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Nutritional Quality of Spinach *(Amaranthus hybridus L.)* using Black Soldier Fly *(Hermetia illucens)* Waste Compost

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Abstract
Organic fertilizer improves spinach's nutritious minerals, vitamins, phytochemicals, and bioactive elements. The study examined (1) the influence of Black Soldier Fly (BSF) waste compost on spinach growth and product quality, and (2) the uptake of compost components in spinach plant tissue. The experiment used a randomized block design with five treatments: (1) soil without compost or urea; (2) soil with BSF compost as household waste substrate without urea; (3) soil with household waste substrate BSF compost with urea; (4) soil with BSF compost as fruit waste substrate without urea; and (5) soil with BSF compost as fruit waste substrate with urea. BSF waste compost with household or fruit waste as a substrate contains macro and micronutrients needed by plants and heavy metals that might injure vegetable plant tissues. The application of BSF waste compost increased the content of vitamin A, vitamin C, chlorophyll, and carotene in spinach production compared to control plants. The fiber, nitrate, nitrite and oxalate content in spinach product was not significantly different between plants given BSF waste compost and control plants. The heavy metals Cu, Pb, Cd and Zn present in the compost are absorbed into the spinach plant tissues but at low concentrations.

Key words: spinach, nutritional quality, compost, waste, black soldier fly (BSF)

Introduction

Consumer demand for nutritious foods and government policies to sustain agricultural environments must be met to build a stable foundation for developing organic farming systems (Maggio et al., 2013). Traditional vegetable cultivation practices can endanger human health due to heavy metal accumulation, chemical contamination, and harmful microbes (Hisham et al., 2021). Using organic fertilizer reduces the concentration of Pb, Cu, and Cr while increasing the efficiency of nutrient absorption in tomatoes (Hameeda et al., 2019). Feaces-made biochar promotes the development and influences heavy metal buildup in spinach plant tissues (Tahir et al., 2018). Compared to control and chemical fertilizers, applying organic cow faeces fertilizer can enhance the number of marketable spinach leaves and plants' nitrogen, phosphorus, sulfur, and selenium content. Cow feces fertilizer can improve production by 8% compared to control and increased in 41.16% when compared to chemical fertilizers (Turkkan & Kibar, 2022). Organic farming will assist society and the environment by producing organic food that is chemical-free, safe, healthful, and nutritious. Organically cultivated spinach contains more carotene, vitamin C,

and calcium (Sharma & Agarwal, 2014). Organic agriculture must be developed in light of the negative impacts of chemicals on human health, natural resources, and the worldwide market demand for quality products (Rathore et al., 2014).

Spinach (vegetable) farming is vital for generating currency, raising revenue, ensuring nutritional security, and alleviating poverty (Mdoda et al., 2022). Spinach is a leaf vegetable that quickly grows and has a high nutritional value. Spinach is high in minerals, vitamins, phytochemicals, and bioactive molecules that are favorable to health, yet it accumulates oxalate and nitrate in its leaves (Giménez et al., 2021). Spinach contains vitamin B6, riboflavin, folate, niacin, soluble fibre, omega 3 fatty acids, and iron, which can help prevent osteoporosis and anaemia. Spinach is excellent for treating digestive issues, therapy in blood formation, growth stimulation in youngsters, hunger stimulation, support and fatigue recovery, as well as anticancer agents and antioxidants (Miano, 2016). Because spinach leaf meal contains accessible iron, it can be used to fortify infant formula and foods (Tedom et al., 2020). Spinach juice as alternative nutrition for therapy to boost Hb and prevent anemia (Purba et al., 2021). Spinach plants provide vitamins, minerals, vital amino acids, high fiber, no cholesterol, and the majority of the low fat and calories can be utilized to overcome people's nutritional deficits (Terfa, 2021).

Fertilization has an impact on the growth, production, and nutrient content of spinach vegetables. The factor that most influences the quality of spinach at harvest and nutrient genotype. Nitrogen, phosphorus, and potassium fertilizers increase spinach plant total phenols, antioxidant activity, flavonoids, and vitamin C (Zikalala et al., 2017). Compost extract increases soil-borne disease resistance, secondary metabolic results, and antioxidant capacity (Giménez et al., 2021). Fertilizing compost with leaf litter and manure reduces N, Zn, Fe, Cu, and Cd in spinach yields while increasing soil P and K (except for N, NO3, and NH4) (Anwar et al., 2017). Slow-release organic fertilizers efficiently use nitrogen and reduce nitrate levels in spinach while increasing ascorbic acid content (Vigardt et al., 2020). Food waste and cow feces increase spinach production, nitrogen, phosphorus, and potassium (Kelley et al., 2022). The spinach varieties retained vitamin C, nitrite, nitrate, and oxalate. Organic and inorganic fertilizers increase stem diameter, roots, height, leaf number, and leaf surface area. Fertilizer increases vitamin C and decreases nitrite and oxalate (Alessa et al., 2017). With the application of 75% waste sludge + 25% NPK and increased growth, yield, and quality of kale and spinach, various plant quality parameters such as ascorbic acid, carbohydrate, and protein content significantly increased (Zafar et al., 2021).

Black soldiers fly (BSF) larvae bioconversion of organic waste is a promising innovation due to its high production rate, low costs, and short production time. The results of bioconversion produce compost for plants and larvae as food for livestock and fish (Siddiqui et al., 2022). Compost from food waste processed with BSF larvae contains 18.37% C-organic, 1.45% Total Nitrogen, 1.58% Total Phosphorus, 12.66 C/N ratio, which meets the requirements of the Indonesian National Compost Standard (SNI) (Widyastuti et al., 2021). Solid organic waste treatment technology with BSF larvae can contribute to meeting the shortage of organic fertilizers and provide new income opportunities for small businesses (Sarpong et al., 2019). Compost from household waste broken down by BSF larvae does not contain toxic elements; it is safe to apply

as fertilizer for plants (Rahmat et al., 2021). Applying 1,240 kg/ha of BSF compost and 322 kg/ha of NPK fertilizer for vegetable crops will improve soil health, increase yields, and improve the nutritional quality of vegetable plants, especially protein and ash content (Anyega et al., 2021). BSF waste compost as an organic fertilizer contains higher ammonium nitrogen and lower nitrate nitrogen, increasing the dry matter weight of vegetables (Kawasaki et al., 2020). Compost produced through the bioconversion process by Black Soldier Fly larvae has the potential to provide phosphorus and potassium for plants (Putra et al., 2017).

Urban agriculture that uses compost as a planting medium encourages changes in healthy food consumption patterns in the form of organic products and self-products produced from yards (Puigdueta et al., 2021). Large-scale urban agriculture contributes to building food security systems and sustainable urban organic waste management (Weidner & Yang, 2020). The balanced application of compost and chemical fertilizers can improve the quality of spinach by increasing the content of vitamin C, reducing the content of nitrite and oxalate, and having a balanced nitrate content (Alessa et al., 2017). The use of urban waste compost as organic fertilizer, particularly in the development of urban agriculture, is getting more popular (Haryanta & Rejeki, 2021). Urban agricultural products contain food safety risks caused by using fertilizers from waste containing hazardous elements, lack of sanitation in the planting and harvesting process, excess nitrate compounds, and pesticide waste (Buscaroli et al., 2021). However, there is concern that urban waste pollutants will enter food crops (Paradelo et al., 2020). The application of compost in urban agriculture is an ideal way of managing organic waste in urban areas with very high production of organic waste. A value-added cycle connecting organic waste as a raw material for compost, the composting process, marketing strategy, and compost application in organic farming systems will ensure long-term organic waste management (Woldeamanuel et al., 2022). Applying compost will generally provide N, P, K, Na, Mn, Zn and Mg elements in vegetable nutrition (Mu et al., 2020). The use of contaminated compost must be avoided because of the potential danger to human health due to the uptake of high concentrations of heavy metals, especially Zn, Ni, Cd and Pb by vegetable plants (Eissa & Negim, 2018).

Compost from urban organic waste can be used as fertilizer in urban agriculture systems. Black soldier fly (BSF) larvae waste with urban organic waste as a substrate can be used as organic fertilizer in urban farming systems to cultivate spinach. Urban waste may contain heavy metals that can be absorbed into the tissues of spinach plants, resulting in harmful products to humans. The waste compost produced by BSF larvae is an organic fertilizer that can be used in urban agriculture. The objectives of this study were to (1) determine the prevalence of heavy metal pollutants in household and market waste, (2) investigate the influence of BSF larvae waste compost on spinach growth and production quality, and (3)) investigate the uptake of compost components in spinach plant tissue.

Materials and Methods

Preparing Black Soldier Fly (BSF) compost

The study used Black Soldier Fly (BSF) larvae compost from the Jambangan recycling center in Surabaya and the Puspa Agro market in Sidoarjo. The BSF larvae were given organic kitchen waste separated from inorganic waste at the Jambangan final disposal site, along with bran or rice bran. BSF larvae were given fruit waste substrates dominated by watermelon and papaya, with expired powdered milk added at the Puspo Agro market. BSF compost is a byproduct of the BSF larvae harvesting process that consists of the remaining substrate that the larvae do not consume, larval faeces, and larval skin released during moulting. Compost from the BSF is placed in bags and left for 60 days to ensure finished and ready for use as fertilizer. Table 1 shows the results of an analysis of the nutrient and heavy metal content of BSF larvae waste compost from the Jambangan final disposal site and the Puspa Agro market in Sidoarjo.

Table 1. The content of nutrients and heavy metals in BSF Larva Compost

The type of analyzed element	BSF Larva Compost from the Jambangan recycling center	BSF Larva Compost from Puspa Agro Market
C/N rasio	15.80	17.90
N (%)	1.22	1.05
P2O5 (%)	0.68	0.48
K2O (%)	0.77	0.51
Ca (%)	0.42	0.31
Mg (%)	0.30	0.23
Pb (ppm)	0.02	0.01
Cu (ppm)	0.10	0.12
Cd (ppm)	0.01	0.02
Zn (ppm)	2.06	2.15

Experimental application of BSF larvae waste compost for spinach plants

Compost from the breeders of BSF larvae is used as organic fertilizer for spinach plants. A randomized block design (RBD) was used for single-factor trials. In this experiment, the treatments were:

P_0K_0 : Without compost and without urea fertilizer
P_1K_0 : Soil: 50%, BSF household waste compost: 50%, without urea fertilizer
P_1K_1 : Soil: 50%, BSF household waste compost: 50%, and 3g/plant urea fertilizer
P_2K_0 : Soil: 50%, BSF fruit waste compost: 50%, without urea fertilizer
P_2K_1 : Soil: 50%, BSF fruit waste compost: 50%, and 3g/plant urea fertilizer

Each treatment was repeated three times, consisting of 15 experiments. The experiment consisted of picking spinach in polybags measuring 40x40 cm.

The experimental procedure is as follows:

a. Prepare the soil as a planting medium in the form of topsoil imported from Mojosari, Mojokerto Regency.
b. There are three types of preparing media as part of the experimental treatment, namely (1) soil without adding compost; (2) soil with BSF larvae waste compost with kitchen waste substrate (from the recycling center) with a ratio of 50%: 50% (v/v); (3) soil with BSF larvae waste compost and fruit waste substrate (from the Puspa Agro market) with a ratio of 50% : 50% (v/v);
c. Put the planting media into a polybag as much as two-thirds of the volume of a 40x40 cm polybag. The polybag size for eggplant is 50 x 50 cm, while for mustard greens and Bok choy is 40 x 40 cm.
d. Polybags filled with media are arranged in as many rows as the number of experimental replicates and rows as many as the experimental treatments. The distance between polybags is 100 cm between rows and 50 cm between rows.
e. Spinach plant nurseries use polybags placed in a place protected from rain and direct sunlight.
f. The nursery is moved to a place that gets direct sunlight when the seedlings are 2 weeks old
g. Transfer of seedlings to trial polybags was carried out on seedlings 3 weeks old or after they had three leaves. Seeds were selected in good condition, fresh, upright, and free from pests and diseases.
h. Treatment of plants by cleaning weeds in polybags or on the land around polybags, irrigation, drying and controlling pests and plant diseases. According to the conditions of the plant.
i. POC is applied by spraying it on the leaves of the plants until evenly distributed during the day when the leaves are not wet, and it is expected that it will not rain for a few hours after the application.
j. Fertilization with urea according to the treatment of 1.5 g/plant was given to plants 1 week old, and the second fertilization of 1.5 g/plant was given to plants 3 weeks after planting..
k. 35-day-old plants are harvested by cutting off above-ground parts, weighing them to determine stover weight, and taking the edible parts to measure consumption weight.
l. Plant samples for analysis of nutrient content were taken from the parts of the plants consumed.
m. The growth variables included the number of leaves and plant height, while the product variables were harvest weight, consumption weight and nutritional content parameters.

Material samples and analysis

The plant sample from the part of the consumed spinach plant was 20-30 g, then dried in an oven until the dry ash of the sample part. After 60 days of incubation, the prepupae or instar 5 BSF larvae were harvested, and a sample of 25 g of compost was taken from the remaining BSF larvae propagation substrate. The analysis of heavy metals Cu, Zn, Pb, and Cd for compost and plant

samples using a spectrophotometer and atomic absorption spectrophotometer (AAS). Analysis of the mineral content of the compost includes the total organic matter determined by the weight loss when the material is dried to ashes, and the total organic C (TOC) is calculated by multiplying the total organic matter by a factor of 0.58. Total N was measured by the Kjeldahl method from dry samples. The content of macro and micronutrients was analyzed by spectrophotometer and AAS methods.

Analysis

The data on growth, production, and nutrient content in spinach plant tissues were statistically processed using analysis of variance (ANOVA), and if there was a significant difference, it was continued with Least Significant Difference Test (LSD) test.

Results and Discussion

The nutritional value of spinach can be determined by its content of fibre, vitamin C, vitamin A, Fe elements, chlorophyll, carotene, and nitrate. The fibre content in harvested spinach ranged from 15.30-17.63%, the vitamin C content was 309.07 - 353.87 mg/100g, the vitamin A content was 38.97 - 42.32 mg/100g, the Fe content was 18.37 - 21.47 mg/100g, the chlorophyll content was 206.93 - 353.50 mg/100g, and the carotene content was 62.57 -.68.57 mg/100g. Figure 1 shows an overview of the fiber, vitamin C, vitamin A, chlorophyll, carotene, and Fe content of spinach vegetables fed with BSF larvae compost. BSF larvae waste compost can increase the vitamin C content of picked spinach. The increase will be more predominant if urea fertilizer is used. Applying BSF larvae waste compost without urea fertilizer significantly increases fibre content, while applying urea fertilizer without compost decreases fibre content.

