Science Journal of Analytical Chemistry
2025, Vol. 13, No. 1, pp. 15-23
https://doi.org/10.11648/j.sjac.20251301.13

Research Article

Preparation and Characterization of Vermicompost Nutrients Made from Different Sources of Organic Materials

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Abstract

Vermicomposting is simple biotechnological process of composting, which certain species of earthworms are used to enhance the process of waste conversion and produce better homogenized end product. Therefore, this study was conducted to prepare and Characterization of vermicompost nutrients made from different sources of organic materials. The experiment was carried out during 2023/24 at Bedele Agricultural Research Center. Vermicomposting was done using Eisenia fetida with seven treatments: wheat straw, maize stalk, sorghum stalk, haricot bean straw, soybean straw, finger millet straw and faba bean straw. The data were analyzed by SAS software version 9.3. Results indicated that for all the seven treatments the pH fluctuated in the range of 6.88 to 8.90, and the highest pH value was recorded from soybean straw with animal manure (8.90) whereas the lowest obtain from wheat straw with animal manure. Electrical conductivity of vermicompost were ranged from 2.02 to 4.44ds/m and the highest value of EC was recorded from soybean with animal manure (4.44ds/m) and the lowest from maize stalk with animal manure (2.02ds/m). The organic carbon of the vermicompost were ranged from 15.18 to 16.54%. The highest and lowest value of organic carbon was recorded from faba bean straw and haricot bean with animal manure (16.54 and 15.18%) respectively. The obtained total nitrogen was ranged from 1.28 to 1.43%. However, the highest was obtained from faba bean straw with animal manure and lowest recorded from maize stalk with cow manure (1.43% and 1.28%) respectively. The available phosphorus of vermicompost ranged from 24.65 to 27.75 ppm, from these results the highest and the lowest was recorded from wheat straw with animal manure and soybean straw with animal manure (27.75 and 24.65 ppm) respectively. The harvested vermicompost had an excellent nutrient rank, confirmed by chemical analysis, and contained all the essential selected macronutrients.

Keywords

Organic Substrate, Eisenia Fetida, Animal Manure

1. Introduction

Soil acidity is a widespread restriction to crop production in many parts of the world [1]. It is a major constraint to agricultural productivity throughout of the Africa where high rainfall is common due to the deficiencies of nitrogen by leaching, phosphorus fixation, and low soil organic matter. Organic fertilizer application has been described to improve crop growth by providing plant nutrients as well as improving soil physical, chemical, and biological properties [2]. Vermicompost is one of the stabilized; finely divided organic fertilizers with a low C: N ratio, high porosity and high-water

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Received: 23 December 2024; **Accepted:** 7 January 2025; **Published:** 23 January 2025

holding capacity, in which most nutrients are present in forms that are readily available for plant [3, 4]. Application of vermicompost showed marked improvements in the overall physical and biochemical properties and at the same time, vermicompost decreases exchangeable acidity which can support a release of plant nutrients in the acidic soils [5]. Recent trends in agriculture are centered on reducing the use of inorganic fertilizers by bio-fertilizers such as vermicompost [6]. When it compared with convectional compost, vermicompost promotes growth from 50 to 100% over convectional compost and from 30 to 40% over chemical fertilizers [7].

Therefore, vermicomposting is a simple biotechnological process of composting, in which certain species of earthworms are used to enhance the process of waste conversion and produce a better end product. Vermicomposting differs from composting in several ways [8]. It is a mesophilic process, by using microorganisms and earth that are active at 10-32 ℃ (not ambient temperature but temperature within the pile of moist organic material). In addition, bulk density, water holding capacity, PH, electrical conductivity, nitrogen, phosphorus, and potassium content are improved by vermicomposting compare to composting material [9, 10]. Furthermore, vermicompost decreases the amount of heavy metal incorporated to soil compare to compost [11] it has been also stated that vermicompost may have more compounds used as a plant hormone which enhances plant growth and development compare to compost [12, 13].

