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# Effect of Biosynthesized Silver Nanoparticles Using Banana Peels (AgNP) on Algae Composting

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**Abstract**
Numerous applications of silver nanoparticles (AgNPs) have been found in the areas of agriculture as well as in cosmetics, textiles, and medicine. The potential of AgNPs in the algae composting process has to be further investigated because there is a lack of information regarding their impact in this process. The production of pure and well-defined nanoparticles through physical and chemical methods is achievable, but these methods are costly and hazardous to the environment. In this study, AgNPs were synthesized from banana peel extract (BPE) and utilized as an enhancer in algae composting. BPE-AgNPs were produced when the reductive compounds in BPE interacted with $Ag^+$ in $AgNO_3$. UV-vis spectroscopy was used to monitor the synthesis of colloidal AgNPs whereas Fourier-Transform infrared spectroscopy (FTIR) was used to identify the functional groups in AgNPs. At low concentration of 2 to 100uL/L, the effect of BPE-AgNPs as an enhancer in algae composting were investigated based on the physical parameter, mineral elements and humic substances analysis, and the results were compared to compost without BPE-AgNPs. This study showed that BPE-AgNPs have been successfully produced, and this has been confirmed by a single peak of Uv-Vis spectrum at 428nm. The colour of the mixture solution changed to reddish brown after incubation at 70°C for 72 hours. Several functional groups responsible for the reduction process of $Ag^+$ to AgNPs were validated by the FTIR analysis of BPE-AgNPs. The addition of BPE-AgNPs in algae composting from 2µL/L concentration had insignificant effect on pH, temperature, moisture content and soil electrical conductivity. Additionally, after 12 days of composting, the NPK content of the compost sample treated BPE-AgNPs did not show any significant difference compared to control without BPE-AgNPs. The magnesium content in compost samples treated BPE-AgNPs was sufficient for healthy plant growth. Due to the small amount and surface transformation of BPE-AgNPs, no silver was found in the compost sample treated BPE-AgNPs. Compost sample treated 100uL/L BPE-AgNPs was immature with a low HA/FA ratio, indicating the short composting period was taken. Future expansion of this study to investigate the effect of BPE-AgNPs on algae composting is possible with the addition of numerous improvements.

**Keywords:** Silver nanoparticles; AgNPs; Banana peels; Algae; Composting

## Introduction

The extensive use of chemical fertilizers to increase the crop yield in agricultural field was shown to cause eutrophication, which was characterized by excessive algal and plant growth in a water body [1]. Chemical fertilizers contain minerals and nutrients, like nitrogen and phosphorus that are necessary for the growth of algae and plants [1]. Eutrophication has a severe impact on biodiversity and ecosystem, including reduce the oxygen levels in the water and eventually cause the death of aquatic organisms [2][3]. Generally, algae waste from eutrophication can be managed by composting it, which can help to increase the crop yield in a local, sustainable and safe way [4]. This is because algae contain macronutrients, micronutrients, vitamins, amino acids and plant-growth promoting compounds, which are the good substrates for composting [4].

Silver nanoparticles (AgNPs), which have size in range of 1 nm and 100nm, is gaining more attention nowadays due to its possible applications in a variety of industries, such as cosmetics, medicine and textile fields [5]. However, conventional methods of producing AgNPs, including chemical and physical methods are usually expensive and poisonous. Biological method using fruit peels on the other hand, is considered as an alternative way to synthesize the AgNPs because it is economical and environmentally friendly [5]. The biological components in fruit peels acts as the reducing agents and reduce the silver ion ($Ag^+$) to the silver nanoparticles ($Ag^0$) [6]. AgNPs are widely used in agricultural techniques, such as nanopesticides, nanofertilizers and nanobiosensors due to its antibacterial and antifungal properties [7]. Hence, adding AgNPs into the composting is believed to have some interesting findings on composting performance.

Although recent research focused on the effect of chemically synthesized nanoparticles on waste composting, the effect of AgNPs synthesized from fruit peels on waste composting is one of the common interests too. Therefore, the present studies aim to investigate the effect of biosynthesized silver nanoparticles using banana peels (BPE-AgNPs) on algae composting in term of physical parameters, mineral elements and humic substances analysis.

