IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736.Volume 9, Issue 8 Ver. I (Aug. 2016), PP 48-53
www.iosrjournals.org

Production of quality organic fertilizer using firewood ash and tea residues produced from tea factories in Sri Lanka

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Abstract: *Sri Lanka is the world's fourth-largest producer of tea and it is one of the main sources of foreign exchange for the country. Through the process of tea manufacturing, huge amount of firewood ash and tea residues are produced as by-products. Although these wastes are not favorable for crops, most factories apply these wastes mainly to the cultivation. Therefore the aim of this study was to find out a sustainable solution for largely produced wastes by producing high quality organic fertilizer. First compost was made using daily kitchen waste of the factory, Gliricidia maculate leaves, tea residues and black soil. Six compost piles were made changing different quantities of raw materials to produce high quality compost. All physical and chemical parameters of compost were measured using standard methods. Then different quantities of compost and firewood ash were mixed to build up new organic fertilizer. This research showed that EC less than 5 µS/cm, 6<pH,8, and pile size 3"x3"x3 is needed for best quality compost. Mixing ratio of Firewood ash:compost in 16 %(V/v) of Formic acid mixture was 2:3 for new fertilizer and it can be utilized for tea plantation in the country reducing waste generation in tea factories.*
Keywords: *Compost, Organic fertilizer, Gliricidia maculate leaves, Firewood ash*

I. Introduction

Tea industry is the biggest agro base industry in Sri Lanka. It is the major income of the up country people. The tea industry plays a crucial role in the economy with its contribution to employment, export earnings, etc. In production of tea, it consumes both thermal and electrical energy in the ratio of about 85:15. The thermal energy is produced by burning mainly firewood in processing of tea. It is the biggest industrial consumer of fuel wood in the country and accounts for about 24 % of the total consumption in the industrial sector [1] accounting for about 326,000 metric tons (1997) of annual consumption of fuel wood [2]. The energy study done on combustion systems in Sri Lanka, mainly in tea drying, has found that moisture content (43 %) and large sizes of firewood used for combustion are directly related to the low combustion efficiency (60%) of the existing furnace [3]. Through the process of tea manufacturing, huge amount of firewood ash is remained as a by-product. Rather than wood ash much of slowly decompose tea residue which are rich in fiber creates through this process. About 4-6% the total product of made tea is refuse tea [4]. The amount of refuse tea produced depends on the method used in manufacturing of tea. Sometimes under the conditions where unsuitable leaves are available for manufacturing such as coarse plucking or under withered or over withered leaf are available, the percentage of refuse tea could increased even to a level of 8-10% [4].

Firewood ash holds many of the elements needed to support new growth and has been used by gardeners and farmers as a natural soil amendment. The physical and chemical properties of ash collected from combustion systems vary significantly depending on the temperature of combustion, the type of fuel (species of wood and amount of bark), and combustion system. Wood ash raises the alkalinity (pH) of the soil similar to limestone[5]. Other indicators like free moisture content, electrical conductivity, organic matter content and over-all nutritional and toxic elements and their mobility in aqueous solutions also confirm that the wood ash is a suitable for soil improver production [6]. They are primarily composed of calcium, potassium, phosphorus, magnesium and trace amounts of iron, manganese, sodium, boron, zinc, copper, and molybdenum. Over a few decades a number of studies have been carried out on the utilization of wood ashes in agriculture and forestry as an alternative method for disposal as they effect on soil properties, on the availability of nutrient elements and on the growth and chemical composition of crops and trees, as well as its impact on the environment [7]. Most factories in Sri Lanka apply tea waste to the lands directly or use for land filling. Therefore the aim of the present work was paid to find out a sustainable solution for largely produced wood ash and tea residues in Ceciliyan tea factory in Kalawana, Sri Lanka by producing high quality organic fertilizer. The outcome of this project will be more helpful to the most factories in Sri Lanka to reduce their daily wastage.

II. Materials And Methods

2.1 Experimental Sites

Compost piles were located at the Ceciliyan Tea estate. Suitable well drained area was selected for compost piles and removed all unwanted things. Stone foundation and black plastic sheet were laid on the foundation. A Nickel coated metal plate was located at the bottom of the each pile. Following materials were used to prepare compost pile according to the literature [8].