Table 2. Quality Data of Spinach product given BSF Larvae Compost Fertilizer

Treatment	Nutritional content / nutrition					
	Serat (%)	Vit C (mg/100g)	Vit A (mg/100g)	Fe (mg/100g)	Khlorofil (mg/100g)	Karoten (mg/100g)
P_0K_0	16.67 ab	309.07 d	39.07 b	18.37 d	206.93 d	62.57 b
P_1K_0	17.14 a	336.13 b	42.32 a	20.57 bc	344.83 b	67.64 a
P_1K_1	15.30 c	353.87 a	39.05 b	21.23 ab	353.50 a	65.97 ab
P_2K_0	17.63 a	321.30 c	41.13 ab	20.38 c	240.57 c	68.57 a
P_2K_1	15.67 bc	350.30 a	38.97 b	21.47 a	344.14 b	65.14 ab
LSD 5%	1.16	11.99	3.15	0.70	6.91	3.71

Note: : Numbers in one column followed by the same letter are not significantly different based on the 5% LSD test

P_0K_0: Without compost and without urea fertilizer

P_1K_0: Soil: 50%, BSF household waste compost: 50%, without urea fertilizer

P_1K_1: Soil: 50%, BSF household waste compost: 50%, and 3g/plant urea fertilizer

P_2K_0: Soil: 50%, BSF fruit waste compost: 50%, without urea fertilizer

P_2K_1: Soil: 50%, BSF fruit waste compost: 50%, and 3g/plant urea fertilizer

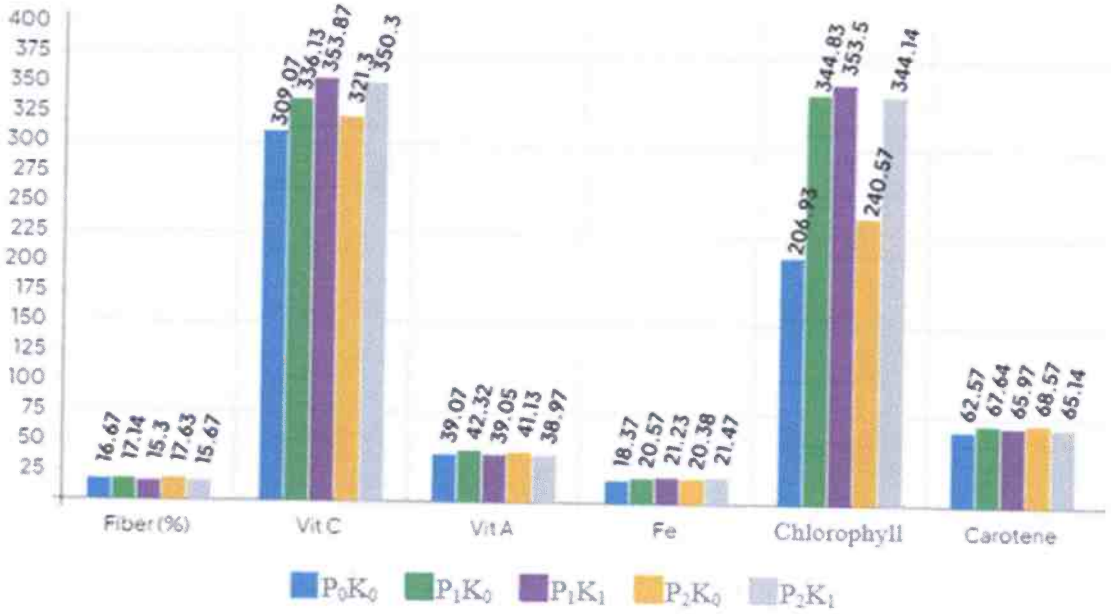

Figure 1. The content of fibre, vitamin C, vitamin A, chlorophyll, carotene, and Fe elements in spinach vegetables that are given BSF larvae waste compost

The nitrate content in spinach ranged from 0.10-0.14 ppm and was not significantly different between BSF larvae waste compost treatment and chemical fertilization, although the nitrite content ranged from 0.10-0.23 ppm and tended to decrease with compost treatment from fruit waste. After treatment of BSF larvae waste compost, the oxalate content was 0.263-0.363 ppm. Figure 2 shows an overview of spinach's nitrate, nitrite, and oxalate content given the compost from BSF larvae waste. Heavy metal elements Cu, Pb, Cd, and Zn were discovered while spinach plants, though they did not exceed the WHO or FAO thresholds. In general, mixing BSF larvae waste compost with kitchen and fruit waste substrates increased the heavy metal content of Cu, Pb, and Cd, but not Zn. Figure 3 shows a summary of the heavy metal content of Cu, Pb, Cd, and Zn in spinach given the BSF larvae waste compost, while Table 3 shows data on nitrate and nitrite content and several heavy metals that are indicators of low-quality spinach vegetable products.

Table 3. Quality Data of Spinach product given BSF Larvae Compost Fertilizer

Treatment	Hazardous material content						
	Nitrates (ppm)	Nitrite (ppm)	Oxalate (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)	Zn (ppm)
P_0K_0	0.120	0.022 a	0.363 a	0.012 c	0.029 c	0.011 c	0.039 a
P_1K_0	0.130	0.023 a	0.293 b	0.020 b	0.030 c	0.011 c	0.022 d
P_1K_1	0.140	0.022 a	0.273 b	0.021 b	0.039 b	0.030 a	0.034 b
P_2K_0	0.130	0.010 b	0.307 b	0.013 c	0.020 d	0.021 b	0.030 c
P_2K_1	0.100	0.018 a	0.263 b	0.034 a	0.049 a	0.021 b	0.021 d
LSD 5%	NS	0.007	0.055	0.002	0.002	0.003	0.003

Note : Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not Significant

P_0K_0: Without compost and without urea fertilizer

P_1K_0: Soil: 50%, BSF household waste compost: 50%, without urea fertilizer

P_1K_1: Soil: 50%, BSF household waste compost: 50%, and 3g/plant urea fertilizer

P_2K_0: Soil: 50%, BSF fruit waste compost: 50%, without urea fertilizer

P_2K_1: Soil: 50%, BSF fruit waste compost: 50%, and 3g/plant urea fertilizer

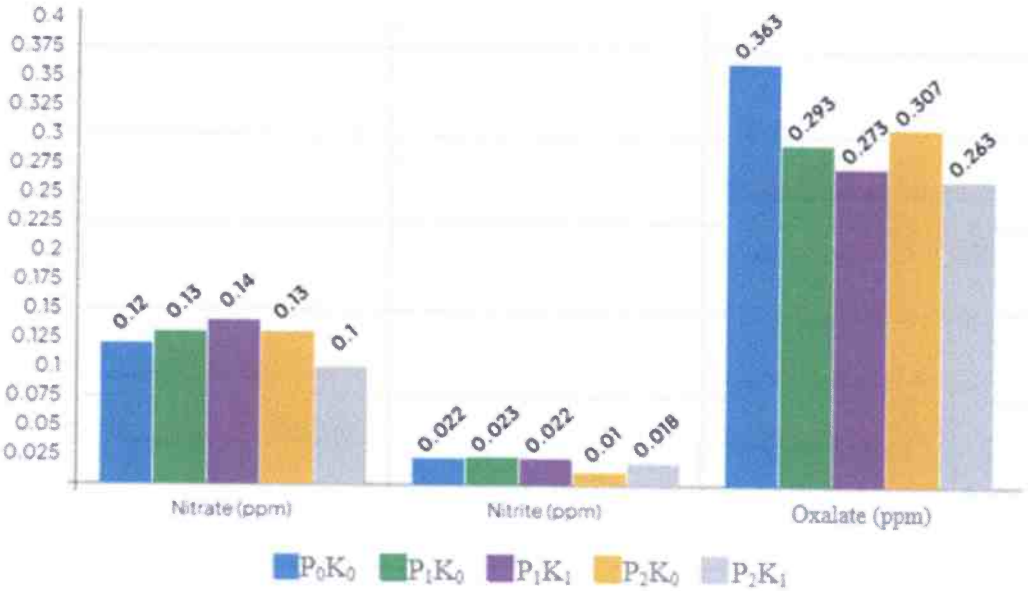

Figure 2. Nitrate, nitrite and oxalate content in spinach vegetables fed with BSF larvae waste compost

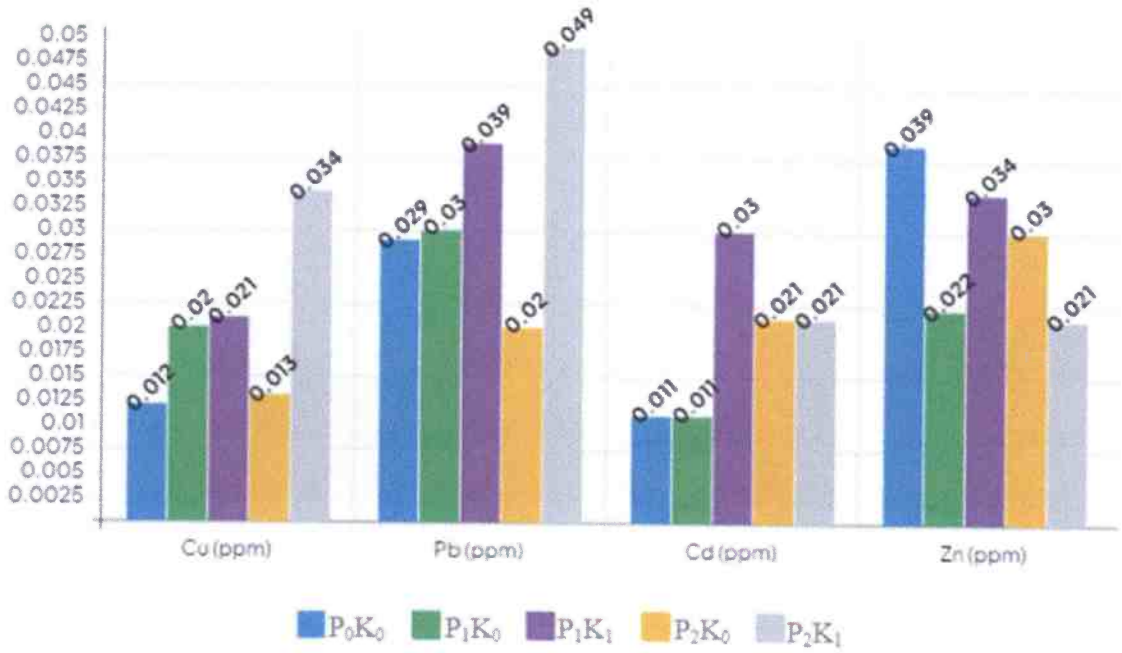

Figure 3. Heavy metal content of Cu, Pb, Cd, and Zn in spinach vegetables fed with BSF larvae waste compost

BSF larvae waste compost and chemical fertilizers affected spinach plant growth, referring to the variable of plant height, the number of leaves, and stem diameter 28 days after planting. In treating BSF larvae waste compost with fruit waste substrate and chemical fertilizers, the highest value of the plant height variable was 83.67 cm, the number of leaves was 89.67, and the stem diameter was 22.57 mm. The control treatment has the lowest value of the growth variable (not given compost and chemical fertilizers). Table 4 shows variable data on the growth of picked spinach 28 days after planting.

Table 4. Data on the Growth of Spinach at the age of 28 days given BSF Larvae Compost Fertilizer

Treatment	Plant height (cm)	Number of leaves	Stem diameter (mm)
P_0K_0	51.33 d	73.67	14.13 c
P_1K_0	80.67 ab	85.67	17.83 bc
P_1K_1	64.67 cd	78.00	19.43 ab
P_2K_0	67.67 bc	78.00	21.40 ab
P_2K_1	83.67 a	89.67	22.57 a
LSD 5%	13.35	NS	3.85

Note: Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not Significant
P_0K_0: Without compost and without urea fertilizer

P_1K_0: Soil: 50%, BSF household waste compost: 50%, without urea fertilizer

P_1K_1: Soil: 50%, BSF household waste compost: 50%, and 3g/plant urea fertilizer

P_2K_0: Soil: 50%, BSF fruit waste compost: 50%, without urea fertilizer

P_2K_1: Soil: 50%, BSF fruit waste compost: 50%, and 3g/plant urea fertilizer

Table 5 shows data on spinach products. The spinach production variable can be calculated by weighing the grain on the ground and the leaves and young shoots that can be eaten. Treatment of BSF larvae, waste compost, and chemical fertilizers increased the weight of stover on the ground more than five times compared to the control. The percentage of material consumed did not differ between the fertilized plants and the control, and there was even a tendency for the control treatment to consume more material. Fertilized plants had more stem and branch organs but not more leaves.

Table 5. Quantitative Data of Spinach product given BSF Larvae Compost Fertilizer

Treatment	Wet weight of stover (g)	Consumed materials	
		Weight (g)	%
P_0K_0	112.67 c	29.03 b	26.59
P_1K_0	646.67 ab	138.23 a	21.33
P_1K_1	547.53 b	135.50 a	27.36
P_2K_0	848.23 a	153.23 a	17.98
P_2K_1	710.67 ab	137.27 a	19.32
LSD 5%	243.51	37.71	NS

Note: Numbers in a column followed by the same letter are not different based on the 5% LSD test; NS = Not Significant

P_0K_0: Without compost and without urea fertilizer

P_1K_0: Soil: 50%, BSF household waste compost: 50%, without urea fertilizer

P_1K_1: Soil: 50%, BSF household waste compost: 50%, and 3g/plant urea fertilizer

P_2K_0: Soil: 50%, BSF fruit waste compost: 50%, without urea fertilizer

P_2K_1: Soil: 50%, BSF fruit waste compost: 50%, and 3g/plant urea fertilizer

Discussion

Black Soldier Fly (BSF) larvae waste compost increases the weight of harvested stover and the part eaten from spinach plants because compost contains organic matter, which releases bound nutrients slowly due to environmental factors (Bziouech et al., 2022). The application of organic fertilizers alone or together with the application of inorganic fertilizers to picking spinach plants

significantly increases leaf area, stem diameter, and fresh weight of vegetative parts, carotene content (Alessa et al., 2017), and weight of dry matter above ground (Kawasaki et al., 2020). According to (Mu et al., 2020), applying compost at a high percentage generally provides elements of N, P, K, Na, Mn, Zn and Mg in vegetable nutrition, while applying at a low percentage increases the content of Ca, Al, and Fe. BSF larvae waste compost also improves the quality of picked spinach vegetables, explicitly increasing the content of vitamin C, vitamin A, chlorophyll, carotene, and the mineral Fe. Kale and spinach plants that were given organic fertilizers showed significantly higher leaf area, ascorbic acid content, carbohydrate content and protein content than the control treatment (Zafar et al., 2021). The interactive effect of compost with NPK fertilizer will increase spinach vegetables' total phenol content, antioxidant activity, flavonoids and vitamin C (Zikalala et al., 2017). The studuy's conclusion (Anyega et al., 2021) states that fertilization with BSF larvae waste compost integrated with chemical fertilizers is the most efficient in utilizing element N, has crude protein, highest ash concentration, improves soil health, increases production and nutritional quality of vegetable plants.

The application of compost had no effect on the content of nitrite, nitrate and oxalate groups in pickled spinach vegetables. According to (Alessa et al., 2017) the application of organic fertilizer alone or together with inorganic fertilizers has no effect on the content of nitrate, nitrite, and oxalate in picking spinach plants. High nitrate and oxalate content in leaf vegetables can be related to plant fertilization activity, lighting and plant nature factors (Solberg et al., 2015). BSF waste compost on mustard plants causes higher ammonium and lower nitrate nitrogen (Kawasaki et al., 2020).

Heavy metal contamination in urban waste has an effect on human health and safety through heavy metal contamination in food as a result of agricultural and environmental activities through the application of compost and polluted water sources (Anani et al., 2020). BSF larvae waste compost, which contains several heavy metals, does not impact the picked spinach quality because the heavy metal content tissue is far below the allowable threshold. Municipal waste compost increases the concentrations of Cd, Cu, Pb, and Zn in spinach leaves above the permitted limits. In contrast, the concentrations of metals (Cd, Cu, Pb, and Zn) in agricultural waste compost are below the threshold, implying that municipal waste compost may contain materials harmful to human health (Saleem et al., 2018).

Compost affects the concentration of heavy metals and nutrient content in lettuce leaf tissue (Alromian, 2020). According to research conclusions (Głodowska & Krawczyk, 2017), the vegetables grown conventionally tends to contain higher concentrations of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) compared to organic farming systems. The application of urban waste compost for leaf vegetable plants shows the presence of the heavy metal Zn, Cu, Pb, and Cd in plant tissues, varying levels depending on the pollution level in the waste materials (Paradelo et al., 2020). Oguntade et al., (2019) recommended that fertilization with compost containing high concentrations of heavy metals but bioaccumulation in leaf vegetables is lower than the maximum allowed by WHO/FAO, namely for Cu the limit is 0.1 mg/kg, and for Mn, Fe and Zn it is 0.3 mg/kg

Black Soldier Fly larvae waste compost contains macro and micro nutrients plants need and contains heavy metals, which can be harmful if they enter vegetable plant tissues. The presence of heavy metals depends on the substrate used in raising BSF larvae. BSF larvae waste compost is slightly alkaline with a pH of 7.5, rich in nutrients, especially micro-nutrients, and low ammonium nitrogen content indicating a slow nutrient release process to supply nutrients in the longer term (Gärttling & Schulz, 2022). According to the findings of Widyastuti et al. 2021, the C-organic content of BSF waste compost was 18.37%, the total nitrogen content was 1.45%, the total phosphorus content was 1.58%, the pH was 6.8, and the C/N ratio was 12.66, which met the standard as an organic fertilizer for vegetables. Micronutrients Zink (60.55ppm), Manganese (36.55ppm), and Boron (12.07 ppm) were discovered in BSF larvae waste compost with the household waste substrate (Rahmat et al., 2021). Because of the heavy metal content, it is safe to use as plant fertilizer. The analysis of compost made from BSF larvae waste revealed that it met the standard for organic fertilizer, with N: 1.04%, P: 2.25%, K: 1.55, and C/N 14.14% (Mutiar & Yulhendri, 2020).