## Materials and methods

### Biosynthesis of BPE-AgNPs

Collected banana peels were washed thoroughly by being rinsed twice with ultrapure water The washed banana peels were cut into smaller pieces and dried in a hot air oven at 55°C for 24 hours. 2g of banana peels powder was then boiled in 100mL of distilled water at 90°C for 20 minutes. The banana peel extract (BPE) was filtrated through Whatman No.1 filter paper after boiling and it was stored at 4°C for further use. On the other hand, silver nitrate ($AgNO_3$) was used as a precursor in the synthesis of BPE-AgNPs. The highest yield of BPE-AgNPs was produced by mixing 3mL of BPE and 25 mL of 2.5mM $AgNO_3$ and incubated at 70°C for 72 hours [8].

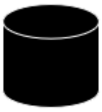
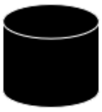
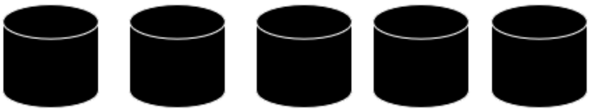
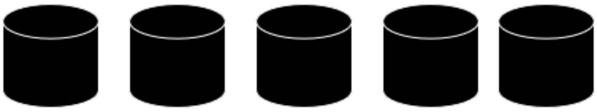
### Characterization of BPE-AgNPs

The characterization of BPE-AgNPs was performed using Ultraviolet-visible (UV-Vis) spectroscopy and Fourier Transform Infrared Spectroscopy (FTIR) to confirm the presence of BPE-AgNPs in the solution. UV-vis spectroscopy was carried out to characterize and monitor the formation of BPE-AgNPs in the solution based on its SPR peak. 3mL of sample that contains diluted BPE-AgNPs was measured in the range 350-750nm by using the Perkin Elmer SP-UV 300 spectrophotometer, USA [9]. FTIR was used to identify the chemical bonds and functional groups in BPE-AgNPs in the range of 500–4000 $cm^{-1}$ using TGA Q500 Fourier Transform Infrared Spectroscopy, UK [8].

### Algal composting process

Algae waste was collected from the sewage treatment plant (STR) at Kolej 9, UTM. The dried leaves were chopped and grinded to smaller particles by using a blender. Four treatments of composting process (Table 1) were carried out in the composting basket by using layering technique. The first (top) layer in composting baskets was dried leaves, second layer was algae waste and followed by organic soil. All composting materials were in a ratio of 1:1:1 in the basket and manually mixed for daily. The composting basket was covered by an insect net to protect the compost from insects. The composting process for all composting basket was terminated at day 12.

**Table 1:** The schematic diagram for the all four treatments in the composting basket

| | |
|---|---|
| **Treatment 1** |  Control without waste |
| **Treatment 2** |  Control without BPE-AgNPs or $AgNO_3$ |
| **Treatment 3** **(Different concentration of BPE-AgNPs)** |  2 ul/l, 10 ul/l, 20 ul/l, 50 ul/l, 100 ul/l |
| **Treatment 4** **(Different concentration of $AgNO_3$)** |  2 ul/l, 10 ul/l, 20 ul/l, 50 ul/l, 100 ul/l |

**Physical parameter, mineral elements and humic substances analysis**

Composting performance of each compost were measured using physical parameter, mineral elements and humic substances analysis. Physical parameters, including temperature, pH value, moisture content (MC) and soil electrical conductivity of each compost were measured and recorded every day, from day 1 to 12, by using direct soil tester (Hanna GroLine brand, UK) and 2 in 1 soil pH & moisture meter (TAKEMURA, Japan). The three mineral elements, which were nitrogen (N), phosphorus (P) and potassium (K) of each compost were measured by using a soil NPK sensor (VBESTLIFR, China) for daily as well.

Following the composting process, only the final compost with significant physical change were sent for mineral elements (silver and magnesium) and humic substances analysis. In the silver and magnesium content analysis, 30g of final compost was dried, homogenized using food processor and sent to Chemistry Anaysis Unit, Universiti Teknologi Malaysia (UTM) for Inductively Coupled Plasma Optical Emission spectroscopy (ICP-OES) test. The ICP-OES test was performed using Perkin Elmer AVIO 200 ICP-OES In-house method, USA. Humic substances analysis was performed to measure the humic acid (HA) and fulvic acid (FA) concentration in the final composts. 30g of final compost was weighed and sent to Soil Chemistry Laboratory, Forest Research Institute Malaysia (FRIM), Kepong, Selangor for this analysis.

