



Tea Refuse as a Material for Compost Production

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ABSTRACT

Direct application of raw tea refuse to crops has shown some toxicity on seedling growth. Thus, decomposition of tea refuse with other readily available materials could be one of the most appropriate solutions. A study was carried out to examine the potential of tea refuse as a composting material. Decomposition of tea refuse was done by mixing three different ratios (1,2 and 3 parts or 33.3%, 50%, and 60% (v/v)) of tea refuse as treatments with an unique mixture of 1:1 cow dung to gliricidia (*Gliricidia sepium*) and cut grasses and the mixture without tea refuse as the control. Decomposition method was conventional aerobic piles designed as Complete Randomized Design (CRD) with three replicates. Presence of macro-organism, colour, particle size, pH, percentages of organic C, total N, available P, exchangeable K, Mg, total polyphenols content were evaluated. Seed germination ability of original and decomposed tea refuse were also tested as a separate experiment. Raw tea refuse was slightly acidic (pH = 4.4), and it contained 31.2%, 2.4%, 0.2%, 2.1%, 0.3%, of organic C, total N, available P, exchangeable K and Mg respectively and 17.4% of total polyphenol. Organic C, total N, exchangeable K, and Mg in treatments at 35 and 75 days of decomposition were significantly higher ($p \geq 0.05$) than those of control but, no significant differences observed among treatments. There were about 80-100% germination of vegetable seeds on decomposed products compared to zero germination on raw tea refuse and total polyphenols were gradually decreased with decomposition. The study suggests decomposition of tea refuse minimize adverse effects of raw tea refuse and the recipe of T₁ which contains the lowest amount (33 % v/v) of tea refuse is the most economical to supply organic nutrients.

KEYWORDS : Compost, Polyphenols, Tea refuse

Introduction

Tea, from the leaves of *Camellia sinensis*, (family: *Theaceae*) is consumed by more than two thirds of the world's population and is the most popular beverage next only to water. Sri Lanka has over 188,000 hectares under tea cultivation yielding about 298,000 tonnes of “made” tea, and accounting for more than 19% of world exports. (Anon, 2014). Refuse tea is the waste produced during the manufacture of tea. According to the tea control act No. 51 of 1957, the refuse tea is defined as sweepings, mature leaves, fluff, mature stalk or any other product (not being made tea) obtained in the process of manufacture of tea. In Sri Lanka, about 4 - 6% of the total product of made tea is refuse tea (Zoysa, 2005).

A compost prepared by tea refuse may create favorable conditions while improving nutrient availability for plants and detoxifying some unfavorable ingredients. Especially, tea wastes are processed in very powerful kiln, so microorganisms are unobtainable on tea waste. (Anon, 2015). In composting process, microbes play an important role and their function of these microorganisms is to decompose the readily available organic materials and stabilize the residual material into finished compost. Another role of microorganisms is to detoxify certain products that may be harmful to soil, plants and animals including people. The process of detoxification can continue even after the compost is applied to soil (Anon, 2004). The compost prepared using tea refuse may be beneficial for the tea land in many ways, as a soil conditioner, a fertilizer, addition of vital humus or humic acids, and as a natural pesticide for soil. Especially, it is beneficial for agricultural crops intercropped with tea as a freely available natural resource to supply plant nutrients. Application of composted refuse tea may also be more economical and environmental friendly. Moreover, organic materials such as compost can act as a valuable source of plant available nutrients (e.g. nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and magnesium (Mg)) and thereby reduce the need for manufactured fertilizer inputs (Rollett *et al.*, 2010).

Though tea refuse is a readily available natural source it has been observed that direct application of tea refuse show some toxicity symptoms in seedlings of black pepper and coffee intercropped in upland tea lands in Nuwaraeliya and Badulla area that may be due to its inherent chemical constituents. Tea is rich in polyphenols. (Matthew and Douglas, 1997) and it is observed in bio-tests that high concentrations of polyphenols suppress the growth processes such as seed germination (Stoms, 1982). However, according to published literature available, no attempts were taken to prepare compost from tea refuse instead of direct use as an organic amendment. Especially it is beneficial for agricultural crops intercropped with tea as a freely available natural resource to supply plant nutrients. Therefore, this study was intended to study the potential use of tea refuse as a material for compost production as the broad objective. The Specific Objectives were to find out the suitable recipe for compost production using tea refuses and to evaluate the physical and chemical properties of decomposed tea refuse.

