Environmental Remediation through the Application of the Vermicomposting Technology for Bio waste Management

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Abstract

The vermicomposting technology is increasingly becoming popular as a bio fertilizer production through the aerobic decomposition of waste by earthworms as a bio waste management initiative. When vermiremediation occurs, the earthworms consume the bio waste which is then converted to vermicompost (solid bio fertilizer) and vermiwash (liquid fertilizer). Several studies have been conducted for various bio wastes worldwide using various earthworms over vermicomposting periods of 30-120 days in vermi reactors. Vermicompost with nitrogen, phosphorous and potassium (NPK) compositions with ranges 0.3-4.2%, 0.2-1.6% and 0.2-6.2% respectively were produced. In addition vermiwash with NPK composition of 0.1-1.6%, 0.1-7.5% and 0.5-1.3% respectively were produced. These bio fertilizers had rich macro nutrients composition that are required by plants and can be used as an alternative to chemical fertilisers promoting sustainable agriculture through vermi remediation.

Keywords: Bio fertilizers, earthworms, environmental remediation, vermicompost, vermiwash

1. Introduction

The vermiremediation process is gradually becoming popular as an environmental remediation through bio waste management (Abbasi et al. 2009; Tharmaraj et al. 2011; Gomez-Brandon et al. 2012; Kiyasudeen et al. 2016). The vermicomposting process involves conversion of waste to vermicompost due to earthworms' action (Manyuchi et al. 2012; Manyuchi et al. 2013a). During vermicomposting, earthworms ingest the bio waste and the earthworm's act as the bio reactor which converts the bio waste to bio fertilizers through various bio chemical reactions (Ansari and Sukhraj 2010; Lim et al. 2011). At the end of the bio conversion process, the vermicompost (vermicasts) produced is rich in nitrogen, phosphorous and potassium (NPK). The vermicasts produced from the vermi remediation process can also contain trace elements (Muthukumaravel et al. 2008; Palsania et al. 2008; Lim et al. 2012; Manyuchi et al. 2013a). The vermiremediation process is a mesophilic process and process parameters which include moisture content (MC), pH, temperature and electrical conductivity (EC) must be closely monitored. The vermiremediation procedure usually takes in vermi reactors with various types such as worm bins, earth bins and earthed pots (Manyuchi et al. 2013b).

Several type of earthworms have been applied in the vermi remediation of bio waste and these include *Eisenia fetida*, *Eisenia andrei*, *Megascolex mauritii*, *Drawida willis*, *Lampito rubellus*, *Lampito mauritii*, *Perionnyx excavatus* and *Eudrilus eugenia* (Singh et al. 2005; Nair et al. 2006; Chanda et al. 2011). Among these earthworm species for vermi remediation, the *Eisenia fetida* is the preferred earthworm of choice due to its flexibility and adaptability in various bio waste (Ndegwa et al. 2000; Ndegwa and Thompson 2000; Ndegwa and Thompson 2001; Sinha et al. 2002; Aira et al. 2007; Nath et al. 2009; Suthar 2009; Ansari and Jaikishun 2010; Ansari and Sukhraj 2010; Hatti et al. 2010; Indrajeet et al. 2010; Ansari 2011; Garg and Gupta 2011; Leon-Anzueto et al. 2011; Liu and Price 2011; Srivastava et al. 2011; Ansari and Rajpersaud 2012; Nath and Singh 2012; Manyuchi et al. 2017). The progress in the vermi remediation process through vermicomposting is determined using the changes in the earthworm length, weight, population density and reproduction rate (Edwards et al. 1998; Gark et al. 2005; Borah et al. 2007; Palsania et al. 2008; Kumari et al. 2011; Lim et al. 2011; Lim et al. 2012).

Several feed stocks were used as raw materials during vermi remediation including plant, animal, sewage and pharmaceutical waste over vermicomposting periods of 30-140 days (Borah et al. 2007). The NPK composition produced ranged from 0.4-1.8%, 0.2-1.6% and 0.7-5.0% (Muthukumaravel et al. 2008; Chanda et al. 2011; Punde and Ganorkar 2012; Manyuchi et al. 2013b, Manyuchi et al. 2013c, Manyuchi et al. 2013d). Temperatures between 20-70°C, pH between 6.0- 8.0 and moisture content between 10-80% have been employed during the vermi remediation of biowaste (Ndegwa and Thompson 2001; Borah et al. 2007; Jadia and Fulekar 2008; Suthar 2009; Indrajeet et al. 2010; Garg and Gupta 2011; Kumari et al. 2011; Narkhede et al. 2011). Electrical conductivity values ranging between 0.70-80 000μscm^{-1} have also been reported to be ideal for vermicompost (Singh and Suthar 2012). A liquid bio fertilizer, vermiwash produced during the vermiremediation process has pH of around 8 (Ansari and Sukhraj 2010). The vermiwash also contains nitrogen of around 0.14% and phosphorous content of around 0.05% (Ndegwa and Thompson 2001).