**Results and discussion**

**Production and characterization of BPE-AgNPs**

Preliminary synthesis of BPE-AgNPs was confirmed by the colour change of solution after addition of BPE and $AgNO_3$ at 70°C for 72 hours. The mixture solution was changed from pale yellow to reddish brown after 72 hours (Figure 1a). The BPE-AgNPs formation in the solution was due to the functional group of reductive compounds, like cellulose, hemicellulose and pectin in BPE reduced $Ag^+$ into metallic silver $Ag^0$ [10][11].

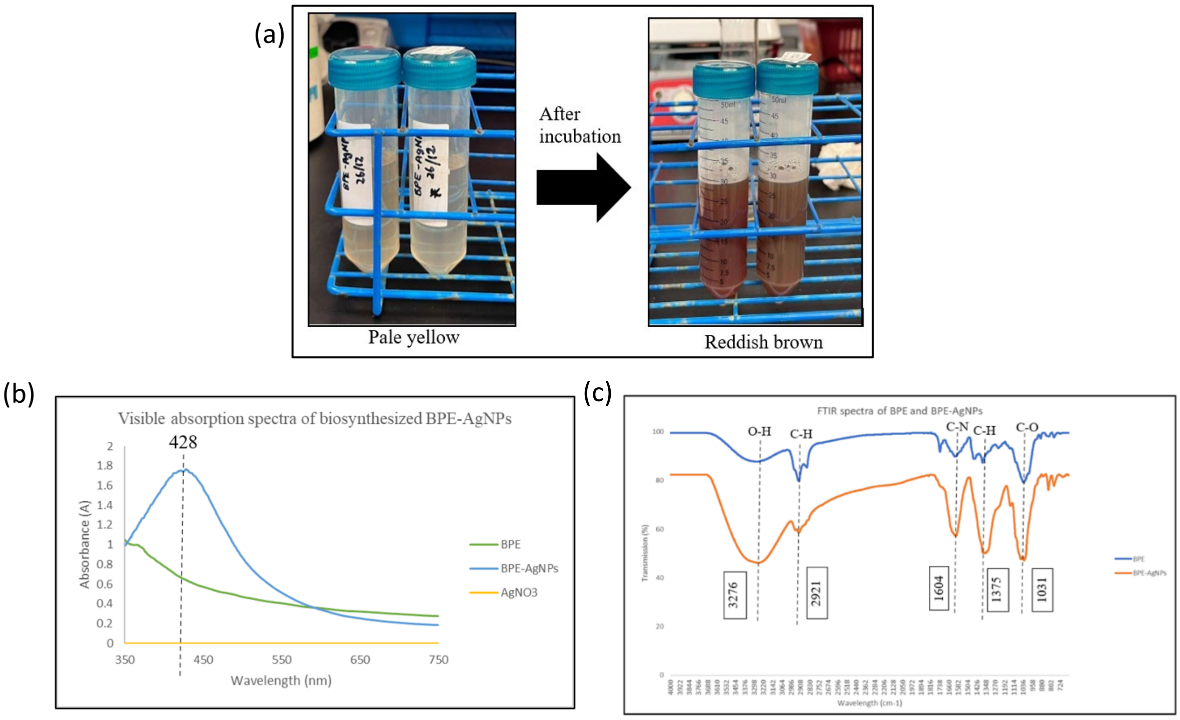



**Figure 1** Characterization of BPE-AgNPs; (a) Colour change of solution after addition BPE and $AgNO_3$, (b) Visible spectra of BPE, BPE-AgNPs and $AgNO_3$, (c) FTIR spectra of BPE and BPE-AgNPs.

In order to further confirm the successful formation of BPE-AgNPs, the sample above was then subjected for the Uv-Vis spectroscopy and FTIR analysis. The SPR peak of synthesized BPE-AgNPs was determined by Uv-Vis spectroscopy analysis. The existence of a SPR peak at 428 nm indicated the formation of BPE-AgNPs because the common SPR peak for AgNPs was in the range of 400-500 nm (Figure 1b) [10].

FTIR analysis was used to identify the chemical bonds and functional groups of BPE-AgNPs. In Figure 1c, it was clearly shown that the FTIR spectra of both BPE and BPE-AgNPs showed a similar pattern, at 3276, 2921, 1604, 1375, 1031 $cm^{-1}$ (Figure 1c). This indicated the presence of O-H stretching vibrations of phenols or alcohol, C-H of alkane, C-N of aliphatic amines or C-O of carboxylic acid/ether/ester/alcohol, which were responsible for reducing $Ag^+$ to $Ag^0$ and stabilizing BPE-AgNPs [8].