Methodology

Selection of Material for Decomposition of Tea Refuse

The composting procedure practiced for the experiment was the conventional heap method. Main ingredient, fresh tea refuse was collected from the Horana tea plantation at Pitakanda. Mixing ingredients for composting recipe with tea refuse were cow dung, readily available *Gliricidia*, other cut grasses. Composting inoculum was taken from an old compost pit. Three different volumes of tea refuse (treatments) were mixed with a 1:1 volumes of cowdung and *gliricidia* plus cut grasses in order to identify the most appropriate level of tea refuse for an efficient decomposition (Table 2). The experimental design was the Complete Randomized Design (CRD) with three replicates and each replicate contained three composting heaps.

Table 2: Mixing ratio of raw materials

Treatments	Parts (volume basis) in the composting recipe			Percentage of tea refuse in final composting mixture (v/v)
	Green materials (<i>Gliricidia</i> and cut grasses)	Cow dung	Tea refuse	
Control	1	1	0	0%
T ₁	1	1	1	33.33%
T ₂	1	1	2	50%
T ₃	1	1	3	60%

Evaluation of Biological, Physical and Chemical Properties of Initial and Decomposed Tea Refuse

Biological, physical and chemical properties of initial and decomposed tea refuse were evaluated at 35 days (mid product) and 75 days (final product) after initiation of compost preparation using the methods given in table 3.

Table 3: Standard methods used for physical and chemical analysis

Parameter	Methods
pH	Soil : water (1:2.5) method
Organic Carbon content	Walkey and black method (Tandon, 1999).
Total Nitrogen content	Semi micro kjeldahl method (Hesse, 1971).
Available Phosphorus	Olsen's bicarbonate method (Olsen <i>et al.</i> , 1954).
Exchangeable Potassium and magnesium	Ammonium acetate extraction - spectrophotometer method
Total Polyphenol content	ISO 14502-1 Method (Anesini <i>et al.</i> , 2008).
Colour	Munsell colour chart
Particle size of compost	sieving method (2mm, 1mm and 0.5mm)

A germination test was conducted to evaluate the germination ability or the toxic effect of tea refuse on germination of vegetable seeds on the initial tea refuse and final product. Five petri plates were taken and half-filled each with initial tea refuse and control, T₁, T₂, T₃ respectively. Pre-soaked unique sized healthy okra and Korean radish seeds were placed in petri plates as 10 seeds /plate with three replicates. After 2 days, germinated seedlings were counted in each plate.

The data were subjected to one way Analysis of Variance (ANOVA) followed by a mean separation, LSD (Least Significant Deference) at $p = 0.05$ of SAS (ver. 9) programme.

Economic analysis of composting procedure was devalued using simple cost analysis of materials used in each treatment. The cost for tea refuse and cow dung were considered as Rs. 10/- and about Rs. 25/- per 1kg respectively. No cost was spent for gliricidia and cut grasses. The labor cost was considered as Rs. 700/- for one person per day.

Results and Discussion

Initial Properties of Tea Refuse

pH, total N , P , exchangeable K and Mg, organic carbon and total polyphenols tested at the initial tea refuse are shown in table 5.

Table 5: Initial properties of tea refuse used for the compost production

	pH	Total N %	Organic Carbon%	C:N ratio	Available P%	K %	Mg %	Total polyphenol
Tea refuse	4.36	2.42	31.18	13:1	0.19	2.14	0.29	17.37%

According to the results, original tea refuse which was used for the study was slightly acidic (pH: 4.36) (Table 5). Ideal pH for composting material should be in a range of 6.5 - 8. (Vincent and Gamage, 2010). In addition, if a soil is acidic, nutrients dissolve slowly or not at all. (Nath, 2013). Thus, direct application of tea refuses as a fertilizer or mulch for acidic soils, which are common in areas with abundant rainfall, may not be suitable. The acidic nature of the tea refuse may be one of the reasons for toxicity symptoms occurred in some export agricultural plants grown in tea lands when those soils were directly treated with tea refuse.

Results showed that fresh tea refuse is rich in nitrogen (2.42 % in dry weight basis) and it is a good source of nitrogen for cellular growth of microorganisms during decomposition process. Liang *et al.* (1990) showed that total nitrogen percentage in tea refuse is high as it contains various types of miscellaneous nitrogen compounds and amino acids. Similarly, this study also found that the tea refuse is rich in nitrogen. In addition, total organic carbon was 31% in dry weight basis. Carbon content in tea refuses is a source of energy for microorganisms and microbial growth. Consequently, the C:N ratio of analyzed tea refuse was 13:1. The preferable level for initial C:N ratio of raw materials for composting was 25 - 30:1. Low C:N ratio is because of high nitrogen value of tea refuse. Mixing of other raw materials which have high C:N

ratio should be more appropriate to increase the efficiency of refuse tea decomposition. Available phosphorus (0.19%) and exchangeable magnesium (0.29%) levels of tea refuses were low compared to other nutrients. But, it is high in exchangeable potassium percentage of (2.13%) compared to the other nutrients.