According to many studies conducted in Ethiopia, vermicompost have high nutrient contents and good quality. Beside increasing plant nutrients, vermicompost also improve growth, total dry matter and grain yield of different crops. The vermicompost process is faster than composting; because the organic materials pass through the earthworm intestines, an important but not yet fully understood transformation takes place, whereby the resulting earthworm castings (worm manure) are rich in microbial activity and plant growth regulators, and encouraged with pest repellence attributes as well. Similarly, [14, 15] earthworms, through a type of biological experimentation, are capable of transforming garbage into ‘gold’. Importance of vermicomposting Source of plant nutrients earthworms eat various organic wastes and reduce the volume by 40–60%. Each earthworm weighs about 0.5 to 0.6 g, eats waste equivalent to its body weight and produces cast equivalent to about 50% of the waste it consumes in a day [16]. Still now the importance of vermicomposting technology is not adapted at Buno Bedele zone at Bedele district and additional it cannot determine the source of organic materials which contain much nutrient composition for crop growth. Therefore, keeping in view the importance of vermicompost, the present objectives of this study was to prepared and characterized the nutrient composition of different sources of organic materials and identify quality vermicompost of different sources of organic materials that contains high composition of essential nutrients.

2. Materials and Methods

2.1. Location

The study was conducted at Bedele Agricultural Research Center in Bedele district of Buno Bedele Zone, Oromia Regional State; Ethiopia. It is located in the southwestern part of the country at 500 km far from Finfine the capital city of Ethiopia.

2.2. Design of Vermiculture

The earthworms usually dig deeply into the substrate observing for food, but do not reach beyond than 40 cm [17]. So, the worm bin where the worms live and produce compost, shallow boxes were constructed in the house from cement with the dimension of the bed should had a depth of 60 cm and 1 m wide; the length 1m on the available area [18]. The bed was protected from rain, sunlight and extreme temperatures in times of frost or winter and the bed framed with bricks where the walls and bottom of the structure was lined with polyethylene sheet. The bottom of the polyethylene sheet was made to have tiny holes to drain the excess water. Mature red earthworms (Eisenia fetida) were introduced a kilo of in each box.

2.3. Experimental Materials and Vermicompost Preparation

Vermicompost was prepared from different substrate organic materials which was locally available to be obtain (from farmers field) such as wheat straw, maize stalk, sorghum stalk, finger millet straw, haricot bean straw, soybean straw and faba bean straw. The collected materials were chopped and added to the worm bin. Animal manure was added to all substrates in equal amount. After all substrates chopped, they added to boxes and was mixed with animal manure as a starter and sprayed with water to maintain optimum moisture for worms. The mixture of substrates was prepared from equal amount and finally mixed with animal manures. Substrates of 20kg mixed with 10kg of animal manure was filled based on the volume of worm bin. After moisture optimized a kilo of earthworms was added to every treatment.

2.4. Vermicompost Sampling and Analysis

To evaluate the various physical and chemical transformations of vermicompost, representative samples were collected from different points of the vermicompost pile (bottom, surface, side and center) at the end of well-prepared. 1kg of vermicompost samples were taken in plastic containers and transported immediately to the laboratory. Chemical properties of vermicompost were analysis was carried out at Bedele Agricultural Research Center following standard procedures.

2.5. Chemical Properties Analysis of Vermicompost

From chemical analysis organic carbon (OC) and total nitrogen (TN) was determined used by dried compost samples which were ground to pass through a 2-mm sieve as described by [19]. For the determination of total N, samples were decomposed using concentrated H_2SO_4 and catalyst mixture in Kjeldahl flask and subsequently, N content in the digest was determined following steam distillation and titration method [20]. Organic carbon was determined by dichromate wet digestion and rapid back titration methods as described by [21]. Analysis for pH and electrical conductivity (EC) was performed in extracts of 1:10 (w/v) compost: distilled water ratio as described by [22]. The C: N ratio was calculated from the individual values of OC (%) and TN (%). Available phosphorus by Olsen method [23]. Cation Exchange Capacity (CEC) was analyzed by neutral 1M ammonium acetate.

