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Generation of Electric Potential from Vermicomposted Fruit Waste

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Abstract: *Vermicomposting is the process of converting organic wastes into valuable organic fertilizer by earthworms. Vermicompost is rich in metal ions and has the potential to be used as an electrolyte. The main aim of this investigation is to explore the potential of earthworms to convert the fruit waste into high quality vermicompost which can serve as a solution to solid waste management issues and act as an environment friendly electrolyte for a cell. The present study has been carried out to identify the macro and micro nutrients, physicochemical parameters and the electrical potential of fruit waste by employing exotic earthworm species, Eudrilus eugeniae. The fruit waste is mixed with soil and allowed for pre-composting for 20 days and earthworms are introduced for vermicomposting for 30 days. The macronutrients (N, P, and K) and micronutrients (Fe, Zn) showed elevated levels in the vermicompost compared to control. The physicochemical parameters of vermicompost namely moisture content exhibited higher levels and pH of vermicompost was nearly acidic. Voltage was measured using copper and zinc plates as electrodes and vermicompost as electrolyte. The lead wired was connected to electrodes, multimeter and LED device in series circuit and the ions in the vermicompost could light up the Light-Emitting Diode (LED) device. The present study reveals that the vermicomposting technique can be used to generate electrical energy from biodegradable waste.*

Keywords: *Eudrilus eugeniae* , voltage, micronutrients, macronutrients, vermicomposting

1. Introduction

The problem of efficient disposal and management of organic solid wastes has become more rigorous due to rapidly increasing population, intensive agriculture and industrialization, over the last few years. The various types of environmental and disposal problems caused by the production of large quantities of organic waste all over the world requires sustainable approach in a cost effective manner and this has become a very important issue for maintaining healthy environment (Wani et al.,2013).

The present trend about waste management is to focus on recycling and the recovery of waste as new materials or as energy. The waste organic materials produced by the city life, such as domestic refuse and food wastes are accumulating to become a significant amount. The vermicomposting of these by-products is more encouraged to avoid the loss of energy. Earthworms feed on the organics and convert material into casting rich in plant nutrients. The chemical analyses of casts show two times available magnesium, 15 times available nitrogen and seven times available potassium compared to the surrounding soil. (Sharma et al., 2015)

India and many other countries are suffering from the entire problem due to urbanization, which are a very rapid process and a worldwide phenomenon. Deteriorating quality of urban environment is one of its important impacts. SOLID WASTE is its major contribution the complexity in character of solid waste and its volume is greatly increasing due to increase of living standards and population density. Hence the importance of efficient “SOLID WASTE MANAGEMENT” is increasingly recognized. Industries produce a large quantity of wastewater and sludge’s during their each processing stage. When this industrial waste comes into contact with the environment they produce serious impacts on it. It is difficult to generalize the industrial wastes since its characteristics differ from industry and also from its different processing plants. Before final disposal one can process and treat the waste so as to reduce the “wasteful wasting of waste”. Some of the techniques available to achieve this objective are volume reduction, recovery of resources, energy recovery. That’s why the world is entering new branch of bio information technology. This study has been done for reducing the pollution problems due to solid waste and industrial sludge's by converting it into compost by using earthworms very successfully, economically and usefully. (Nweke, 2013)

2. VERMICOMPOSTING

Vermicomposting is a very useful biotechnique for converting solid organic waste into vermicompost. The vermicomposting provides for the use of earthworms as natural bioreactors for cost-effective and eco friendly waste management. Earthworm has the efficiency to consume all types of organic rich waste material including tea waste, vegetable wastes, leaf litter waste, industrial, dairy farm wastes, garden waste, sugar mill residues, slaughter house waste, hatchery waste and municipal wastes. (Reddy et al., 2010)

The ability of the exotic composting species, *Eudrilus eugeniae* to transform the spent fruit waste into valuable compost is considerable. Other than being an organic fertilizer, this secreted chemical mixture which is rich in metal ions, acids, salts and enzymes have the potential to be used as an electrolyte. Vermicompost being harmless do not cause any environmental pollution like the chemical electrolytes used in battery. The ions present in the vermicompost can react with the metal electrodes used in the cell and can produce a potential difference across the electrodes. This potential difference can generate enough voltage similar to that produced by a commercial battery cell. The waste to energy can be considered as a renewable technology and a better solution to solid organic waste management. Even though food, plant and animal waste have been used as alternative resources for electricity generation, they have several drawbacks. Conventional composting and anaerobic digestion produces foul smell and harmful methane gas. According to the considerations of low cost, eco-friendly, fast and efficient, we choose to explore the suitability of vermicompost from spent tea waste as an alternative to replace chemical electrolytes (Prabha et al., 2014).