Polyphenol content of tea refuse examined was about 17.37 %. Because, tea plant produces a diverse number of polyphenolic constituents, presumably as a means of chemical defense against insects, birds, and animals, which would consume the plant as food (Beart *et al.*, 1985). The polyphenols are principally responsible for the color and astringency and partially responsible for the flavor of the tea beverage (Matthew and Douglas, 1997).

Physical Properties of Products of Decomposition Process

As physical properties color, percentage of particle sizes were analyzed in mid and final product of compost and are discussed below.

Color of the final product was dark in treatments and acceptable as a qualitative compost product. Color intensity (Brownish black) of the T₁, T₂ and T₃ were higher than that of the control. According to the munsell color chart, color of the control was 5YR 5/4 while the treatments color was 5YR 4/4.

Rate of decomposition can also be determined according to relative proportion of the particle sizes of the product or the texture. Control and T₃ in mid product had relatively higher proportion of coarse materials (>2mm) indicating slower rate of decomposition or the still the decomposition process was in progress. (Figure 1). Compared to other treatments both T₁, containing the lowest volume of initial tea refuse (33%) showed more finer parts in their final decomposed product and it indicates efficient decomposition (Figure 2) in T₁ treatment . However, treatments, T₂ and T₃ containing 2 parts and 3 parts of tea refuse respectively may require more time than observed to complete their decomposition. Therefore, T₁ is comparatively the best product considering the decomposition process.

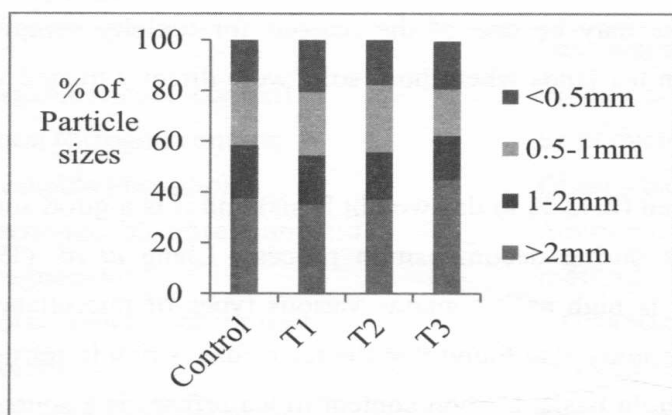


Figure 1: Percentages of particle size of the mid product

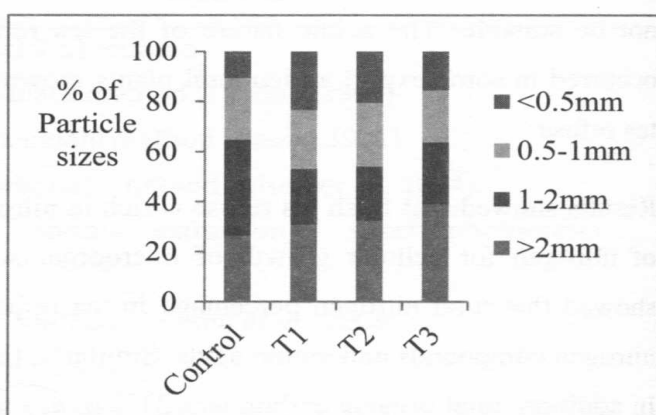


Figure 2: Percentages of particle size of the final product

Germination Ability of Vegetable Seeds on Decomposed Products

The germination ability of two types of vegetable seeds such as radish and okra was zero in fresh or raw tea refuse in all replicates. In contrast, the germination was high as 80-100 % in all composted products containing tea refuse (Table 6). Non germination status of vegetable seeds on the substrate of fresh tea refuse indicate some toxicity or any other unfavorable condition occurred due to pH or chemical constituents in tea refuse. The study showed that unfavorable condition converted to favorable condition for the germination of seeds.

