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Fish Waste Compost - A Fertilizer for Organic Agriculture

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Fish markets produce a large amount of fish waste such as fish head, gut, intestine, fines, bones and scales that are generally dumped in the river or land-filling areas causing great intuitive pollution to the environment. Such impulsively growing contamination can be mitigated and checked though waste management in the form of organic composting. This study investigates the potential of fish waste compost as a sustainable organic fertilizer by converting fish waste, including gut, head, skin, bones, and fins, into compost using sawdust, banana and jaggery as supplementary materials. The matured compost was then analyzed for nutrient content and maturity through physical, sensory, biological, and chemical tests. Results showed that the

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compost, reduced to 70% of its original volume, had significant nutrient content with a C:N ratio of 28.6:1, a pH of 6.80, and an electrical conductivity of 1.45 dS/m. Biological tests demonstrated high germination rates, indicating non-phytotoxicity. Fish waste containing 10.56, 2.12, 0.82 and 0.10 percents of C, N, P and K respectively can be converted into an effective organic fertilizer which can enhance soil fertility. This approach not only addresses waste management but also offers a viable solution for recycling fish waste into valuable agricultural resources.

Keywords: Fish waste; organic compost; physical; sensory; biological; chemical tests.

1. INTRODUCTION

Organic farming is a method of agricultural production that depends on natural processes such as using animal manure, organic waste, crop rotation, legumes, and biological pest control. The core principle of organic farming is to nourish the soil instead of directly focusing on the crops. This approach enhances soil health, vitality, and resilience, enabling it to provide all the necessary nutrients for crops to grow and develop properly. Organic farming seeks to sustain and boost productivity by improving soil health and enhancing the entire agricultural ecosystem. The use of chemical fertilizers has depleted soil fertility and led to health and environmental issues. Conversely, using organic waste as fertilizer enhances soil structure, increases water retention, boosts microbial biomass, and improves nutrient availability, promoting sustainable agricultural practices [1].

India is the world's second-largest fish producer after China, with output rising from 0.75 million tonnes in 1950 to 9.6 million tonnes in 2012-13 [2]. During processing, about 75% of the fish's total weight turns into solid waste, consisting of the gut, head, skin, bones, fins, and frames. The waste is frequently not reused and is instead discarded in landfills, incinerated, or dumped into rivers. Therefore, there is an urgent need to develop eco-friendly methods for repurposing these materials [3]. Composting has been recommended as a feasible solution [4]. Some fish wastes are also reutilized for the fish meal production [5 and 6]. To date, there have been only a few reports on the repurposing of biodegraded waste products. Fish wastes, which are high in nitrogen, potassium, phosphorus, and trace minerals, can be used as raw material for producing various nutritive and non-nutritive products [7]. The solid waste material of the fish will be transformed into compost for the improvement of soil fertility. In this context, the study aimed to assess whether fish compost could be a viable method for recycling and creating high-quality organic fertilizer for organic farming systems.

2. MATERIALS AND METHODS

2.1 Preparation of Fish Waste Compost

Before compost preparation, the nutrient contents of fish waste, sawdust, banana, and jaggery were analyzed through their chemical composition [Table 1]. The solid fish waste, including the gut, head, skin, bones, fins, scales, and intestines, was collected and finely chopped. This chopped fish waste [80% by weight] was then mixed with 20% sawdust, 12 whole bananas, 50 grams of jaggery, and soaked in distilled water. These percent contents were then placed in layers within the compost basket bin. The Basket bins were assembled using 10 ltr plastic basket, grommet, adapter and end-cap. Afterward, the compost was stirred regularly every 3-4 days until the fish waste compost was fully formed. The process took 120-140 days to reach full maturity [Fig. 1]. The mature fish waste compost was sieved through a 20 mm mesh screen, and its analysis was conducted.

2.2 Maturity Test of Fish Waste Compost

Maturity test of the fish waste compost was done by physical and sensory, biological and chemical tests. The above test was done as prescribed by the Kristine and Daryl [8].