2.6. Data Analysis

The collected data was subjected to analysis ANOVA by SAS software version 9.3.

3. Results and Discussions

Vermicompost Analysis Results

The collected vermicompost samples were analyzed for pH (H_2O), Electrical conductivity (EC), Available phosphorus, total nitrogen (%TN), organic carbon (%OC) and cation exchange capacity (CEC) were analyzed and explained accordingly.

PH (H_2O) and Electrical conductivity (EC in ds/m) of Vermicompost

According to results (Table 1) showed that the highest pH values were obtained from vermicompost of soybean followed by faba bean (8.90 and 8.24) respectively. whereas, the lowest pH values were gained from vermicompost made from wheat straw followed by finger millet straw (6.88 and 7.11) (Table 1) respectively. And the pH of wheat straw showed that significance($p<0.05$) difference from the rest of organic materials used to prepare vermicompost's. These results showed that the obtained pH of vermicompost were neutral to strongly alkaline which ranges from PH values 6.88 to 8.90 (Table 1). These results agreed with [24] and [25] who reported similarly results of pH of the vermicompost ranged from neutral to alkaline. According to [26] stated that a pH ranges from 5 to 9 during the process, the value reaching near neutrality when the vermicompost was ready for the harvest**.** The obtained results of electrical conductivity of vermicompost a little bit it showed significantly difference between each other depending on the source of organic materials (Table 1). Classify the salinity hazard of a vermicompost, electrical Conductivity (EC) measurements were conducted. The electrical conductivity salt content of a vermicompost was predictable by suspension in distilled water. The vermicompost results showed that the highest (4.44ds/m) obtained from soybean straw however the lowest (2.02ds/m) EC was gained from maize stalk (Table 1) respectively. The electrical conductivity of Vermicompost made from soybean and haricot bean straw indicated moderately saline. However, the rest of electrical conductivity of vermicompost made from wheat straw, maize stalk, sorghum stalk, Finger millet straw and faba bean straw were showed slightly alkaline (Table 1). The electrical conductivity of vermicompost results was indicates well for crop growth even though applied to the soil. This finding was linked with [24] who stated that electrical conductivity of vermicompost under this study was alkalinity range was suitable for growth of most crops**.** As [27] stated that vermicompost is ideal organic manure for better growth and yield of many plants**.**

Table 1. *pH (H_2O) and Electric conductivity (ds/m) of vermicompost.*

Treatment No.	Treatment description	Mean of pH (H_2O)	Mean of EC (ds/m)
1	Wheat straw with animal manure	6.88^{c}	3.97^{a}
2	Maize stalk with animal manure	8.11^{ab}	2.02^{b}
3	Sorghum stalk with animal manure	7.86^{b}	3.28^{ab}
4	Finger millet straw with animal manure	7.71^{bc}	2.89^{ab}
5	Haricot bean straw with animal manure	8.02^{b}	4.31^{a}
6	Soybean straw with animal manure	8.90^{a}	4.44^{a}
7	Faba bean straw with animal manure	8.24^{ab}	2.95^{ab}
	Grand mean	7.96	3.41
	LSD (0.05)	0.920	1.88
	CV (%)	6.49	31.02

Organic carbon (%OC), Carbon to Nitrogen ratio (C: N)

The results of organic carbon and carbon to nitrogen ratio of vermicompost indicated that it shows significantly difference between faba bean, soybean straw and the remained organic materials (Table 2). The results showed that the highest organic carbon of vermicompost was recorded from faba bean straw followed by soybean (16.55 and 16.48) respectively and the lowest was obtained from maize stalk by followed haricot bean (14.82, 15.18) respectively (Table 2). Overall, the organic carbon of vermicompost were ranged from 14.82 to 16.54 which results revealed that the quality of vermicompost production and good for most crops for growth. Almost all the results were recorded C to N ratio of vermicompost were showed significance difference faba bean straw and maize stalk (Table 2). The carbon to nitrogen (C: N) ratio, observed that which one of the most generally used indicators of the organic waste maturity, it was reduced in the process of vermicomposting, it was satisfactory according to [26]. Microbial respiration and nitrogenous excretion reduce the C: N ratio of the source of carbon is dried plant material and animal manure provides nitrogen input during the decomposition process of vermicomposting [28].