Table 6: Germination of radish and okra seeds on final product of decomposition

Medium for germination of seeds	Percentage germination of seeds	
	Okra	Radish
Fresh/raw tea refuse	0%	0%
Control	90%	90%
T ₁	90%	100%
T ₂	80%	80%
T ₃	80%	90%

Chemical Properties

pH

Average pH of different compost treatments and control are shown in figure 3. pH of treatments 1,2, and 3 was significantly lower ($p \leq 0.05$) than control in both mid and final products and it is not significantly ($p \leq 0.05$) different between T₂ and T₃ in both products. This may be due to slightly acidic pH values of the initial tea refuse. As pH in the treatments in this study are significantly lower than that of control, there is a possibility to store more nitrogen in the compost heap prepared with tea refuses. As inferred higher N content in treatments is evident in the study (table 7).

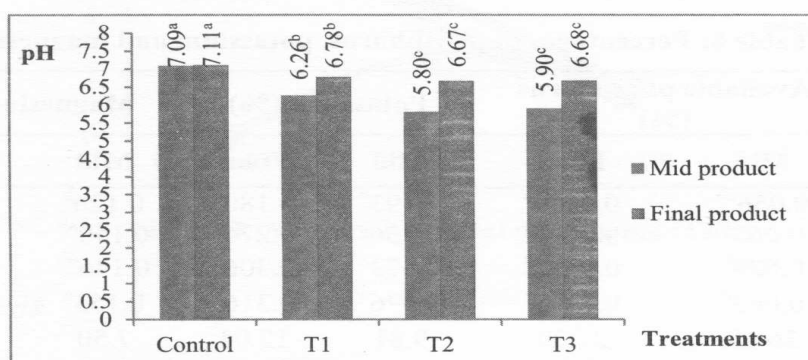


Figure 3: pH of mid product and final product

Organic Carbon and Total Nitrogen Content

Organic matter in compost improves soil structure and water holding capacity. The organic carbon percentages of the treatment 03 where more tea refuse was used, contained significantly higher amount than the control. Moreover, organic carbon content were significant ($p < 0.05$) higher in treatments compared to the control at 75 days of decomposition (Table 7). This infers that adding tea refuse as a material in

compost production improves the carbon content of the compost. Total nitrogen content was found as the lowest in the control both in mid and end product. In treatments, total nitrogen was ranged from 0.72 to 0.84 % and significantly ($p < 0.05$) higher in treatments than the control. However, there were no significant differences observed among three treatments either in Organic C % or Total N % contents of final products (Table 7).

Table 7: Percentages of carbon and nitrogen content

Treatments	Organic carbon %		Total nitrogen %		Estimated C:N	
	Mid	Final	Mid	Final	Mid	Final
Control	3.45 ^a	4.43 ^b	0.39 ^b	0.43 ^c	9:1	10:1
T ₁	4.82 ^a	6.55 ^a	0.77 ^a	0.76 ^{ab}	6:1	9:1
T ₂	4.96 ^a	6.96 ^a	0.73 ^a	0.72 ^b	7:1	10:1
T ₃	5.57 ^b	6.76 ^a	0.69 ^a	0.84 ^a	8:1	8:1
Co. variance (%)	10.97	9.11	19.63	8.21		
LSD	1.08	1.18	0.25	0.11		

Within columns, means followed by the same letter are not significantly different at $p \leq 0.05$

Available Phosphorus, Exchangeable Potassium and Magnesium (%)

The phosphorus contents of the mid and final product were low and not significantly ($p \leq 0.05$) different among the treatments (Table 8). Results revealed that tea refuse is not a good source of phosphorus. Potassium percentages of the treatments (0.28% - 0.32%) were significantly higher than the control in final product (Table 8), but there were no significant differences among the treatments. No significance differences were observed in Magnesium contents among treatments and control (Table 8).

Table 8: Percentages of phosphorus, potassium and magnesium

Treatments	Available phosphorus (%)		Potassium (%)		Magnesium (%)	
	Mid	Final	Mid	Final	Mid	Final
Control	0.056 ^{ab}	0.0190 ^a	0.193 ^b	0.180 ^b	0.126 ^b	0.130 ^{ab}
T ₁	0.063 ^a	0.0193 ^a	0.336 ^a	0.276 ^a	0.140 ^{ab}	0.150 ^a
T ₂	0.020 ^b	0.0193 ^a	0.373 ^a	0.306 ^a	0.146 ^{ab}	0.126 ^b
T ₃	0.063 ^a	0.0193 ^a	0.376 ^a	0.316 ^a	0.153 ^a	0.120 ^b
Co. variance	36.65	27.20	9.81	12.04	7.50	8.49
LSD	0.03	0.01	0.06	0.06	0.02	0.02

