Algae Involved Generation of Compost

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Abstract

This research investigated the potential application of blue-green algae to improve the quality of composts generated from multiple waste streams including- fly ash, fish waste, and sludge from a local wastewater treatment plant. The alga strain used is called Anabaena 387, which was obtained from the Canadian Phycological Culture Centre. Different mixture ratio of fly ash, fish waste compost, sludge and algae and different reaction period were tested to generate different levels of compost products. The parameters including trace elements concentration, carbon to nitrogen ratio, pH level, moisture content, organic matter, and germination index were monitored for evaluating the quality of composts. Three different levels of compost were generated, which are Type AA, A, and B. The algae treated compost could be used as an amendment for agriculture application.

Keywords: algae, compost, fish waste compost, fly ash, sewage.

Introduction

Compost as a soil amendment is widely used in agricultural activities. It can improve the soil qualities by adding more nutrients, organic matters, and adjusting the carbon to nitrogen ratio of the soil (Epstein, 1997). Because of the harsh environment and barren soil condition in Newfoundland and Labrador (NL), the generation of applicable compost products through using local resources including waste streams are getting more and more attention.

Sludge comes from the wastewater treatment plant is always a serious environmental concern in the City of St John's. Usually after the 'dewater process' the remaining solids are compressed and disposed into the landfill directly. These wastes thus account for a large area in the landfill (Chen *et al.*, 2012; Werther and Ogada, 1999). Basically, dried sewage is bio-solid or organic material which can be further biodegraded and then has a potential to be used as a compost amendment for agricultural purposes.

Fly ash is also a waste stream generated in NL. It is the main by-product generated by coal-burned power plants (Ahmaruzzaman, 2009; Scheetz and Earle, 1998; Zacco *et al.*, 2014). Fly ash consists of fine particles ranging in size from 2 μm to 10 μm. Because of its physical properties, the improper management of fly ash would lead to air pollution and human respiratory disease (Scheetz and Earle, 1998; Wang and Wu, 2006). One important characteristic of fly ash that can be taken advantage of is the high organic matter content, which is upwards of 95 %. If the fly ash can be utilized as an amendment for the compost product, it is not only providing an environmentally friendly method for recycling fly ash but also generating useful soil ameliorant.

Nowadays, *fish waste* is considered as perfect composting material (Lopez-Mosquera, 2011). Fishery in NL has a long history and it plays a very important role in the economic development. The fish wastes generated from the seafood manufacturer firm are usually enriched in nutrients, especially nitrogen and phosphorus and the wastes can be decomposed quickly (Colon, 2010; Lopez-Mosquera, 2011; Neklyudov, 2005). These properties make fish waste a very good fertilizer for agricultural application.

The ‘Anabaena’ is local available blue - green algae, which can cause blooms. Such a bloom has been observed in several Northeast Avalon ponds in 2007 (Government of NL, 2007). Alga has the capacity of bioremediation (Sivakumar, 2012; Takacova, 2014) so that it might be applicable to improve the chemical qualities of compost.

In this research, the Anabaena was used to improve the qualities of compost generated by using waste streams including sludge, fly ash, and fish waste compost after extraction for other purposes. Three different levels of compost were generated, which are Type AA, A, and B. The algae treated compost could be used as an amendment for agriculture application.

Methodology

Algae Culturing

The blue-green algae has been used in this paper is called Anabaena strain 387, which can be obtained from the Canadian Phycological Culture Centre (CPCC) list of cultures (CPCC, 2011) and then be cultured in the lab. Modified Bold’s Basal Medium (3NBBM) (Andersen, 2005) was selected as the optimal medium for culturing Anabaena.

Characterization of Raw Materials and Generated Composts

In order to have a better understanding of the sources used in this research, characterizations for raw materials – fly ash, sewage, and fish waste compost was conducted based on the following six parameter: carbon to nitrogen ratio (C:N), germination index (GI), moisture content, organic matter (OM), pH and trace element. All parameters are tested following the standard methods (Agnew, 2003; Lopez-Mosquera, 2011; Seal, 2012; Wichuk, 2010). For each sample, all parameters were tested three times in parallel and the mean value of three results was used for analysis.