Table 2. *Organic carbon (%) and Carbon to Nitrogen ratio of vermicompost.*

Treatment No.	Treatment description	Mean of O.C(%)	Mean of C: N
1	Wheat straw with animal manure	15.28^{ab}	11.60^{ab}
2	Maize stalk with animal manure	14.82^{b}	11.59^{b}
3	Sorghum stalk with animal manure	15.89^{ab}	11.60^{ab}
4	Finger millet straw with animal manure	16.09^{ab}	11.61^{ab}
5	Haricot bean straw with animal manure	15.18^{ab}	11.60^{ab}
6	Soybean straw with animal manure	16.48^{a}	11.61^{ab}
7	Faba bean straw with animal manure	16.55^{a}	11.63^{a}
	Grand mean	15.75	11.60
	LSD (0.05)	1.572	0.041
	CV (%)	5.6	0.2

Total nitrogen (TN%) of Vermicompost

The obtained results of total nitrogen in faba bean and soybean revealed that non significantly influenced from each other (Table 3), however it was significantly different from the rest of vermicompost made from difference source of organic materials (Table 3). The highest total nitrogen (TN%) was obtain from vermicompost that made from faba bean straw (1.43%) followed by soybean straw (1.42%) respectively. However, the lowest total nitrogen (TN%) was recorded from vermicompost made from maize stalk (1.28%) followed by haricot bean (1.31%) respectively (Table 3). These results revealed that the total nitrogen content in vermicompost was greater than the total nitrogen present in soil. This result agreement with the finding of [29] who rated of total nitrogen in a soil the total nitrogen in a vermicompost made from all substrates was high (>1%) and significantly greater than in a soil. Even though, applying vermicompost to soil could increase total nitrogen in soil. These results indicated that addition of different substrate to cow dung it had different nitrogen content in vermicompost. Similarly, [24] stated that different types of straw were contains different nitrogen contents.

Table 3. *TN (%) of vermicompost.*

Treatment No.	Treatment description	Mean of TN (%)	Equivalent ratio of N in vermicompost into urea kg/ha
1	Wheat straw with animal manure	1.32^{ab}	3499.0^{ab}
2	Maize stalk with animal manure	1.28^{b}	3607.6^{a}
3	Sorghum stalk with animal manure	1.37^{ab}	3363.9^{ab}

Treatment No.	Treatment description	Mean of TN (%)	Equivalent ratio of N in vermicompost into urea kg/ha
4	Finger millet straw with animal manure	1.38^{ab}	3323.0^{ab}
5	Haricot bean straw with animal manure	1.31^{ab}	3530.6^{ab}
6	Soybean straw with animal manure	1.42^{a}	3245.5^{b}
7	Faba bean straw with animal manure	1.43^{a}	3235.9^{b}
	Grand mean	1.36	3400.78
	LSD (0.05)	0.138	335.97
	CV (%)	5.69	5.55

Available phosphorus of vermicompost

Available phosphorus obtained from wheat straw, faba bean and soybean straw of vermicompost was significance difference from the rest of vermicompost made from different organic materials. But, faba bean and soybean con not showed significance difference between them (Table 4) The analyzed result indicated that the highest available phosphorus was obtained from wheat straw followed by haricot bean straw (27.75 and 27.43ppm) respectively. Whereas the lowest value was recorded from the vermicompost made from soybean followed by maize stalk (24.65 and 25.09ppm) (Table 4) respectively. Their difference might be attributed due to nature of the substrates. The improved phosphorus level in vermicompost proposes phosphorous mineralization during the process. During the vermicomposting preparation worms converted the insoluble phosphorus into soluble forms with the help of Phosphorus solubilizing microorganisms through phosphatases present in the instinctive, making it more available to plants [25]. When compared the available phosphorus of vermicompost with soil, available phosphorous from vermicompost made from all substrates were higher than the available in the soil. Similarly, [30] indicated that the available phosphorous in vermicompost was much higher than the soil and addition to conventional compost. Thus, application of vermicompost could improve phosphorus level of the soil and increases the amounts of phosphorus to more uptakes by crop.

