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Evaluation of some additives on coffee residue (coffee husk and pulp) quality as compost, southern Ethiopia

Henok Kassa¹, Tenaw Workayehu²

¹Environmental Science Program, Mizan Teferi University, southern Ethiopia, P.O.BOX 391, Mizan Teferi, Ethiopia
²Hawassa Agricultural Research Center, southern Ethiopia, P.O.Box 366, Awassa, Ethiopia

Abstract

Coffee residue (by-product) is generated from coffee processing stations and is disposed into arable land and surface water leading to environmental pollution, and environmentally friendly disposal method is needed in a useable way. The objective was to evaluate some additives on coffee residue quality as compost. The treatments: (1) coffee husk/pulp (CHP) (as control), (2) Coffee husk/pulp + cow dung (Cd), (3) Coffee husk/pulp + Millettia ferruginea (Mf), (4) Coffee husk/pulp + Cd + Mf, and (5) Coffee husk/pulp + effective microorganism (EM) were used to prepare compost. The experiment was laid out in randomized complete block design with three replications. The physico-chemical properties of the compost were determined at 25, 45 and 70 days of composting. The pH in CHP amended with Mf was highly significant (P<0.0001) compared with CHP and amended with Cd and EM. The contents of TN, av. P, exch. K and CEC of coffee compost treated with both Cd and Mf were significantly high. The levels of total N, OM, and C/N ratio on the 25 days of composting were highly significant compared to the 70 days; however, the finding indicates that composting coffee residue up to 70 days was important to acquire quality compost, and for its quality compost coffee residue amended with Mf and/or Cd was better than the other treatments. Amending coffee by-product with organic materials such as Millettia ferruginea and/or cow dung before composting to improve the quality of the compost is thus necessary.

Key word: Coffee by product; coffee residue; composting, quality compost.

INTRODUCTION

Ethiopia is the primary center of origin and genetic diversity of arabica coffee (Coffea arabica L.). Coffee farming systems in Ethiopia are conventionally divided into four categories: forest coffee, semi-forest coffee, garden coffee and modern plantation (Paulos and Demil, 2000). Coffee, which earns more than 60% of foreign income to the country, is one of the few export crops grown in Ethiopia. The major growing areas of coffee are in the south, south western and south eastern parts of Ethiopia (Hofner, 1987). The total area of coffee is about 400,000 ha with a total production of 200,000 tons of clean coffee per annum (CTA, 1999; FAO, 1997). This yield is associated with an estimated amount of 242,000 tons of by-product as coffee residue (coffee husk and pulp). Other report (MoFED, 2006) also indicates that the production capacity of the country is targeted to increase the production and productivity.

Nearly 25% of the Ethiopian population depends directly or indirectly on coffee for livelihood (CTA, 1999). Coffee plantation accounts for 9.2% of the total cultivated and 2.7% of the total agricultural land in the southern region of Ethiopia (BoPED, 1996). The region contributes more than 38% of the total coffee export of the country (SNNPRS/UNECA, 1996) and is grown by most farmers. On average, 12% of the total income of the farm household comes from coffee (Getahun et al., 1991).

For export, coffee is processed by either the wet or dry method. Coffee pulp is the by-product/residue from wet processing while coffee husk is the by-product of dry processing. Seventy percent of the coffee exported from...
Ethiopia is sun-dried while the rest (30%) is wet processed (washed) (FDRE, 2006). About 33,750 metric tons of coffee residues are produced per season in the southern region of Ethiopia from coffee processing factories (Tsige-Yohannes and Steinbach, 1996). The residue from dry processing is burnt while those from wet processing are dumped into rivers, both being disposed into arable land and surface water. The residue from the wet coffee processing factories particularly coffee processing effluent and discharge from the factory can cause considerable pollution to water courses (Anon, 1991), which are mainly the source of water not only for coffee processing but also for domestic and agricultural requirements. According to Yared (2008), people living around coffee processing stations have complains about pollution of rivers and its associated health impact. They report skin disease and sometimes death of domestic animals on the livestock. Use of coffee residue in agriculture is restricted and thus imposes environment problem due to the presence of polyphenols, which are considered as anti-nutritional and phytotoxic substances, such as caffeine, tannin, and organic acids (Bressani, 1979). However, these wastes contain high concentrations of biodegradable organic and minerals of plant origin, which can better be utilized by composting with other organic materials (additives). Thus, both disposal methods have brought about environmental hazard (pollution). The objective of this study was to investigate the physico-chemical properties and composting time of coffee residue alone or together with locally available organic amendments, and determine the nutrient content of the matured compost for soil amendment.