Table 1. Fish waste compost maturity test [8]

Test category	Potential test for maturity
Physical and sensory test	Colour Odour
Biological test	Phytotoxicity (plant bioassay)
Chemical test	Carbon: Nitrogen ratio Organic matter Cation exchange capacity pH Electrical conductivity

Fig. 1. Collection of fish waste and preparation of fish waste compost

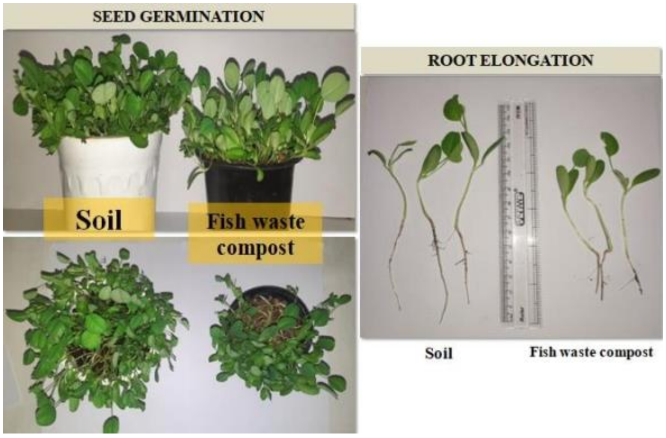

Fig. 2. Phytotoxicity (Plant biossay) test in Fenugreek (*Trigonella foenum-graecum*)

2.3 Phytotoxicity Test

The compost's maturity and toxicity were evaluated to confirm its suitability for agricultural use. Fenugreek (*Trigonella foenum-graecum*) seeds were used in a germination experiment to evaluate the phytotoxicity of the final fish waste compost [9 and 10] [Fig. 2]. To calculate the germination index, seed germination and root elongation were initially measured using the formula provided below.

$$Seed\ germination\ (\%) = \frac{No.of\ seeds\ germinated\ in\ compost\ extract}{No.of\ seeds\ germinated\ in\ control} \times 100$$

$$Root\ elongation\ (\%) = \frac{Mean\ root\ length\ in\ compost\ extract}{Mean\ root\ length\ in\ control} \times 100$$

$$Germination\ index\ = \frac{Seeds\ germination\ (\%) \times Root\ elongation\ (\%)}{100}$$

2.4 Statistical Analysis

All experimental data were statistically analyzed, and critical differences (cd) were calculated at a 5 percent probability level [11].

3. RESULTS AND DISCUSSION

3.1 Nutrient Contents of Agricultural Waste

Fish waste compost was prepared by mixing fish waste, sawdust, banana and jaggery. Before mixing it, each nutrient content of the component was analysed. Total major nutrient content in fish waste was 2.12% nitrogen, 0.82% phosphorus, 0.10 per% potassium and 10.55% carbon [Table 2]. The pH of the sawdust was found to be 5.9. The organic carbon content of the saw dust was 25.58%, 44% organic matter, 2.18% nitrogen content, 0.71% of phosphorus and 1.17% potassium [Table 2]. The chemical composition of banana was analysed and their results were 3% phosphorus and 8% potassium [Table 2]. Chemical composition of jaggery were also analysed and were found to be as 0.35% protein, 0.19% phosphorus and 0.16% potassium [Table 2].

3.2 Fish Waste Compost Maturity Test

After 4.5 months of composting, the final product reduced to 70% of its volume. The fish waste compost was tested its maturity by physical and sensory test, biological test and chemical test [Table 3]. Similarly Ieshita Pan et al., [12] noted that during composting, the textures of the raw materials gradually changed after 30 days, and a black, humus-like substance developed after 120 days of decomposition. Wheat straw (substrate C6) was composted in 75 days [12]. Physical and sensory tests of the fish waste compost showed changes in color and odor as it stabilized and matured. The compost transformed to an earthy brown color, and the odor became less offensive, evolving from foul and ammonia-like to rich and earthy. The similar way of testing physical and sensory test of the compost was reported by Kristine and Daryl [8].