- Carbon source – fresh kitchen waste from tea factory, tea residues
- Nitrogen source- *Gliricidia maculate*
- Microbial activator- soil from the tea field

This experiment was the initial step to find most suitable combination of above materials for rapid composting process (Table 1). First kitchen wastes were sorted and allowed to dry. Then they were chopped in to small pieces (between 1/2 to 1-1/2 inches in size). 50 kgs of tea residues was mixed with 100 kgs chopped kitchen wastes. Stem of the *Gliricidia* were removed and leaves were sorted and chopped for compost piles. Black soil also was sorted well and large stones and woody materials were removed. For the experiment six compost piles were prepared as follows.

Table 1 Production of six compost piles with different layers

Layers and materials	Depth of various material in Piles (inches)					
	01	02	03	04	05	06
Bottom layer with chopped *Gliricidia maculate* leaves	1	1	1	1	1	1
1st layer- dried food scraps and tea residues	7	7	7	7	7	7
2nd layer- dried *Gliricidia maculate* leaves	1	2	3	4		
3rd layer – Black soil	1	1	1	1	1	1
4th layer –repeat 1-3 step until the pile height = 3 inches	x	x	x	x		
4th layer –repeat 1 and 2 step until the pile height= 3 inches					x	
5th layer - cover with a 1/2 " of *Gliricidia maculate* leaves	x	x	x	x		x
5th layer - cover with a 1/2 " of firewood ash					x	

Piles were kept seven days until it reaches optimum temperature and water was added when the piles become dry. After seven days 1st turning was done and moisture content was measured and regular turning was done in every day by controlling moisture content, temperature, pH, and EC to optimize compost process in the pile. After twenty four days compost was analyzed for pH, Electric Conductivity, Coarse Fragments, Moisture Content, Volatile Matter, Organic Carbon, Organic matter, Total Nitrogen, available PO_4^{3-} and C: N ratio.

2.2 Ash sample collection

Ash samples were collected from furnace. Ash sample was made by mixing firewood ash from middle, front and the back of the furnace. Developed compost and firewood ash mixed in different composition to build up a new organic fertilizer in two conditions as follows.

i. Mixed firewood ash with produced compost in normal condition
a. Firewood ash : compost = 1 :9
b. Firewood ash : compost = 1 :4
c. Firewood ash : compost = 3 :7
d. Firewood ash : compost = 2 :3
e. Firewood ash : compost = 1 :1

ii. Mixed firewood ash with produced compost in Formic acid medium.
a. Firewood ash : compost (2:3) in 64%(V/v) of Formic acid
b. Firewood ash: compost (2:3) in 32 %(V/v) of Formic acid.
c. Firewood ash : compost (2:3) in 21%(V/v) of Formic acid
d. Firewood ash : compost (2:3) in 16%(V/v) of Formic acid

2.3 Chemical Analysis

Then physical and chemical parameters of compost samples and developed organic fertilizer were checked using standard methods at Environmental and Biological Laboratory, Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka. Major cations and trace heavy metals of wood ash and tea residues were analyzed at Department of Geology, Faculty of Science, University of Peradeniya.

Table 2- Analytical Methods of different Parameters

Analytical Parameter	Method/ Instrument &Condition
Ph	pH meter
Electrical Conductivity	Thermo orient Model 145A
Total Nitrogen (N %)	Kjeldahl method.
Available PO_4^{3-}	Olsen's method
Organic Carbon and Organic matter content	Walkley and Black method
Major cations and heavy metals	Atomic Absorption Spectrophotometer
pH	pH meter
Coarse fragments	
Bulk density	Calibrated cylinder
Moisture content	ASTM Method D3173
Volatile matter	ASTM Method D3172

III. Results And Discussion

According to soil analysis reports of the estate, many of soil nutrient deficiencies were detected in the soil as well as tea leaves. It was evident that the entire fields showed very low K, P & Mg concentrations in the soil as well as plants. The soil C level was very poor and reported as less than 2% in all the fields which are surrounding the state. According to the recommendations of the Tea Research institute in Thalawakale, soil organic C content should be about 3% to retain substantial amount of nutrients in sufficient quantities in soil available form for plant uptake. Therefore develop compost process can be continued in the state to increase soil C surrounding soil since tea residues and kitchen waste are generate every day as huge quantities.

3.1 Qualitative analysis of produced compost

3.1.1 Moisture content

Composting process in the piles was optimum when Moisture Content was around 50%. An initial moisture content of the piles was 50–60% by weight and it generally considered optimum for composting as it is provided sufficient water to maintain microbial growth. Decomposition by microorganisms is occurred most rapidly in the thin films of water surrounding compost particles. Pile No 05 and pile No 06 were highly affected by rain. Due to high organic matter content in piles water holding capacity was higher. At the beginning solid content % in all piles was around 70-55% and moisture contents were around 45-55%. When the composting process was completed solid content was around 50-60% and moisture content was 40-45%.

