Innovative Acceleration of Composting using Mixed Municipal Solid Waste Materials via Enzymatic Process: Summary

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Composting is a natural process which converts the nutrients of biodegradable materials into a usable form known as compost. Compost can be reintegrated back to soil for its enrichment, in order to accelerate and improve the growth of plants. Soil that is enriched with organic compost has been known to support and improve plant growth. However, the process of composting normally requires 30 to 60 days to finish (Wang et al., 2004). Because of the long period required to complete natural or microbial-based composting, the cost of production increases and quality of compost produced is compromised. The long waiting period for composting is usually the problem in the accumulation of biodegradable waste. Thus, the need for a more efficient way to manage waste arises. Adding industrial enzymes into compost may be able to solve this problem by accelerating the composting process, increasing the mass of the product, improving the quality of the produced fertilizer, and promoting further the growth of plants.

Waste production has significantly increased over the years and is one of many notable problems that the world is currently facing. A combination of many factors, such as increasing population, rapidly growing economy, and the rise of living standards in communities, has significantly affected the rate of waste production. This is most apparent in developing countries (Zhu et al., 2009; Guerrero et al., 2013). In the East Asia and Pacific region, which includes nations with large economies such as China and developing countries like the Philippines, the average waste produced per year reaches approximately 270 million tons and an average of 0.95 kg/capita per day. Space for storing waste is constantly decreasing. For example, the San Pedro sanitary landfill in Laguna, where the International Rice Research Institute (IRRI) and the neighboring towns of Bay, Calamba, and Los Baños dispose their municipal solid waste, will soon reach its maximum capacity and is scheduled for closure (Sundo et al., 2013). The Philippines is faced with the challenge of finding a way to control this ever-growing problem.

Composting could potentially be a way to solve the growing problem of increasing waste production. Compost is “an organic soil conditioner that has been stabilized to a humus-like product, that is free of viable human and plant pathogens and plant seeds, that does not attract insects or vectors, that can be handled and stored without nuisance, and that is beneficial to the growth of plants” (Haug, 1993), while composting is a natural process in which microorganisms decompose organic matter (Tiquia et al., 2002). Various physico-chemical properties (temperature, moisture, C:N ratio, pH, etc.) affect the speed of the composting process and the quality of the end product of compost (Raabe, 1981; Richard et al., 1996; Maynard, 2000; Geisel et al., 2001; Christensen, 2009).

In the East Asia Pacific region, organic waste makes up 62% of the total produced waste in the area and 46% of all the organic waste produced worldwide (Hoornweg et al., 2012). As compost uses organic waste, much of this waste can be used to create compost. But given the increasing rate of waste production, there arises a need to improve current waste management methods.

There have not been many studies that focus on how the composting process can be improved. A study conducted by Raabe (1981) describes a way to accelerate the composting process so that compost can be created in as fast as 14 to 21 days. However, this method requires having to turn the compost once a day. Thus, a lot of effort from the composter is required, and while the composting method is very quick, the tedious work that this method demands makes this method not practical enough for widespread use.

Certain kinds of enzymes can potentially be used to improve the composting process to help solve waste production problems. There has been research on enzymatic activity in composting and how it affects the composting process. Enzymes are key to initiating numerous biological processes in which the organic matter is transformed into a form that is more appropriate for soil conditioning. Enzymatic activities help solubilize the nutrients in the soil, making them a crucial part in plants' absorption of soil nutrients (Chitravadivu et al., 2009). Studies have shown that the amount of enzymatic activity during composting is directly proportional to the rate of decomposition of organic matter (Tiquia et al., 2002). Some examples of enzymes that are important in composting, and which could be used to accelerate the composting process, include cellulases, sulphatases, phosphatases, nitrogenase, and protease (Tiquia et al., 2002; Singh et al., 2014).