Conclusion

Black Soldier Fly (BSF) larvae waste compost with household waste or fruit waste as a substrate contains macro and micronutrients needed by plants and contains heavy metals, which can be harmful if they enter vegetable plant tissues. The application of BSF larvae waste compost increased growth, the weight of harvested stover and the weight of the part consumed from the picked spinach plants. Treatment of BSF larvae waste compost significantly increased the content of vitamin A, vitamin C, chlorophyll and carotene in spinach plants, had no effect on the content of fiber, nitrate, nitrite and oxalate. The heavy metals Cu, Pb, Cd and Zn present in the compost are absorbed into the spinach plant tissues but at low concentrations below the limits permitted by WHO/FAO. This study concludes that BSF larvae waste compost with household waste or fruit waste as a substrate can be used as organic fertilizer for spinach plants because it can increase the growth, yield and nutritional value of spinach vegetables. Processing organic waste using BSF larvae must be integrated with urban farming development to produce healthy food products through independent urban organic farming.

Acknowledgements

We would like to take this opportunity to thank the Rector of Universitas Wijaya Kusuma Surabaya who has motivated the authors to publish a reputable international journal

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233396225 (Cogent Food & Agriculture) A revise decision has been made on your submission

3 messages

Cogent Food and Agriculture <em@editorialmanager.com> Mon, Apr 10, 2023 at 11:41 AM
Reply-To: Cogent Food and Agriculture <agriculture@cogentoa.com>
To: Fungki Sri Rejeki <fungki_tip@uwks.ac.id>

Ref: COGENTAGRI-2023-0058
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture

Dear Rejeki,

Your manuscript entitled "Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia illucens) Waste Compost", which you submitted to Cogent Food & Agriculture, has now been reviewed.

The reviews, included at the bottom of the letter, indicate that your manuscript could be suitable for publication following revision. We hope that you will consider these suggestions, and revise your manuscript.

Please submit your revision by May 10, 2023, if you need additional time then please contact the Editorial Office.

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If you are unsure how to submit your revision, please contact us on agriculture@cogentoa.com

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Please ensure that you clearly highlight changes made to your manuscript, as well as submitting a thorough response to reviewers.
Three referees have reviewed your manuscript. I advise you to revise your manuscript following ALL the suggestions of those reviewers. For this, I recommend that you highlight in different colors the changes made in accordance with the suggestions of each referee in the revised manuscript. Since there have been three referees, you must use three different colors (one for each referee).
This is very important to me, because in this way I can know if you have followed ALL the suggestions that these referees indicate.

We look forward to receiving your revised article.

Best wishes,

María Luisa Escudero Gilete
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Reviewer 1: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Objective / Hypothesis – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Figures and Tables – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Results / Data Analysis – overall evaluation
Reviewer 1: Sound

Interpretation / Discussion – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 1: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 1: Sound

Writing – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 1: Not applicable

Comments to the author
Reviewer 1: Title: The title is confusing. The authors need to indicate that the spinach was "cultivated" using Black Soldier Fly Waste Compost
Abstract: Please revise the abstract. Include a brief background and rationale of this research. The research questions should be clearly stated. Please mention the study area, research approach, and the methods used. The results were poorly written and descriptive. The significance of the study is vague.

Introduction: The introduction lacks focus and organisation. The rationale of the research is unclear. Kindly address the following questions: Is there any reported problem on cultivation of spinach elsewhere? Kindly cite. Why this sole species of vegetable? What is the importance of this plant? What are the research questions the authors would like to answer in their experiment? Is there anything novel or innovative in this research project? Briefly discuss and please highlight the significance of this work.

Materials and Methods:
Please describe the methods/protocols used in the nutrient and heavy metal analysis. Cite your reference.
The experimental procedure should be presented as flow chart or diagram.
Results and discussion:
Kindly improve the construction of sentences and check some errors in grammar and spelling (for example, "Zink" instead of Zinc; "studuy's" instead of study). The results should be solely based on the data. Avoid anecdotal statements such as "The increase will be more predominant if urea fertilizer is used". Provide support of such statement.
In the statement, "Heavy metal elements Cu, Pb, Cd, and Zn were discovered while spinach
plants, though they did not exceed the WHO or FAO thresholds" – Please mention/cite the specific WHO or FAO publications.
Overall, please improve the writing of the discussion. Expound the potential application of your research findings.
Conclusion:
The use of the term "household waste or fruit waste" is confusing. Overall, please improve the technical construction of sentences. Please consider revising the manuscript with an English language editor.

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Reviewer 2: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 2: Sound

Objective / Hypothesis – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

Figures and Tables – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

Results / Data Analysis – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

References – overall evaluation
Reviewer 2: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Writing – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 2: Not applicable

Comments to the author
Reviewer 2: please consider the comments in the main text

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Reviewer 3: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Objective / Hypothesis – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Figures and Tables – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Results / Data Analysis – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 3: Unsound or fundamentally flawed

Conclusions – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 3: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 3: Not applicable

Writing – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 3: Not applicable

Comments to the author
Reviewer 3: Review report
The use of organic fertilizers like compost is nowadays very critical for sustainable production of crops like vegetables. It has various advantages like enhancement water holding capacity, supply and availability of essential nutrients and improvement of physical and chemical properties of the growing media. In this regard, the authors evaluated the effects of composts made up of household and fruit wastes using Black Soldier Fly on growth, yield and quality of spinach, an important ingredient for production of baby food. Although an important research area, the study has limitations in all parts of the document (abstract, introduction, methodology, results and discussion). Moreover, it has serious grammatical errors whereby some sentences are difficult to understand. For more details please refer the comments in each part of the document below and attached original document.
Title: Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia illucens) Waste Compost
Journal: Cogent Food & Agriculture
Abstract:

- The design of the experiment is not clear.
- What is randomized block design meant?
- What is control meant? It should be specified
- No conclusion and or recommendation

Keywords
- Better to use words or phrases that are not included in the title of the document, as they are automatically considered as keywords.

Introduction
- Be careful in using words like cow feces. Use alternative words like dung, manure and the like.
- Some sentences are not clear what the authors want to say?
- Abbreviations should be fully written by its first use. Then after, they can be abbreviated.
- The introduction part is not well structured. The paragraphs are not interconnected and there is repetition of ideas. The gaps to be solved by this work is not clear and it is not well justified. The introduction is generally stuffed with full of information with lose connectivity.

Materials and methods

Compost preparation
- It is difficult to understand weather the composts are self-prepared or obtained from elsewhere.
- Table 1: What does it mean % unit of measurement? What is the base for percentile calculation? It needs clarification. Selection of media for spinach production should be made with due attention, as they are mostly used for preparation of baby foods. In this regard, it is necessary to show the maximum level of heavy metals in a given medium to be used for vegetable/spinach production. The authors should clearly show that the composts are suitable for spinach production from the heavy metal point.

Experimental application of BSF larvae waste compost for spinach plants
- The title of subtopics should be smart and express the content.
- The subtopic here is not in-line with the content. The content is the experimental treatment rather than the application.

Treatments
- It is suggested to change P0K0 as 100% soil rather than without compost and urea fertilizer
- What would be happen if you use 100% soil + urea? It would be interesting to see if the results of 50% soil and 50% compost could compensate that of 100% soil + urea.
- It is also not clear weather phosphorous or other fertilizers are applied or not.
- It is not clear by 15 treatments? There are only 5 treatments, which were replicated 3 times.

Procedures
- The procedures for compost preparation are not well described. It seems that fruit and household waste are used as medium for BFS compost preparation. The one written here is not to the standard of scientific journal article. It looks like recipe.
- There is a sentence "The polybag size for eggplant is 50 x 50 cm, while for mustard greens and Bok choy is 40 x 40 cm", which is not clear.
- There sentence "The distance between polybags is 100 cm between rows and 50 cm between rows" is not clear. Write the distance between rows and the distance between plants within rows.
- Methodology should be supported by references.
- Please specify the name of the spinach variety used.

Results
- The way results presented is not to the standard of scientific journal article. It is not systematically presented and described.
- The same results cannot be presented in two different ways (Table and Figure). It is suggested to choose either table or figure for presentation of results.
- Result description is limited to selected parameters. The results of the remaining parameters should be also described.
- It is advised to put the thresholds of heavy metals recommended by WHO or FAO.
- Every tables and figures should be cited at least once in the text at the appropriate place. Otherwise it has to be removed from the document.
- Avoid the use of terminologies that are not suitable for vegetables like spinach.

Discussion

While discussing it is necessary to relate the findings of the present study with others. Otherwise listing and describing the results of other researchers is not as such discussion. Try to justify your results by comparing your results with the findings of others.

Conclusion

Relatively Okay

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2 attachments

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fungki sri. rejeki uwks <fungki_tip@uwks.ac.id> Mon, Apr 10, 2023 at 7:03 PM
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To: Cogent Food and Agriculture <agriculture@cogentoa.com>

Sat, May 6, 2023 at 9:46 AM

Dear Editor of Cogent Food & Agriculture

Thank you for reviewing our manuscript entitled "Nutritional Quality of Spinach (*Amaranthus hybridus* L.) using Black Soldier Fly (*Hermetia illucens*) Waste Compost", manuscript ID 233396225.

In order to respond to review from three reviewers, we request an additional time until May 17, 2023.

Thank you for your attention and cooperation.

Best regard,

Fungki Sri Rejeki

Universitas Wijaya Kusuma Surabaya

[Quoted text hidden]

233396225 (Cogent Food & Agriculture) A revise decision has been made on your submission

External
Inbox

Cogent Food and Agriculture <em@editorialmanager.com>

11:41 AM (9 hours ago)

to me

Ref: COGENTAGRI-2023-0058
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture

Dear Rejeki,

Your manuscript entitled "Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia illucens) Waste Compost", which you submitted to Cogent Food & Agriculture, has now been reviewed.

The reviews, included at the bottom of the letter, indicate that your manuscript could be suitable for publication following revision. We hope that you will consider these suggestions, and revise your manuscript.

Please submit your revision by May 10, 2023, if you need additional time then please contact the Editorial Office.

To submit your revised manuscript please go to https://rp.cogentoa.com/dashboard/ and log in. You will see an option to Revise alongside your submission record.

If you are unsure how to submit your revision, please contact us on agriculture@cogentoa.com

You also have the option of including the following with your revised submission:

* public interest statement - a description of your paper of NO MORE THAN 150 words suitable for a non-specialist reader, highlighting/explaining anything which will be of interest to the general public

* about the author - a short summary of NO MORE THAN 150 WORDS, detailing either your

own or your group's key research activities, including a note on how the research reported in this paper relates to wider projects or issues.

* photo of the author(s), including details of who is in the photograph - please note that we can only publish one photo

If you require advice on language editing for your manuscript or assistance with arranging translation, please do consider using the Taylor & Francis Editing Services (www.tandfeditingservices.com).

Please ensure that you clearly highlight changes made to your manuscript, as well as submitting a thorough response to reviewers.
Three referees have reviewed your manuscript. I advise you to revise your manuscript following ALL the suggestions of those reviewers. For this, I recommend that you highlight in different colors the changes made in accordance with the suggestions of each referee in the revised manuscript.
Since there have been three referees, you must use three different colors (one for each referee). This is very important to me, because in this way I can know if you have followed ALL the suggestions that these referees indicate.

We look forward to receiving your revised article.

Best wishes,

María Luisa Escudero Gilete
Senior Editor
Cogent Food & Agriculture

Comments from the Editors and Reviewers:

Do you want to get recognition for this review on Publons? Don't let your reviewing work go unnoticed! Researchers the world over use Publons to effortlessly track their valuable peer review contributions for any journal. If you opt in, your Publons profile will automatically be updated to show a verified record of this review in full compliance with the journal's review policy. If you don't have a Publons
profile, you will be prompted to create a free account. [Learn more]

Reviewer 1: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Objective / Hypothesis – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Figures and Tables – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Results / Data Analysis – overall evaluation
Reviewer 1: Sound

Interpretation / Discussion – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 1: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 1: Sound

Writing – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 1: Not applicable

Comments to the author
Reviewer 1: Title: The title is confusing. The authors need to indicate that the spinach was "cultivated" using Black Soldier Fly Waste Compost
Manuscript Title revised to be: Nutritional Quality of Spinach *(Amaranthus hybridus L.)* Cultivated Using Black Soldier Fly *(Hermetia illucens)* Waste Compost

Abstract: Please revise the abstract. Include a brief background and rationale of this research. The research questions should be clearly stated. Please mention the study area, research approach, and the methods used. The results were poorly written and descriptive. The significance of the study is vague.
Response: Abstract have been revised in manuscript

Introduction: The introduction lacks focus and organisation. The rationale of the research is unclear. Kindly address the following questions: Is there any reported problem on cultivation of spinach elsewhere? Kindly cite. Why this sole species of vegetable? What is the importance of this plant? What are the research questions the authors would like to answer in their experiment?

Is there anything novel or innovative in this research project? Briefly discuss and please highlight the significance of this work.

Response:

1. Research on the use of compost in spinach cultivation has been described in the introduction section in the third paragraph.
2. Spinach is a vegetable that has high nutritional value, was added in the introduction section in the second paragraph.
3. Research question of this research is whether BSF compost is safe to use as a medium for growing spinach, was added in introduction section in fourth paragraph.
4. The novelty of this research is detecting the presence of heavy metals in BSF compost which are absorbed in the spinach tissue, was added in the introduction section in the sixth paragraph.
5. The benefit of the research is to provide information that not all compost can be used as a media for spinach plants. It is necessary to pay attention to the presence of heavy metal contamination in the composted material was added in introduction section in sixth paragraph.

Materials and Methods:
Please describe the methods/protocols used in the nutrient and heavy metal analysis. Cite your reference.

Response: the methods/protocols used in the nutrient and heavy metal analysis based on Raden et al, 2017 and Tiwow et al, 2019, was added in Experimental Design subsection in third paragraph

The experimental procedure should be presented as flow chart or diagram.

Response:
Research flow chart was added in Material and Method section.

Results and discussion:
Kindly improve the construction of sentences and check some errors in grammar and spelling (for example, "Zink" instead of Zinc; "studuy's" instead of study).

Response: Overall typographical and grammatical errors have been corrected.

The results should be solely based on the data. Avoid anecdotal statements such as "The increase will be more predominant if urea fertilizer is used". Provide support of such statement.

Response: Revised in the Result and Discussion section in the first paragraph

In the statement, "Heavy metal elements Cu, Pb, Cd, and Zn were discovered while spinach plants, though they did not exceed the WHO or FAO thresholds" – Please mention/cite the specific WHO or FAO publications.

Response: has been added to the Discussion section of the fourth paragraph

Overall, please improve the writing of the discussion. Expound the potential application of your research findings.

Response: the writing of the discussion as a whole has been improved. The potential application has been listed in the conclusion

Conclusion:
The use of the term "household waste or fruit waste" is confusing.

Response: It has been fixed in the Materials and methods section of the first paragraph.

Overall, please improve the technical construction of sentences. Please consider revising the manuscript with an English language editor.