**Physical parameter analysis**

**pH value**

pH is one of the important physical parameters to analyze the compost maturity and stability made with various type of waste [12]. Figure 2a showed all compost samples have an increment of pH from 6.5 to 7 from day 1 to 12. Whereas, control sample, which was not added algae waste showed stable pH at pH 7 from day 1 to 12. The pH of compost samples moves towards the alkaline side over day was due to the production of the alkaline, like ammonium during the decomposition and microbial activity in the composting process [13].

**Temperature**

Temperature can be used to determine the microbial activity in the compost samples [14]. Figure 2b showed all compost samples displayed a similar pattern in the temperature, which was increased over day and started to decrease at day 6. The temperature increased from day 1 to 6 was due to the mesophilic and thermophilic microorganisms produced a lot of heat energy during the organic matter degradation process [15]. When the available organic molecules in the compost samples have been used up, the microbial activity was slowed down, causing decline in temperature at day 6 [16].

**Moisture content**

Moisture content (MC) is crucial moving the dissolved nutrients needed for the microbes' physiological and metabolic activities in composting process [17]. Figure 2c displayed all compost samples have a decline trend in MC from day 1 to 12. The reduction of MC from day 1 to day 12 was due to the heat release from decomposition and microbial activity that caused the vaporization of water in the soil [18].

**Soil electrical conductivity**

Soil electrical conductivity can be used to determine the conductance and salinity level of the compost [19]. Figure 2d displayed all compost samples have an increment of soil electrical conductivity from day 1 to day 12. The increase of soil electrical conductivity from day 1 to 12 was due to the loss of organic matter and salt release, which cannot be mitigated by salt leaching or binding to stable organic complexes binding from the decomposition activity [19].

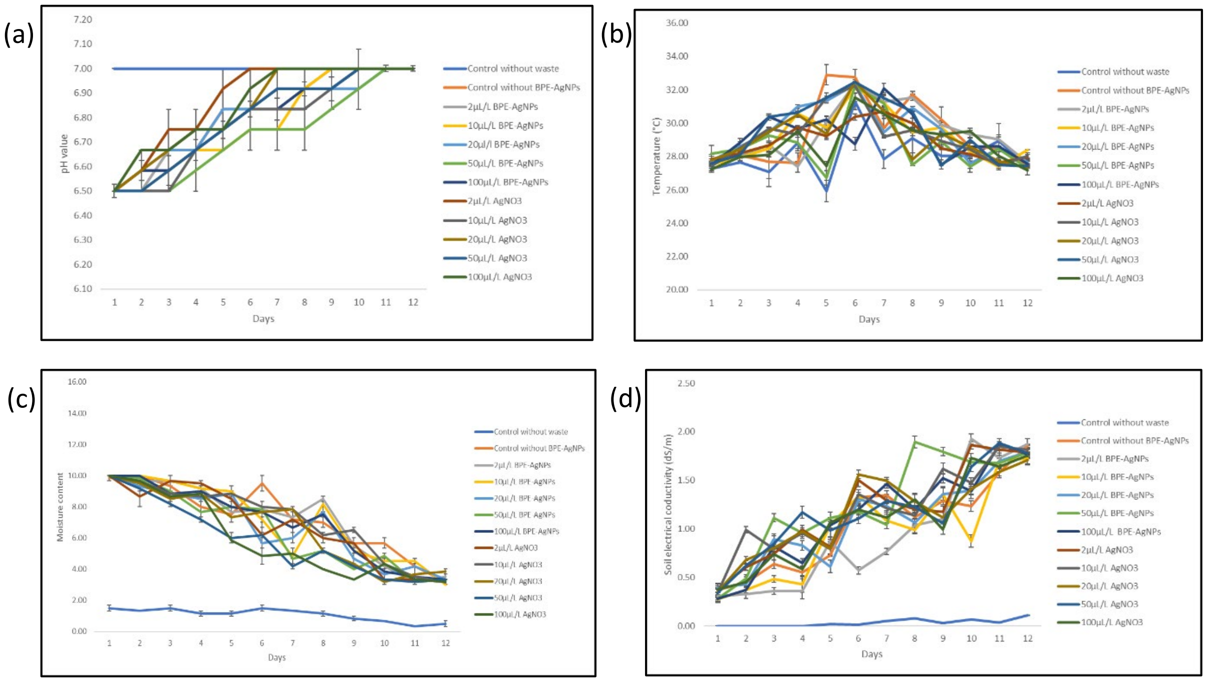



**Figure 2** Average changes in different physical parameters of compost samples from day 1 to 12; (a) pH value, (b) temperature, (c) moisture content, (d) soil electrical conductivity.