Determination of Mixing Ratio

Based on the characterizations of each raw material, eight mixture ratios (R) – R1, R2, R3, R4, R5, R6, R7 and R8 were established. After mixing, the same 6 parameters were tested again. According to the classification criteria provided by BNQ (2005), some of these eight ratios were qualified for Type B compost, but other ratios are not qualified. The low chemical quality compost would undergo the algal biodegradation treatment.

Determination of Operation Period

Anabaena is used to improve the chemical characteristics of the 'non-qualified' mixtures. The non-qualified ratios experienced an algal biodegradation process. Day one (D1) represents the first day of the biodegradation period. As the biodegradation process moved on, the six parameters were tested all six days until some parameters, such as C:N and OM content, until stable values were reached. At the end of this biodegradation process, the optimal reaction days were clarified. Meanwhile, in order to find the effects of different doses of algae, three doses – 5 mL, 10 mL, and 20 mL with 20 g samples were conducted in parallel. Therefore, six runs were established and their representations were: Run 1 means 20 g of Ratio 7 mixture samples with 5 mL algal solution; Run 2 means 20 g of Ratio 7 mixture samples with 10 mL algal solution; Run 3 means 20 g of Ratio 7 mixture samples with 20 mL algal solution; Run 4 means 20 g of Ratio 8 mixture samples with 5 mL algal solution; Run 5 means 20 g of Ratio 8 mixture samples with 10 mL algal solution and Run 6 means 20 g of Ratio 8 mixture samples with 20 mL algal solution.

<u>Compost Classification</u>

After the biodegradation process, different quality compost products were generated. According to the classification criteria provided by Bureau de normalization du Quebec (BNQ, 2005) and Canadian Council of Ministers of the Environment (CCME, 1996), qualified compost products were classified into Type AA, Type A and Type B, respectively. While some samples were still not qualified for either.

Results and Discussion

<u>Characterization of Raw Materials</u>

Characteristics of fly ash, sewage, and fish waste compost are shown in the Table 1 and Table 2.

Table 1. Raw Material Index.

Raw Materials	C:N	GI (%)	Moisture (%)	Organic Matters (%)	pH	Trace Elements
Standards	<25	>90	<60	Type AA >50; Type A >40; Type B >30;	NA	See Table 2
Fish Waste Compost	12.03	61.62	66.73	26.87	8.93	
Sewage	13.32	24.73	92.45	5.19	5.15	
Fly Ash	126.54	10.11	0.15	96.26	3.1	

Fish waste compost has much less GI compared with standard requirements, which reach levels of 90 %. The OM is not qualified either, even for Type B. The concentrations of all the trace elements however, are under the limited values. For the sewage sample, the GI is only 24.73 %. The moisture and OM content are also barriers for sewage to be qualified as compost. Meanwhile, the concentration of Cu is 110.6 ppm which is higher than the acceptable maximum concentration = 100 ppm. Se concentration is 10.097 ppm, which is higher than the limited value = 2 ppm. C:N is good for both sewage and fish waste compost. For fly ash however, C:N is 126.54 which is way higher than standard. GI for fly ash is only 10.11 %, much lower than the required value. OM content is high enough to be classified as Type AA. The concentrations of Mo and Ni are 14.698 ppm and 876.698 ppm respectively, which are over the limited concentrations of 5 ppm and 62 ppm respectively. In summary, each raw material is not qualified to be compost directly alone. However, all the raw materials have their special characteristics and potentials to generate good quality compost product after mixing in a particular ratios.

Table 2. Trace Elements in Raw Materials and Standard Values (ppm).

Trace Elements	Type AA and A	Type B	Fly ash	Sewage	Fish waste compost
As	13	75	0.728	1.888	6.988
Co	34	150	0.815	1.79	0.831
Cr	210	1060	7.835	17.369	3.672
Cu	100	757	<LD*	110.6	7.95
Mo	5	20	14.698	3.119	0.307
Ni	62	180	876.698	8.87	3.436
Se	2	14	<LD*	10.097	<LD*
Zn	500	1850	13.74	162.83	78.855
Cd	3	20	<LD*	<LD*	0.698
Hg	0.8	5	<LD*	0.018	<LD*
Pb	150	500	2.531	19.295	3.864

Note: <LD* means the concentration is lower than limited detection.