Response: The manuscript has been revised with a certified English language editor

Do you want to get recognition for this review on Publons? Don't let your reviewing work go unnoticed! Researchers the world over use Publons to effortlessly track their valuable peer review contributions for any journal. If you opt in, your Publons profile will automatically be updated to show a verified record of this review in full compliance with the journal's review policy. If you don't have a Publons
profile, you will be prompted to create a free account. [Learn more]

Reviewer 2: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 2: Sound

Objective / Hypothesis – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

Figures and Tables – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

Results / Data Analysis – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 2: Unsound or fundamentally flawed

References – overall evaluation
Reviewer 2: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Writing – overall evaluation
Reviewer 2: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 2: Not applicable

Comments to the author
Reviewer 2: please consider the comments in the main text

Response: Thank you for the review. We have improved our manuscript based on the comments of all reviewers.

more]</i></p>

Reviewer 3: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Methodology / Materials and Methods – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Objective / Hypothesis – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Figures and Tables – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Results / Data Analysis – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 3: Unsound or fundamentally flawed

Conclusions – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 3: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 3: Not applicable

Writing – overall evaluation
Reviewer 3: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 3: Not applicable

Comments to the author
Reviewer 3: Review report
The use of organic fertilizers like compost is nowadays very critical for sustainable production of crops like vegetables. It has various advantages like enhancement water holding capacity, supply and availability of essential nutrients and improvement of physical and chemical properties of the growing media. In this regard, the authors evaluated the effects of composts

made up of household and fruit wastes using Black Soldier Fly on growth, yield and quality of spinach, an important ingredient for production of baby food. Although an important research area, the study has limitations in all parts of the document (abstract, introduction, methodology, results and discussion). Moreover, it has serious grammatical errors whereby some sentences are difficult to understand. For more details please refer the comments in each part of the document below and attached original document.

Title: Nutritional Quality of Spinach (Amaranthus hybridus L.) using Black Soldier Fly (Hermetia
illucens) Waste Compost

Journal: Cogent Food & Agriculture

Abstract:

- The design of the experiment is not clear.
- What is randomized block design meant?
- What is control meant? It should be specified
- No conclusion and or recommendation

Response: Thank for your review.
We have improved our manuscript based on your review and the other reviewers

Keywords

- Better to use words or phrases that are not included in the title of the document, as they are automatically considered as keywords.

Response: Keywords have been revised in the manuscript

Introduction

- Be careful in using words like cow feces. Use alternative words like dung, manure and the like.

Response: It has been corrected by using the term Cow Manure, in the introduction of the first paragraph

- Some sentences are not clear what the authors want to say?

Response: It has been revised in the manuscript.

- Abbreviations should be fully written by its first use. Then after, they can be abbreviated.

Response: Haemoglobin

- The introduction part is not well structured. The paragraphs are not interconnected and there is repetition of ideas. The gaps to be solved by this work is not clear and it is not well justified. The introduction is generally stuffed with full of information with lose connectivity.

Response: It has been revised in the manuscript.

Materials and methods

Compost preparation

- It is difficult to understand weather the composts are self-prepared or obtained from elsewhere.
- Table 1: What does it mean % unit of measurement? What is the base for percentile calculation? It needs clarification. Selection of media for spinach production should be made with due attention, as they are mostly used for preparation of baby foods. In this regard, it is necessary to show the maximum level of heavy metals in a given medium to be used for vegetable/spinach production. The authors should clearly show that the composts are suitable for spinach production from the heavy metal point.

Experimental application of BSF larvae waste compost for spinach plants

- The title of subtopics should be smart and express the content.
- The subtopic here is not in-line with the content. The content is the experimental treatment rather than the application.

Treatments

- It is suggested to change P0K0 as 100% soil rather than without compost and urea fertilizer
- What would be happen if you use 100% soil + urea? It would be interesting to see if the results of 50% soil and 50% compost could compensate that of 100% soil + urea.
- It is also not clear weather phosphorous or other fertilizers are applied or not.
- It is not clear by 15 treatments? There are only 5 treatments, which were replicated 3 times.

Procedures

- The procedures for compost preparation are not well described. It seems that fruit and household waste are used as medium for BFS compost preparation. The one written here is not to the standard of scientific journal article. It looks like recipe.
- There is a sentence "The polybag size for eggplant is 50 x 50 cm, while for mustard greens and Bok choy is 40 x 40 cm", which is not clear.
- There sentence "The distance between polybags is 100 cm between rows and 50 cm between rows" is not clear. Write the distance between rows and the distance between plants within rows.
- Methodology should be supported by references.
- Please specify the name of the spinach variety used.

Response:
Overall, we have restructured and improved the Material and Method sections of the manuscript according to comments from all reviewers

Results

- The way results presented is not to the standard of scientific journal article. It is not systematically presented and described.

Response: It has been revised in the manuscript.

- The same results cannot be presented in two different ways (Table and Figure). It is suggested to choose either table or figure for presentation of results.

Response: presentation using tables and images has been removed.

- Result description is limited to selected parameters. The results of the remaining parameters should be also described.

Response: all parameters have been explained in the revised manuscript

- It is advised to put the thresholds of heavy metals recommended by WHO or FAO.

Response: improvements have been made in the manuscript.

- Every tables and figures should be cited at least once in the text at the appropriate place. Otherwise it has to be removed from the document.

Response: improvements have been made in the manuscript.

- Avoid the use of terminologies that are not suitable for vegetables like spinach.

Responsw: it has been replaced with Biomass Weight

Discussion

While discussing it is necessary to relate the findings of the present study with others. Otherwise listing and describing the results of other researchers is not as such discussion. Try to justify your results by comparing your results with the findings of others.

Response: improvements have been made in the manuscript.

Conclusion

Relatively Okay

Response: Thank you for your review.

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/cogentagri/login.asp?a=r). Please contact the publication office if you have any questions.

2 Attachments • Scanned by Gmail

mail UWKS

fungki sri. rejeki uwks <fungki_tip@uwks.ac.id>

233396225 (Cogent Food & Agriculture) A revise decision has been made on your submission

4 messages

Cogent Food and Agriculture <em@editorialmanager.com> Wed, Jun 14, 2023 at 11:36 AM
Reply-To: Cogent Food and Agriculture <agriculture@cogentoa.com>
To: Fungki Sri Rejeki <fungki_tip@uwks.ac.id>

Ref: COGENTAGRI-2023-0058R1
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture

Dear Rejeki,

Your manuscript entitled "Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost", which you submitted to Cogent Food & Agriculture, has now been reviewed.

The reviews, included at the bottom of the letter, indicate that your manuscript could be suitable for publication following revision. We hope that you will consider these suggestions, and revise your manuscript.

Please submit your revision by Jul 14, 2023, if you need additional time then please contact the Editorial Office.

To submit your revised manuscript please go to https://rp.cogentoa.com/dashboard/ and log in. You will see an option to Revise alongside your submission record.

If you are unsure how to submit your revision, please contact us on agriculture@cogentoa.com

You also have the option of including the following with your revised submission:

* public interest statement - a description of your paper of NO MORE THAN 150 words suitable for a non-specialist reader, highlighting/explaining anything which will be of interest to the general public

* about the author - a short summary of NO MORE THAN 150 WORDS, detailing either your own or your group's key research activities, including a note on how the research reported in this paper relates to wider projects or issues.

* photo of the author(s), including details of who is in the photograph - please note that we can only publish one photo

If you require advice on language editing for your manuscript or assistance with arranging translation, please do consider using the Taylor & Francis Editing Services (www.tandfeditingservices.com).

Please ensure that you clearly highlight changes made to your manuscript, as well as submitting a thorough response to reviewers.
Two referees have reviewed your manuscript. I advise you to revise your manuscript following ALL the suggestions of those reviewers. For this, I recommend that you highlight in different colors the changes made in accordance with the suggestions of each referee in the revised manuscript. Since there have been two referees, you must use two different colors (one for each referee).
This is very important to me, because in this way I can know if you have followed ALL the suggestions that these referees indicate.

We look forward to receiving your revised article.

Best wishes,

María Luisa Escudero Gilete
Senior Editor
Cogent Food & Agriculture

Comments from the Editors and Reviewers:

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Reviewer 1: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 1: Sound

Methodology / Materials and Methods – overall evaluation
Reviewer 1: Sound

Objective / Hypothesis – overall evaluation
Reviewer 1: Sound

Figures and Tables – overall evaluation
Reviewer 1: Sound

Results / Data Analysis – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 1: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 1: Sound

Writing – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 1: Sound

Comments to the author
Reviewer 1: I strongly suggest that the authors consider an English language editor. Whilst the content of the revised manuscript was improved, misspelled words such as "spectrofotometric", "Constanta", and "Zink" should be corrected.The usage of the term "fertilization" to imply the application of fertilizers must be checked. Also, the inconsistent use of British and American English such as "fiber and fibre". Overall, the content of the paper was sound but the writing and grammar should be further improved.

Do you want to get recognition for this review on Publons? Don't let your reviewing work go unnoticed! Researchers the world over use Publons to effortlessly track their valuable peer review contributions for any journal. If you opt in, your Publons profile will automatically be updated to show a verified record of this review in full compliance with the journal's review policy. If you don't have a Publons profile, you will be prompted to create a free account. [Learn more]

Reviewer 2: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 2: Sound

Methodology / Materials and Methods – overall evaluation
Reviewer 2: Sound

Objective / Hypothesis – overall evaluation
Reviewer 2: Sound

Figures and Tables – overall evaluation
Reviewer 2: Sound

Results / Data Analysis – overall evaluation
Reviewer 2: Sound

Interpretation / Discussion – overall evaluation
Reviewer 2: Sound

Conclusions – overall evaluation
Reviewer 2: Sound

References – overall evaluation
Reviewer 2: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 2: Not applicable

Writing – overall evaluation
Reviewer 2: Sound

Supplemental Information and Data – overall evaluation
Reviewer 2: Not applicable

Comments to the author

Reviewer 2: Consistency of some terms to checked before publication

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fungki sri. rejeki uwks <fungki_tip@uwks.ac.id> Wed, Jun 14, 2023 at 12:44 PM
To: wedowati77@gmail.com

[Quoted text hidden]

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fungki sri. rejeki uwks <fungki_tip@uwks.ac.id> Wed, Jun 14, 2023 at 1:30 PM
To: dwi_haryanta@uwks.ac.id

[Quoted text hidden]

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fungki sri. rejeki uwks <fungki_tip@uwks.ac.id> Wed, Oct 25, 2023 at 9:33 AM
To: Cogent Food and Agriculture <agriculture@cogentoa.com>

Dear María Luisa Escudero Gilete
Senior Editor
Cogent Food & Agriculture

Previously, I apologized for asking for information regarding the status of our manuscript entitled Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost.

On June 14 2023 we received an email to revise our manuscript with the reference:
Ref: COGENTAGRI-2023-0058R1
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture.

On June 26 2023 we sent the second revision to our manuscript, and it has been received by Cogent with Submission ID: 233396225.R2.
However, until now we have not received any further information regarding the progress of the status of our manuscript.
For this reason, we ask that you obtain information regarding the status of our manuscript.

Thank you for your attention and cooperation.

Best Regards,
Fungki Sri Rejeki
Universitas Wijaya Kusuma Surabaya, Indonesia
[Quoted text hidden]

Nutritional Quality of Spinach *(Amaranthus hybridus L.)* Cultivated Using Black Soldier Fly *(Hermetia illucens)* Waste Compost

Fungki Sri Rejeki[1]*, Endang Retno Wedowati[1], Dwi Haryanta[2]
[1.] Agroindustrial Technology Study Program, [2] Agrotechnology Study Program
Universitas Wijaya Kusuma Surabaya, Indonesia
Email: fungki_tip@uwks.ac.id

Abstract

The spinach can be cultivated on urban farms using compost from black soldier fly (BSF) larvae and urban organic waste. The study examined (1) the existence of heavy metal pollutants in household and market waste, (2) the impact of BSF larvae waste compost on spinach growth and product quality, and (3) the ingestion of compost components in spinach plant tissue. The experiment used a complete randomised block design (RCBD) with five treatments, specifically: (1) soil media without compost or urea; (2) soil with BSF compost as household waste substrate without fertiliser; (3) soil with household waste substrate BSF compost fertilised with urea; (4) soil with BSF compost as fruit waste substrate without fertiliser; and (5) soil with BSF compost as fruit waste substrate with fertiliser. Spinach growth and product, nutrient content, and heavy metal absorption in spinach tissue were parameters. BSF larva waste compost with household or fruit waste as a substrate contains macro and micronutrients required by plants and heavy metals that may harm vegetable plant tissues. Applying BSF larvae waste compost increased the vitamin A, vitamin C, chlorophyll, and carotene content in spinach production. The spinach product showed no significant difference in fibre, nitrate, nitrite, and oxalate levels compared to the control (100% soil). While the plant did absorb heavy metals (Cu, Pb, Cd, Zn) from the compost, the concentrations were below the threshold set by WHO/FAO. The use of compost for organic vegetable cultivation ought to be appropriately evaluated due to the potential existence of heavy metals.

Keywords: Vegetables, nutrition, food safety, organic fertiliser, urban waste.

Introduction

Consumer demand for nutritious foods and government policies to sustain agricultural environments must be met to establish a stable foundation for developing organic farming systems (Maggio et al., 2013). Conventional vegetable cultivation methods can present hazards to human health because of the accumulation of heavy metals, chemical pollution, and detrimental microorganisms (Hisham et al., 2021). Using organic fertiliser reduces the concentration of Pb, Cu, and Cr while amplifying nutrient absorption efficiency in tomatoes (Hameeda et al., 2019). Biochar derived from faecal matter promotes growth and influences the build-up of heavy metals in spinach plant tissues (Tahir et al., 2018). Compared to control and chemical fertilisers, the use of organic cow manure as a fertiliser improves the quantity of marketable spinach leaves and improves the nitrogen, phosphorus, sulphur, and selenium levels

of plants. Cow manure enhances production by 88.08% compared to the control group (without fertiliser) and shows a 41.16% increase compared to chemical fertilisers like N, P2O5, and K2O (Turkkan & Kibar, 2022). Organic farming will benefit society and the environment by producing chemical-free, safe, healthful, and nutritious organic food. Organically cultivated spinach contains higher levels of carotene, vitamin C, and calcium (Sharma & Agarwal, 2014). The development of organic agriculture must consider the detrimental effects of chemicals on human health, natural resources, and the global demand for high-quality products (Rathore et al., 2014).

Spinach (vegetable) farming plays an essential role in earning income, increasing revenue, ensuring food security, and alleviating poverty (Mdoda et al., 2022). Spinach is a leafy green vegetable that grows quickly and has significant nutritional value. It is rich in minerals, vitamins, phytochemicals, and bioactive compounds that are beneficial to health, although it does accumulate oxalate and nitrate in its leaves (Giménez et al., 2021). Spinach is a great source of vitamin B6, riboflavin, folate, niacin, soluble fibre, omega-3 fatty acids, and iron, which can prevent conditions such as osteoporosis and anaemia. It is known for its effectiveness in treating digestive issues, promoting blood formation, stimulating growth in children, stimulating appetite, aiding in fatigue recovery, and acting as an antioxidant and anticancer agent (Miano, 2016). Spinach leaf meal, due to its available iron content, can be utilised to fortify infant formula and other food products (Tedom et al., 2020). Spinach juice can be utilised as an alternative nutritional therapy to improve haemoglobin (Hb) levels and prevent anaemia anemia (Purba et al., 2021).Spinach plants provide crucial vitamins, minerals, essential amino acids, high fibre content, no cholesterol, and are low in fat and calories, making them a precious resource for tackling nutritional deficiencies in individuals (Terfa, 2021).

