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ORIGINAL RESEARCH

Effects of compost from food waste on growth of lettuce (*Lactuca sativa Var Crispa* L.)

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Abstract

Purpose Thailand generates approximately 18 million tons of urban food waste per year, which is disposed of with municipal waste and largely goes to landfills. However, this approach not only takes up a large area but also causes environmental problems. The easiest way to manage food waste is by separating it at the source and composting it. Bioaxel Co., Ltd. has developed an innovative approach for composting food waste, with the output commercially marketed as “BA compost”. However, the use of BA compost has not been independently studied.

Method BA compost was mixed with soil in various proportions (0% - 70% v/v) for planting lettuce to find the proper BA proportion. Growth characteristics and nutrient contents were investigated.

Results The BA compost improved the soil nutrients. 10% BA compost in soil gave the highest growth parameters among the proportions tested, with the highest root length (21.83 ± 0.83 cm), plant length (30.00 ± 1.00 cm), number of leaves (23.33 ± 1.15 leaves), thickness (12.47 ± 0.57 mm), width of bush (26.33 ± 0.58 mm), fresh plant weight (113.03 ± 1.28 g), dry plant weight (4.58 ± 0.14 g), chlorophyll a and b (0.38 and 0.38 mg/mL), carotenoid (155.28 mg/mL), protein (443.38 μg/mL), carbohydrate (4,321.31 μg/mL) and reducing sugar (683.33 μg/mL).

Conclusion BA compost from food waste demonstrated its potential in sustainable food waste management and could be used as a fertilizer. It supports an environmentally closed-loop approach to return the food waste back to the source as plant food.

Keywords Agriculture chain, BA organic soil, Food waste, Lettuce plant, Pot plant systems

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Introduction

Urban food waste accounts for one-third of all food left over from consumption. In most parts of the world, food waste isdiscarded instead of being properly used. Untreated food waste can be seen everywhere, and it contributes to environmental pollution of water resources, air and land (Chun et al.

2020). In Thailand, 64% of total garbage is food waste, and only 2% of it is recycled. The remaining part is disposed of with municipal waste and then taken to landfill where hygiene is not a priority (Srisuwannaket and Liumpetch 2019), resulting in environmental pollution as a breeding ground for pathogens that is unhealthy to humans. There are a number of ways to tackle this problem, such as making safe food choices in supermarkets, and donating the surplus food from a hotel instead of throwing it away. However, when this is done and there are still food scraps left, the easiest approach is to separate this waste for composting. BIOAXEL Co., Ltd. has developed an innovation in recycling by converting food waste to compost. This compost is commercially marketed as "BA compost". In preliminary experiments, the BA compost was tested for its nutrient contents (total nitrogen, total phosphorus, and total potassium contents) and it satisfied the Thai Agricultural Standard for compost with 2.44% w/w total nitrogen, 1.18% w/w total phosphorus, 1.69% w/w total potassium, and carbon to nitrogen ratio of 13:1. This showed that the compost from food waste had enough nutrients for use as an organic fertilizer. However, no data on the utilization of BA compost in agriculture has been reported. The use of BA compost in plant production not only reduces waste, but also the good quality organic compost should have growth benefits to the plants. In addition, the food waste compost also reduces the use of chemically synthesized fertilizers that cause severe issues in agricultural products and to the environment (Khan et al. 2019). Green oak lettuce (*Lactuca sativa Var*. *Crispa* L.) is in the *Asteraceae* family, native to Asia and Europe, and is one of the most consumed fresh leafy salads (Chiesa et al. 2009). Lettuce is an economically valuable crop that can generate income to farmers and greatly improve the quality of life of the consumers. Lettuce is high in nutrients and contains substances that promote good health, such as vitamins A and C, minerals calcium, potassium, magnesium, sodium and iron, along with antioxidants like quercetin that is anti-carcinogenic, caffeic acid, lactupicrin, manganese, copper, zinc and selenium (Kawashima and Soares 2003). The pigments involved in the photosynthesis are chlorophyll and carotenoids (Llorach et al. 2008). Mauromicale et al. (2006) reported that the amounts of pigments in a plant are affected by plant age and nutrient availability. In general, salad vegetables are commonly grown in pots. This uses a comparatively small area and planting conditions can be controlled, and the plants are easy to move or otherwise manipulate. Moreover, it is easy to control the weeds. Yuan et al. (2012) revealed that the growth and development of lettuce plants are strongly dependent on the nitrogen, a nutrient which is required for protein, and the chloroplast in compost from food waste has a high nitrogen content. The proper dose level of BA compost is needed for its optimal use. Therefore, the main objective of this research was to study the effects of BA compost on lettuce plants during pot cultivation. BA compost was mixed with soil in different ratios, 0-70% by total volume, in order to find the proper dose of BA compost for growing lettuce plants in a pot system. The lettuces were planted for 45 days in 8-inch single plant pots before harvesting to measure growth parameters (root length, plant length, number of leaves, thickness, width of bush, fresh plant weight, dry plant weight) and nutrient contents (chlorophyll a, b, carotenoid, carbohydrate, protein, and reducing sugar).

