methods should be promoted. Further research is needed to explore the impact of nutrient-rich compost on plant growth under optimal conditions.

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