MATERIAL AND METHODS

Description of the Study Area

The Experiment was conducted at Hawassa Agricultural Research Center. Hawassa is located in 7°3′N of latitude and 38°28′E longitude and with an altitude of 1700-1750 m (AARC, 2004). The rainfall is bimodal with a long term mean rainfall of 1021 mm, and about 36.4% of this is received from February to May and 51.3% from June to September. The long term mean maximum and minimum temperatures in May vary from 24 to 27°C and in September from 12.8 to 13.8°C. The soil of the experimental site was loam.

Collection of composting material

The basic organic raw materials used for composting were coffee husk (CH) and pulp (CP) (CHP = by-product = coffee residue) and other additives such as parts of leguminous tree foliage of *Millettia ferruginea* (Mf), cow dung (Cd), and effective microorganism (EM). Coffee residue was collected from Yergalem wet and dry coffee processing station. Cow dung was collected from a dairy farm of Hawassa Agricultural Research Center. Leguminous tree foliage of *Millettia ferruginea* was collected from Hawassa Agricultural College. Effective microorganism was obtained from Addis Ababa (Ethiopia Agricultural Research Organization). The top soil, a common bulking agent, was taken from Hawassa Agricultural Research center.

Preparation of compost

Based on the treatments, an individual heap having the size of 1m length, 1m width and 1m height (ground area for compost heap 1m²) was prepared, based on the recommendation of the Henry Doubleday Research Association (HDRA, (2001) and with some modifications in basic layering sequence. The composting material was piled up in different thickness and set up on the earth’s surface. The heap was shuffled after one week in order to enhance the composting process by blending and breaking up the composting materials (Harold et al., 1994). The most efficient method of composting coffee residue was used (Adams and Dougan, 1980 and 1981), which was an aerobic windrow composting method. Composting method involved mixing of organic amendments (additives) with the respective “pure” by-product (coffee residue which is a mixture of pulp and husk) at different proportions (Table 1). The top soil was added to each layer to aid the composting process.

Methods of physico-chemical analysis

The physico-chemical parameters were determined for all treatments before and after composting at different times of composting and maturity (Tables 2 and 3). The composite samples from all the replicates were collected and sub-sampled using a process called quartering. Quartering involves spreading the material to an even level, dividing the sample into quarters, removing the two diagonal quarters and mixing the remaining. The sample was oven-dried at 70°C for 24 hr until a constant weight was obtained. The sample was then grounded to obtain particle size of less than 2 mm and analyzed for electrical conductivity, pH, cation exchange capacity, nitrogen, phosphorous, potassium, and organic matter using standard method.

Bulk density

Bulk density of matured compost was determined by using a five meter cubical cage with some modification and expressed as: Bulk density (kg m⁻³) = weight of the
sample (kg) / volume of the container (m\(^3\)) (Tiquia and Tam, 2002; Rynk et al., 1992).

**Moisture content**

The moisture content was examined at 25 (D25), 45 (D45), and 70 (D70) days of composting. Samples of 500 g fresh compost was weighted and placed in a forced-air oven at 105 \(^{\circ}\)C for 24 hours. The percentage of moisture content was calculated using standard formula (United States composting council TMECC, 2000; Epstein, 1997; Rynk et al., 1992):

\[
\text{Moisture content} = \frac{\text{Initial weight} - \text{Dry weight}}{\text{Initial weight}} \times 100
\]

**pH**

The pH was measured using 1:5 (compost: water) water suspension. Then, the pH was measured using pH meter model CP-501 Elmetron modified from (Rice, 1996).

**Total nitrogen (TN)**

The total N of the raw material and compost was determined by the Kjeldahl method as described by Bremner (1965). The carbon to nitrogen ratio was calculated from the respective organic carbon and total nitrogen values.

**Available Phosphorus (AP)**

Available phosphorus was determined by spectrophotometer model 6400 using Olsen method (Olsen et al., 1954).

**Cation Exchange capacity (CEC)**

Cation exchange capacity was determined using Sodium acetate as described by FAO (1993).

**Exchangeable potassium (ex.K)**

Exchangeable potassium was determined by using flame photo meter (Chapman, 1965; FAO, 1993).

**Electrical conductivity (EC)**

The electrical conductivity was measured using 1:5 (compost: water) water suspension. Then, electrical conductivity was measured using conductivity meter model Hanna HI 8733 as described by (FAO, 1993).

**Organic matter**

Loss in Ignition: The total organic matter content of the samples was measured at initial, 25, 45, and 70 days of composting using standard formula from loss in ignition. The compost sample used to determine moisture content was ground, thoroughly mixed and 5g sub-sample was placed in a crucible and thermally ignited at 375 \(^{\circ}\)C for 4h using a muffle furnace (Manjula et al., 2006; FAO, 1993).