For biological test, mostly phytotoxicity [plant bioassay] was measured. The seed germination was [94.56%], root elongation [97.14%] and germination index were 91.86% [Table 3]. This indicates that the compost was non-toxic to plants and it can be further used for as compost for plant nutrient supplement. For biological test phytotoxicity test gives the best result of the maturity of the fish waste compost. Similarly result was obtained by María and Remigio [13], Zucconi et al., [14] and [15,16], Sullivan and Miller [17] as germination index of the mustard seed was 81.1%, which shows the nonexistence of phytotoxic substances in the fish waste compost. Numerous other species have also been utilized, including horticultural varieties such as tomato (*Lycopersicum esculentum* Mill.), carrot (*Daucus carota* L.), cucumber (*Cucumis sativus* L.), cabbages (*Brassica oleracea* L. var. italica, Brassica rapa L. var. pekinensis, *Brassica parachinensis* B.), radish (*Raphanus sativus* L.), lettuce (*Lactuca sativa* L.), and beans (*Phaseolus vulgaris* L.). Additionally, cereals like barley (*Hordeum vulgare* L.), Italian ryegrass (*Lolium multiflorum* Lam.), rice (*Oryza sativa* L.), wheat (*Triticum vulgare* L.), rye (*Secale cereale* L.), soy (*Glycine max* L.), and corn (*Zea mays* L.) have been used, as well as other plants such as sunflowers (*Helianthus annuus* L.), petunia (Petunia x hybrida), and amaranth (*Amaranthus tricolor* L.). Various studies involving these species are referenced in Warman [18]. Furthermore, Emino and Warman [19] conducted an extensive experiment testing a wide range of species. It should be noted that some protocols, such as ISO11269-2:2005, recommend the use of at least one monocotyledonous and one dicotyledonous species in these tests, as indicated by María and Remigio [13]. Zucconi et al. [15] detailed a germination test using cress seeds exposed to compost extracts, which were obtained by pressing moistened compost. This test assessed seed germination and root elongation in comparison to results obtained using distilled water.

The germination index is regarded as the most sensitive parameter for detecting the phytotoxicity of compost and evaluating its suitability as a soil amendment or growing medium. It is an integrated parameter that combines relative germination and relative root elongation. However, several authors have reported that root elongation is more sensitive to the presence of toxins than seed germination. [19, 20, 21 and 22]. Germination index values below 50% indicate high phytotoxicity, values between 50% and 80% suggest moderate phytotoxicity, and values above 80% indicate no phytotoxicity. An index exceeding 100% suggests that the compost may act as a phytonutrient or phytostimulant [23 and 13].

In chemical test, after the fish waste compost was fully matured, the compost's nutrient content was assessed. The pH of the fish waste compost was 6.80. EC was 2.97 [dS/m] [Table 3]. Jagadabhi et al., [24] reported that the initial pH of all the straws and sawdust was low, ranging from 6 to 7. This pH decreased further between days 1 and 10 of the composting process, when temperatures in the reactors were high due to increased microbial fermentation activity. During this period, the degradation of readily available or soluble organic substances led to the release of organic acids, causing a drop in pH. After 10 days, as the temperature and thermophilic microbial activity began to decrease, the pH gradually rose to 8 and above. By the end of the first month, the pH ranged from 7.5 to 8, indicating that the decomposition of readily degradable compounds was complete and showing progress in the maturity of the composted materials. The increased pH also suggests a rise in ammonium content in the compost. Turning or aerating the compost during the first 10 days did not significantly affect the pH, likely due to the prevailing thermophilic fermentation activity.

Electrical conductivity (EC) measures the concentration of soluble ions [i.e., salts] in a compost product, which can affect its potential phytotoxicity. Elevated salt levels can harm plant roots, disrupt nutrient uptake, decrease soil water availability, or inhibit seed germination [25]. A decrease in EC was observed over time as municipal solid waste [MSW] compost matured, with the stabilization of EC correlating closely with the compost's attainment of maturity. EC measurements proved to be effective predictors of plant growth in wheat-straw and manure composts, and it was recommended to use EC as a straightforward quality-control measure for on-site applications [26]. Similarly, Jagadabhi et al., [24] found that electrical conductivity [EC] gradually increased over time in all composting reactors [27 and 28]. This rise in EC is due to the loss of weight from organic substances as they mineralize into soluble forms, which then become more concentrated as the compost dries. The drying process results in the accumulation of mineral salts, such as phosphate and ammonium ions, contributing to the higher EC [29]. Jagadabhi et al., [24] observed that the electrical conductivity (EC) of compost materials increased from an initial range of 0.2–0.7 mS cm^{-1} to a final range of 0.8–1.2 mS cm^{-1}. This increase remains within the range considered favorable for promoting seed germination. Typically, a high electrical conductivity [EC] in composts, greater than 4 dS m^{-1}, is reported to inhibit seed germination. Therefore, seed germination assays are often employed to assess both the maturity and phytotoxicity of composts [30 and 31].