Materials and methods

Composting process

Food waste was obtained from the canteen of Panyadee the British International School of Samui, Koh Samui, Surat Thani, Thailand. The food waste was fed into the Bioaxel machine and mixed with super bacteria in rice bran, which are the characteristic mixed *Bacillus* species active in composting.The Bioaxel machine shown in Fig. 1 is an innovation for converting food waste into compost within a short period of time, supplied by BIOAXEL Co., Ltd., Koh Sa-mui, Surat Thani, Thailand (https://www.bioaxelth.com). There is a stirring system inside the machine for aerobic fermentation and the composting temperature was controlled at 60 °C for 24 h. The moisture content of the composting materials was also controlled at 50-60% by weight. After 24 h, the fertilizer is taken out and stored in the open air until the temperature of the fertilizer pile was equal to the room temperature, which took about 5-7 days before use. The moisture of compost was reduced to 20% by weight. The obtained food waste was analyzed for nutritional values as regards contents of protein, fat and fiber according to AOAC 2001.11 (2016), AOAC 920.39 (2016) and AOAC 978.10 (2016), respectively. The food waste and the obtained compost (or BA compost by the commercial name) were tested for quality characteristics according to the Thai Agriculture Standards for compost (TAS 9503 2014) before further study. The Thai Agriculture Standards for compost include requirements on pH, electrical conductivity, organic matter, total nitrogen, total phosphorus, total potassium, and carbon to nitrogen (C: N) ratio. The microorganisms of food waste and the obtained compost were also counted using spread plate technique according to Sanders (2012). Total number of viable microorganisms, namely bacteria, yeasts or fungi were grown on the surface of culture media and divided into groups called colonies and counted for colony forming units.

Effects of the BA compost on lettuce growth

Preparation of seedlings: 100 seeds of green oak lettuce (*Lactuca sativa Var. crispa* L.) were purchased from a local market in Hat Yai, Songkhla, Thailand. The seeds were sown in the nursery in pits under plastic (11×21 inches, 200 wells) for 14 days (Pinto et al. 2014) before transplantation to 8-inch pots (4 L each by volume) (Jarsaing 2012). Planting materials: BA compost, topsoil, and coconut coir were mixed well in different ratios, with 0-70% by total volume of the BA compost as shown in Table 1, for testing effects on lettuce growth in a pot system, with commercial planting soil as baseline for comparisons. The commercial planting soil was purchased from a local tree shop in Hat Yai, Songkhla, Thailand. The commercial planting soil consisted of topsoil, manure, coconut coir and organic compost. After this, the mix was called “BA organic soil”.

The plants were grown under field conditions at the Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Songkhla 90110, Thailand, from October to November 2021 as the growing season. The lettuce plants were watered regularly for 45 days, then harvested for plant growth measurements and biochemical analyses.

Plant growth measurements and biochemical analyses

After transplanting for 45 days, the lettuces were harvested in order to measure the physiological parameters plant length, root length, number of leaves, thickness, width of bush, fresh plant weight, and dry plant weight, according to Deepika and Mubarak Ali (2020). In the harvest of the lettuces, they were cut at the ground level and immediately determined for their physiological parameters, except for the dry weight. The dry plant weight was recorded after oven drying at 65 °C for 3 days. Biochemical analyses: the harvested lettuces were analyzed for total chlorophyll, carotenoids, carbohydrate, protein, and reducing sugar, by methods explained below.

-Total chlorophyll and carotenoids: at least 4 fresh leaves were randomly sampled and crushed, and 5 g was added in a glass bottle containing 15 mL of 99.5% acetone (AR grade, RCI Labscan, Thailand) to extract the chlorophyll for 48 h. The extracts from several bottles were pooled together and centrifuged at 5,000 rpm for 15 min. The upper supernatant layer was used to measure the optical density with a UV-vis spectrophotometer (Thermo Fisher Scientific, USA) to determine the amount of chlorophyll and carotenoids. The optical density of the solution was measured at 470 nm (OD_{470}), 645 nm (OD_{645}) and 663 nm (OD_{663}). The chlorophyll a, chlorophyll b, and carotenoid contents were calculated using equations (1), (2), and (3), respectively (Dash et al. 2017; Sapkota et al. 2019).

$$\text{Chlorophyll a} = [12.7(A_{663})] - 2.69[A_{645}] \times V/ (1000 \times W) \quad (1)$$

$$\text{Chlorophyll b} = [22.9(A_{645})] - 4.68(A_{663})] \times V/ (1000 \times W) \quad (2)$$

$$\text{Carotenoid} = [1000(A_{470})] + 3.27\{(\text{Chlorophyll a} - \text{Chlorophyll b})\}] \times V/ (W \times 229) \quad (3)$$

where V is total volume of acetone used (L), W is weight of fresh leaf (g), A_{470} is absorbance at the wavelength of 470 nm, A_{645} is absorbance at 645 nm, and A_{663} is absorbance at 663 nm.

- Carbohydrate: 1 g of the mashed vegetable sample was placed in a test tube before adding 10 mL of 2.5 N HCl, mixing with a mixer for 5 min, and left for overnight at 4 °C. The mixture was then vortexed for 10 min, boiled for 1 h, and centrifuged at 10,000 rpm for 15 min to separate the sample sludge from the solution. The solution was sampled for analysis of carbohydrate content. Total soluble carbohydrates were determined with the Anthrone method. The Anthrone reagent was prepared by dissolving 0.2 g Anthrone in 100 mL concentrated sulfuric acid (98%, RCI Labscan, Thailand).

Glucose (D-glucose anhydrous, KEMAUS, Australia) was used to prepare standard solutions containing 0, 20, 40, 60, 80 and 100 µg/mL. Each solution was added with 5 mL of the Anthrone reagent and mixed well by vortexing before placing in a boiling water bath for 10 min; then cooling down to room temperature and measuring the optical density at 630 nm (Ohemeng-Ntiamoah and Datta 2018).