Earthworms act as an aerator, grinder, crusher, chemical degrader and a biological stimulator and degrade waste by multiple actions. 1) Grinding action: The waste feed material ingested is finely ground (with the aid of stones in their muscular gizzard) into small particles to a size of 2-4 microns and passed on to the intestine for enzymatic actions. The gizzard and the intestine work as a "bioreactor"; 2) Enzymatic action: The gizzard and the intestine work as a "bioreactor". Worms secrete enzymes proteases, lipases, amylases, cellulases and chitinases in their gizzard and intestine which bring about rapid biochemical conversion of the cellulosic and the proteinaceous materials in the waste organics. They ingest the food materials, cull the harmful microorganisms, and deposit them mixed with minerals and beneficial microbes as "vermicasts" in the soil. 3) Worms Reinforce Decomposer Microbes & Act Synergistically: Worms promotes the growth of "beneficial decomposer microbes" (bacteria, actinomycetes & fungi) in waste biomass. They hosts millions of decomposer microbes in their gut which is described as "little bacterial factory". They devour on microbes and excrete them out (many times more in number than they ingest) in soil along with nutrients nitrogen (N) and phosphorus (P) in their excreta. The nutrients N and P are further used by the microbes for multiplication and vigorous action. Reference showed that the number of bacteria and "actinomycetes" contained in the ingested material increased up to 1000 fold while passing through the gut. (Zirbes, 2011)

The vermicomposting process is a method which can convert wastages such as used sugarcane, spent tea and grated coconut meat into valuable vermicompost which produces high voltage. The increase of compartments increases the voltage produced. The voltage produced by one compartment of vermicompost is equivalent to the voltage produced by one dry cell. Based on the experiment, it is concluded that the vermicompost generates electricity and light up the LED. The vermicompost can be used in battery to replace the chemicals used. The treatment of wastes is usually costly and required a large space to compost it. Due to high cost of treatment, most of irresponsible parties choose to dispose their wastages in open dump sites or illegal dumping. Areas like field and river are the most popular places for people illegal dumping. Illegal dumping can cause river and land pollution. Besides, some irresponsible parties managed their wastages using incineration method. As the method of incineration involves combustion, therefore it is also known as thermal treatment. Hence, to tackle these problems, more solid waste management alternatives such as vermicomposting are needed. Batteries that are disposed incorrectly can seriously harm the environment. A battery convert chemical to electrical energy. The chemical by-products are hazardous which is dangerous and harmful. In general, the battery contains harmful substances mainly Zn, Hg, Ni, Pb and other heavy metals such as a variety of alkaline batteries and lithium batteries. (Majlessi et al., 2012)

Today's alkaline batteries may contain approximately 0.025 percent mercury. Mercury (Hg) and its compounds, especially organic mercury compounds, have high toxicity, bioaccumulation faster rate and a longer biological half-life of the brain organ. Easy cadmium, Cd accumulation in plants and animals affecting the growth of the plants and animals, is highly poisonous. Lead, Pb on human breast, kidney, reproductive, cardiovascular and other organ and system adverse effects, observed as mental retardation, kidney damage, infertility and high blood pressure. The toxicity of zinc (Zn) and nickel (Ni) is relatively small, but over a certain concentration range, would cause horrible effects and hazards. Used batteries in acid, alkali solution will affect the soil quality and thus affect the pH value of the water. Eventually this caused of water acidification or water alkalization. The high chemical doze in the electrolyte of batteries caused pollution to the environment. Battery of heavy metal ions in soil or water soluble are absorbed by the roots of plants and thus starting the food chain. Finally, human body will mount up heavy metals. The heavy metal ions in the body are hard to excrete eventually they destroy the nervous system and liver function. The acidic or alkaline electrolyte in all types of batteries contain dangerous substances that effects human being and the environment. Electrolyte in batteries function as to react with the casings (anode and cathode) materials and to produce force in order to move the electrons. The other burning issue nowadays is the hazard of chemicals inside the batteries that can lead to environment contamination. If the batteries are left in the environment, the chemicals can drain out and leech into water supplies, causing people to be exposed to the hazardous chemicals (Karim et al., 2011).

3. MATERIALS AND METHODS

Collection of waste

Fruit wastes were collected from Karunya University Ladies hostel, Tamil Nadu, India. Many researchers have highlighted the role of earthworms in breaking down the organic waste. Earthworms can consume almost all kind f organic waste and convert it into vermicompost. In the present study fruit waste is used as the biodegradable waste.