**Mineral elements analysis**

Nitrogen (N), phosphorus (P) and potassium (K) are the three essential nutrient content that required for the healthy plant growth. Hence, a good quality and mature compost should be containing these three NPK mineral elements [20]. In this study, we observed that the NPK contents in all compost samples increased from day 1 to 12 (Figure 3). However, the control without waste has the significant lowest NPK contents from day 1 to 12, if compared to other compost samples.

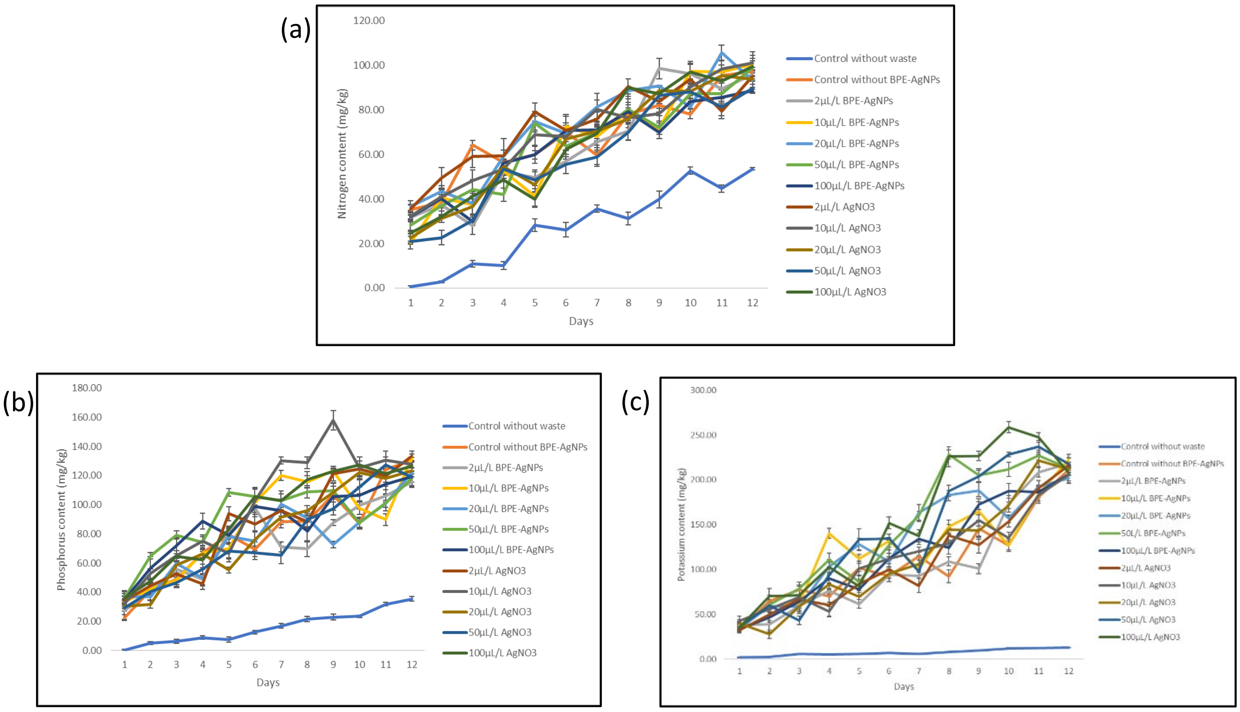



**Figure 3** Average changes in NPK contents of compost samples from day 1 to 12; (a) N content, (b) P content, (c) K content.

The increase of N content in the compost was mainly due to the release of N from the microbial activity [21]. On the other hand, the increase of P and K content in the compost was due to the presence of phosphate and potassium solubilizing microbes that have the ability to convert the insoluble form of P and K into the soluble form by releasing the organic acid [22][23]. The lowest NPK content in control without waste from day 1 to 12 was due to no algae waste was added and low microbial activity.