- Protein: 1 g of the mashed vegetable sample was extracted similarly as in the carbohydrate analysis procedure. The solution was analyzed for protein content with Lowry's method. To prepare standard solutions, 0.2, 0.4, 0.6, 0.8, and 1 mL sample of the working standard were pipetted into a series of test tubes, and 0.1 mL of the sample extract into two other test tubes. 5 mL of Lowry's reagent solution was then added and mixed before leaving the tubes at room temperature for 10 min. A 0.5 mL aliquot of the Folin–Ciocalteu reagent was then added immediately and the tubes were left at room temperature for 30 min. The absorbances were measured at 750 nm. A standard graph was drawn and used as the calibration curve to calculate the amount of protein in the sample (Ghosh et al. 2022).

- Reducing sugar: 1 g of the mashed vegetable sample was placed in a test tube before adding to 10 mL of 2.5 N HCl, mixed with a mixer for 5 min, and left overnight at 4 °C. The mixture was then vortexed for 10 min, boiled for 1 h, and centrifuged at 10,000 rpm for 15 min to separate the sample sludge from the solution. The solution was collected for analysis to determine reducing sugar. The reducing sugar was released from hydrolysis by 3, 5-dinitro salicylic acid (DNS) (Devi and Kumar 2012). For the measurement, 0.5 mL of DNS reagent was pipetted into a test tube containing 0.5 mL of plant extract (1 mg/mL) and boiled in water for 5 min. After immediately immersing the test tubes in cold water they were allowed to cool down. Glucose solution (D-glucose anhydrous, KEMAUS, Australia) was used to prepare standard solutions containing 0, 200, 400, 600, 800 and 1,000 µg/mL. Then 0.5 mL of each solution was added with 0.5 mL of DNS reagent and boiled in water for 5 min. After immediately immersing the test tubes in cold water they were allowed to cool down. Each sample was then measured for absorbance at 570 nm to draw a calibration curve for standard D-glucose, and to determine the reducing sugar content in actual samples (Neureiter et al. 2002).

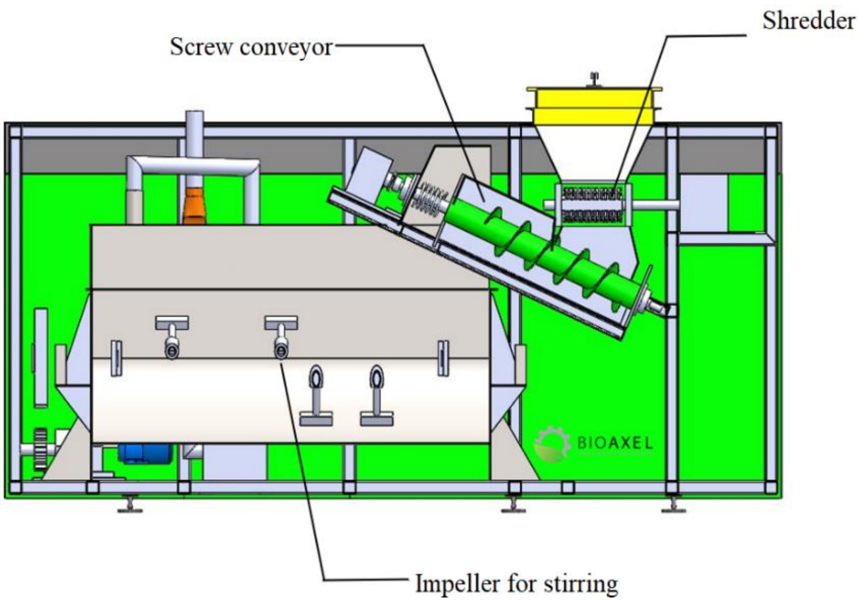

Fig. 1 Bioaxel machine for converting food waste into compost within a short period of time

Table 1 Experimental design for testing green oak lettuce growth when using BA compost

Treatment	Description (% v/v)
T1	100% Soil (control)
T2	95% Soil + 5% BA compost
T3	90% Soil + 10% BA compost
T4	70% Soil + 30% BA compost
T5	50% Soil + 50% BA compost
T6	30% Soil + 70% BA compost
T7	Commercial planting soil

Note: Soil is a mix of 70% v/v top soil and 30% v/v coconut coir; the BA compost is the food waste compost obtained from BIOAXEL Co., Ltd.; commercial planting soil was purchased from a tree shop in Hat Yai, Songkhla, Thailand.

Statistical analysis

The results are shown as mean values with standard deviations. The homogeneity of variance was assessed using the Levene test, and the normality of distributions with the Shapiro-Wilk test. The analysis of variance (ANOVA) combined with the Tukey honestly significant differences (HSD) test was used to analyze parametric data, and the Kruskal-Wallis test combined with the *post hoc* Dunn test was used to analyze nonparametric data. The significance level was set at 5% ($p < 0.05$) for all tests. The statistical analyses were conducted using the R program version 4.10.