Total major nutrient content in fish waste compost was 3.66% nitrogen, 1.03% phosphorus, 1.2% potassium, organic matter content was 18.70 %, cation exchange capacity was 119.6 [me/100 g] and C: N ratio was 28.6:1 [Table 3].

The carbon-to-nitrogen [C/N] ratio of composting substrates is a crucial indicator of compost maturity. It significantly impacts microbial growth and, consequently, the rates of decomposition [32]. A high C/N ratio indicates the presence of unutilized complex carbon content, while a decrease in the C/N ratio to less than 25:1 signifies an efficient decomposition process [33]. Substrates with higher carbon and nitrogen contents typically require more time to complete the maturation phase. Compost maturity is generally achieved when the C:N ratio decreases to between 25 and 30:1 [34].

Cation exchange capacity [CEC] tends to increase during composting as organic materials undergo humification and form carboxyl and phenolic functional groups. As a result, CEC has been investigated as an indicator of compost stability and maturity [35]. During the humification process, complexation and condensation reactions produce high molecular weight, fairly stable compounds [36].

Table 2. Description of the materials used in preparation of fish waste compost and their values

Constituents	Values	Method used	References
Chemical composition of fish waste			
Carbon	10.55%	Wet digestion method	Walkley and Black [37]
Nitrogen	2.12%	Modified macro Kjeldahl digestion method	Jackson [38]
Phosphorus	0.82%	Triacid digestion by developing Vanadomolybdo phosphoric yellow colour	Greweling [39]
Potassium	0.10%	Triacid digestion and flame photometer reading	Pickett and Koirtyohann [40]
Chemical composition of sawdust.			
pH	5.9	In1:2 sawdust - water suspension	Jackson [38]
Organic carbon	25.58%	Wet digestion method	Walkley and Black [37]
Organic matter	44%	Wet digestion method	Walkley and Black [37]
Nitrogen	2.18%	Modified macro Kjeldahl digestion method	Jackson [38]
Phosphorus	0.71%	Triacid digestion by developing Vanadomolybdo phosphoric yellow colour	Greweling [1976]
Potassium	1.17%	Triacid digestion and flame photometer reading	Pickett and Koirtyohann [40]
Chemical composition of banana.			
Phosphorus	3%	Triacid digestion by developing Vanadomolybdo phosphoric yellow colour	Greweling [39]

Constituents	Values	Method used	References
Potassium	8%	Triacid digestion and flame photometer reading	Pickett and Koirtyohann [40]
Chemical composition of jaggery			
Protein	0.35%	Kjeldahl method multiplied with 6.25	Humphries, 1956 and Doubetz and Wells [1968]
Phosphorus	0.19%	Triacid digestion by developing Vanadomolybdo phosphoric yellow colour	Greweling [39]
Potassium	0.16%	Triacid digestion and flame photometer reading	Pickett and Koirtyohann [40]

Table 3. Test category of the final fish waste compost and their results

Test category	Potential test for maturity	Remarks	Method used	References
Physical and sensory test	Colour	Earthy brown	Physical and sensory test	Kristine and Daryl [8]
	Odour	Odourless	Physical and sensory test	Kristine and Daryl [8]
Biological test	Phytotoxicity [plant bioassay]			
	Seed germination [%]	94.56	Zucconi mehtod	Zucconi et al. [14]
	Root elongation [%]	97.14	Zucconi mehtod	Zucconi et al. [14]
	Germination index	91.86	Zucconi mehtod	Zucconi et al. [14]
Chemical test	pH	6.80	In1:2 fish waste compost-water suspension	Jackson [38]
	Electrical conductivity [$dS\ m^{-1}$]	1.45	In1:2 fish waste compost-water suspension	Jackson [38]
	Nitrogen [%]	3.66	Modified macro Kjeldahl digestion method	Jackson [38]
	Phosphorus [%]	1.03	Triacid digestion by developing vanadomolybdo phosphoric yellow colour	Greweling [39]
	Potassium [%]	1.2	Triacid digestion and flame photometer reading	Pickett and Koirtyohann [40]
	Organic matter [%]	18.70	Wet digestion method	Walkley and Black [37]
	Cation exchange capacity [me/100 g]	119.6	Yasuo Harada and Akio Inoko Method	Yasuo and Akio [41]
	Carbon : Nitrogen ratio	28.6:1	Li method	Li et al. [42]