Collection of earthworms

The exotic earthworm *Eudrilus eugeniae* was collected from Udumalpet, Tamil Nadu, India.

Vermicomposting technique

Clay pots were used as containers for vermicomposting as it can maintain moisture and low temperature required for the worms to grow. Totally 3 pots were maintained for the experimental purposes. T1 was control for soil. T2 was maintained as control for fruit waste (without earthworms). The pot T3 was taken for vermicomposting of fruit waste (with earthworms). In pot T2 and T3, equal amount of fruit waste was taken and mixed with proper amount of soil to neutralize the pH of the waste. The earthworm *Eudrilus eugeniae* was released into the pot T3. Care was taken to avoid light and rainfall. Samples were taken from the control as well as the experimental pots on 30th day for the analysis of macro and micro nutrients, physicochemical analysis and electric potential.

NUTRIENT CONTENT

Macronutrients and Micronutrients

Vermicompost has higher content of macro and micro nutrients like nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients namely iron, copper, zinc and manganese (Prabha et al., 2014).

4. ESTIMATION OF TOTAL NITROGEN

Principle

The nitrogen in organic material is converted to ammonium sulphate by sulphuric acid during digestion. This salt, on steam-distillation, liberates ammonia which is collected in boric acid solution and titrated against standard acid.

Procedure

1. 10g of vermicompost was measured and transferred to 30ml digestion flasks followed by the addition of 1.9g potassium sulphate, 80mg mercuric oxide and 2 ml of concentrated H_2SO_4.

2. Boiling chips were then added and the samples were digested till the solution becomes colourless.

3. After cooling, the digest was diluted with a small quantity of distilled ammonia - free water and transferred to the distillation apparatus.

4. The flask should be rinsed with successive small quantities of water.

5. 100ml conical flasks containing 5ml of boric acid solution with a few drops of mixed indicator with the tip of the condenser dipping below the surface of the solution were placed.

6. 10ml of sodium hydroxide thiosulphate solution was added to the test solution in the apparatus. It was then distilled and the ammonia was collected on boric acid.

7. The solution was titrated against the standard acid until the first appearance of violet colour, the end point.

8. A reagent blank was run with an equal volume of distilled water and subtracted the titration volume from that of sample volume.

Calculation

The nitrogen content of the samples can be calculated based on the following formula

$$\%\ \text{Nitrogen} = \frac{(ml\ \text{H}_2\text{SO}_4 - \text{ml blank}) \times \text{normality} \times 1.4007}{\text{weight(g)}}$$

5. Estimation of Total Phosphorus

Principle

Inorganic phosphate reacts with ammonium molybdate in an acid solution to form phosphomolybdic acid. Addition of a reducing agent reduces the molybdenum in the phosphomolybdate to give a blue colour, but does not affect the uncombined molybdic acid. The blue colour produced is proportional to the amount of phosphorus present in the samples.

Procedure

1. 10g of vermicompost was taken in test tubes and 10ml of the triple acid mixture was added into each. The samples were digested over heated stand bath, made up the volume to 500ml with distilled water.
2. Aliquots of 2.5ml of the test sample are taken in two labelled test tubes.
3. In a series of test tubes, 1.0 to 5.0ml of working standard phosphorus solutions is taken.
4. The volume of all the test tubes is made up to 5ml with distilled water and a blank is also prepared with 5ml of distilled water.
5. 5ml of molybdate reagent is added to all tubes and mixed well
6. 2ml of amino napthol sulphonic acid reagent is added to all the test tubes.
7. The contents are allowed to stand for 10 minutes and the blue colour developed is read at 650nm.Intensity of the colour of each standard was measured on the colorimeter and a standard curve was drawn.
8. From the standard curve, the concentration of phosphorus in the sample was read in ppm

Estimation of total potassium

Principle

In flame photometry, the solution under test is passed under carefully controlled conditions as a very fine spray in the air supply to a burner. In the flame, the solution evaporates and the salt dissociates to given neutral atoms. A very small proportion of this move into a higher energy state, when these excited atoms fall back to the ground state, the light emitted is of characteristic wavelength which is measured.

Procedure

1. For potassium estimation 10g of the vermicompost was taken in the flask and 10ml of triple acid was added and the samples were digested over heated stand bath and made up to 50ml with distilled water.

2. The potassium content was fed directly to the flame photometer after adjusting the flame photometer to zero with blank and standardizing with 100 ppm of potassium solution with 100 galvanometer readings.