Results and discussion

Food waste and BA compost characteristics

The composition of food waste obtained from the cafeteria was 30% rice and noodles, 45% vegetables and fruit peels, 23% meat and bones, and 2% egg shells. The nutritional values of the food waste in terms of protein, fat and fiber were 12.57% w/w, 0.76% w/w and 27.60% w/w, respectively. The physicochemical properties of the food waste and BA compost are summarized in Table 2. Not all the physiochemical properties of food waste passed the Thai Agricultural Standards for compost (TAS 9503 2014). However, when considering the nutrient contents such as total nitrogen, total phosphorus and total potassium, the food waste met these parts of the standard. It is interesting that only the moisture content and the carbon nitrogen (C: N) ratio among the parameters that did not meet the standard, so composting was necessary before use as fertilizer. Meanwhile, the physiochemical properties of the food waste after composting in the Bioaxel machine passed the Thai Agricultural Standards for compost. The food waste was broken down into the simplest components by microorganisms in composting process (Rastogi et al. 2020). Moreover, the obtained compost's nutrient contents such as total nitrogen, total phosphorus and total potassium were also higher than those in food waste due to microbial activity during composting process. Mixed *Bacillus* species in the form of super bacteria consisted of *Bacillus* sp. capable of producing amylase, protease, lipase and cellulase for digestion of food waste. They played an important activity in conversion of organic materials into stable form through the various biochemical processes, until it eventually became the fiber-rich carbon containing humus rich also in inorganics such as nitrogen, phosphorus, and potassium, corresponding to Palaniveloo et al. (2020). The counts of total number of viable microorganisms in food waste and BA compost were 89.0 × 10^{12} cfu/g and 25.8 × 10^{6} cfu/g, respectively. The finished compost had a pH about 7, which is in the pH range of mature compost (7-8 pH) (Jamaludin et al. 2017). This food waste after composting was acceptable to be used as a fertilizer. In addition, when comparing the nutrient contents data of BA compost and food waste compost from banana peel, tapioca peel, bread, fruit peel and coconut husk, it was found that the BA compost showed higher nutrient contents. The different nutrient contents indicate that the proportions of different types of food waste affects the amounts of NPK (Jamaludin et al. 2017). So, the BA compost was used in further studies on planted vegetables.

Optimum BA organic soil recipes

The growth characteristics of lettuce plants that were grown in different planting materials are shown Fig. 2. The results showed great variation in the growth characteristics between the different compost treatments. It was found that lettuce plant grown in BA compost mixed with soil in ratios from 5% to 50% by volume grew better than those in the other treatments. The increased application of the compost resulted in an increase in plant dry weight of the lettuce yield, because it enhanced the physicochemical properties of the soil (Farag et al. 2013). In the absence of fertilizer (control), the growth was comparatively poor, because the fertilizer contributed the required nutrients to the soil, corresponding to Farag et al. (2013). But at 70% fraction, the BA compost may be too concentrated to be well suited for plant growth. Moreover, on measuring the growth characteristics of lettuces, including plant length, root length, number of leaves, width of bush, thickness of plant, plant fresh weight, and plant dry weight (Table 3), it was found that 10% BA compost mixed with soil gave the highest growth yield with 30.00 ± 1.00 cm plant length, 21.83 ± 0.83 cm root length, 23.33 ± 1.15 leaves, 26.33 ± 0.58 mm width of bush, 12.47 ± 0.57 mm plant thickness, 113.03 ± 1.28 g plant fresh weight, and 4.58 ± 0.14 g plant dry weight. It was also found that the planting soil purchased at a plant shop gave the poorest growth among the treatments tested.

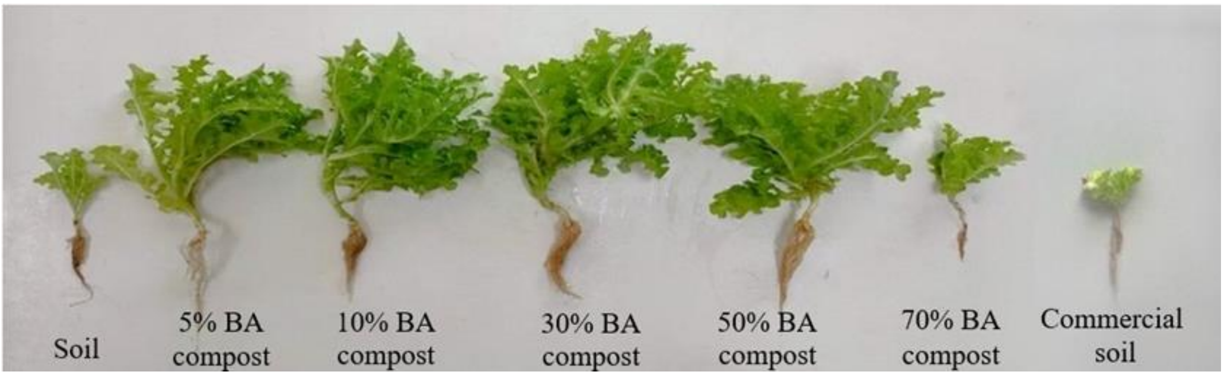

Fig. 2 Representative samples of lettuce plants grown in various pot soil formulations for 45 days