4. CONCLUSION

Using renewable resources is essential for maximizing crop yields and reducing environmental hazards associated with chemical residues. Composting, a time-honored practice, biologically converts organic waste into a humus-like substance that enhances the physical, chemical, and biological properties of soil. Composting fish waste with sawdust significantly reduces the volume of fisheries waste. The stability and maturity of the compost are crucial for its effective application, particularly in agriculture. Experiments indicate that the compost product is non-phytotoxic, mature, stable, and suitable for agricultural use. Thus, the proposed fish waste compost can be a valuable organic fertilizer in agriculture.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Murthy SM, Tejaswini A, Uthappa RK. Comparative effect of chemical and organic fertilizers on primary metabolite contents of *Ocimum bascilicum* L. and

Majorana hortensis Moench. GSC Biological and Pharmaceutical Sciences. 2018;5(01):104–108

2. Spreij M. Trends in national aquaculture legislation (part II). FAO Aquaculture Newsletter. 2004;31:22–24.
3. Rosamond LN, Ronald WH, Alejandro HB, Simon RB, Ling Cao, Dane HK, David CL, Jane Lubchenco, Sandra ES, Max Troell. A 20-year retrospective review of global aquaculture Nature. 2021;591:551–563.
4. Liao PH, Jones L, Lau AK, Walkemeyer S, Egan S, Holbek N. Bioresource Technology. 1997;59:163.
5. Keller S. Making profits out of seafood wastes. In Jensen, N.C. ed. Quality fish meal: specifications and use in aquaculture and fur farming. Alaska; 1990.
6. Hall GM. Fish processing technology. In Ockerman, H.W. ed. Fishery byproducts, New York: VCH publishers. 1992;155-192.
7. Ghaly AE, Ramakrishnan VV, Brooks MS, Budge SM, Dave D. Fish processing wastes as a potential source of proteins, amino acids and oils: A critical review, Journal of Microbial & Biochemical Technology. 2013;5(4):107-129.
8. Kristine W, Daryl M. Compost stability and maturity evaluation - A literature review, Canadian Journal of Civil Engineering. 2010;37(11):1505-1523.
9. Nazareth. Phytotoxkit. Seed germination and early growth microbiotest with higher plants. Standard operation procedure. Micro Bio Tests Inc. 2004;1–24.
10. Zhang L, Sun XY. Addition of fish pond sediment and rock phosphate enhances the composting of green waste. Bioresour. Technol. 2017;233:116–126.
11. Panse VG, Sukhatme PV. Statistical methods for agricultural workers, ICAR Publications. New Delhi; 1985.
12. Ieshita P, Bomba D, Sen SK. Composting of common organic wastes using microbial inoculants. 3 Biotech. 2012;2(2):127–134.
13. María TB, Remigio P. A review on the use of phytotoxicity as a compost quality indicator. dynamic soil, Dynamic Plant. 2011;5(2):36-44.
14. Zucconi F, Forte M, Monaco A, De Bertoldi M. Biological evaluation of compost maturity. BioCycle. 1981(a);22:27-29.
15. Zucconi F, Pera A, Forte M, De Bertoldi M. Evaluating toxicity of immature compost. Bio Cycle. 1981(b); 22:54-57.
16. Zucconi F, Monaco A, Forte M. Phytotoxins during the stabilization of organic matter. In: Gasser JKR (Ed) Composting of Agricultural and Other Wastes, Elsevier, London. 1985;73-85.
17. Sullivan DM, Miller RO. Compost quality attributes, measurements, and variability. In compost utilization in horticultural cropping systems. Edited by P.J. Stofella and B.A. Kahn. Lewis Publishers, Boca Raton, Fla. 2001;95–120.
18. Warman PR. Evaluation of seed germination and growth tests for assessing compost maturity. Compost Science and Utilization. 1999;7:33-37.
19. Emino ER, Warman PR. Biological assay for compost quality. Compost Science and Utilization. 2004;12:342-348.
20. Fuentes A, Lloréns M, Saéz J, Aguilar M, Ortuño JF, Meseguer VF. Phytotoxicity and heavy metals speciation of stabilized sewage sludge. Journal of Hazardous Materials. 2004;108:161-169.
21. Di Salvatore M, Caraza AM, Carratú G. Assessment of heavy metals phytotoxicity using seed germination and root elongation tests: A comparison of two growth substrates. Chemosphere. 2008; 73:1461-1464.
22. Paradelo R, Moldes A, Rodríguez M, Barral MT. Relationship between heavy metals and phytotoxicity in composts. Ciencia y Tecnología Alimentaria. 2008; 6:143-151.
23. Moldes AB, Vázquez M, Domínguez JM, Diaz-Fierros F, Barral MT. Evaluation of mesophilic biodegraded grape marc as soil fertilizer. Applied Biochemistry and Biotechnology. 2007; 141:27-36.
24. Jagadabhi PS, Wani SP, Kaushal M, Patil M, Vemula AK, Rathore A. Physico-chemical, microbial and phytotoxicity evaluation of composts from sorghum, finger millet and soybean straws, International Journal of Recycling of Organic Waste in Agriculture. 2019;8: 279–293.
25. Avnimelech Y, Moshe Bruner, Itai Ezrony, Roy Sela, Malka Kochba. Stability indexes for municipal solid waste compost, Compost Science and Utilization, 1996;4 (2):13-20.
26. Wang CM, Changa CM, Watson ME, Dick WA, Chen Y, Hoitink H.A.J. Maturity indices of composted dairy and pig manures. Soil Biology and Biochemistry. 2004;36:767–776.
27. Manios T. The composting of different organic solid wastes: Experience from the