Fertilisers impact the growth, production and nutrient content of spinach vegetables. Nitrogen, phosphorus and potassium fertilisers enhance spinach plants' total phenols, antioxidant activity, flavonoids and vitamin C (Zikalala et al., 2017). The use of compost extract improves resistance to soil-borne illnesses, secondary metabolic results, and antioxidant capacity (Giménez et al., 2021). Fertilising compost with leaf litter and manure reduces N, Zn, Fe, Cu, and Cd levels in spinach production while increasing soil P and K (except for N, NO3, and NH4) (Anwar et al., 2017). Slow-release organic fertilisers effectively use nitrogen and reduce nitrate levels in spinach while increasing ascorbic acid content (Vigardt et al., 2020). Food waste and cow manure improve spinach production, nitrogen, phosphorus, and potassium (Kelley et al., 2022). The various spinach varieties maintain their vitamin C, nitrite, nitrate, and oxalate levels. Both organic and inorganic fertilisers enhance stem diameter, root development, plant height, leaf number, and leaf surface area. Using fertiliser increases vitamin C content and decreases nitrite and oxalate levels (Alessa et al., 2017).Utilising a blend consisting of 75% remaining sludge and 25% NPK leads to improved kale and spinach growth, yield, and quality. Several parameters associated with plant quality, such as ascorbic acid, carbohydrate, and protein content, exhibit noteworthy increments (Zafar et al., 2021).

Black soldier fly (BSF) larvae bioconversion of organic waste is a promising innovation due to its high production rate, cost-effectiveness, and short production time. The consequences of bioconversion lead to compost for plants and larvae as a feed source for livestock and fish (Siddiqui et al., 2022). Compost produced from food waste processed with BSF larvae comprises 18.37% organic carbon, 1.45% total nitrogen, 1.58% total phosphorus, and a C/N

ratio of 12.66, satisfying the criteria of the Indonesian National Compost Standard (SNI) (Widyastuti et al., 2021). The technology for treating solid organic waste using BSF larvae can contribute to addressing the shortage of organic fertilisers and provide new income opportunities for small businesses (Sarpong et al., 2019). Compost produced from household waste by BSF larvae does not contain any toxic elements and is safe for use as plant fertiliser (Rahmat et al., 2021). The use of 1,240 kg/ha of BSF compost and 322 kg/ha of NPK fertiliser for vegetable crops can improve soil health, improve production, and enhance the nutritional quality of vegetable plants, particularly in protein and ash content (Anyega et al., 2021). BSF waste compost, which acts as an organic fertiliser, displays high levels of ammonium nitrogen and reduced levels of nitrate nitrogen, resulting in a rise in vegetable dry matter weight (Kawasaki et al., 2020). Compost produced via the bioconversion process by BSF larvae can offer phosphorus and potassium for plants (Putra et al., 2017).

Urban agriculture, which uses compost as a planting medium, encourages people to shift towards healthier food consumption habits, focusing on organic and locally-produced produce from residential areas (Puigdueta et al., 2021). Extensive urban agriculture has a significant role in establishing strong food security systems and promoting sustainable management of organic waste in urban areas (Weidner & Yang, 2020). The careful application of compost and chemical fertilisers can improve the quality of spinach by augmenting vitamin C content, diminishing nitrite and oxalate levels, and upholding a balanced nitrate content (Alessa et al., 2017). The use of compost obtained from urban waste as organic fertiliser, particularly in the context of urban agriculture, has grown increasingly popular (Haryanta & Rejeki, 2021). Urban agricultural products, however, pose food safety risks associated with the use of fertilisers derived from waste containing hazardous elements, inadequate sanitation during planting and harvesting, excessive nitrate compounds, and pesticide waste (Buscaroli et al., 2021). There are concerns regarding the potential contamination of food crops by urban waste pollutants crops (Paradelo et al., 2020). The use of compost in urban agriculture offers a perfect solution for handling the copious organic waste produced in urban areas. By establishing a value-added cycle that involves using organic waste as raw material for compost, implementing composting processes, developing effective marketing strategies, and applying compost in organic farming systems, long-term organic waste management can be ensured (Woldeamanuel et al., 2022). The use of compost usually improves vegetable nutrition with components like nitrogen (N), phosphorus (P), potassium (K), sodium (Na), manganese (Mn), zinc (Zn), and magnesium (Mg) (Mu et al., 2020). Nonetheless, one must be careful to keep clear of using compost that is contaminated, as it may present a potential hazard to human health by assisting the digestion of high levels of heavy metals, particularly zinc (Zn), nickel (Ni), cadmium (Cd), and lead (Pb) by vegetable plants (Eissa & Negim, 2018).

Compost made from urban organic waste can be fertilised in urban agriculture systems. Black soldier fly (BSF) larvae waste with urban organic waste as a substrate can be used as organic fertiliser in urban farming systems to cultivate spinach. Urban rubbish may contain heavy metals that can be absorbed into the tissues of spinach plants, resulting in harmful substances to humans. The waste compost produced by BSF larvae is an organic fertiliser that can be used in urban agriculture. The objectives of this study were to (1) determine the occurrence of heavy metal pollutants in household and market rubbish, (2) examine the impact of BSF larvae rubbish compost on spinach growth and production quality, and (3) investigate the absorption of compost constituents in spinach plant tissue. The advantage of the research is to provide information that not every compost can be used as a medium for spinach plants,

it is necessary to pay attention to the presence of heavy metal contamination in the composted material.

Materials and Methods

BSF compost

Black Soldier Fly (BSF) larvae compost consists of the waste produced during the breeding of BSF larvae, which includes the leftover substrate, larval excrement, and the exoskeleton discarded during moulting. The BSF larvae compost, using household waste substrate, was acquired from the Jambangan Recycling Centre operated by Surabaya City, while the BSF larvae compost using fruit waste substrate was obtained from the Puspa Agro Market managed by the East Java Province. To ensure proper maturation and preparation of the compost for use as fertiliser, it was carefully packed in bags and stored at the Black Soldier Fly breeding site for a period of 60 days. The results of the analysis on the nutrient and heavy metal content in the BSF Larvae Compost are displayed in Table 1. The percentages and parts per million (ppm) measurements are expressed in relation to the dry weight of the material.

Table 1. Nutrient and heavy metal content in the BSF Larvae Compost

Indicator	BSF Larvae Compost from Jambangan Recycling Center	BSF Larvae Compost from Puspa Agro market
C/N ratio	15.80	17.90
N (%)	1.22	1.05
P2O5 (%)	0.68	0.48
K2O (%)	0.77	0.51
Ca (%)	0.42	0.31
Mg (%)	0.30	0.23
Pb (ppm)	0.02	0.01
Cu (ppm)	0.10	0.12
Cd (ppm)	0.01	0.02
Zn (ppm)	2.06	2.15

Experimental Design

The experiment aimed to investigate BSF Larvae Compost's effect on spinach's nutritional quality. The treatments consisted of the following additions to the growing media:

P_0K_0 : Control - 100% soil
P_1K_0 : 50% soil and 50% BSF Larvae Compost from household waste, without urea
P_1K_1 : 50% soil and 50% BSF Larvae Compost from household waste, with urea
P_2K_0 : 50% soil and 50% BSF Larvae Compost from fruit waste, without urea
P_2K_1 : 50% soil and 50% BSF Larvae Compost from fruit waste, with urea

Each treatment was repeated thrice, resulting in 15 plot units. A plot unit of one spinach plant cultivated in a black polythene container with a diameter of 25.5 cm and a height of 40 cm, filled with 30 cm of planting substrate. The 15 plot units were arranged in a randomised complete block design (RCBD), with three rows serving as blocks, each containing five plot units. The distance between rows was 150 cm, while the distance between plot units within a row was 100 cm.

Spinach Cultivation

Certified *Spinacia oleracea var. caudatus* seeds were procured from an esteemed agricultural establishment in Surabaya. The seeds underwent germination using rockwool media. The planting media was meticulously prepared by blending vertisol soil (sourced from Mojosari, Mojokerto Regency) with BSF larva compost, adhering to the prescribed proportions outlined in the treatment design. The meticulously prepared planting media was subsequently filled into black plastic bags, possessing a diameter of 25.5 cm and a height of 40 cm. The media was carefully filled up to 30 cm within the bags. Transplantation of the spinach seedlings occurred when they attained age 15 days or possessed three fully formed leaves. Plant maintenance encompassed essential tasks such as watering, weed control, and implementing necessary pest and disease management measures following the plant's requirements. Urea fertiliser was applied as per the treatment design, with a dosage of 1.5 g per plant, administered at the 7-day and 21-day mark. The spinach harvest was conducted precisely 35 days after the initial planting.

Heavy Metal Content Analysis

A comprehensive analysis was carried out to evaluate the heavy metal content in both the samples of BSF larva compost and the harvested spinach vegetables. Around 20-30 g of the edible part for the plant samples was carefully gathered and then dried in an oven until it turned into dry ash. On the other hand, the BSF larva waste compost sample was obtained from a measured quantity of 25 g, extracted from the residual substrate used in larva rearing. Heavy metals, particularly Cu, Zn, Pb, and Cd, were analysed using accurate spectrophotometric and atomic absorption spectrophotometric techniques (Raden et al., 2017; Tiwow et al., 2019).

Nutrient Content of Spinach Measurement

The measurement of nutrient content in spinach involves the examination of samples obtained from the consumed portion of the plant. The quantification of total nitrogen (N) within the plant tissue is carried out using the Kjeldahl method, employing dry samples (Zikalala et al., 2016). Furthermore, the levels of Vitamin C, Vitamin A, chlorophyll, phenols, flavonoids, tannins, total antioxidants, nitrate, nitrite, oxalate, and saponin are determined using a spectrophotometer and AAS methods (Jabeen et al., 2019). Moreover, spinach's fibre content is evaluated using the distillation-gravimetry method (Rashid et al., 2022).

Plant Growth Measurement

Plant growth is measured using indicators such as plant height, number of leaves, and stem diameter every 7 days starting from 7 days after planting until harvest, while above-ground biomass is measured at harvest. Plant height is measured from the soil surface (root collar) to the highest point of growth using a ruler. The number of leaves is counted for fully grown leaves that have not yet yellowed and are still green. Leaf area is calculated using the formula length times width times a constant.

Area = Length x Width x Constant

The constant is obtained from the average of five leaf samples and is calculated using the formula:

$$\text{Constant} = \frac{The\ actual\ leaf\ area}{Length\ x\ Width}$$

The actual leaf area is obtained by drawing the leaf on millimeter paper.
The stem diameter is measured using a caliper at half of the plant height, the above-ground biomass is obtained by weighing the plant parts above the soil surface, and the consumption weight is obtained by weighing the edible leaves at harvest using an analytical balance.

Statistical Analysis

Spinach plants growth, production, and nutritional content data were analysed using Analysis of Variance (ANOVA). If the F-test result shows a significant treatment variance, a post-hoc comparison test using Least Significant Difference (LSD) test with $\alpha = 5\%$ is conducted to determine the significantly different treatment means. Statistical analysis was performed using Excel program.

Research flow chart
The stages of the research are outlined in the flowchart shown in Figure 1.

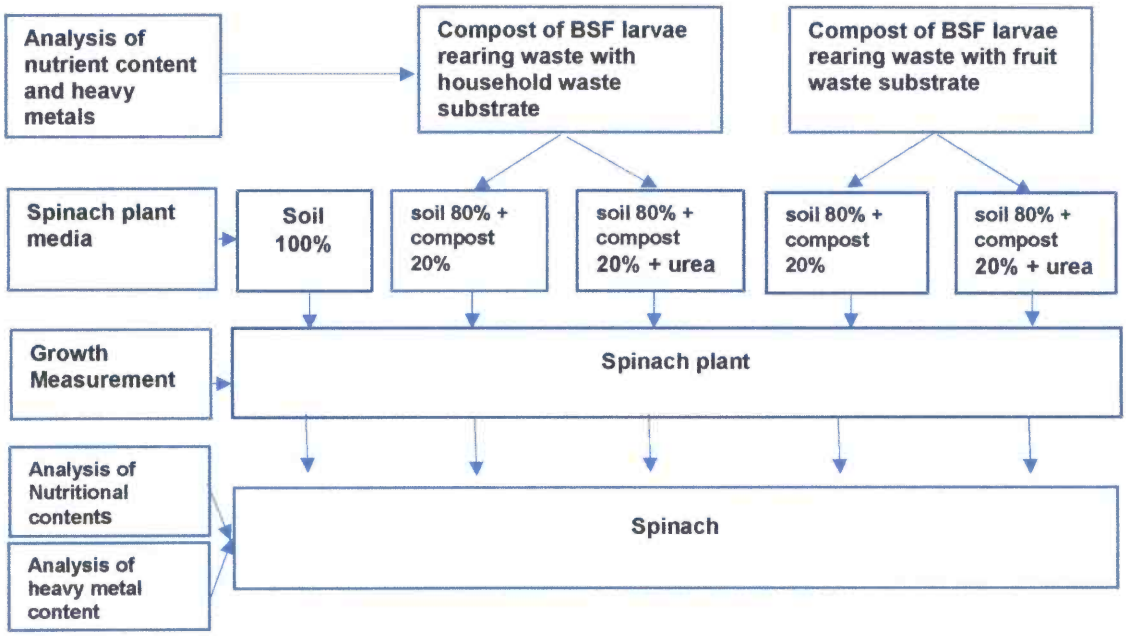

Figure 1. Research stages

Results

The nutritional composition of spinach can be evaluated by analysing its constituents, including fibre, vitamin C, vitamin A, iron (Fe) elements, chlorophyll, carotene, and nitrate. The fibre content of harvested spinach samples was 15.30% to 17.63%. Similarly, the vitamin C content was between 309.07 mg/100g and 353.87 mg/100g, while the vitamin A content was 38.97 mg/100g to 42.32 mg/100g. Moreover, the Fe content ranged from 18.37 mg/100g to 21.47 mg/100g, the chlorophyll content was between 206.93 mg/100g and 353.50 mg/100g, and the carotene content was from 62.57 to 68.57 mg/100g (Table 2). The fibre content in the BSF larvae waste compost treatment was not significantly different from the control. The Vitamin C, Vitamin A, Fe elements, chlorophyll and carotene content in the compost treatment of BSF larvae waste was higher than the control.

Table 2. Quality Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Nutritional content/nutrition					
	Fibre (%)	Vit C (mg/100g)	Vit A (mg/100g)	Fe (mg/100g)	Chlorophyll (mg/100g)	Carotene (mg/100g)
P_0K_0	16.67 ab	309.07 d	39.07 b	18.37 d	206.93 d	62.57 b
P_1K_0	17.14 a	336.13 b	42.32 a	20.57 bc	344.83 b	67.64 a
P_1K_1	15.30 c	353.87 a	39.05 b	21.23 ab	353.50 a	65.97 ab
P_2K_0	17.63 a	321.30 c	41.13 ab	20.38 c	240.57 c	68.57 a
P_2K_1	15.67 bc	350.30 a	38.97 b	21.47 a	344.14 b	65.14 ab
LSD 5%	1.16	11.99	3.15	0.70	6.91	3.71

Note: : Numbers in one column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil

P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea

P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea

P_2K_0: soil : BSF compost fruit waste 50% : 50%, without urea

P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

The nitrate content in spinach ranged from 0.10-0.14 ppm and was not significantly different between BSF larvae waste compost treatment and control, although the nitrite content ranged from 0.10-0.23 ppm and tended to decrease with compost treatment from fruit waste. Following BSF larvae waste compost treatment, the oxalate content was 0.263-0.363 parts per million. Though they did not exceed the WHO or FAO thresholds, heavy metal elements Cu, Pb, Cd, and Zn were discovered while spinach plants. The WHO/FAO permits a maximum limit of heavy metal content in vegetable tissue, with Fe at 425 mg/kg, Pb at 0.3 mg/kg, Zn at 99.4 mg/kg, Cd at 0.2 mg/kg, and Cu at 73 mg/kg (Alkhatib et al., 2022). Generally speaking, blending BSF larvae waste compost with household and fruit waste substrates increased the heavy metal content of Cu, Pb, and Cd, but not Zn. Table 3 displays nitrate and nitrite levels and various heavy metals that serve as indicators of substandard spinach production.