Table 2 Food waste and BA composts' characteristics

No.	Parameter	*Criteria of TAS 9503 (2014)	Food waste	BA compost	Testing method
1	pH	Not configured standard	5.11	6.66	AOAC (2000), Method 973.04
2	Total Nitrogen	≥ 1.0% w/w	1.67	2.53	AOAC (2000), Method 955.04
3	Total P_2O_5	≥ 0.5% w/w	0.88	1.40	AOAC (2000), Method 958.01
4	Total K_2O	≥ 0.5% w/w	0.60	1.43	AOAC (2000), Method 983.02
5	Organic matter, OM	≥ 20% w/w	74.27	66.31	AOAC (2000), Method 967.05
6	C/N Ratio	≤ 20:1	26:1	15:1	BS 7755 (1995)
7	Electrical Conductivity, (EC)	≤ 10 ds/m	4.31	3.42	BS EN 13038 (2000)
8	Na	≤ 1 %w/w	0.63	0.18	Official Methods of Analysis of fertilizer (1987)
9	Particle size ≤ 12.5x12.5 mm.	100% w/w	100	100	CATM01 (2000)
10	Rock and Gravels, size ≥ 5 mm.	≤ 2% w/w	Not detected	Not detected	CATM01 (2000)
11	Moisture	≤ 30% w/w	60.80	9.18	AOAC (2000), Method 950.01
12	Plastic, glass, sharp materials and other materials	Not detected	Not detected	Not detected	CATM01 (2000)
13	Arsenic	≤ 50 mg/kg	Not detected	6.211	EPA (1998), Method 7061 A
14	Cadmium	≤ 5 mg/kg	0.049	0.292	EPA (1996), Method 3050 B or equivalent
15	Chromium	≤ 300 mg/kg	0.684	16.29	EPA (1996) Method 3050 B or equivalent
16	Copper	≤ 500 mg/kg	8.594	9.087	EPA (1996), Method 3050 B or equivalent
17	Lead	≤ 500 mg/kg	0.586	1.334	EPA (1996), Method 3050 B or equivalent
18	Mercury	≤ 2 mg/kg	Not detected	Not detected	EPA (1992), Method 7471 B

Note: *Criteria of Thai Agriculture Standard for compost (TAS 9503 2014), BA compost is food waste compost obtained from Bioaxel machine, BIOAXEL Co., Ltd.

Table 3 Growth parameters of lettuce in the various pot soil formulations

Treat-ment	Plant length (cm)	Root length (cm)	Number of leaves (leaves)	Width of bush (mm)	Thickness of plant (mm)	Plant fresh weight (g)	Plant dry weight (g)
T1	6.00 ± 1.32^{de}	5.00 ± 1.00^{d}	7.67 ± 1.53^{c}	7.00 ± 1.00^{c}	3.36 ± 0.61^{c}	2.01 ± 0.68^{e}	0.32 ± 0.05^{e}
T2	20.00 ± 1.73^{b}	13.33 ± 1.53^{bc}	16.33 ± 1.53^{b}	21.33 ± 2.08^{b}	8.63 ± 0.39^{b}	32.12 ± 2.22^{c}	2.26 ± 0.31^{c}
T3	30.00 ± 1.00^{a}	21.83 ± 0.83^{a}	23.33 ± 1.15^{a}	26.33 ± 0.58^{a}	12.47 ± 0.57^{a}	113.03 ± 1.28^{a}	4.58 ± 0.14^{a}
T4	22.33 ± 3.30^{b}	15.03 ± 0.55^{b}	22.33 ± 0.58^{a}	25.33 ± 0.58^{a}	8.27 ± 0.28^{b}	90.50 ± 1.32^{b}	3.17 ± 0.08^{b}
T5	15.00 ± 2.00^{c}	13.33 ±0.58^{bc}	17.67 ± 0.58^{b}	20.67 ± 2.08^{b}	7.99 ± 0.87^{b}	26.33 ± 2.25^{d}	1.51 ± 0.19^{d}
T6	9.33 ± 1.53^{d}	2.07 ± 0.12^{e}	9.00 ± 2.00^{c}	8.67 ± 0.58^{c}	2.72 ± 1.18^{c}	3.77 ± 1.73^{e}	0.24 ± 0.09^{e}
T7	4.33 ± 0.58^{e}	12.50 ± 0.50^{c}	7.66 ± 0.58^{c}	7.33 ± 0.58^{c}	4.20 ± 0.10^{c}	2.99 ± 0.50^{e}	0.33 ± 0.03^{e}

Note: Different superscripts in the same column indicate significant differences at $p < 0.05$ according to ANOVA F-test and Tukey HSD. The values are shown as mean ± standard deviation; T1: 100% soil (control), T2: 5% BA compost, T3: 10% BA compost, T4: 30% BA compost, T5: 50% BA compost, T6: 70% BA compost, and T7: commercial soil.

Biochemical analysis

After 45 days of growing in pots, the lettuces were harvested for biochemical analyses of reducing sugar, carbohydrate, total chlorophyll a and b, carotenoids, and protein. Biochemical analysis of green oak lettuce grown with 5%, 10%, 30%, or 50% BA compost, or in commercial soil, gave the results shown in Fig. 3. The cases grown with 70% BA compost and with topsoil (control) had too low survival rates to provide sufficient samples for analysis. The highest protein (443.38 µg/mL), carbohydrate (4,321.31 µg/mL) and reducing sugar (683.33 µg/mL) contents were found in plants grown with 10% BA compost in pot soil, while the total chlorophyll a, chlorophyll b, and carotenoids were similar when grown with 10% or with 30% compost. Higher chlorophyll content in a plant may indicate stress caused by changes in endogenous hormonal balance (Marschner 1995; Rady et al. 2016), causing the treatment with 10% BA compost to give the highest growth parameters. Thus, using 10% BA compost in the soil mix suffices for growing green oak lettuce. When considering the physical and chemical properties of the soil before treatments and 45 days after planting the lettuces (Table 4), it was found that in treatment (T3) with BA compost, the soil's EC and pH had decreased from those before planting. The reduced pH was due to the accumulation of active organic acids and the cation exchange capacity of humate (Rady et al. 2016). Generally, the organic substances in soil were decomposed by the microorganism activity in the compost. While the organic matter was decomposing, it released various nutrients that the plant roots can absorb and use, and these decreased the pH. The reduction of soil EC occurred by conversion of the humate to chelate with the cations in inactive forms (Semida et al. 2015; Ouni et al. 2014). In addition, the EC is a salt concentration index and an indicator of electrolyte concentration of the solution.