Compost may be used to create two types of fertilizer – soil conditioner and natural organic fertlilizer. Soil conditioner simply improves soil structure by "binding soil structures into larger aggregates", improving air exchange, water movement and root growth. On the other hand, natural organic fertilizers are more sought after because they also provide a significant amount of growth-promoting nutrients, like NPK, proteins and carbohydrates, in addition to the benefits of soil conditioner (Traunfeld et al., 2013). The main variable that has to be considered in order for compost to be considered organic fertilizer is the total nitrogen, phosphorus, and potassium ratio (5-7%) (Cañeda et al., 2013). Enzymes improve various biological processes in composting; thus, it may help in the production of high-quality compost that can be used as natural organic fertilizer and not simply soil conditioner.

Natural organic fertilizer and the more desirable nutrient content it contains may help create a more sustainable form of agriculture and revitalize farming and production needs by helping plants grow faster and better. Enzymatic composting may, therefore, be able to solve not only worldwide waste management problems, but also environmental protection and food security problems.

This study was conducted to find innovative ways to accelerate the composting process using solid municipal waste through the use of enzymes. The quality of the compost produced was established to verify if the product complies with the requirements set by the Philippine Fertilizer and Pesticide Authority for organic fertilizer. Likewise, the produced compost was applied for the cultivation of plants like radish, corn, and cabbage. The research used waste mostly produced by South Hill School, Inc. of Los Baños, Laguna, with other materials coming from multiple sources from the University of the Philippines, Los Baños, Laguna. The waste used for this experiment was a simulation of waste that may be produced by small communities in the area.

The composting was done first by making two separate piles of compost. The layers in the compost were arranged as shown in the diagram below An amount of 225 kg of chicken manure (around 37.5 kg per layer) was used, along with 15.7 kg of sawdust, 9.25 kg of shredded paper, 3.75 kg of dry leaves (around 1.25 kg per layer), 1.5 kg of green leaves, and 5 kg of assorted food waste (bananas, rice, lettuce, etc), for a total dry mass of 260.2 kg per compost pile.

The chicken manure came from a poultry farm in Barangay Putho-Tuntungin, Los Baños, Laguna, while the shredded paper and the leaves were sourced from the school premises. The food waste, on the other hand, came from small-scale food establishments near the school. The chicken manure used was sanitized and deodorized first with commercial Double Q (lemongrass QUAT based disinfectant solution). About 100 mL of this deodorizer was mixed with 20 liters of water. The Double Q solution was used to disinfect and deodorize the chicken manure used in the experiment. On the other hand, the water solution used to moisten the pile of compost was fermented from solution containers using extracts from 10 kg of madre de cacao (*Gliricidia sepium*), 5 kg of ipil-ipil (*Leucaena leucocephala*), and 3.75 kg of acacia (*Samanea saman*) leaves, all of which were soaked in water in a 1:2 ratio (2 L of water per kg of dried leaves). Soaking of leaves was done using drums which were isolated for 3 days before the resulting water solution was used.

For the control pile, the water solution and deodorizer were applied as is; however, for the treated pile, aside from the water solution and deodorizer, 1 kg of industrial enzyme mixture was introduced into the compost pile for every 1000 kg (1 metric ton) of waste materials for composting. The industrial enzymes came in the form of enzyme mixtures that were made up of cellulolytic and hemicellulolytic enzymes, as well as amylolytic and protein hydrolyzing enzymes. These industrial enzymes and the deodorizing liquid used in the experiment were provided by CTC Far East and Dell Biologics Incorporated of Los Baños, Laguna.

After assembling the two compost piles, the temperatures of these piles were observed twice daily, once each at 8AM and at 4PM. Every 3 days, mixing of the materials contained in each compost pile occurred. Four thermometers were inserted about ¾ of a foot deep into the compost pile, and at right angles to each other. The temperatures were read and recorded after 5 min. For each pile, the mean value of the temperatures was calculated and recorded as the temperature of the pile at that time.