Table 4. *Available phosphorus (ppm) of vermicompost.*

Treatment No.	Treatment description	Mean of Avai. P(ppm)
1	Wheat straw with animal manure	27.75^{a}
2	Maize stalk with animal manure	25.09^{bc}
3	Sorghum stalk with animal manure	26.47^{abc}
4	Finger millet straw with animal manure	25.31^{abc}
5	Haricot bean straw with animal manure	27.43^{ab}
6	Soybean straw with animal manure	24.65^{c}
7	Faba bean straw with animal manure	25.96^{abc}
	Grand mean	26.09
	LSD (0.05)	2.503
	CV (%)	5.39

Exchangeable Calcium and Magnesium (Ca^{2+} and Mg^{2+}) of Vermicompost

Calcium is constituents of the wall an activator of different plant enzymes and necessary for cell membranes. It improves the intake of other plant nutrients specially nitrogen and trace element by adjusting the soil pH. Whereas, Magnesium is a constituent of chlorophyll and chromosome. It also works as a catalyst for enzyme. It regulates the uptake of

nitrogen and phosphorous from the soil. The vermicompost results obtained prepared from different source of organic materials revealed that non-significance different ($p>0.05$) between each other of Calcium as well as magnesium. However, the results of Calcium content in vermicompost ranged from medium to high (1666.7 to 2006.7 mg/kg of VC) in table 5. This shows that the calcium (Ca^{2+}) in vermicompost prepared from finger millet straw and haricot bean straw with animal manure range under high level and the remain calcium contents in vermicompost made from wheat straw, maize stalk, sorghum, soybean and faba bean shows medium. Similarly, the results of magnesium in vermicompost obtained ranged from medium to high (315.2 to 555.1 mg/kg) in Table 5 comparing with calcium and magnesium in the soil. The results agreed with [29]. This is due to increased rate of mineralization and degree of humification by the action of earthworms [31]. Depending on the obtained results application of vermicompost from all organic materials mention in this study on soil acidity it used to improve soil pH and enhance availability of nutrient for plant growth.

Table 5. *Exchangeable Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) in Vermicompost (mg/Kg VC).*

Treatment No.	Treatment description	Mean of Ca^{2+} (mg/kg VC)	Mean of Mg^{2+} (mg/kg VC)
1	Wheat straw with animal manure	1666.7	467.7
2	Maize stalk with animal manure	1726.7	315.2
3	Sorghum stalk with animal manure	1633.3	459.5
4	Finger millet straw with animal manure	2006.7	555.1
5	Haricot bean straw with animal manure	2006.7	392.4
6	Soybean straw with animal manure	1640.0	494.1
7	Faba bean straw with animal manure	1933.3	321.3
	Grand mean	1801.91	429.32
	LSD (0.05)	NS	NS
	CV (%)	21.46	58.97

Cation Exchange Capacity (CEC) of vermicompost

Cation exchange capacity is the capacity of the soil to hold and exchange cations. The recorded CEC of vermicompost results showed that highly significantly ($p<0.01$) influenced between each other. The Cation Exchange Capacity (CEC) of vermicompost results indicated that the highest values obtained from maize stalk followed by finger millet (54.47 and 50.13 cmol(+)/kg vermicompost) (Table 6) respectively. However, the lowest vermicompost was recorded from faba bean followed by haricot bean (40.87, 46.20 cmol(+)/kg in VC) (Table 4) respectively. The CEC of vermicompost made from all substrates were rated to very high status [32]. Though the result obtained in this study showed very high level of vermicompost which agreed with this author. So, application of vermicompost made from all substrates could increase CEC content of the soil in areas where soil with low CEC [24]. Overall, the results cation exchange capacity of vermicompost showed that it is very good while application to soil and enhance to improved cation exchange capacity of the soil.