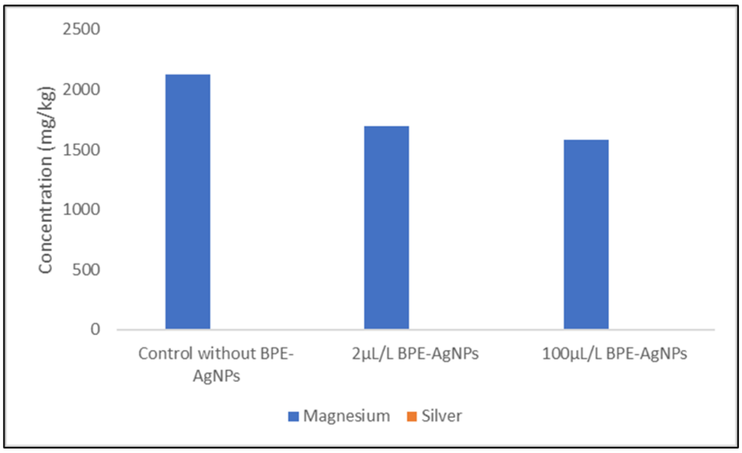



**Figure 4** Magnesium and silver concentration in three types of final composts.

Besides NPK, magnesium and silver were the other mineral elements that used to determine the compost maturity as they are important for the plant growth as well. In this study, we observed that the final compost samples treated BPE-AgNPs had sufficient magnesium concentration for healthy plant grow (Figure 4). However, silver was not detected in three final composts (Figure 4). The magnesium concentration for compost samples treated BPE-AgNPs was acceptable as they were in the normal range of 1500 to 3500 mg/kg for healthy plant growth [18]. Meanwhile, the undetected of silver in the final composts was mainly due to the little amount of BPE-AgNPs used in this study and the surface transformation of BPE-AgNPs to the other less toxic compounds, like AgCl and $Ag_2S$ [24][25].

**Humic substances analysis**

Humic substances, including humic acid (HA) and fulvic acid (FA) content, were used to measure the compost stability [26]. In this study, we observed the presence of HA and FA content in the final composts. Additionally, we also found the FA concentration was higher than HA concentration, with a ratio HA/RA of 1:10 (0.1) in each final composts (Figure 5).

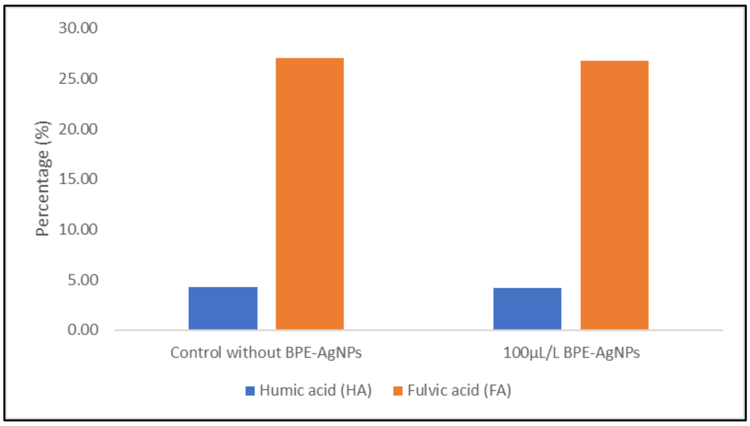



**Figure 5** Humic acid (HA) and fulvic acid (FA) content in two types of final compost.

The high FA concentration and HA/FA ratio of 0.1 in the final composts indicated the two final composts were immature due to a short composting process period. This was because a good quality and mature final compost should have high HA concentration but low FA concentration, with a HA/FA ratio higher than 1 [26][27].

**Conclusion**

In a nutshell, BPE was effective in acting as a reducing and stabilizing agent in the biosynthesis of BPE-AgNPs. The SPR peak of the BPE-AgNPs in this study was observed to be at 428nm, and the FTIR result showed that the functional groups in BPE were responsible for reducing $Ag^+$ to the AgNPs. BPE therefore had the potential to serve as an alternative to the chemical and physical methods for producing AgNPs. This study also revealed that after 12 days of composting process, the amount of BPE-AgNPs (2, 10, 20, 50 and 100uL/L) had insignificant impact on the algae composting in terms of physical parameter and mineral elements (N, P, K) analysis. Furthermore, due to the small amount and surface transformation of BPE-AgNPs, compost sample treated with BPE-AgNPs did not show any effect on soil silver contents. The magnesium content in compost sample treated 100uL/L BPE-AgNPs was suitable for healthy plant growth and the low HA/FA ratio in the compost sample treated with 100uL/L BPE-AgNPs suggested that compost was not yet mature. Further investigation on the effect of higher BPE-AgNPs concentration on algae composting with the microbiological and statistical analysis are recommended to confirm the impact of BPE-AgNPs on algae composting.

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