island of Crete. Environ International. 2004;29:1079–1089.
28. Mupondi LT, Mnkeni PNS, Brutsch MO. The effects of goat manure, sewage sludge and effective microorganisms on the composting of pine bark. Compost Science and Utilization. 2006;14:201–210.
29. Mhindu RL, Menas W, Esther N. Composting of selected organic wastes from peri-urban areas of Harare, Zimbabwe. International Journal of Recycling Oragnic Waste in Agriculture. 2013;2:14.
30. Nakasaki K, Marui T. Progress of organic matter degradation and maturity of compost produced in a large-scale composting facility. Waste Management Research. 2011;29:574–581.
31. Singh S, Nain L. Microorganisms in the conversion of agricultural wastes to compost. Proceedings of Indian National Science Academy. 2014;80:473–481.
32. Chauhan HK, Singh K. Effect of tertiary combinations of animal dung with agrowastes on the growth and development of earthworm *Eisenia fetida* during organic waste management. International Journal of Recycling of Organic Waste in Agriculture. 2013; 2: 1-7.
33. Pan I, Dam B, Sen SK. Composting of common organic wastes using microbial inoculants. 3 Biotech. 2012;2:127–134.
34. Hardy V, Klaus F, Thomas T. Quality physical characteristics nutriment content heavy metals and organic chemicals in biogenic waste compost. Compost Science and Utilization. 1993;1:69–87.
35. Butler TA, Sikora LJ, Steinhilber PM and Douglass W. Compost age and sample storage effects on maturity indicators of biosolids compost. Journal of Environmental Quality. 2001;30:2141-2148.
36. Lax A, Roig A, Costa F. A method for determining the cation-exchange capacity of organic materials. Plant Soil. 1986;94:349– 355.
37. Walkley A., Black IA. Determination of organic matter in the soil by chromic acid digestion. Soil Science. 1947;63: 251-564.
38. Jackson ML. Soil chemical analysis. Prentice-Hall of India Pvt. Ltd., New Delhi, India. 1973;111-204.
39. Greweling T. Chemical analysis of plant tissue. Agronomy No. 6. Cornel University Agricultural Experimentation Station, Ithaca, NY. Search Agriculture. 1976; 6(8):1-35.
40. Pickett EE, Koirtyohann SR. Emission flame photometry—A new look at an old method. Analytical Chemistry. 1969;41 (14):28A–42A.
41. Yasuo H, Akio I. The measurement of the cation-exchange capacity of composts for the estimation of the degree of maturity. Soil Science and Plant Nutrition. 1980;26(1):127-134.
42. Li Z, Hongwei L, Lixia R, Li H. Experimental and modeling approaches for food waste composting: A review, chemosphere. 2013;93(7):1247-1257.

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