Determination of Mixing Ratio

Based on the characteristics of each raw material, 8 ratios were established. Table 3 shows the corresponding mixture ratios in percentage. 20 g was set as the final sample mass.

Table 3. Mixture Ratio (% of 20g mixture).

Mixture	Fish waste compost (%)	Slurry (%)	Fly ash (%)
R1	88	10	2
R2	80	10	10
R3	70	20	10
R4	80	14	6
R5	76	16	8
R6	50	40	10
R7	90	6	4
R8	79	14	7

Fish waste compost accounts for the major percentage and fly ash accounts for the lowest percentage for each individual sample. The high concentration of OM in fly ash can make a contribution to improve the overall OM content in the mixtures; meanwhile, the high C:N and over limited concentrations of heavy metal should be taken into consideration. The high moisture content in sewage also needs to be considered when adjusting the 8 ratios. Ratio 6 has the highest percentage for both sewage and fly ash, which should generate the lowest quality compost; however, ratio 7 has the highest percentage of fish waste compost and relative lower sewage and fly ash content, which supposed to generate the best compost product. After mixing the fly ash, sewage and fish waste compost in 8 different ratios, the characterizations for each ratio were conducted in the same way.

For R1, the GI, C:N, and moisture content meet the standard, especially with the high OM content. However, the concentration of Se is 8.846 ppm, which is higher than 2 ppm (Type AA and A level) but still lower than 14 ppm (Type B level). So R1 can be classified as Type B level compost, even though the OM is higher than 50 % (Type AA level). For R2, the GI, C:N, and moisture content are qualified for compost application. However, the concentration of Ni is 107.764 ppm, which is higher than 62 ppm (Type AA and A level) but still lower than 180 ppm (Type B level). The concentration of Se is 4.45 ppm, which is higher than 2 ppm (Type AA and A level) but lower than 14 ppm (Type B level). Therefore, R2 can also be classified as Type B level compost, even though the organic matter is 60.36 % (Type AA level).

Similar situation for R4, the concentration of Se is 2.004 ppm, which is just a little bit higher than 2 ppm (Type AA and A level) and is lower than 14 ppm (Type B level). Thus it can still be classified as Type B level compost. All other parameters are qualified. Unfortunately, R3, R5 and R6 are not qualified as compost products because of the high C:N and high trace element concentrations. According to the CCME (1996) and BNQ (2005) standards, C:N should be lower than 25. For R3, R5 and R6, the C:N is 28.14, 42.65 and 35.27, respectively. Based on the restrictions of the trace elements, the maximum acceptable concentration of Ni is 180 ppm; in R3, R5 and R6, however Ni is 182.507 ppm, 237.831 ppm, and 302.525 ppm, respectively. For R7 and R8, all the parameters meet the requirements. According to the standard values about concentration of trace elements and OM, both R7 and R8 can be classified as Type A level compost.

As a result, R1, R2 and R4 are qualified as Type B level compost product. R3, R5 and R6 are not qualified for any type of compost. R7 and R8 are qualified for Type A level compost products. In order to further improve the quality of R7 and R8 to reach Type AA level, algal biodegradation was conducted in the next section.

Determination of Operation Period

Algal treatment was conducted for both R7 and R8 and for each ratio; 3 different doses of algal solutions were added, which were 6 runs in total. The following figures show the trend along the 24 day biodegradation period based on the OM, organic carbon, nitrogen, and C:N. Figure 1 to Figure 6 demonstrates the biodegradation trend along the process for 6 runs respectively.

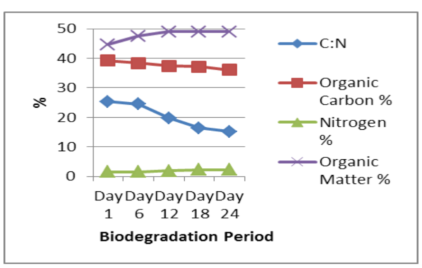

Figure 1. Charaterization for Run 1.