The bio fertilizers from the vermi remediation process has seen application on various plants such as tomatoes, rice, okra, chilli pepper, medicinal and flowering plants, peas, corn and soy bean (Zambare et al. 2008; Gopal et al. 2010; Kalantari et al. 2010; Kumari et al. 2011; Pant et al. 2011; Rawgol et al. 2011). The effect of the bio fertilizers on plants have been monitored using the yield, height, number of leaves as well as the number of plants produced (Vijaya et al. 2008; Manyuchi et al. 2013c; Manyuchi et al. 2013d; Ali et al. 2015).

2. Vermicomposting as an environmental remediation technique

The vermicomposting of organic waste to vermicompost (biofertilizers) can be regarded as a bio remediation exercise in terms of waste management and mitigation of green houses gases emissions (Pant et al. 2011; Manyuchi et al. 2012). During the vermi remediation process, it is critical to monitor the earthworm activity as this determines the effectiveness of the process (Gurav and Pathade 2011; Ansari and Rajpersaud 2012; Manyuchi et al. 2012; Manyuchi et al. 2013a).

2.1 Vermi remediation products

The use of vermicomposting as an environmental vermi remediation strategy results in the generation of various products such as vermicompost, vermiwash and the earthworms.

2.1.1 Earthworms

Several types of earthworms have been used in vermi remediation as indicated in Table 1. Various types of bio waste are employed however the *Eisenia fetida* is predominantly used in vermiremediation (Sinha et al. 2002; Aira et al. 2007; Nath et al. 2009; Ansari 2011; Manyuchi et al. 2012). The activity of the earthworms has been successfully studied using the gain in weight, cocoons produced as well as boost in earthworms' number and length (Lim et al. 2012).

The growth rate of the earthworms during vermi remediation is calculated in accordance to Equation 1 as defined by (Garg and Gupta 2011).

$$G = \frac{B_2 - B_1}{T\,X\,n} \quad (1)$$

Where: G is the growth rate of the earthworms (mg/worm/day), B_1 is the original mass of the earthworms (mg), B_2 is the maximum biomass of the earthworms (mg), T is the vermi remediation period and N is the earthworms quantity used.

The total amount of earthworms gained per unit bio waste (mg/g) is determined in accordance to the Equation 2 (Garg and Gupta 2011):

$$\frac{B_2 - B_1}{W} \quad (2)$$

Where: W is the total amount of bio waste used (g), B_1 is the initial biomass of earthworm (mg) and B_2 is the maximum biomass obtained by earthworm (mg)

Whereas the reproduction rate of the earthworms is calculated in accordance to Equation 3 (Garg and Gupta 2011):

$$R = \frac{C}{E} \quad (3)$$

Where: R is the earthworms' rate of reproduction, C is the final number of cocoons produced and E is the amount of earthworms used.

2.1.2 Vermicompost

The vermiremediation process of bio waste results in the production of vermicompost which dark brown in colour and is odourless (Aalok et al. 2008; Abbasi et al. 2009; Manyuchi et al. 2017). Various NPK compositions for several types of bio waste are shown in Table 2. The yield of the vermicompost produced from the vermiremediation process ranges from 30-50% depending on the bio waste used (Chaudhuri et al. 2000).

The vermicompost quality is measured using the bio degradability coefficient (Garg and Gupta 2011). The bio degradability coefficient (K_b) is calculated in accordance to Equation 4:

$$K_b = \frac{(\mathrm{OM_i} - \mathrm{OM_f})\, X\, 100}{\mathrm{OM_i}\,(100 - \mathrm{OM_f})} \quad (4)$$

Where: OM_f represents the bio waste amount at the finish of the vermi remediation process and OM_i is the bio waste amount at the start of the vermi remediation.

2.1.3. Vermiwash

A leachate is produced during the vermi remediation process and this is termed vermiwash (Jadia and Fulekar 2008; Sundaravadivelan et al. 2011; Manyuchi et al. 2013d).

2.2 Effect of vermi remediation products as bio fertilizers

The vermiremediation products (vermicompost and vermiwash) obtained from the vermicomposting process can be applied as bio fertilizers (Sudhakar et al. 2002; Manyuchi et al. 2013c; Manyuchi et al. 2013d). The bio fertilizers impact positively on the soil physicochemical properties. The bio fertilizers produced using the vermicomposting technology has shown positive effect on the plants yield, number of flowers and leaves as well as the plant height (Indrajeet et al. 2010; Srivastava et al. 2011; Ansari and Rajpersaud 2012).