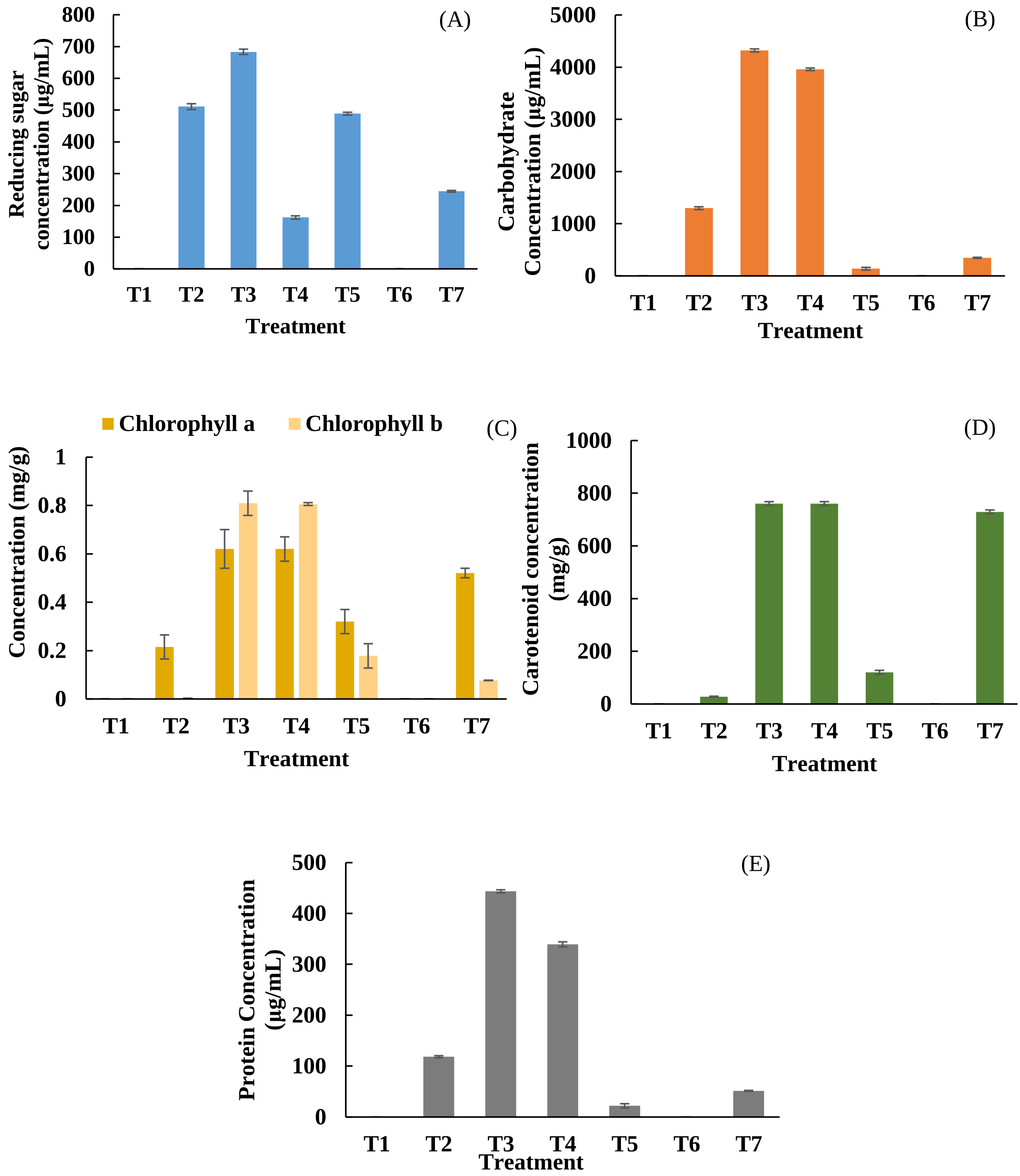

Fig. 3 Comparative assessment of components in green oak lettuce: reducing sugar (A), carbohydrate (B), total chlorophyll a and b (C), carotenoids (D), and protein (E) in the plants

T1: 100% soil (control), T2: 5% BA compost, T3: 10% BA compost, T4: 30% BA compost, T5: 50% BA compost, T6: 70% BA compost and T7: commercial planting soil.

The higher EC values hindered the absorption of nutrients by increasing the osmotic pressure of the nutrient solution while the lower EC values limited the plant growth due to the nutrient deficiency (Signore et al. 2016). The too low and too high EC values also affected the chlorophyll and sugar contents (Ding et al. 2018). This was consistent with the results of vegetables grown in the topsoil (T1) with low EC value

(< 100 µS/cm) and vegetables grown in the commercial planting soil (T7) with high EC value (> 500 µS/cm), giving the lower chlorophyll and sugar values than those of vegetables grown with BA compost. Moreover, regarding the nitrogen nutrient in planting soil, the treatment T3 showed the highest nitrogen content, resulting in the lettuce having the highest protein content as seen in Fig. 3, in accordance with Alromian (2020) who stated that nitrogen content or protein of plant was high when the planting soil had high total N content.