3.1.2 Bulk density

Bulk density was measured in compost per unit volume (g/cm^3). Variation in bulk density was attributed to specific gravity (true density) of soil and the porosity of the final compost product. With organic matter content in the piles bulk densities were changed. Pile no 05 and 06 were got higher values for the bulk density. Decomposition rate of those piles were very low due to higher moisture content and lack of enough N.

3.1.3 Coarse fragments

The coarse fragment of compost was that percentage of compost (dry weight basis) that was larger than 2mm. Coarse fragments may include wood chips, roots, gravel etc.

3.1.4 Total nitrogen

Evaluating the "availability" of N for growing crops is more difficult. Most compost mixtures were contained about 1% total N on a dry weight basis. A total N level which ranged between 0.75% - 2.5% is normal. Values below this range is often indicated a high mineral content in the compost. N contents above 2.5% are most often associated with high organic matter levels (>60%), and/ or nitrogen rich starting components.

3.1.5 Organic carbon and Organic matter

Composting process depend microbes which digest organic matter to chemical forms usable for other microbes, invertebrates and plants. Millipedes, Centipedes, Ants, Beetles and Earth worms were observed during composting process. Organic matter content was decreased during composting period. Organic matter content was reduced from 60% to 25% from starting to end of the composting process. Amount of organic matter in compost samples were depended on the nature of the starting materials and the degree of decomposition. When all factors related to the biochemical decomposition are fulfilled organic matter % in compost will be nearly 25% by weight.

3.1.6 C:N ratio

The C:N ratio of all compost piles were closed to 30. Composts with high C:N ratios (> 30) will immobilize N when they apply to soil while low C:N ratios (< 20) will mineralize or break-down organic N to inorganic N [9]. Depending on the nature of the raw materials, C:N ratio of final product was changed. Decomposition rate was increased with *Gliricidia maculate* and C:N ratio was decreased with time. It was indicated by rapid increasing of temperature of pile No.01-No.04. Lack of enough carbon substrate for the microbial activities was caused very low C:N ratio of the final product. Excess nitrogen was liberated as ammonia gas, causing undesirable odors in pile No.04. According to the results pile No. 02 was the best pile which having proper C:N ratio in feeding materials.

3.1.7 Electric conductivity

Electric Conductivity (EC) was a measure of dissolve salt present in the compost. Acceptable levels were determined on the basis of the intended use of the compost. EC values below 2.0 are considered for all applications. Composts are with EC values higher than 5.0 not used as soil amendment.

3.1.8 pH

Final stage of most compost piles pH level was ranged from 5.0 to 7.5. Values below 6.0 and above 8.0 may indicate a problem with the starting materials, and the process of composting. pH variation of six piles were showed in Fig. 1. High pH variation was varied in the pile with applied *Gliricidia maculate* amount. With increasing N source of piles, pH values were low due to rapid consuming of N by microbes and NH4-N is dominant at the initial stages. NO3-N and organic nitrogen are in mature stages.