Table 3. Quality Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Hazardous material content						
	Nitrates (ppm)	Nitrite (ppm)	Nitrite (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)	Zn (ppm)
P_0K_0	0.12	0.022 a	0.022 a	0.012 c	0.029 c	0.011 c	0.039 a
P_1K_0	0.13	0.023 a	0.023 a	0.020 b	0.030 c	0.011 c	0.022 d
P_1K_1	0.14	0.022 a	0.022 a	0.021 b	0.039 b	0.030 a	0.034 b
P_2K_0	0.13	0.010 b	0.010 b	0.013 c	0.020 d	0.021 b	0.030 c
P_2K_1	0.10	0.018 a	0.018 a	0.034 a	0.049 a	0.021 b	0.021 d
LSD 5%	NS	0.007	0.007	0.002	0.002	0.003	0.003

Note : Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil
P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea
P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea
P_2K_0: soil : BSF fruit waste compost 50% : 50%, without urea
P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

BSF larva waste compost and chemical fertilisers affected spinach plant growth, referring to the variable of plant height, the number of leaves, and stem diameter 28 days after planting. When treating BSF larvae waste compost with fruit waste substrate and chemical fertilisers, the highest value of the plant height variable was 83.67 cm, the number of leaves was 89.67, and the stem diameter was 22.57 mm. The control treatment has the lowest value of the growth variable (without compost and chemical fertilisers). Table 4 displays variable data on the growth of harvested spinach 28 days post-planting.

Table 4. Data on the Growth of Spinach at the age of 28 days given BSF Larvae Compost Fertiliser

Treatment	Plant height (cm)	Number of leaves	Stem diameter (mm)
P_0K_0	51.33 d	73.67	14.13 c
P_1K_0	80.67 ab	85.67	17.83 bc
P_1K_1	64.67 cd	78.00	19.43 ab
P_2K_0	67.67 bc	78.00	21.40 ab
P_2K_1	83.67 a	89.67	22.57 a
LSD 5%	13.35	NS	3.85

Note: Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil
P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea
P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea

P_2K_0: soil: BSF fruit waste compost 50% : 50%, without urea
P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

Data on spinach crop yields are presented in Table 5. The variables for the harvest production of spinach are measured by the biomass weight and the weight of consumable materials, such as leaves and young shoots, which are measured at harvest. The treatment with black soldier fly larvae compost and chemical fertiliser can increase the above-ground biomass weight more than five times compared to the control. The percentage of material consumed did not differ between the fertilised plants and the control, and there was even a tendency for the control treatment to consume more material. Fertilised plants had more stem and branch organs but not more leaves.

Table 5. Quantitative Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Biomass weight (g)		Consumed materials		
			Weight (g)		%
P_0K_0	112.67	c	29.03	b	26.59
P_1K_0	646.67	ab	138.23	a	21.33
P_1K_1	547.53	b	135.50	a	27.36
P_2K_0	848.23	a	153.23	a	17.98
P_2K_1	710.67	ab	137.27	a	19.32
LSD 5%	243.51		37.71		NS

Note: Numbers in a column followed by the same letter are not different based on the 5% LSD test; NS = Not significant
P_0K_0: Control - 100% soil
P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea
P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/soil urea
P_2K_0: soil : BSF fruit waste compost 50% : 50%, without urea
P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/soil urea

Discussion

BSF larva waste compost increases the weight of harvested stover and the portion consumed from spinach plants because it consists of of organic matter that gradually releases bound nutrients owing to environmental factors (Bziouech et al., 2022). The application of organic fertilisers alone or together with the application of inorganic fertilisers to picking spinach plants significantly increases leaf area, stem diameter, and fresh weight of vegetative parts, carotene content (Alessa et al., 2017), and weight of dry matter above ground (Kawasaki et al., 2020). According to (Mu et al., 2020), applying compost at a high percentage generally provides elements of N, P, K, Na, Mn, Zn and Mg in vegetable nutrition, while applying at a low percentage increases the content of Ca, Al, and Fe. BSF larva waste compost also improves the quality of harvested spinach vegetables, specifically increasing the content of vitamin C, vitamin A, chlorophyll, carotene, and the mineral iron. Kale and spinach plants that were given organic fertilisers showed significantly higher leaf area, ascorbic acid content, carbohydrate content and protein content than the control treatment (Zafar et al., 2021).The synergistic

impact of compost with NPK fertiliser will enhance the overall phenol content, antioxidant activity, flavonoids and vitamin C of spinach vegetables (Zikalala et al., 2017). The conclusion of the study (Anyega et al., 2021) suggests that the most effective way to use element N, increase ash concentration, enhance soil health, boost production, and improve the nutritional quality of vegetable plants is by fertilising with compost made from BSF larvae waste and chemical fertilisers.

The application of compost did not affect the content of nitrite, nitrate and oxalate groups in pickled spinach vegetables. According to Alessa et al., (2017), the application of organic fertiliser alone or together with inorganic fertilisers has no effect on the content of nitrate, nitrite, and oxalate in picking spinach plants. High nitrate and oxalate content in leaf vegetables can be related to plant fertilisation activity, lighting and plant nature factors (Solberg et al., 2015). BSF waste compost on mustard plants causes higher ammonium and lower nitrate nitrogen (Kawasaki et al., 2020).

Heavy metal contamination in urban waste affects human health and safety through heavy metal contamination in food due to agricultural and environmental activities through compost and polluted water sources (Anani et al., 2020). BSF larva waste compost, which contains various heavy metals, does not affect the harvested spinach quality because the tissue's heavy metal content is well below the permitted threshold. Council waste compost increases Cd, Cu, Pb, and Zn levels in spinach leaves beyond the authorised thresholds. On the other hand, the concentrations of metals (Cd, Cu, Pb, and Zn) in agricultural waste compost are beneath the threshold, suggesting that municipal waste compost could comprise substances detrimental to human health (Saleem et al., 2018).

Compost affects the concentration of heavy metals and nutrient content in lettuce leaf tissue (Alromian, 2020). As per research findings (Głodowska & Krawczyk, 2017), conventionally grown vegetables tend to contain more significant amounts of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in comparison to organic farming methods. The use of urban waste compost for leafy vegetable plants displays the existence of the heavy metal Zn, Cu, Pb, and Cd in plant tissues, with differing levels depending on the pollution level in the waste materials (Paradelo et al., 2020). Oguntade et al., (2019) suggested that fertilisation with compost containing high concentrations of heavy metals but bioaccumulation in leaf vegetables is lower than the maximum allowed by WHO/FAO, specifically for Cu the limit is 0.1 mg/kg, and for Mn, Fe and Zn it is 0.3 mg/kg. The WHO/FAO permits a maximum limit of heavy metal content in vegetable tissue, which includes Fe at 425 mg/kg, Pb at 0.3 mg/kg, Zn at 99.4 mg/kg, Cd at 0.2 mg/kg, and Cu at 73 mg/kg (Alkhatib et al., 2022).

BSF larva waste compost contains macro and micro nutrients that plants require and contains heavy metals, which can be harmful if they enter vegetable plant tissues. The presence of heavy metals is dependent on the substrate utilised in rearing BSF larvae. BSF larvae waste compost is slightly alkaline with a pH of 7.5, rich in nutrients, especially micro-nutrients, and low ammonium nitrogen content indicating a slow nutrient release process to supply nutrients in the longer term (Gärttling & Schulz, 2022). As per the discoveries of Widyastuti et al. 2021, the C-organic content of BSF waste compost was 18.37%, the total nitrogen content was 1.45%, the total phosphorus content was 1.58%, the pH was 6.8, and the C/N ratio was 12.66, which fulfilled the criterion as an organic fertiliser for vegetables. Micronutrients Zinc (60.55ppm), Manganese (36.55ppm), and Boron (12.07 ppm) were discovered in BSF larvae

waste compost with the household waste substrate (Rahmat et al., 2021). Due to the high metal content, it is safe to utilise as plant fertiliser. The analysis of compost made from BSF larvae waste revealed that it met the standard for organic fertiliser, with N: 1.04%, P: 2.25%, K: 1.55, and C/N 14.14% (Mutiar & Yulhendri, 2020).

Conclusion

BSF larva waste compost with household waste or fruit waste as a substrate contains macro and micronutrients required by plants and comprises of heavy metals that can be detrimental if they enter vegetable plant tissues. The application of BSF larvae waste compost increased growth, the weight of harvested stover, and the weight of the part consumed from the picked spinach plants. Treatment of BSF larvae waste compost significantly increased the content of vitamin A, vitamin C, chlorophyll, and carotene in spinach plants and had no effect on fibre, nitrate, nitrite, and oxalate content. The heavy metals Cu, Pb, Cd, and Zn present in the compost are absorbed into the spinach plant tissues but at low concentrations below the limits permitted by WHO/FAO. This study concludes that compost made from BSF larvae and household or fruit waste can be used as organic fertiliser for spinach plants to enhance the growth, yield, and nutritional value of spinach vegetables. Processing organic waste using BSF larvae must be integrated with urban farming development to produce healthy food products through independent urban organic farming.

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Re: Re: 233396225 (Cogent Food & Agriculture) A revise decision has been made on your submission #TrackingId:16810175

2 messages

agriculture@cogentoa.com <agriculture@cogentoa.com> Thu, Oct 26, 2023 at 10:59 AM
To: fungki_tip@uwks.ac.id

Ref.: Ms. No. COGENTAGRI-2023-0058R2

Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost

Fungki Sri Rejeki

Cogent Food & Agriculture

Dear Dr. Rejeki,

Thank you for your email.

I have checked the status of your revised manuscript within our online submission system and I can confirm that your submission is currently being handled by the editor for a decision without any problems.

I am unable to provide any more specific information regarding your submission at this time, aside from assuring you that we will do our best to deliver a decision to you as soon as possible.

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Sent:25-10-2023 10:35
To: NeilPaulo.Santiago@straive.com
Cc:
Subject: Re: Re: 233396225 (Cogent Food & Agriculture) A revise decision has been made on your submission

Dear María Luisa Escudero Gilete
Senior Editor
Cogent Food & Agriculture

Previously, I apologized for asking for information regarding the status of our manuscript entitled Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost.

On June 14 2023 we received an email to revise our manuscript with the reference:
Ref: COGENTAGRI-2023-0058R1
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture.

On June 26 2023 we sent the second revision to our manuscript, and it has been received by Cogent with Submission ID: 233396225.R2.
However, until now we have not received any further information regarding the progress of the status of our manuscript.
For this reason, we ask that you obtain information regarding the status of our manuscript.

Thank you for your attention and cooperation.

Best Regards,
Fungki Sri Rejeki
Universitas Wijaya Kusuma Surabaya, Indonesia

On Wed, Jun 14, 2023 at 11:36 AM Cogent Food and Agriculture <em@editorialmanager.com> wrote:

Ref: COGENTAGRI-2023-0058R1
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture

Dear Rejeki,

Your manuscript entitled "Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost", which you submitted to Cogent Food & Agriculture, has now been reviewed.

The reviews, included at the bottom of the letter, indicate that your manuscript could be suitable for publication following revision. We hope that you will consider these suggestions, and revise your manuscript.

Please submit your revision by Jul 14, 2023, if you need additional time then please contact the Editorial Office.

To submit your revised manuscript please go to https://rp.cogentoa.com/dashboard/ and log in. You will see an option to Revise alongside your submission record.

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Please ensure that you clearly highlight changes made to your manuscript, as well as submitting a thorough response to reviewers.
Two referees have reviewed your manuscript. I advise you to revise your manuscript following ALL the suggestions of those reviewers. For this, I recommend that you highlight in different colors the changes made in accordance with the suggestions of each referee in the revised manuscript.
Since there have been two referees, you must use two different colors (one for each referee).
This is very important to me, because in this way I can know if you have followed ALL the suggestions that these referees indicate.

We look forward to receiving your revised article.

Best wishes,

María Luisa Escudero Gilete
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Reviewer 1: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 1: Sound

Methodology / Materials and Methods – overall evaluation
Reviewer 1: Sound

Objective / Hypothesis – overall evaluation
Reviewer 1: Sound

Figures and Tables – overall evaluation
Reviewer 1: Sound

Results / Data Analysis – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Interpretation / Discussion – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Conclusions – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

References – overall evaluation
Reviewer 1: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 1: Sound

Writing – overall evaluation
Reviewer 1: Sound with minor or moderate revisions

Supplemental Information and Data – overall evaluation
Reviewer 1: Sound

Comments to the author
Reviewer 1: I strongly suggest that the authors consider an English language editor. Whilst the content of the revised manuscript was improved, misspelled words such as "spectrofotometric", "Constanta", and "Zink" should be corrected.The usage of the term "fertilization" to imply the application of fertilizers must be checked. Also, the inconsistent use of British and American English such as "fiber and fibre". Overall, the content of the paper was sound but the writing and grammar should be further improved.

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Reviewer 2: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 2: Sound

Methodology / Materials and Methods – overall evaluation
Reviewer 2: Sound

Objective / Hypothesis – overall evaluation
Reviewer 2: Sound

Figures and Tables – overall evaluation
Reviewer 2: Sound

Results / Data Analysis – overall evaluation
Reviewer 2: Sound

Interpretation / Discussion – overall evaluation
Reviewer 2: Sound

Conclusions – overall evaluation

Reviewer 2: Sound

References – overall evaluation
Reviewer 2: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 2: Not applicable

Writing – overall evaluation
Reviewer 2: Sound

Supplemental Information and Data – overall evaluation
Reviewer 2: Not applicable

Comments to the author
Reviewer 2: Consistency of some terms to checked before publication

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fungki sri. rejeki uwks <fungki_tip@uwks.ac.id> Thu, Oct 26, 2023 at 11:09 AM
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2 messages

Cogent Food and Agriculture <em@editorialmanager.com> Thu, Nov 2, 2023 at 4:25 AM
Reply-To: Cogent Food and Agriculture <agriculture@cogentoa.com>
To: Fungki Sri Rejeki <fungki_tip@uwks.ac.id>

Ref: COGENTAGRI-2023-0058R2
233396225
Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Cogent Food & Agriculture

Dear Fungki Rejeki,

I am pleased to tell you that your work was accepted for publication in Cogent Food & Agriculture on Nov 01, 2023.

Please note: only minor, or typographical changes can be introduced during typesetting and proofing of your manuscript. Major changes to your manuscript will not be permitted.

For your information, comments from the Editor and Reviewers can be found below if available, and you will have an opportunity to make minor changes at proof stage.

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Best wishes

María Luisa Escudero Gilete
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Reviewer 3: Yes

Title, Abstract and Introduction – overall evaluation
Reviewer 3: Outstanding

Methodology / Materials and Methods – overall evaluation
Reviewer 3: Sound

Objective / Hypothesis – overall evaluation
Reviewer 3: Outstanding

Figures and Tables – overall evaluation
Reviewer 3: Sound

Results / Data Analysis – overall evaluation
Reviewer 3: Sound

Interpretation / Discussion – overall evaluation
Reviewer 3: Sound

Conclusions – overall evaluation
Reviewer 3: Outstanding

References – overall evaluation
Reviewer 3: Sound

Compliance with Ethical Standards – overall evaluation
Reviewer 3: Sound

Writing – overall evaluation
Reviewer 3: Sound

Supplemental Information and Data – overall evaluation
Reviewer 3: Sound

Comments to the author
Reviewer 3: The authors addressed most of the comments given in the previous review. However, there are still some minor comments which should be revisited once again before publication. Moreover, the document requires grammatical and editorial corrections.