Table 4 Physicochemical properties of the soil before treatments and 45 days after lettuce planting

Parameter	T1		T3		T7	
	Before	**After 45 days**	**Before**	**After 45 days**	**Before**	**After 45 days**
pH	5.14	6.48	6.53	5.54	7.02	3.85
EC (µS/cm)	87.3	58.6	509	316	258	1300
Total Nitrogen (% w/w)	0.02	0.04	0.26	0.17	0.09	0.27
Total P_2O_5 (% w/w)	0.20	0.03	0.26	0.12	0.06	0.14
Total K_2O (% w/w)	0.16	0.01	0.60	0.13	0.18	0.61
Carbon (% w/w)	0.75	0.91	4.30	3.90	7.16	16.08

Note: T1 is 100% soil (control), T3 is 10% BA compost and T7 is commercial soil.

Conclusion

The utilization of food waste in compost prepared with the Bioaxel machine was investigated for the biochemical nutrients and the growth effects on lettuce, with varied mixing proportions by volume with soil, and in a comparison with a commercial planting soil. Among the tested treatments, 10% food waste compost or "BA compost" (commercial name) in the pot soil exhibited the highest growth and the highest levels of biochemical nutrients in the plants. When comparing the results with a commercial planting soil, it was found that the soil mix with BA compost gave superior growth and nutrient contents of lettuces. The compost made from food waste thus could be a sustainable waste recycling method to manage household wet waste, and this returns nutrients to the agriculture chain via an efficient fertilizer, reducing the costs of using chemical fertilizers.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest associated with this study.

References

Alromian FM (2020) Effect of type of compost and application rate on growth and quality of lettuce plant. J Plant Nut 43(3):1-13. https://doi.org/10.1080/01904167.2020.1793185

AOAC (2016) Official methods of analysis fat (crude) or ether extract in animal feed. Method 920.39. Association of Official Analytical Chemists. USA

AOAC (2016) Official methods of analysis fiber (crude) in animal feed and pet food. Method 978.10. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis nitrogen (total) in fertilizers. Method 955.04. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis organic matter in peat. Method 967.05. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis pH of peat. Method 973.04. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis phosphorus (total) in fertilizers. Method 958.01. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis potassium (total) in fertilizers. Method 983.02. Association of Official Analytical Chemists. USA

AOAC (2016) Official methods of analysis protein (crude) in animal feed, forage (plant tissue), grain and oil seeds. Method 2001.11. Association of Official Analytical Chemists. USA

AOAC (2000) Official methods of analysis water (total) in fertilizers. Method 950.01. Association of Official Analytical Chemists. USA

BS 7755 (1995) British standard soil quality. Chemical methods. Determination of organic and total carbon after dry combustion (elementary analysis). British Standards Institution

BS EN 13038 (2000) British standard soil improvers and growing media. Determination of electrical conductivity. British Standards Institution

CATM 01 (2000) A method to determine particle size distribution of physical contaminants in composted organic materials. Compost Association

Chiesa A, Mayorga I, Leon A (2009) Quality of fresh cut lettuce (*Lactuca sativa* L.) as affected by lettuce genotype, nitrogen fertilization and crop season. Adv Hort Sci 23:143-149

Chun Ng CW, Ismail AF, Zaini Makhtar MM, Fikri Jamaluddin MN, Tajarudin HA (2020) Conversion of food waste via two-stage fermentation to controllable chicken feed nutrients by local isolated microorganism. Int J Recycl Org Waste Agric 9:33–47. https://doi.org/10.30486/IJROWA.2020.671208

Dash S, Dixit S, Sahoo S (2017) Phytochemical and biochemical characterizations from leaf extracts from *Azadirachta Indica*: An important medicinal plant. Biochem Anal Biochem 06 (January) 6(2):2-6. https://doi.org/10.4172/2161-1009.1000323

Deepika P, MubarakAli D (2020) Production and assessment of microalgal liquid fertilizer for the enhanced growth of four crop plants. Biocat aAgricl Biotechnol 28 (September): 101701

Devi MC, Kumar MS (2012) Production, optimization and partial purification of cellulase by *Aspergillus niger* fermented with paper and timber sawmill industrial wastes. J Microbiol Biotechnol Res 2 (1):120–128

Ding X, Jiang Y, Zhao H, Guo D, He L, Liu F, Zhou Q, Nandwani D, Hui D, Yu J (2018) Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (*Brassica campestris* L. ssp. *Chinensis*) in a hydroponic system. 1-15. https://doi.org/10.1371/journal.pone.0202090

EPA (1992) Mercury in solid or semisolid waste quantity analysis method (Manual Cold – Vapor Technique). Methods 7471B.United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2015-12/documents/7471b.pdf. Accessed 20 July2022

EPA (1996) Acid digestion of sediments, sledges and soils. Method 3050B. United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2015-06/documents/epa-3050b.pdf. Accessed 20 July 2022

EPA Methods 7061(1998) Arsenic quantity analysis method (Atomic Absorption, Gaseous Hydride). United States Environmental Protection Agency. https://www.epa.gov/sites/default/files/2015-12/documents/7061a.pdf. Accessed 20 July2022

Farag AAA, Abdrabbo MAA, Abd-Elmoniem, EM (2013) Using different nitrogen and compost levels on lettuce grown in coconut fiber. J Hortic For 5(2):21–8

Ghosh P, Saha M, Chatterjee S (2020) Quantification of total protein content from some traditionally used edible plant leaves: A comparative study. J Med Plants Stud 8(4):166-170. https://doi.org/10.22271/plants.2020.v8.i4c.1164

Jamaludin SN, Kadir AA, Azhari NW (2017) Study on NPK performance in food waste composting by using agricultural fermentation. MATEC Web Conf 103:05015. https://doi.org/10.1051/matecconf/201710305015