Within columns, means followed by the same letter are not significantly different at $p \leq 0.05$

Total Polyphenols

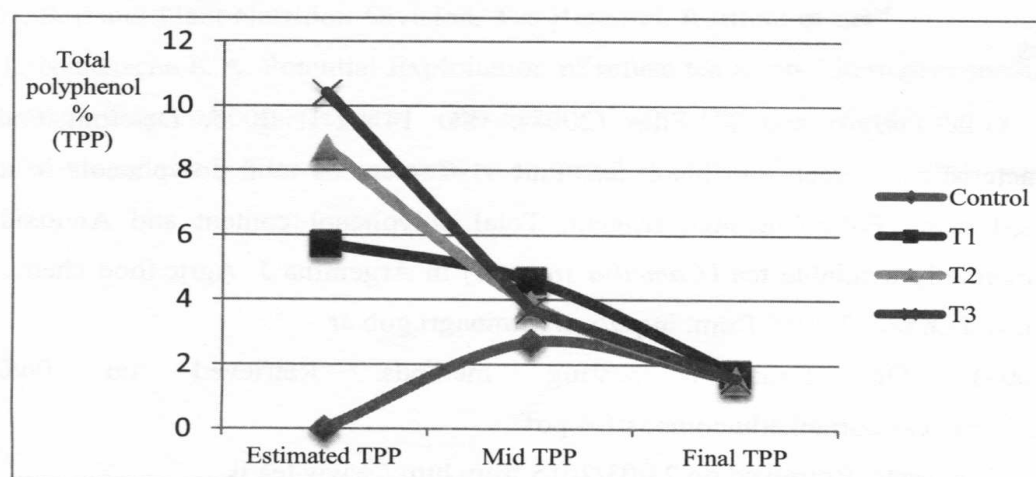
Total polyphenol of the control (2.7%) was significantly lower ($p \leq 0.05$) than the treatments in mid product and among the treatments, T₁ recorded higher than the T₂ and T₃. But total polyphenol content of the final product was not significantly ($p \leq 0.05$) different among control and the treatments.

Table 9: Total polyphenol percentage of mid product and final product

Treatments	Total polyphenol %	
	Mid	Final
Control	2.687 ^c	1.56 ^a
T ₁	4.6 ^a	1.72 ^a
T ₂	3.88 ^{ab}	1.55 ^a
T ₃	3.69 ^b	1.56 ^a
Co.variance	11.45	12.43
LSD	0.85	0.39

Within columns, means followed by the same letter are not significantly different at $p \leq 0.05$

The total polyphenol content of the initial fresh /raw tea refuse was high as 17.37 % (Table 5). When compared to estimated polyphenol values of each treatment, there was a gradual reduction in polyphenol (%) in mid and final product (Figure 5). Reduction in polyphenol content is a good indication for beneficial changes such as detoxification happened during decomposition. This decrease may be a result of lowering the concentration by mixing of other ingredients and transformations of responsible chemical constituents facilitated by microbial activities as well.

**Figure 5: Alteration of total polyphenol (TPP)**

Economic Analysis

Economic analysis was done using the rates given in methodology. Among the treatments the most profitable composting recipe was T₁. It records the lowest expenditure than other treatments (Table 10).

Table 10: Estimated cost per heap

Treatments	Estimated cost (Rs.) per heap*
Control	248/-
T ₁	413/-
T ₂	578/-

Conclusions and Recommendations

From this study it is revealed that tea refuses can be used as a composting material by mixing with readily available cut grasses, gliricidia and cow dung etc. Total polyphenol contents of tea refuse can be lowered by making compost with the other ingredients and germination tests proved its nontoxicity to vegetable seed germination. Tea refuse compost contains considerable higher amounts of C, N, K and Mg nutrients compared to normal compost produced without tea refuse. Therefore, tea refuse compost is nutritionally rich to supply plant nutrients. According to economic analysis, T₁ (1:1:1; tea refuse: cow dung:gliricidia and cut-grasses) which contained 33% of tea refuse was identified as the most economical ratio for the composting recipe.

Further studies are needed to modify the recipe for production of tea refuse compost using other readily available sources. The exact reason for toxicity effect of tea refuses should be further evaluated by future studies. Field testing of tea refuse compost for export agricultural crops such as coffee, cocoa or pepper is suggested to study the usage of composted tea refuse at field.

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