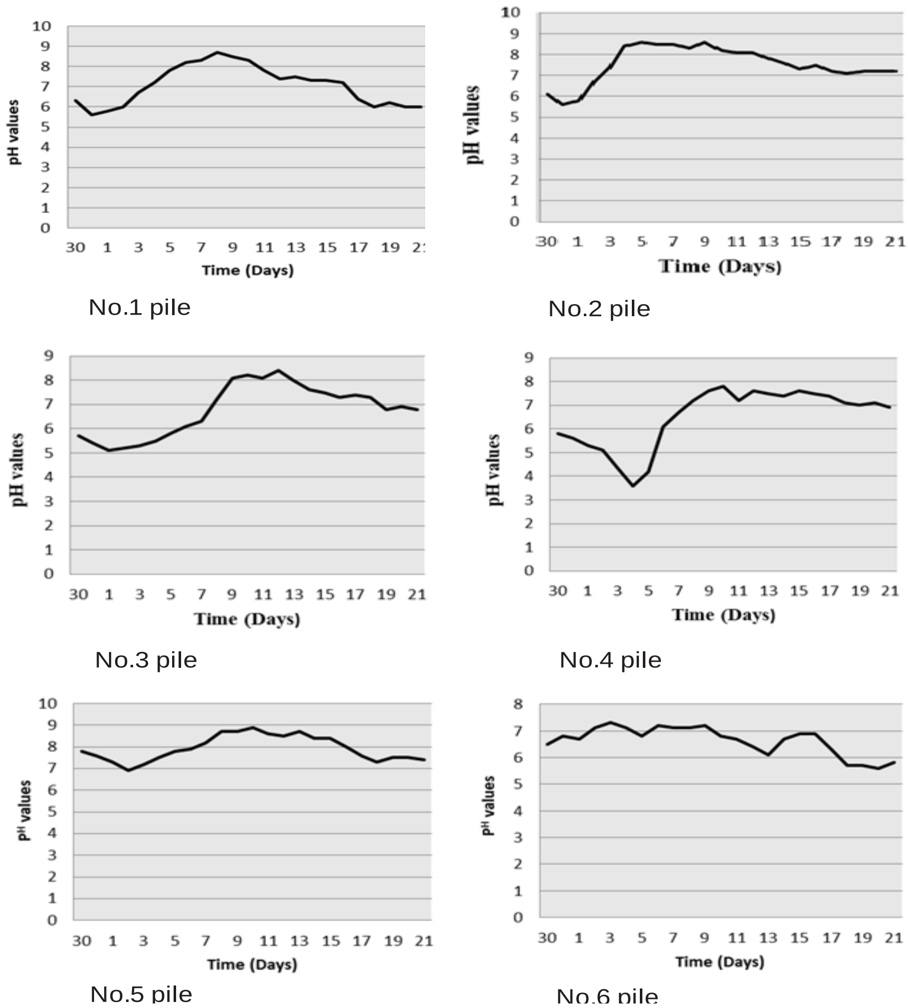

Figure 1 Variation of pH level in the piles

During the therophilic conditions pH was increased in No. 2 pile and then gradually decreased with time. In pile No. 05 high pH value was observed at initial stages due to firewood ash. In pile No 06; there were no enough nitrogen sources for the microbial activities and it was affected by rain. Anaerobic conditions were observed in pile No 06. Foul odor was observed during composting process and coarse fragments were observed in higher amount after 24 days. Consuming rate of Nitrogen source by microbes directly affected by C: N ratio of the feeding materials. According to the chemical analysis results of six compost piles No 02 and No 03 piles were observed as best processing of composting and No.2 pile was recognized as most suitable method for rapid composting process.

Size of the piles was highly affected on the thermophilic decomposing process. If it too small, heat retention within the pile was poor. It was needed at least 3’×3’×3’ in size to ensure sufficient heat and moisture retention.