During the 16th day of composting, the material in the compost pile that was not fully decomposed was separated through sieving, then the fully decomposed compost with desirable aesthetic quality was weighed. The compost yield for each pile was calculated based on the amount of compost that was harvested over the total amount of composted matter. A kilogram of each from both the control and enzyme-treated pile were submitted for NPK, moisture, organic matter, as well as Zn, Pb, Cu, Cr and Cd content analyses at the Central Analytical Services Laboratory of the Philippine National Institute of Molecular Biology and Biotechnology, Los Baños, Laguna (BIOTECH UPLB). The Kjeldahl method was used to analyze the nitrogen content of the compost samples, while the spectrophotometric method was used to analyze the phosphorus content of the samples, and the flame photometric method was used to analyze their potassium content. The gravimetric analysis method was used to analyze the moisture content of the samples, the Walkley-Black method was used to analyze their organic matter content, and the AAS method was used to analyze their Zn, Pb, Cu, Cr and Cd content. The enzyme-treated compost also underwent VRBA, PDA and PCA analyses to observe its coliform, fungi and bacteria count, respectively.

The compost was used to cultivate *Raphanus sativus* (radish), *Zea mays* (corn), and *Brassica rapa* (pechay). Five plots were made where the *Raphanus sativus* was grown. The first plot contained pure garden soil. The second plot had a control compost-to-garden soil ratio of 1:5. The third plot also had a compost-to-garden soil of 1:5, except it used the enzyme-treated compost instead. The fourth plot had a control compost-to-garden soil ratio of 1:10, and finally, the fifth plot had a treated compost-to-garden soil ratio of 1:10. After 3 weeks of cultivation, five leaves from a given plot were selected at random and their length and width were measured. Afterwards, five groups of leaves were randomly selected per plot of land, and each group of leaves was measured for its leaf quantity.

The compost was also applied in *Zea mays* and *Brassica rapa* plants. After the growth of the cultivated *Zea mays w*as observed over the course of 1 month, their heights were measured. Similarly to how the plots for *Raphanus sativus* cultivation were organized, five distinct plots of land were used for the cultivation of the *Zea mays* and *Brassica rapa* plants. These plots of land contained pure garden soil, 1:5 control compost, 1:5 treated compost, 1:10 control compost, and 1:10 treated compost, respectively. Also, after 3 weeks of cultivation, measurements were taken of the mean height of the cultivated *Zea mays* plants, as well as the mean length and width of 5 randomly selected *Brassica rapa* leaves, per plot of land.

The measurements taken of the mean leaf quantity, leaf length and leaf width of the *Raphanus sativus* plants were sufficient to perform statistical analyses. Comparisons of the mean leaf quantities of the different *Raphanus sativus* treatments were statistically analyzed using Analysis of Variance (ANOVA). On the other hand, comparisons of the mean leaf lengths and leaf widths of the different *Raphanus sativus* treatments were done using T-test at 95% level of confidence.

Enzymatic technology was employed in composting of municipal solid waste materials to verify its efficiency in the acceleration of the composting process. Various analyses were done, based on the requirements set by the Philippine Food and Pesticide Authority to check the quality of the compost produced.

After analysis, the treated compost pile output yielded an NPK ratio of 0.94%:2.47%:1.88%, moisture content of 14% and organic matter content of 24.89%. In comparison, the control compost pile output yielded an NPK ratio of 0.77%:1.84%:1.74%, moisture content of 27% and organic matter content of 11.42%.

The enzymatic compost yielded superior NPK and organic matter content compared to the control compost. Unlike the control compost sample which contained a total NPK content amount of 4.35% and an organic matter content of 11.42%, analysis of the enzymatic compost sample showed that it contained a total NPK content amount of 5.29% and an organic matter content of 24.89%, which satisfied the NPA's 5% total NPK content and 20% organic matter content minimum for compost to be considered plain organic fertilizer.