Jarsaing K (2012) Nitrate accumulation on green oak Bachelor degree of science Biology. Faculty of Science and Technology.Rajamangala University of Technology Thanyaburi. http://www.research.rmutt.ac.th/wp-content/uploads/2014/03/127208.pdf. Accessed 20 July 2022

Kawashima ML, Soares VML (2003) Mineral profile of raw and cooked leafy vegetables consumed in southern brazil. J Food Compos Anal 16 (5):605–11. https://doi.org/10.1016/S0889-1575(03)00057-7

Khan S, Yu H, Li Q, Gao Y, Sallam BN, Wang H, Liu P, Jiang W (2019) Exogenous application of amino acids improves the growth and yield of lettuce by enhancing photosynthetic assimilation and nutrient availability. Agron 9:266-282. https://doi.org/10.3390/agronomy9050266

Llorach R, Martínez-Sánchez A, Tomás-Barberán A, Gil I, Ferreres F (2008) Characterization of polyphenols and antioxidant properties of five lettuce varieties and escarole. Food Chem 108 (3): 1028–38. https://doi.org/10.1016/j.foodchem.2007.11.032

Marschner H (1995) Mineral nutrition of higher plants, 2nd edn. Academic Press Publication, New York, pp 559–579

Mauromicale G, Ierna A, Marchese M (2006) Chlorophyll fluorescence and chlorophyll content in field-grown potato as affected by nitrogen supply, genotype, and plant age. Photosynthetica 44 (March):76–82. https://doi.org/10.1007/s11099-005-0161-4

Neureiter M, Danner H, Thomasser C, Saidi B, Braun R (2002) Dilute-acid hydrolysis of sugarcane bagasse at varying condition. Biochem Biotechnol 98/100(1/3), 49-58. https://doi.org/10.1385/ABAB:98-100:1-9:49

Official Methods of Analysis of fertilizer (1987) National Institute of Agro-Environmental Sciences, Ministry of Agriculture, Forestry, and Fisheries 141 pages

Ohemeng-Ntiamoah J, Datta T (2018) Evaluating analytical methods for the characterization of lipids, proteins and carbohydrates in organic substrates for anaerobic co-digestion. Bioresour Technol 247: 697-704. http://dx.doi.org/10.1016/j.biortech.2017.09.154

Ouni Y, Ghnaya T, Montemurro F, Abdelly Ch, Lakhdar A (2014) The role of humic substances in mitigating the harmful effects of soil salinity and improve plant productivity. Int J Plant Prod 8(3):353–374. https://doi.org/10.22069/IJPP.2014.1614

Palaniveloo K, Amran MA, Norhashim NA, Mohamad-Fauzi N, Peng-Hui, F, Hui-Wen L, Kai-Lin Y, Jiale L, Chian-Yee MG, Jing-Yi L, Gunasekaran B, Razak SA (2020) Food waste composting and microbial community structure profiling. Processes 8: 723-753. https://doi.org/10.3390/pr8060723

Pinto E, Almeida AA, Aguiar AARM, Ferreira IMPLVO (2014) Changes in macrominerals, trace elements and pigments content during lettuce (*Lactuca sativa* L.) growth: Influence of soil composition. Food Chem 152: 603 – 611. https://doi.org/10.1016/j.foodchem.2013.12.023

Rady MM, Semida WM, Hemida KA, Abdelhamid MT (2016) The effect of compost on growth and yield of *Phaseolus vulgaris* plants grown under saline soil. Int J Recycl Org Waste Agric 5:311-321. https://doi.org/10.1007/s40093-016-0141-7

Rastogi M, Nandal M, Khosla B (2020) Microbes as vital additives for solid waste composting. J Exp Biol Ecol. 6: e03343. http://dx.doi.org/10.1016/j.heliyon.2020.e03343

Sanders ER (2012) Aseptic laboratory techniques: Plating methods. J Vis Exp 63: 3064-3082. https://dx.doi.org/10.3791/3064

Sapkota TB, Vetter SH, Jat ML, Sirohi S, Shirsath PB, Singh R (2019) Cost-effective opportunities for climate change mitigation in Indian agriculture. Sci Total Envi 655:1342–1354

Semida WM, Rady MM, Abd El-Mageed TA, Howladar SM, Abdelhamid MT (2015) Alleviation of cadmium toxicity in common bean (*Phaseolus vulgaris* L.) plants by the exogenous application of salicylic acid. J Hortic Sci Biotechnol 90(1):83–91. https://doi.org/10.1080/14620316.2015.11513157

Signore A, Serio F, Santamaria P (2016) A targeted management of the nutrient solution in a soilless tomato crop according to plant needs. Front Plant Sci 7:391-406. https://doi.org/10.3389/fpls.2016.00391

Srisuwannaket T, Liumpetch C (2019) Tackling Thailand's food-waste crisis. Thailand Development Research Institute. https://tdri.or.th/en/2019/10/tackling-thailands-food-waste-crisis

TAS 9503 (2014) Thai Agricultural Standard. Compost. National Bureau of Agricultural Commodity and Food Standards. Ministry of Agriculture and Cooperatives. Royal Gazette.122 Section 114Dc Effects of media mixed with local residues in Narathiwat Provincefor *lactuca sativa var. crispa* L. growth. Khon Kaen Agr J 46 1156-1160

Yuan L, Yuan Y, Du J, Sun J, Guo S (2012) Effects of 24-epibrassinolide on nitrogen metabolism in cucumber seedlings under Ca (NO (3)) (2) stress. Plant Physiol Biochem 61:29–35. http://dx.doi.org/10.1016/j.plaphy.2012.09.004