3. Materials and methods

Municipal bio waste and *Eisenia fetida* earthworms were used in this study. The municipal bio waste was obtained from a local landfill whilst the *Eisenia fetida* earthworms were obtained from local fishermen. Vermi reactors from Full Cycle South Africa were used for the vermiremediation process. Vermicomposting was allowed to take place at standard room temperature and pressure. Vermicomposting was allowed to take place for a period of 30 days as a vermi remediation process. The physicochemical parameters were measured during the vermicomposting process using standard methods. These parameters included moisture content, pH, temperature and electrical conductivity. In addition, the volatile matter, fixed matter and ash content were also determined. The N, P and trace elements composition was determined using a Shimadzu 1800 uv-vis spectrophotometer and the K composition was determined using a Shimadzu AA 7000 AAS.

4. Results and discussion

4.1 Effect of vermi remediation on bio waste physicochemical properties

As the vermicomposting time increased, the ash content increased by about 150% and this was attributed to the conversion of the waste to the bio fertilizers through the vermi remediation process (Singh et al. 2005; Shweta 2011). This was also shown by the increase in the volatile matter by more than 500% in the vermicompost. Increase in the volatile matter is a good indication of bio degradability of the bio waste (Palsania et al. 2008). This can be further attributed to the decrease in the fixed carbon by more than 80%. A summary of the changes in the bio waste physicochemical properties is shown in Table 1.

Table 1. Effect of vermiremediation on the bio waste physicochemical properties

Parameter (%)	Bio waste	Vermicompost
Volatile matter (VM)	1.5	10
Moisture content (MC)	27.7	52.4
Ash content (AC)	11.4	28.2
Fixed carbon (FC)	59.5	9.4

4.2 Effect of vermi remediation on process conditions

4.2.1 Moisture content

During the vermi remediation process, the moisture content increased by about 50%. This was attributed to the production of vermiwash as the vermicomposting process occurred (Palsania et al. 2008). A normal increase in the moisture content also enhances the earthworm performance and reproduction ultimately optimizing the vermi remediation process (Palsania et al. 2008).

4.2.2 Electrical conductivity

Generally as the vermiremediation process occur, the electrical conductivity decreases and a 25% decrease was noted for this study. The decrease is attributed to the increase in moisture content and this allows for optimal nutrient adsorption of nutrients by plants (Ansari and Rajpersaud 2012).

4.2.3 Temperature

The vermiremediation process being a biological process requires moderate temperatures (Palsania et al. 2008). Temperatures that were ranging between 20-25 °C were observed. The slight temperature fluctuations in the vermiremediation process maybe due to changes in the temperature outside the vermireactor.

4.2.4 pH

Vermi remediation of bio waste also allows for neutralisation of the waste as the vermicomposting occurs. In this study, the ph changed from 6 to around 7.7 and this can be attributed to the vermiwash generated during the vermicomposting period (Singh et al. 2005; Ansari and Sukhraj 2010; Tharmaraj et al. 2011).

4.3 Nutrient composition of the vermiremediation products

As discussed earlier, the vermicompost and vermiwash obtained were rich in bio fertilizer nutrients components. The vermicompost from this study had a nitrogen content of 4.2% which is generated due to the nitrogenous metabolic products from the vermicasts and urine. The municipal waste vermicompost contained total nitrogen of 4.2% (Muthukumaravel et al., 2008). The vermicompost phosphate composition was 1.2% and this was due to the mobilization and mineralization of phosphorous ions due to earthworm movement (Ansari and Rajpersaud, 2012). The potassium content in the vermicompost was 6.2% and a summary of the nutrients composition is given in Table 2. In addition, the vermiwash generated had an NPK composition of 1.6%, 7.5% and 1.3% respectively.

Table 2. Vermiproducts nutrient composition

Nutrient	Feedstock composition	Vermicompost composition	Vermiwash composition
Nitrogen (%)	2.6	4.2	1.6
Phosphorous (%)	0.6	1.2	7.5
Pottasium (%)	5.0	6.2	1.3

5. Conclusion

Vermiremediation can be applied as a bio waste management and value addition technology to produce bio fertilizers. The vermicompost produced was dark brown and odourless. A positive change in the physicochemical properties in the bio waste was noted with moisture content (28-52%), temperature (20-25◦C), pH (6.0-7.7) and electrical conductivity (60 000-80 000 µS/cm) being optimal. The vermicompost's NPK content 4.2%, 1.2% and 6.2% respectively.

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