Both the control compost pile and enzymatic compost pile yielded compost containing acceptable levels of all the analyzed heavy metals. The produced enzymatic compost was analyzed for its coliform, fungi and bacteria count. The VRBA analysis showed that there were no coliforms present in the compost.

Composting was done for 16 days, after which the compost material was harvested via sieving. The amount of harvested compost from the control pile reached a total mass of 101 kg, while the amount of harvested compost from the enzyme-treated pile reached a total mass of 188.5 kg. The percent yield from the control pile was 38.81% relative to the pile's initial dry mass, while the percent yield from the enzyme-treated pile was 72.44% relative to the pile's initial dry mass. Table 4.1 shows the mass harvested from the two piles, along with the percent yield.

The temperature readings from the composting phase show that the average daily temperature of the control compost pile was consistently greater than that of the treated pile. The mean temperature difference between the two piles was 3 °C. The minimum temperature of the control pile was 58 °C, while its maximum temperature was 67 °C. Meanwhile, the treated pile's lowest temperature was 54 °C and its highest temperature was 62 °C.

The lower temperature suggests that increasing the amount of enzymes does not increase the amount of microbial activity, and only the opposite is true [increased microbial activity results in an increase in enzymes (Tiquia et al., 2002)].

The measurements taken of the leaf lengths, leaf widths and leaf quantities of the plants showed that the *Raphanus sativus* plants grown using enzymatic compost yielded significantly greater mean leaf length, leaf width and leaf quantity compared to the *Raphanus sativus* plants cultivated with the control compost. The mean leaf quantity, length and width of the *Raphanus sativus* plants grown using purely garden soil were 7 leaves, 74.6 mm and 41.8 mm, while the mean leaf quantity, length and width of the *Raphanus sativus* plants grown using a control compost-to-soil ratio of 1:10 were 11.6 leaves, 141.4 mm and 74.4 mm, and the mean leaf quantity, length and width of the *Raphanus sativus* plants grown using a treated compost-to-soil ratio of 1:10 were 15.2 leaves, 193 mm and 84.4 mm. The mean leaf quantity, length and width of the *Raphanus sativus* plants grown using a control compost-to-soil ratio of 1:5 were 11.2 leaves, 169.4 mm and 69.2 mm, while the mean leaf quantity, length and width of the *Raphanus sativus* plants grown using a treated compost-to-soil ratio of 1:5 were 14.4 leaves, 198.6 mm and 89.8 mm.

The leaf lengths and widths of the different treatments were compared via T-test analyses using a maximum benchmark P-value of 0.050 (a minimum level of confidence of 95%). The control compost had some significance in the growth of the plants compared to cultivating the plants using purely garden soil, with the P-value when comparing garden soil and 1:10 control compost-to-soil *Raphanus sativus* plant leaf length at 0.001 (99.9% level of significance) and the P-value when comparing leaf width at 0.000 (100% level of significance). However, when comparing the *Raphanus sativus* plants grown using a control compost-to-soil ratio of 1:10 and those grown using a treated compost-to-soil ratio of 1:10, T-test analysis reached a P-value of 0.004 (99.6% level of significance) when comparing the mean leaf lengths of these two treatments, and a P-value of 0.043 (95.7% level of significance). Using a compost-to-soil ratio of 1:5 yields no significant difference in plant growth compared to using a compost-to-soil ratio of 1:10 in both the control and treated compost. Statistically comparing the mean leaf lengths of the *Raphanus sativus* plants grown using a control compost-to-soil ratio of 1:5 and the *Raphanus sativus* plants grown using a control compost-to-soil ratio of 1:10 yields a P-value of 0.126 (87.4% level of significance), while comparing their mean leaf widths yields a P-value of 0.39 (61% level of significance). Furthermore, comparing the mean leaf lengths of the *Raphanus sativus* plants grown using a treated compost-to-soil ratio of 1:5 and the *Raphanus sativus* plants grown using a treated compost-to-soil ratio of 1:10 yields a P-value of 0.55 (45% level of significance), while comparing their mean leaf widths yields a P-value of 0.494 (50.6% level of significance).