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Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost

--Manuscript Draft--

Full Title:	Nutritional Quality of Spinach (Amaranthus hybridus L.) Cultivated using Black Soldier Fly (Hermetia illucens) Waste Compost
Manuscript Number:	COGENTAGRI-2023-0058R2
Article Type:	Research Article
Keywords:	Vegetables; nutrition; food safety; organic fertiliser; urban waste
Manuscript Classifications:	10.1.1.6 Agriculture and Food; 10.5.1 Food Additives & Ingredients; 30.2.30.3 Clean Technologies
Abstract:	The spinach can be cultivated on urban farms using compost from black soldier fly (BSF) larvae and urban organic waste. The study examined (1) the existence of heavy metal pollutants in household and market waste, (2) the impact of BSF larvae waste compost on spinach growth and product quality, and (3) the ingestion of compost components in spinach plant tissue. The experiment used a complete randomised block design (RCBD) with five treatments, specifically: (1) soil media without compost or urea; (2) soil with BSF compost as household waste substrate without fertiliser; (3) soil with household waste substrate BSF compost fertilised with urea; (4) soil with BSF compost as fruit waste substrate without fertiliser; and (5) soil with BSF compost as fruit waste substrate with fertiliser. Spinach growth and product, nutrient content, and heavy metal absorption in spinach tissue were parameters. BSF larva waste compost with household or fruit waste as a substrate contains macro and micronutrients required by plants and heavy metals that may harm vegetable plant tissues. Applying BSF larvae waste compost increased the vitamin A, vitamin C, chlorophyll, and carotene content in spinach production. The spinach product showed no significant difference in fibre, nitrate, nitrite, and oxalate levels compared to the control (100% soil). While the plant did absorb heavy metals (Cu, Pb, Cd, Zn) from the compost, the concentrations were below the threshold set by WHO/FAO. The use of compost for organic vegetable cultivation ought to be appropriately evaluated due to the potential existence of heavy metals.
Response to Reviewers:	

Response to Reviewer 1

Comments to the author
Reviewer 1: I strongly suggest that the authors consider an English language editor. Whilst the content of the revised manuscript was improved, misspelled words such as "spectrofotometric", "Constanta", and "Zink" should be corrected. The usage of the term "fertilization" to imply the application of fertilizers must be checked. Also, the inconsistent use of British and American English such as "fiber and fibre". Overall, the content of the paper was sound but the writing and grammar should be further improved.

Overall, the manuscript has been checked and improved for the writing and grammar using British English Style.

The corrected part of the manuscript highlighted.

Response to Reviewer 2

Comments to the author
Reviewer 2: Consistency of some terms to checked before publication

Overall, the manuscript has been checked and improved for the writing and grammar using British English Style.

The corrected part of the manuscript highlighted.

Nutritional Quality of Spinach *(Amaranthus hybridus L.)* Cultivated Using Black Soldier Fly *(Hermetia illucens)* Waste Compost

Fungki Sri Rejeki[1]*, Endang Retno Wedowati[1], Dwi Haryanta[2]
[1.] Agroindustrial Technology Study Program, [2] Agrotechnology Study Program
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Abstract

The spinach can be cultivated on urban farms using compost from black soldier fly (BSF) larvae and urban organic waste. The study examined (1) the existence of heavy metal pollutants in household and market waste, (2) the impact of BSF larvae waste compost on spinach growth and product quality, and (3) the ingestion of compost components in spinach plant tissue. The experiment used a complete randomised block design (RCBD) with five treatments, specifically: (1) soil media without compost or urea; (2) soil with BSF compost as household waste substrate without fertiliser; (3) soil with household waste substrate BSF compost fertilised with urea; (4) soil with BSF compost as fruit waste substrate without fertiliser; and (5) soil with BSF compost as fruit waste substrate with fertiliser. Spinach growth and product, nutrient content, and heavy metal absorption in spinach tissue were parameters. BSF larva waste compost with household or fruit waste as a substrate contains macro and micronutrients required by plants and heavy metals that may harm vegetable plant tissues. Applying BSF larvae waste compost increased the vitamin A, vitamin C, chlorophyll, and carotene content in spinach production. The spinach product showed no significant difference in fibre, nitrate, nitrite, and oxalate levels compared to the control (100% soil). While the plant did absorb heavy metals (Cu, Pb, Cd, Zn) from the compost, the concentrations were below the threshold set by WHO/FAO. The use of compost for organic vegetable cultivation ought to be appropriately evaluated due to the potential existence of heavy metals.

Keywords: Vegetables, nutrition, food safety, organic fertiliser, urban waste.

Introduction

Consumer demand for nutritious foods and government policies to sustain agricultural environments must be met to establish a stable foundation for developing organic farming systems (Maggio et al., 2013). Conventional vegetable cultivation methods can present hazards to human health because of the accumulation of heavy metals, chemical pollution, and detrimental microorganisms (Hisham et al., 2021). Using organic fertiliser reduces the concentration of Pb, Cu, and Cr while amplifying nutrient absorption efficiency in tomatoes (Hameeda et al., 2019). Biochar derived from faecal matter promotes growth and influences the build-up of heavy metals in spinach plant tissues (Tahir et al., 2018). Compared to control and chemical fertilisers, the use of organic cow manure as a fertiliser improves the quantity of marketable spinach leaves and improves the nitrogen, phosphorus, sulphur, and selenium levels

of plants. Cow manure enhances production by 88.08% compared to the control group (without fertiliser) and shows a 41.16% increase compared to chemical fertilisers like N, P2O5, and K2O (Turkkan & Kibar, 2022). Organic farming will benefit society and the environment by producing chemical-free, safe, healthful, and nutritious organic food. Organically cultivated spinach contains higher levels of carotene, vitamin C, and calcium (Sharma & Agarwal, 2014). The development of organic agriculture must consider the detrimental effects of chemicals on human health, natural resources, and the global demand for high-quality products (Rathore et al., 2014).

Spinach (vegetable) farming plays an essential role in earning income, increasing revenue, ensuring food security, and alleviating poverty (Mdoda et al., 2022). Spinach is a leafy green vegetable that grows quickly and has significant nutritional value. It is rich in minerals, vitamins, phytochemicals, and bioactive compounds that are beneficial to health, although it does accumulate oxalate and nitrate in its leaves (Giménez et al., 2021). Spinach is a great source of vitamin B6, riboflavin, folate, niacin, soluble fibre, omega-3 fatty acids, and iron, which can prevent conditions such as osteoporosis and anaemia. It is known for its effectiveness in treating digestive issues, promoting blood formation, stimulating growth in children, stimulating appetite, aiding in fatigue recovery, and acting as an antioxidant and anticancer agent (Miano, 2016). Spinach leaf meal, due to its available iron content, can be utilised to fortify infant formula and other food products (Tedom et al., 2020). Spinach juice can be utilised as an alternative nutritional therapy to improve haemoglobin (Hb) levels and prevent anaemia anemia (Purba et al., 2021).Spinach plants provide crucial vitamins, minerals, essential amino acids, high fibre content, no cholesterol, and are low in fat and calories, making them a precious resource for tackling nutritional deficiencies in individuals (Terfa, 2021).

Fertilisers impact the growth, production and nutrient content of spinach vegetables. Nitrogen, phosphorus and potassium fertilisers enhance spinach plants' total phenols, antioxidant activity, flavonoids and vitamin C (Zikalala et al., 2017). The use of compost extract improves resistance to soil-borne illnesses, secondary metabolic results, and antioxidant capacity (Giménez et al., 2021). Fertilising compost with leaf litter and manure reduces N, Zn, Fe, Cu, and Cd levels in spinach production while increasing soil P and K (except for N, NO3, and NH4) (Anwar et al., 2017). Slow-release organic fertilisers effectively use nitrogen and reduce nitrate levels in spinach while increasing ascorbic acid content (Vigardt et al., 2020). Food waste and cow manure improve spinach production, nitrogen, phosphorus, and potassium (Kelley et al., 2022). The various spinach varieties maintain their vitamin C, nitrite, nitrate, and oxalate levels. Both organic and inorganic fertilisers enhance stem diameter, root development, plant height, leaf number, and leaf surface area. Using fertiliser increases vitamin C content and decreases nitrite and oxalate levels (Alessa et al., 2017).Utilising a blend consisting of 75% remaining sludge and 25% NPK leads to improved kale and spinach growth, yield, and quality. Several parameters associated with plant quality, such as ascorbic acid, carbohydrate, and protein content, exhibit noteworthy increments (Zafar et al., 2021).

Black soldier fly (BSF) larvae bioconversion of organic waste is a promising innovation due to its high production rate, cost-effectiveness, and short production time. The consequences of bioconversion lead to compost for plants and larvae as a feed source for livestock and fish (Siddiqui et al., 2022). Compost produced from food waste processed with BSF larvae comprises 18.37% organic carbon, 1.45% total nitrogen, 1.58% total phosphorus, and a C/N

ratio of 12.66, satisfying the criteria of the Indonesian National Compost Standard (SNI) (Widyastuti et al., 2021). The technology for treating solid organic waste using BSF larvae can contribute to addressing the shortage of organic fertilisers and provide new income opportunities for small businesses (Sarpong et al., 2019). Compost produced from household waste by BSF larvae does not contain any toxic elements and is safe for use as plant fertiliser (Rahmat et al., 2021). The use of 1,240 kg/ha of BSF compost and 322 kg/ha of NPK fertiliser for vegetable crops can improve soil health, improve production, and enhance the nutritional quality of vegetable plants, particularly in protein and ash content (Anyega et al., 2021). BSF waste compost, which acts as an organic fertiliser, displays high levels of ammonium nitrogen and reduced levels of nitrate nitrogen, resulting in a rise in vegetable dry matter weight (Kawasaki et al., 2020). Compost produced via the bioconversion process by BSF larvae can offer phosphorus and potassium for plants (Putra et al., 2017).

Urban agriculture, which uses compost as a planting medium, encourages people to shift towards healthier food consumption habits, focusing on organic and locally-produced produce from residential areas (Puigdueta et al., 2021). Extensive urban agriculture has a significant role in establishing strong food security systems and promoting sustainable management of organic waste in urban areas (Weidner & Yang, 2020). The careful application of compost and chemical fertilisers can improve the quality of spinach by augmenting vitamin C content, diminishing nitrite and oxalate levels, and upholding a balanced nitrate content (Alessa et al., 2017). The use of compost obtained from urban waste as organic fertiliser, particularly in the context of urban agriculture, has grown increasingly popular (Haryanta & Rejeki, 2021). Urban agricultural products, however, pose food safety risks associated with the use of fertilisers derived from waste containing hazardous elements, inadequate sanitation during planting and harvesting, excessive nitrate compounds, and pesticide waste (Buscaroli et al., 2021). There are concerns regarding the potential contamination of food crops by urban waste pollutants crops (Paradelo et al., 2020). The use of compost in urban agriculture offers a perfect solution for handling the copious organic waste produced in urban areas. By establishing a value-added cycle that involves using organic waste as raw material for compost, implementing composting processes, developing effective marketing strategies, and applying compost in organic farming systems, long-term organic waste management can be ensured (Woldeamanuel et al., 2022). The use of compost usually improves vegetable nutrition with components like nitrogen (N), phosphorus (P), potassium (K), sodium (Na), manganese (Mn), zinc (Zn), and magnesium (Mg) (Mu et al., 2020). Nonetheless, one must be careful to keep clear of using compost that is contaminated, as it may present a potential hazard to human health by assisting the digestion of high levels of heavy metals, particularly zinc (Zn), nickel (Ni), cadmium (Cd), and lead (Pb) by vegetable plants (Eissa & Negim, 2018).

Compost made from urban organic waste can be fertilised in urban agriculture systems. Black soldier fly (BSF) larvae waste with urban organic waste as a substrate can be used as organic fertiliser in urban farming systems to cultivate spinach. Urban rubbish may contain heavy metals that can be absorbed into the tissues of spinach plants, resulting in harmful substances to humans. The waste compost produced by BSF larvae is an organic fertiliser that can be used in urban agriculture. The objectives of this study were to (1) determine the occurrence of heavy metal pollutants in household and market rubbish, (2) examine the impact of BSF larvae rubbish compost on spinach growth and production quality, and (3) investigate the absorption of compost constituents in spinach plant tissue. The advantage of the research is to provide information that not every compost can be used as a medium for spinach plants,

it is necessary to pay attention to the presence of heavy metal contamination in the composted material.

Materials and Methods

BSF compost

Black Soldier Fly (BSF) larvae compost consists of the waste produced during the breeding of BSF larvae, which includes the leftover substrate, larval excrement, and the exoskeleton discarded during moulting. The BSF larvae compost, using household waste substrate, was acquired from the Jambangan Recycling Centre operated by Surabaya City, while the BSF larvae compost using fruit waste substrate was obtained from the Puspa Agro Market managed by the East Java Province. To ensure proper maturation and preparation of the compost for use as fertiliser, it was carefully packed in bags and stored at the Black Soldier Fly breeding site for a period of 60 days. The results of the analysis on the nutrient and heavy metal content in the BSF Larvae Compost are displayed in Table 1. The percentages and parts per million (ppm) measurements are expressed in relation to the dry weight of the material.

Table 1. Nutrient and heavy metal content in the BSF Larvae Compost

Indicator	BSF Larvae Compost from Jambangan Recycling Center	BSF Larvae Compost from Puspa Agro market
C/N ratio	15.80	17.90
N (%)	1.22	1.05
P2O5 (%)	0.68	0.48
K2O (%)	0.77	0.51
Ca (%)	0.42	0.31
Mg (%)	0.30	0.23
Pb (ppm)	0.02	0.01
Cu (ppm)	0.10	0.12
Cd (ppm)	0.01	0.02
Zn (ppm)	2.06	2.15

Experimental Design

The experiment aimed to investigate BSF Larvae Compost's effect on spinach's nutritional quality. The treatments consisted of the following additions to the growing media:

P_0K_0 : Control - 100% soil
P_1K_0 : 50% soil and 50% BSF Larvae Compost from household waste, without urea
P_1K_1 : 50% soil and 50% BSF Larvae Compost from household waste, with urea
P_2K_0 : 50% soil and 50% BSF Larvae Compost from fruit waste, without urea
P_2K_1 : 50% soil and 50% BSF Larvae Compost from fruit waste, with urea

Each treatment was repeated thrice, resulting in 15 plot units. A plot unit of one spinach plant cultivated in a black polythene container with a diameter of 25.5 cm and a height of 40 cm, filled with 30 cm of planting substrate. The 15 plot units were arranged in a randomised complete block design (RCBD), with three rows serving as blocks, each containing five plot units. The distance between rows was 150 cm, while the distance between plot units within a row was 100 cm.

Spinach Cultivation

Certified *Spinacia oleracea var. caudatus* seeds were procured from an esteemed agricultural establishment in Surabaya. The seeds underwent germination using rockwool media. The planting media was meticulously prepared by blending vertisol soil (sourced from Mojosari, Mojokerto Regency) with BSF larva compost, adhering to the prescribed proportions outlined in the treatment design. The meticulously prepared planting media was subsequently filled into black plastic bags, possessing a diameter of 25.5 cm and a height of 40 cm. The media was carefully filled up to 30 cm within the bags. Transplantation of the spinach seedlings occurred when they attained age 15 days or possessed three fully formed leaves. Plant maintenance encompassed essential tasks such as watering, weed control, and implementing necessary pest and disease management measures following the plant's requirements. Urea fertiliser was applied as per the treatment design, with a dosage of 1.5 g per plant, administered at the 7-day and 21-day mark. The spinach harvest was conducted precisely 35 days after the initial planting.

Heavy Metal Content Analysis

A comprehensive analysis was carried out to evaluate the heavy metal content in both the samples of BSF larva compost and the harvested spinach vegetables. Around 20-30 g of the edible part for the plant samples was carefully gathered and then dried in an oven until it turned into dry ash. On the other hand, the BSF larva waste compost sample was obtained from a measured quantity of 25 g, extracted from the residual substrate used in larva rearing. Heavy metals, particularly Cu, Zn, Pb, and Cd, were analysed using accurate spectrophotometric and atomic absorption spectrophotometric techniques (Raden et al., 2017; Tiwow et al., 2019).

Nutrient Content of Spinach Measurement

The measurement of nutrient content in spinach involves the examination of samples obtained from the consumed portion of the plant. The quantification of total nitrogen (N) within the plant tissue is carried out using the Kjeldahl method, employing dry samples (Zikalala et al., 2016). Furthermore, the levels of Vitamin C, Vitamin A, chlorophyll, phenols, flavonoids, tannins, total antioxidants, nitrate, nitrite, oxalate, and saponin are determined using a spectrophotometer and AAS methods (Jabeen et al., 2019). Moreover, spinach's fibre content is evaluated using the distillation-gravimetry method (Rashid et al., 2022).