Table 6. *Cation Exchange Capacity (CEC cmol(+)/kg in VC) of vermicompost.*

Treatment No.	Treatment description	Mean of CEC. (cmol(+)/kg in VC)
1	Wheat straw with animal manure	46.67^{b}
2	Maize stalk with animal manure	54.47^{a}
3	Sorghum stalk with animal manure	46.53^{b}
4	Finger millet straw with animal manure	50.13^{ab}
5	Haricot bean straw with animal manure	46.20^{bc}

Treatment No.	Treatment description	Mean of CEC. (cmol(+)/kg in VC)
6	Soybean straw with animal manure	48.80[b]
7	Faba bean straw with animal manure	40.87[c]
	Grand mean	47.67
	LSD (0.05)	5.64
	CV (%)	6.65

4. Conclussions and Reccomendations

The results recorded of vermicompost made from different source of organic material had different nutrient contents based on source of feed for vermiworms. The highest pH value of vermicompost was obtained from soybean straw with cow manure (8.90). Whereas the lowest pH was recorded from wheat straw with animal manure (6.88). The PH results of this study were ranged from 6.88 to 8.90 which indicated neutral to slight alkaline and suitable for most crop growth. The electrical conductivity of vermicompost made from different source of organic materials were ranged from 2.02 to 4.44ds/m. The vermicompost made from faba bean with animal manure and soybean straw animal manure was rich by TN% than the rest of vermicompost other organic materials. The highest value of total nitrogen was recorded from vermicompost prepared from faba bean followed by soybean straw with animal manure (1.43 and 1.42%) respectively. Overall, the results of TN% in this study ranged from 1.28 to 1.43%. Although available phosphorus in vermicompost which made from different organic materials were ranged 24.65 to 27.75 ppm. From this result the highest and lowest available phosphorus of vermicompost obtained from wheat straw with cow manure and soybean straw with animal manure (27.75 and 24.65ppm) respectively. This result was sufficient while adding to soil for most crop to well growth. In this study the cation exchange capacity of vermicompost was ranged 40.87 to 54.47 cmol(+)/kg of vermicompost. According to this result all range CEC of vermicompost made from different source of organic material was showed the quality of vermicompost. Depending on this study vermicompost could be used as a source of macronutrients and as organic fertilizers for soil lacking with macronutrients. According, to this study, amount 3.2359t/ha of vermicompost made from faba bean can replaces the commercial fertilizer of nitrogen content fertilizer (urea of 46kg/ha).

5. Recommendations

Farmers should be use vermicompost most as organic fertilizers rather use of inorganic fertilizers. Research center, agricultural office and NGO should be creating awareness on preparation and use of vermicompost for crop and the effects of vermicompost on soil physicochemical properties. For further information verification of this study result application appropriate rate of vermicompost and effect on soil physicochemical properties on the farmers field should be done. At the final depending on the obtained results nitrogen contents of vermicompost farmers should be use vermicompost made from faba bean followed by soybean and finger millet based on the availability of organic composting materials.

Abbreviations

C:N	Carbon to Nitrogen Ratio
CEC	Cation Exchange Capacity
CV	Vermicompost
ds/m	Decisimen per Meter
EC	Electrical Conductivity
TN	Total Nitrogen
Ppm	Parts per Million
Cmol(+)/kg	Centmole per Kilogram
t/ha	Ton per Hector
NGO	Non-governmental Organization

Acknowledgments

The authors would like to thank Oromia Agricultural Research Institute and Bedele Agricultural Research Center for funding the research and providing all the necessary facilities required respectively. Additional laboratory analysis team of Bedele Agricultural Research Center for their support and unreserved effort to provide reliable samples analysis data on time.

Conflicts of Interest

The authors declare no conflicts of interest.

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