Using a compost-to-soil ratio of 1:10, the treated compost allows the radish to grow significantly better than in the control compost. However, the significance of the increase in plant growth was observed as insignificant when changing the compost-to-soil ratio from 1:10 to 1:5 when using either the control or enzyme-treated compost.

The observation of the number of leaves showed similar results, with the plants cultivated using 1:10 treated compost growing more leaves than the plants cultivated with 1:10 control compost. However, using a 1:5 ratio decreased the average amount of leaves grown by the plants. The information analyzed with the one-way ANOVA test revealed that the differences between the means were 100% significant. This information revealed that there may be a point when, as the ratio between soil and compost increases, the significance of the compost decreases when the ratio reaches a certain point.

Observing the measurements for the *Zea mays* (corn) that was grown using the compost shows a trend of increasing height as the ratio between soil and compost increases. The measurements showed that, on average, the garden soil *Zea mays* reached a height of 699 mm, the height of the 1:10 control *Zea mays* reached 368 mm, the height of the 1:10 treated *Zea mays* reached 864 mm, the 1:5 control *Zea mays* reached a height of 705 mm, and the height of the 1:5 treated *Zea mays* reached 953 mm. The height of the corn grown using garden soil was much higher than that of the corn grown using 1:10 control compost. This may have been due to environmental problems as storms hit the area in the middle of cultivation, which may have damaged some cultivated crops.

The *Brassica rapa* plants cultivated with the 1:10 treated compost grew larger than the ones cultivated with the 1:10 control compost, which grew larger than the ones cultivated purely with garden soil. The *Brassica rapa* plants cultivated using a control compost-to-soil ratio of 1:10 grew to a length of 103 mm and a width of 72.2 mm, while the *Brassica rapa* plants cultivated using a treated compost-to-soil ratio of 1:10 grew to a length of 169 mm and a width of 152 mm.

This study showed the effects of increasing the quantity of enzymes in compost in relation to the total mass and content of the resulting compost. Enzymatic composting allows the harvesting of a significantly greater amount of compost in a short period of time, and the nutrient content in the enzymatic composting was more desirable than the nutrient content in similarly-grown, non-enzymatic compost. Based on the results of this research, it can be concluded that enzymatic composting allows composters to harvest what is generally more desirable compost in terms of quality and quantity, in a shorter amount of time, and with it, grow plants faster and better. These results can also help us conclude that enzymatic composting can, indeed, be used as a new way to solve waste management and agriculture problems. The study has proven that the new concept of using mixed municipal solid waste materials in enzymatic composting is practical and can be highly effective in helping improve agriculture and solve waste management problems, making this concept truly innovative. Although the information obtained has helped us conclude that enzymatic composting can be used to help solve municipal waste management problems, research can be continued in many more aspects of this composting method. First, there is a greater level of heavy metals in enzymatic compost, implying that the introduction of too much enzymes into compost may result in an increase in biological activity that may result in the increase of heavy metal quantity up to an unsafe amount. It could be possible to further study at what concentration of enzymes does the heavy metal quantity increase to unsafe levels. Second, it was shown in this study that adding more compost does not necessarily mean a more significant increase in growth. Observing at what ratio the significance of the growth of plants using this compost reduces to insignificant levels may be the basis for further study. Third, although only three types of crops were cultivated for this experiment (*Raphanus sativus, Zea mays* and *Brassica rapa*) as they are some of the most commonly grown types of crops in the Philippines, the effect of enzymatic compost on other types of crops, such as rice (*Oryza sativa*), can also be studied in order to evaluate the effects of enzymatic compost on these crops. Finally, since this experiment used materials and ratios that were selected specifically to simulate municipal waste on a small scale, further study can be conducted on the effects of other kinds of composting materials and ingredient ratios on the quality of enzymatic compost, as well as the effects of large-scale implementation of enzymatic composting in municipalities and communities on the compost quality and waste management.