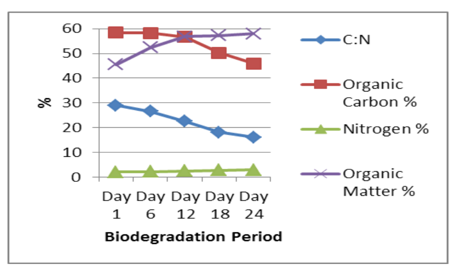

Figure 2. Charaterization for Run 2.

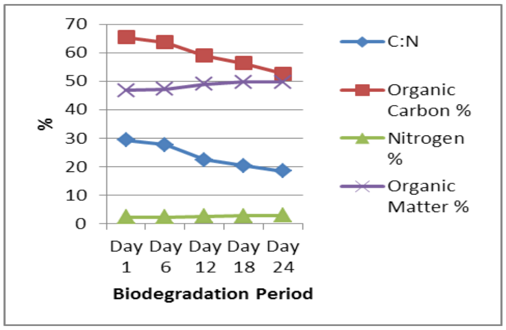

Figure 3. Charaterization for Run 3.

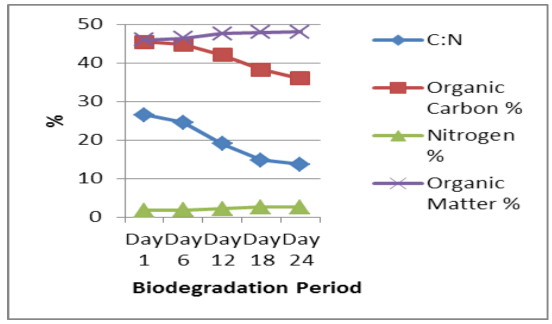

Figure 4. Charaterization for Run 4.

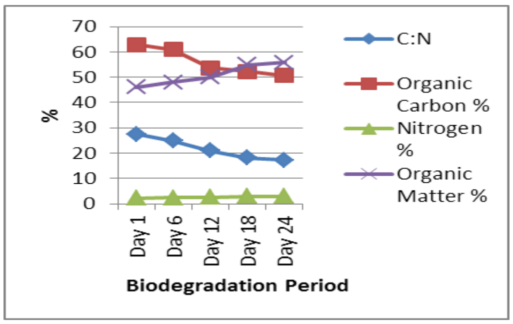

Figure 5. Charaterization for Run 5.

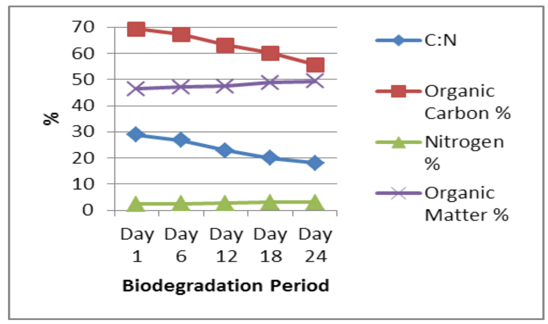

Figure 6. Charaterization for Run 6.

All the 6 runs show a similar trend. After adding algal solution, no obvious difference in the first 5 days happened with C:N. But after 6 days, it decreased gradually and eventually reached a stable stage after 18 days. For nitrogen also, no big difference occurred in the first 5 day; however, it increased a significantly in the next 12 days and then kept stable for the remaining days. A little bit of difference was noted with OM content - the curve increased dramatically in the first 6 days and then plateaued after 12 days. No obvious increase was noted in the next 12 days. Overall, all the parameters reached a stable status after 18 days, which means the algal biodegradation process was almost done. By adding another 6 days to that, established the 24 day investigation period. From an economical point of view, 18 days can be considered as sufficient reaction time instead of 24 days.

Compost Classification

The classification of compost products is summarized in Table 4. Unfortunately, still some mixtures were not qualified as compost application. They are: R3, R5, R6, Run 3 and Run 6.

Table 4. Classification of compost.

	Type AA	Type A	Type B
Compost products	Run 2 after 18 days biodegradation; Run 5 after 18 days biodegradation	Run 1 after 18 days biodegradation; Run 4 after 18 days biodegradation	R1; R2; R4.

Conclusions

This research provides an innovative method for generation of different levels of compost products based on waste streams. It leads to not only valuable compost products for local agriculture applications but also an effective way for solid waste management and recycling. Additionally, involving algae in generation of compost is a new application in the algal bioremediation field.

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