Plant Growth Measurement

Plant growth is measured using indicators such as plant height, number of leaves, and stem diameter every 7 days starting from 7 days after planting until harvest, while above-ground biomass is measured at harvest. Plant height is measured from the soil surface (root collar) to the highest point of growth using a ruler. The number of leaves is counted for fully grown leaves that have not yet yellowed and are still green. Leaf area is calculated using the formula length times width times a constant.

Area = Length x Width x Constant

The constant is obtained from the average of five leaf samples and is calculated using the formula:

$$\text{Constant} = \frac{\textit{The actual leaf area}}{\textit{Length x Width}}$$

The actual leaf area is obtained by drawing the leaf on millimeter paper.
The stem diameter is measured using a caliper at half of the plant height, the above-ground biomass is obtained by weighing the plant parts above the soil surface, and the consumption weight is obtained by weighing the edible leaves at harvest using an analytical balance.

Statistical Analysis

Spinach plants growth, production, and nutritional content data were analysed using Analysis of Variance (ANOVA). If the F-test result shows a significant treatment variance, a post-hoc comparison test using Least Significant Difference (LSD) test with α = 5% is conducted to determine the significantly different treatment means. Statistical analysis was performed using Excel program.

Research flow chart
The stages of the research are outlined in the flowchart shown in Figure 1.

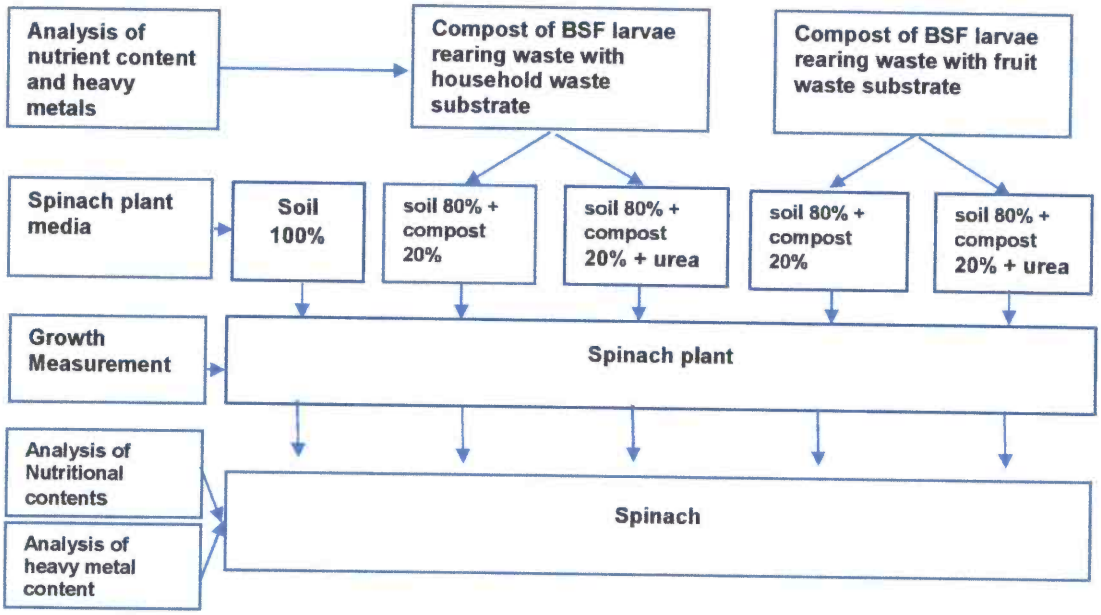

Figure 1. Research stages

Results

The nutritional composition of spinach can be evaluated by analysing its constituents, including fibre, vitamin C, vitamin A, iron (Fe) elements, chlorophyll, carotene, and nitrate. The fibre content of harvested spinach samples was 15.30% to 17.63%. Similarly, the vitamin C content was between 309.07 mg/100g and 353.87 mg/100g, while the vitamin A content was 38.97 mg/100g to 42.32 mg/100g. Moreover, the Fe content ranged from 18.37 mg/100g to 21.47 mg/100g, the chlorophyll content was between 206.93 mg/100g and 353.50 mg/100g, and the carotene content was from 62.57 to 68.57 mg/100g (Table 2). The fibre content in the BSF larvae waste compost treatment was not significantly different from the control. The Vitamin C, Vitamin A, Fe elements, chlorophyll and carotene content in the compost treatment of BSF larvae waste was higher than the control.

Table 2. Quality Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Nutritional content/nutrition					
	Fibre (%)	Vit C (mg/100g)	Vit A (mg/100g)	Fe (mg/100g)	Chlorophyll (mg/100g)	Carotene (mg/100g)
P_0K_0	16.67 ab	309.07 d	39.07 b	18.37 d	206.93 d	62.57 b
P_1K_0	17.14 a	336.13 b	42.32 a	20.57 bc	344.83 b	67.64 a
P_1K_1	15.30 c	353.87 a	39.05 b	21.23 ab	353.50 a	65.97 ab
P_2K_0	17.63 a	321.30 c	41.13 ab	20.38 c	240.57 c	68.57 a
P_2K_1	15.67 bc	350.30 a	38.97 b	21.47 a	344.14 b	65.14 ab
LSD 5%	1.16	11.99	3.15	0.70	6.91	3.71

Note: : Numbers in one column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil

P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea

P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea

P_2K_0: soil : BSF compost fruit waste 50% : 50%, without urea

P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

The nitrate content in spinach ranged from 0.10-0.14 ppm and was not significantly different between BSF larvae waste compost treatment and control, although the nitrite content ranged from 0.10-0.23 ppm and tended to decrease with compost treatment from fruit waste. Following BSF larvae waste compost treatment, the oxalate content was 0.263-0.363 parts per million. Though they did not exceed the WHO or FAO thresholds, heavy metal elements Cu, Pb, Cd, and Zn were discovered while spinach plants. The WHO/FAO permits a maximum limit of heavy metal content in vegetable tissue, with Fe at 425 mg/kg, Pb at 0.3 mg/kg, Zn at 99.4 mg/kg, Cd at 0.2 mg/kg, and Cu at 73 mg/kg (Alkhatib et al., 2022). Generally speaking, blending BSF larvae waste compost with household and fruit waste substrates increased the heavy metal content of Cu, Pb, and Cd, but not Zn. Table 3 displays nitrate and nitrite levels and various heavy metals that serve as indicators of substandard spinach production.

Table 3. Quality Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Hazardous material content						
	Nitrates (ppm)	Nitrite (ppm)	Nitrite (ppm)	Cu (ppm)	Pb (ppm)	Cd (ppm)	Zn (ppm)
P_0K_0	0.12	0.022 a	0.022 a	0.012 c	0.029 c	0.011 c	0.039 a
P_1K_0	0.13	0.023 a	0.023 a	0.020 b	0.030 c	0.011 c	0.022 d
P_1K_1	0.14	0.022 a	0.022 a	0.021 b	0.039 b	0.030 a	0.034 b
P_2K_0	0.13	0.010 b	0.010 b	0.013 c	0.020 d	0.021 b	0.030 c
P_2K_1	0.10	0.018 a	0.018 a	0.034 a	0.049 a	0.021 b	0.021 d
LSD 5%	NS	0.007	0.007	0.002	0.002	0.003	0.003

Note : Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil

P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea

P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea

P_2K_0: soil : BSF fruit waste compost 50% : 50%, without urea

P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

BSF larva waste compost and chemical fertilisers affected spinach plant growth, referring to the variable of plant height, the number of leaves, and stem diameter 28 days after planting. When treating BSF larvae waste compost with fruit waste substrate and chemical fertilisers, the highest value of the plant height variable was 83.67 cm, the number of leaves was 89.67, and the stem diameter was 22.57 mm. The control treatment has the lowest value of the growth variable (without compost and chemical fertilisers). Table 4 displays variable data on the growth of harvested spinach 28 days post-planting.

Table 4. Data on the Growth of Spinach at the age of 28 days given BSF Larvae Compost Fertiliser

Treatment	Plant height (cm)	Number of leaves	Stem diameter (mm)
P_0K_0	51.33 d	73.67	14.13 c
P_1K_0	80.67 ab	85.67	17.83 bc
P_1K_1	64.67 cd	78.00	19.43 ab
P_2K_0	67.67 bc	78.00	21.40 ab
P_2K_1	83.67 a	89.67	22.57 a
LSD 5%	13.35	NS	3.85

Note: Numbers in a column followed by the same letter are not significantly different based on the 5% LSD test; NS = Not significant

P_0K_0: Control - 100% soil

P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea

P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/plant urea

P_2K_0: soil: BSF fruit waste compost 50% : 50%, without urea
P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/plant urea

Data on spinach crop yields are presented in Table 5. The variables for the harvest production of spinach are measured by the biomass weight and the weight of consumable materials, such as leaves and young shoots, which are measured at harvest. The treatment with black soldier fly larvae compost and chemical fertiliser can increase the above-ground biomass weight more than five times compared to the control. The percentage of material consumed did not differ between the fertilised plants and the control, and there was even a tendency for the control treatment to consume more material. Fertilised plants had more stem and branch organs but not more leaves.

Table 5. Quantitative Data of Spinach product given BSF Larvae Compost Fertiliser

Treatment	Biomass weight (g)	Consumed materials	
		Weight (g)	%
P_0K_0	112.67 c	29.03 b	26.59
P_1K_0	646.67 ab	138.23 a	21.33
P_1K_1	547.53 b	135.50 a	27.36
P_2K_0	848.23 a	153.23 a	17.98
P_2K_1	710.67 ab	137.27 a	19.32
LSD 5%	243.51	37.71	NS

Note: Numbers in a column followed by the same letter are not different based on the 5% LSD test; NS = Not significant
P_0K_0: Control - 100% soil
P_1K_0: Soil: 50% BSF household waste compost: 50%, without urea
P_1K_1: soil: 50% BSF household waste compost: 50%, and 3g/soil urea
P_2K_0: soil : BSF fruit waste compost 50% : 50%, without urea
P_2K_1: soil: 50% BSF fruit waste compost: 50%, and 3g/soil urea

Discussion

BSF larva waste compost increases the weight of harvested stover and the portion consumed from spinach plants because it consists of of organic matter that gradually releases bound nutrients owing to environmental factors (Bziouech et al., 2022). The application of organic fertilisers alone or together with the application of inorganic fertilisers to picking spinach plants significantly increases leaf area, stem diameter, and fresh weight of vegetative parts, carotene content (Alessa et al., 2017), and weight of dry matter above ground (Kawasaki et al., 2020). According to (Mu et al., 2020), applying compost at a high percentage generally provides elements of N, P, K, Na, Mn, Zn and Mg in vegetable nutrition, while applying at a low percentage increases the content of Ca, Al, and Fe. BSF larva waste compost also improves the quality of harvested spinach vegetables, specifically increasing the content of vitamin C, vitamin A, chlorophyll, carotene, and the mineral iron. Kale and spinach plants that were given organic fertilisers showed significantly higher leaf area, ascorbic acid content, carbohydrate content and protein content than the control treatment (Zafar et al., 2021).The synergistic

impact of compost with NPK fertiliser will enhance the overall phenol content, antioxidant activity, flavonoids and vitamin C of spinach vegetables (Zikalala et al., 2017). The conclusion of the study (Anyega et al., 2021) suggests that the most effective way to use element N, increase ash concentration, enhance soil health, boost production, and improve the nutritional quality of vegetable plants is by fertilising with compost made from BSF larvae waste and chemical fertilisers.

The application of compost did not affect the content of nitrite, nitrate and oxalate groups in pickled spinach vegetables. According to Alessa et al., (2017), the application of organic fertiliser alone or together with inorganic fertilisers has no effect on the content of nitrate, nitrite, and oxalate in picking spinach plants. High nitrate and oxalate content in leaf vegetables can be related to plant fertilisation activity, lighting and plant nature factors (Solberg et al., 2015). BSF waste compost on mustard plants causes higher ammonium and lower nitrate nitrogen (Kawasaki et al., 2020).

Heavy metal contamination in urban waste affects human health and safety through heavy metal contamination in food due to agricultural and environmental activities through compost and polluted water sources (Anani et al., 2020). BSF larva waste compost, which contains various heavy metals, does not affect the harvested spinach quality because the tissue's heavy metal content is well below the permitted threshold. Council waste compost increases Cd, Cu, Pb, and Zn levels in spinach leaves beyond the authorised thresholds. On the other hand, the concentrations of metals (Cd, Cu, Pb, and Zn) in agricultural waste compost are beneath the threshold, suggesting that municipal waste compost could comprise substances detrimental to human health (Saleem et al., 2018).

Compost affects the concentration of heavy metals and nutrient content in lettuce leaf tissue (Alromian, 2020). As per research findings (Głodowska & Krawczyk, 2017), conventionally grown vegetables tend to contain more significant amounts of heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) in comparison to organic farming methods. The use of urban waste compost for leafy vegetable plants displays the existence of the heavy metal Zn, Cu, Pb, and Cd in plant tissues, with differing levels depending on the pollution level in the waste materials (Paradelo et al., 2020). Oguntade et al., (2019) suggested that fertilisation with compost containing high concentrations of heavy metals but bioaccumulation in leaf vegetables is lower than the maximum allowed by WHO/FAO, specifically for Cu the limit is 0.1 mg/kg, and for Mn, Fe and Zn it is 0.3 mg/kg. The WHO/FAO permits a maximum limit of heavy metal content in vegetable tissue, which includes Fe at 425 mg/kg, Pb at 0.3 mg/kg, Zn at 99.4 mg/kg, Cd at 0.2 mg/kg, and Cu at 73 mg/kg (Alkhatib et al., 2022).

BSF larva waste compost contains macro and micro nutrients that plants require and contains heavy metals, which can be harmful if they enter vegetable plant tissues. The presence of heavy metals is dependent on the substrate utilised in rearing BSF larvae. BSF larvae waste compost is slightly alkaline with a pH of 7.5, rich in nutrients, especially micro-nutrients, and low ammonium nitrogen content indicating a slow nutrient release process to supply nutrients in the longer term (Gärttling & Schulz, 2022). As per the discoveries of Widyastuti et al. 2021, the C-organic content of BSF waste compost was 18.37%, the total nitrogen content was 1.45%, the total phosphorus content was 1.58%, the pH was 6.8, and the C/N ratio was 12.66, which fulfilled the criterion as an organic fertiliser for vegetables. Micronutrients Zinc (60.55ppm), Manganese (36.55ppm), and Boron (12.07 ppm) were discovered in BSF larvae

waste compost with the household waste substrate (Rahmat et al., 2021). Due to the high metal content, it is safe to utilise as plant fertiliser. The analysis of compost made from BSF larvae waste revealed that it met the standard for organic fertiliser, with N: 1.04%, P: 2.25%, K: 1.55, and C/N 14.14% (Mutiar & Yulhendri, 2020).

Conclusion

BSF larva waste compost with household waste or fruit waste as a substrate contains macro and micronutrients required by plants and comprises of heavy metals that can be detrimental if they enter vegetable plant tissues. The application of BSF larvae waste compost increased growth, the weight of harvested stover, and the weight of the part consumed from the picked spinach plants. Treatment of BSF larvae waste compost significantly increased the content of vitamin A, vitamin C, chlorophyll, and carotene in spinach plants and had no effect on fibre, nitrate, nitrite, and oxalate content. The heavy metals Cu, Pb, Cd, and Zn present in the compost are absorbed into the spinach plant tissues but at low concentrations below the limits permitted by WHO/FAO. This study concludes that compost made from BSF larvae and household or fruit waste can be used as organic fertiliser for spinach plants to enhance the growth, yield, and nutritional value of spinach vegetables. Processing organic waste using BSF larvae must be integrated with urban farming development to produce healthy food products through independent urban organic farming.

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