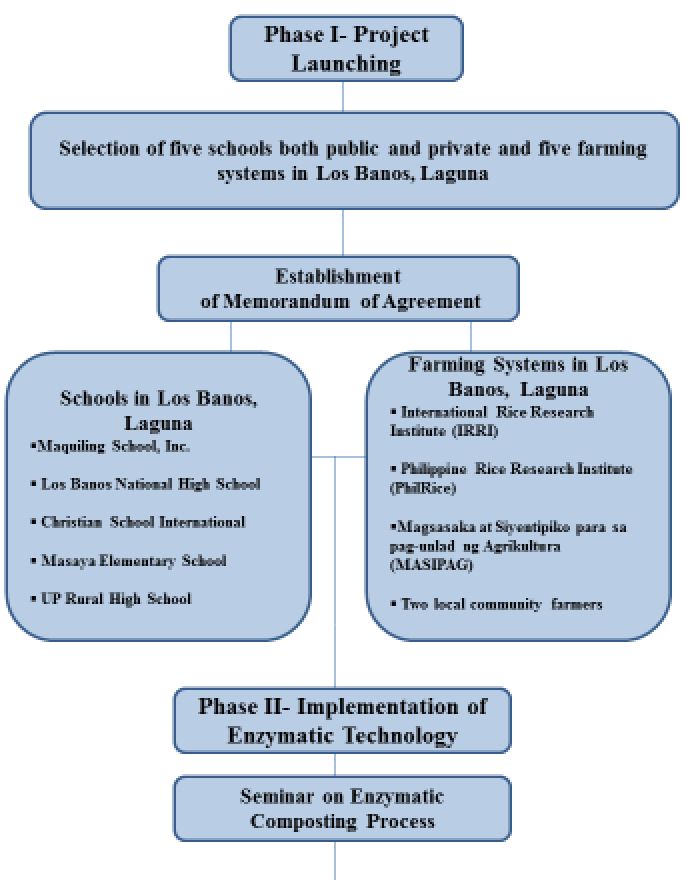
A major recommendation of this study is to launch enzymatic composting through a community project: *Embedding Sustainability in Schools and Farming Systems through Innovative Acceleration of Composting Using Mixed Municipal Solid Waste Materials via Enzymatic Process.* The main objective of this project is to facilitate the embedding of environmental sustainability in schools and farming systems in Los Banos, Laguna through enzymatic composting. The project primarily aims to develop a strategy to incorporate greening practices in community based education through the promotion of enzymatic composting and implementing the involved processes of collection, separation, and the use of compost products as practiced by more developed countries with regards to solid waste management. Moreover, this is an action of exploration towards the development of strategies of delivery and finding the logistics and machinery of delivery of training to the schools, to reach students, young adults, their parents and their educators as stake holders of community solid waste management and as the eventual benefactors of mitigating the onset and impact of climate change. Mainly, the project targets technology transfer of such innovation on the development of sustainable agricultural productivity.