3. The galvanometer readings were noted. From the standard curve drawn the corresponding ppm was read. From the ppm, the percentage of sodium and potassium was calculated.

6. Estimation of Iron, Zinc

Principle

The technique involves determination of concentration of a substance by the measurement of absorption of the characteristic radiation by the atomic vapour of an element. When radiation characteristic to a particular element passes through the atomic vapour of the same element, absorption of radiation occurs in proportion to the concentration of the atoms in the light path.

Procedure

1. 10g of vermicompost was taken into test tubes and added 10ml of triple acid, digested the samples over heated sand bath, made up to 100 ml with distilled water.

2. The contents were directly fed in to the atomic absorption spectrophotometer with the nm of 248.3, 279.5; the corresponding iron, zinc were respectively estimated.

3. The corresponding ppm was read from the standard curve drawn.

7. Estimation of Physicochemical Parameters

pH

5gm of finely powdered vermicompost was taken in a volumetric beaker and 50ml of distilled water was added and the pH was measured by pH meter.

Moisture

The moisture content was then calculated as follows:

P = Weight of the empty plate

PW = Weight of the plate with wet sample

PD = Weight of the plate with the dry sample

$$Percentage\ of\ moisture\ content = \frac{(PW - PD)}{(PD - P) + (PW - PD)} \times 100$$

8. Estimation of Electric Potential

Electrode was used as an electrical conductor to touch base with a non-metallic part of a circuit. Electrode was referred as either anode or cathode. Determination of anode or cathode was -depending on the direction of current through the cell. Determination of electrodes was based on the metal elements in periodic table. Two different metals, copper and zinc plates were used as electrodes and vermicompost as electrolyte. The electrode plates were polished using sand papers to remove oxides formed due to oxidation of metals. The copper plate acts as cathode and zinc plate acts as anode. The anode and cathode were then immersed into the vermicompost that is moistened to enhance the contact with the metal plates. The lead wires were connected to the electrodes, multimeter and LED in series circuit. Multimeter is used to measure the voltage between two electrodes.

Fig 3.1 Fruit Waste

Fig 3.2 SOIL (pH 7.4)

Fig 3.3 Pre composting of fruit waste without earthworms (20 days)

Fig 3.4 Earthworm species (*Eudrilus eugeniae*)

Fig 3.5 Earthworms introduced into the sample pot for vermicomposting (30 days)

9. Results

Assay of Physicochemical Parameters in Vermicompost

Table 1. pH value, moisture and voltage of the three samples

Sample	pH value	Moisture (%)	Voltage(V)
Soil(S1)	7.4	18.65	1.0
Soil sample with waste without worms (S2)	6.44	18.0	1.2
Vermicompost(S3)	6.27	19.59	1.6

Macronutrients and Micronutrients Present in the Samples

Table 2. Macronutrients

Macronutrients	Soil(S1)	Soil sample with waste without worms (S2)	Vermicompost(S3)
Nitrogen(ppm)	7.5	10.2	14.4
Phosphorus(ppm)	13	22.5	34
Potassium(ppm)	19	32	37

Table 3. Micronutrients

Micronutrients	Soil(S1)	Soil sample with waste without worms (S2)	Vermicompost(S3)
Iron(ppm)	1496.2	1536.6	1609.4
Zinc(ppm)	32.6052	36.5888	44.6075