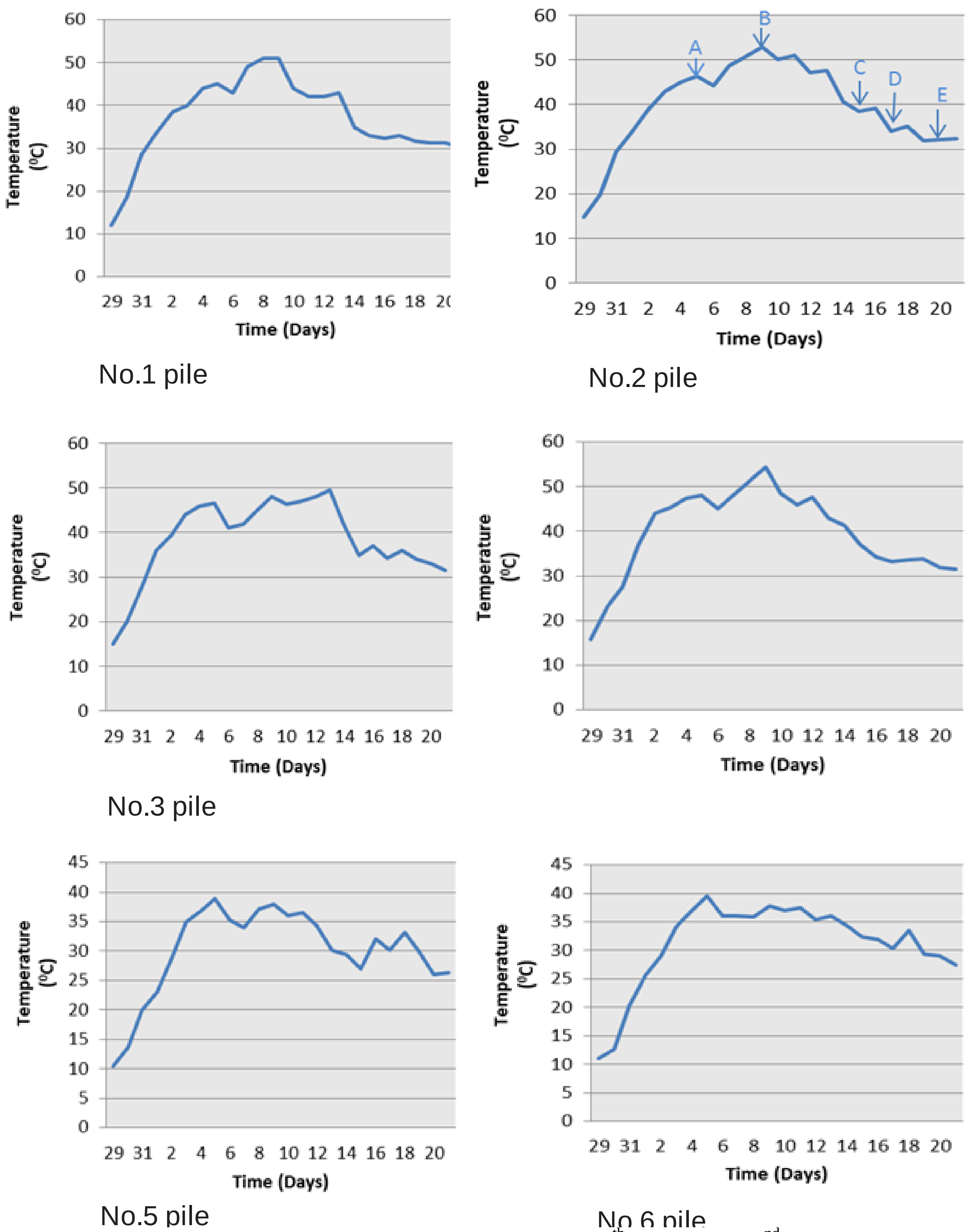

Figure 2 Variation of temperature in piles with time 29th Oct. 2015-22nd Nov. 2015)

During the turning process piles were cool down temporally (A and B points in Fig. 2) and pile temperature was begun to drop. At this stage turning piles were produced warming up of temperature (Points C and D in Figure 2). After the thermophilic phase was completed, the pile’s temperatures drop and it was not restored by turning or mixing (Point E in Fig. 2).

3.1.9 Development of nutrient rich fertilizer

Two methods were used to done this.

Table 2 Results of developed fertilizer in normal condition

Parameters	Mixture No 01	Mixture No 02	Mixture No 03	Mixture No 04	Mixture No 05
pH	**10.5**	**10.8**	**11.7**	**12.1**	**12.2**
Electric conductivity (µS/cm)	**8.8**	**11.9**	**12.5**	**11.5**	**8.5**
Total Nitrogen (%)	**0.56**	**0.28**	**0.14**	**0.00**	**0.00**

Total nitrogen of original compost sample was 0.84%. Total nitrogen was reduced when mixed with firewood ash in normal conditions. When firewood ash mix with produced compost ammonia gas was liberated and Ammonia gas was identified by odor. The results indicated that the maximum quantity could mix firewood ash with produced compost was 1:9.

Table 3 Results of developed fertilizer in acidic condition

Parameters	Mixture No 01	Mixture No 02	Mixture No 03	Mixture No 04
pH	**9.5**	**9.3**	**8.8**	**8.3**
Electric Conductivity (µs/ cm)	**4.16**	**4.52**	**4.92**	**6.76**
Total Nitrogen (%)	**0.00**	**0.02**	**0.28**	**0.56**

An Economically advantageous proportion of firewood ash and produced compost mixture was used. Average formic acid concentration of the waste water that generated from the rubber processing unit of the factory was 17.5% (V/v). 16% (V/v) concentration of formic acid medium was used for this experiment. During these three components were mixing, Hydrogen sulfides were liberated with rotten egg smell. Thus it was possible to retained substantial amount of Nitrogen by this experiment. As the final outcome Firewood ash: compost (2:3) in 16 %(V/v) of Formic acid mixture was identified as the best developed rich compost mixture.

IV. Conclusion

It can be concluded that proper composting process is occurred when the pile EC less than 5 µS/cm. Proper pH range is 6-8 and pile size (volume) should be around 3”x3”x3. Mixing ratio of Firewood ash:compost in 16 %(V/v) of Formic acid mixture was 2:3 for high quality fertilizer and developed rich compost mixture can be utilized for tea plantation in the country reducing waste generation of any tea factory in Sri Lanka.

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