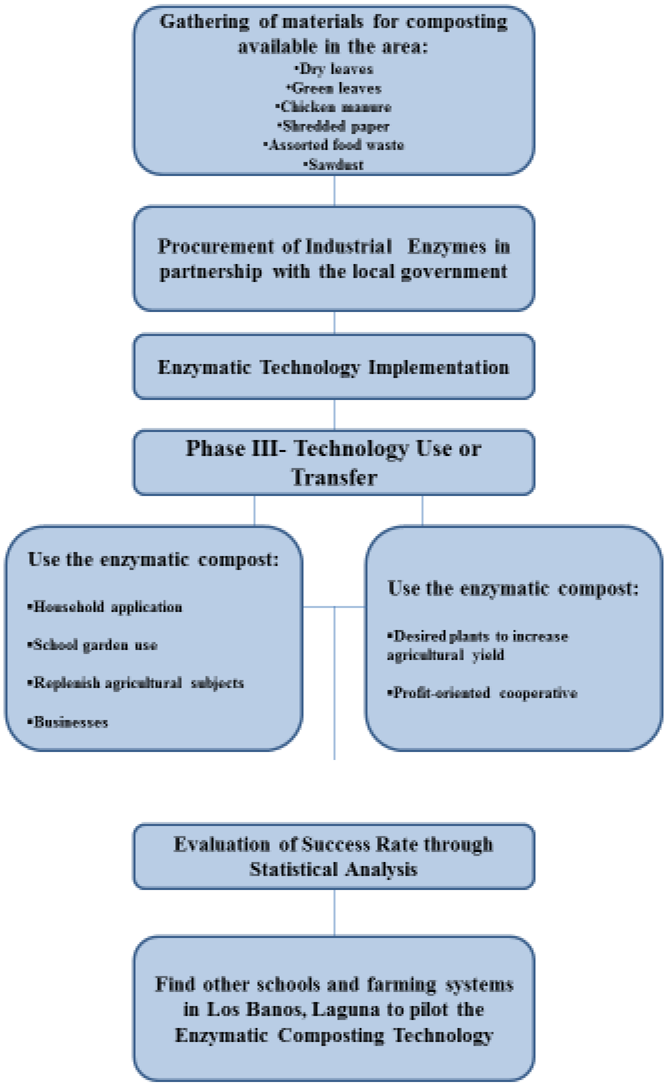
The Philippines has not adopted solid waste management practices to accommodate the needs of an expanding population on a shrinking land area. There are garbage segregation practices that few households adopt: and once the materials are collected, these materials are still placed in landfills, instead of being converted into nutrient rich compost, usually sharing a site with the materials they were previously segregated from. However, if schools could be repurposed as a composting facility and farming systems will implement enzymatic composting, the community can reduce their solid waste output as well as develop a means for schools and farming systems to top-up their earnings. It is very important that students and citizens are given education on the processes, skills and benefits of composting to ensure the communities participation. By creating a money-making project for the community, the community's buy-in to project is also assured.

While waste production has significantly increased over the years and is one of many notable problems that the world is currently facing and is most apparent in developing countries like the Philippines, enzymatic composting is a potent way to control this ever-growing problem. The project is innovative in that it works on the premise of another person's trash is another person's treasure- except it seeks to make everyone a stakeholder: everyone's trash is everyone's treasure. It invests in the participation of students to guarantee sustainability of good practices. The project positions itself as a profitable to engage communities to support, practice and sustain the technology. Outside the school setting, solid waste management as a cooperative endeavor for generating income can translate into communities, small and medium enterprises and even corporations as the responsibility for solid waste management is removed from local and national government and turned into a profitable business of its own.

The program has value for money and is sustainable in the manner that it will eventually pay for itself. Although infrastructure in schools and the enzymes to initiate the composting process will require investment, the schools will eventually be generating income for the community and thus be paying for the perpetuation of the project.

Detailed Steps/ Activities




Gathering of materials for composting available in the area:
•Dry leaves
•Green leaves
•Chicken manure
•Shredded paper
•Assorted food waste
•Sawdust
Procurement of Industrial Enzymes in partnership with the local government
Enzymatic Technology Implementation
Phase III- Technology Use or Transfer
Use the enzymatic compost:
•Household application
•School garden use
•Replenish agricultural subjects
•Businesses
Use the enzymatic compost:
•Desired plants to increase agricultural yield
•Profit-oriented cooperative
Evaluation of Success Rate through Statistical Analysis
Find other schools and farming systems in Los Banos, Laguna to pilot the Enzymatic Composting Technology