Fig 4.1. *Single vermicompost cell produces 1.6V*

Fig 4.2. *Three vermicompost cells in series produce 5.4V*

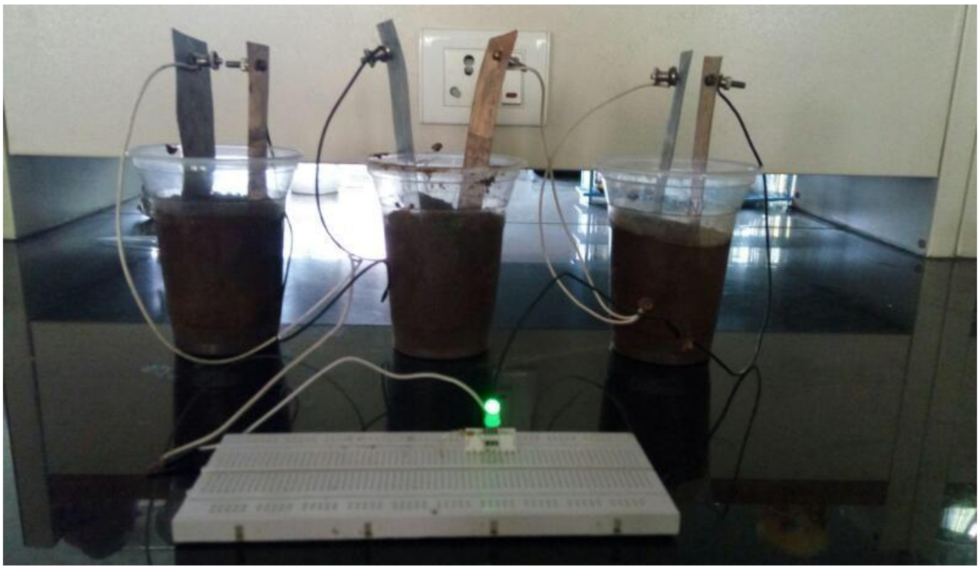

Fig 4.3. *Vermicompost cell light up LED*

10. Discussion

Vermicomposting can be used as a method to treat fruit wastes. The vermicompost has significantly larger nutrient content than that of conventional compost. The various macro and micro nutrients and the salts present in vermicompost enhance the ionic content there by increasing the flow of charge. The pH shows slightly acidic at the end of vermicomposting. This may be due to the various enzymes that are released from the worm's gut. The acidic nature makes it suitable for using as an electrolyte. A single compartment of 200g vermicompost mixed with 50ml of water produces a voltage of 1.6V. Whereas use of three isolated compartments of vermicompost gave a voltage of 5.4V that could light up an LED bulb. The study shows that the higher number of beakers containing vermicompost used, the higher the voltage and current produced in a circuit. The amount of voltage and current produced also depends on the size of the electrode, amount of electrolyte (vermicompost), area of contact between the electrode and electrolyte and the length of wires used. If the wires are too long, the resistance in the circuit may be high resisting the current flow. However, the voltage remains high.

Electricity generated in the vermicompost cell is because of the presence of metals such as zinc (Zn), nickel (Ni) and copper (Cu) in the vermicompost. These elements provide ions which can undergo chemical reaction and produce force called electromotive force (EMF). This reaction occurs between the electrodes and the vermicompost solution. The ions inside the solution react with copper and zinc electrode. The force produced is measured using a digital multimeter. The current is enough to light up LED device. This shows that the wastes can be subject to vermicomposting and the vermicompost can be used to generate electricity. This is due to the ions such as Zn^{2+} and Cu^{2+} inside the vermicompost as a result of the enzymatic reaction by *Eudrilus eugeniae*(earthworm).

The vermicompost has good moisture content. The experimental study reveals that the moisture content and the water holding capacity increased at the end of vermicomposting. The moisture content in the vermicompost gives proper contact with the electrode for the chemical reactions. Hence this can also be used in compressed state without addition of water to form a vermicompost cell. This compressed condition of vermicompost is more practical to be used compared to the vermicompost in aqueous solution. This is because in compressed condition, the vermicompost is easier to carry and easier to be used. Moreover, the compressed vermicompost is more appropriate to be used as dry cells compared to vermicompost in aqueous solution. For application purposes, the vermicompost can light up the LED bulb and hence can be used for all application where a chemical battery is used since it has the same capacity in generating electric current.

11. Conclusion

The vermicompost can be used as an alternative method to replace the chemical electrolytes. As the vermicomposting process is a low cost technology, this process can be used to produce harmless vermicompost which can produce high voltage and generate electricity. The ions inside the vermicompost react with the electrodes to produce high potential difference. Our present investigation revealed that the vermicompost can not only be used as an organic fertilizer but also generate electricity in a circuit. By using only worms as its catalyst and main component, the product can be used for many benefits to mankind. As a conclusion, the vermicomposting process is a method which can convert biodegradable waste into valuable vermicompost which produces high voltage. The increase of compartments increases the voltage produced. The voltage produced by one compartment of vermicompost is equivalent to the voltage produced by one dry cell. Based on the experiment, it is concluded that the vermicompost generates electricity and light up the LED bulb. The vermicompost can be used in battery to replace the chemicals used. This research can be upgraded in further research whereas this battery of vermicompost can replace ultimately the usage of chemical electrolyte in dry cells. Furthermore, it can also be upgraded and studied to be used as fertilizers in an area and at the same time the vermicompost produced electricity. The vermicompost can also be used more widely as it will solve the problems of solid waste management and also can be used in applications that benefits mankind. Besides, further research can be conducted to find solution for increasing current in the vermicompost.

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