**Experimental Treatments and design**

**The treatments were**

- Treatment 1 (T1) (Control): Coffee by-products (coffee husk and pulp)(CHP)
- Treatment 2 (T2): Coffee by-products plus cow dung (CHPCd)
- Treatment 3 (T3): Coffee by-products plus leaf of *Millettia ferruginea* (CHPMf)
- Treatment 4 (T4): Coffee by-products plus cow dung and leaf of *Millettia ferruginea* (CHPCdMf)
- Treatment 5 (T5): Coffee by-products plus Effective Microorganism (EM) (CHPEM)

The top soil was added to each treatment to aid the composting process. The experiment was laid out in randomized complete block design with three replications.

**Statistical analysis**

Data collected were compost temperature, moisture content, total N, pH, OM, av. P, exch. K, CEC, and C/N ratio of the compost were taken before and after composting was analyzed using SAS (2000).

**RESULTS**

**Nutrient contents of coffee residue and the additives**

Analysis of the composting additives showed that pH and N content of coffee pulp and *Millettia ferruginea* was high but low in coffee husk and cow dung, and is within the range of acceptable limit. Carbon: nitrogen ratio of coffee pulp and *Millettia ferruginea* was below the acceptable limit (Table 2).

**Additives on compost quality**

**Temperature**

There were significant differences in temperature among
Table 1. Proportion of coffee by-products and some additives of organic materials (cow dung, leaf of *Millettia ferruginea*, and effective microorganism (EM)) in compost heap

<table>
<thead>
<tr>
<th>Materials used</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1(control)</td>
</tr>
<tr>
<td>Coffee pulp</td>
<td>60%</td>
</tr>
<tr>
<td>Coffee husk</td>
<td>30%</td>
</tr>
<tr>
<td>Cow dung</td>
<td>___</td>
</tr>
<tr>
<td>Leaf of <em>Millettia ferruginea</em></td>
<td>___</td>
</tr>
<tr>
<td>Effective microorganism</td>
<td>___</td>
</tr>
<tr>
<td>Top soil</td>
<td>10%</td>
</tr>
</tbody>
</table>

Table 2. Physical and chemical characteristics of composting materials before composting

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>MC (%)</th>
<th>pH</th>
<th>EC (mS/cm)</th>
<th>OM (g kg⁻¹)</th>
<th>TN (g kg⁻¹)</th>
<th>C:N ratio</th>
<th>TP (mg kg⁻¹)</th>
<th>ex. K (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee husk</td>
<td>10.50</td>
<td>6.63</td>
<td>2.00</td>
<td>815</td>
<td>11.7</td>
<td>40:1</td>
<td>12567</td>
<td>9.4</td>
</tr>
<tr>
<td>Coffee pulp</td>
<td>56.50</td>
<td>8.93</td>
<td>4.40</td>
<td>705</td>
<td>23.8</td>
<td>16:1</td>
<td>11867</td>
<td>21.8</td>
</tr>
<tr>
<td><em>Millettia ferruginea</em></td>
<td>59.00</td>
<td>5.93</td>
<td>3.73</td>
<td>864</td>
<td>28.5</td>
<td>17:1</td>
<td>12183</td>
<td>11.8</td>
</tr>
<tr>
<td>Cow dung</td>
<td>48.50</td>
<td>9.04</td>
<td>4.43</td>
<td>582.6</td>
<td>10.3</td>
<td>31:1</td>
<td>12033</td>
<td>14.8</td>
</tr>
<tr>
<td>Top soil</td>
<td>7.10</td>
<td>7.34</td>
<td>0.11</td>
<td>128.6</td>
<td>2.5</td>
<td>30:1</td>
<td>75.8</td>
<td>0.0038</td>
</tr>
<tr>
<td>Soil of media</td>
<td>10.70</td>
<td>7.1</td>
<td>0.10</td>
<td>125.1</td>
<td>2.1</td>
<td>34:1</td>
<td>65.2</td>
<td>0.0034</td>
</tr>
</tbody>
</table>

MC-moisture content, EC-electrical conductivity, OM-organic matter, TN-total nitrogen, C: N-carbon nitrogen ratio, TP-total phosphorus, ex.K-exchangeable potassium

†Source of acceptable limit (Rynk *et al.*, 1992; Myers *et al.*, 1994)

the treatments at P< 0.0045. Temperature variation was not observed among all the treatments except the control which had lower temperature (Table 2). On the other hand, decrease in temperature was observed as time of composting increased from 25 to 70 days of composting.

### Moisture content

Variation in moisture was observed among the different composts of coffee residue (Table 3). The moisture content of coffee residue treated with cow dung, *Millettia ferruginea* and their combinations (Cd and Mf) had more moisture but not significantly different from each other. There was a significant decrease in moisture content as time of composting extended to 45 days even beyond (Table 4).

### pH

The pH of coffee residue amended with *Millettia ferruginea* (CHPMf) was not significantly different from the residue treated with combination of both cow dung and *Millettia ferruginea* (CHPCdMf) and the control (Table 3). Lower pH was observed in the residue amended with effective microorganism (CHPEM). The pH in coffee residue treated with *Millettia ferruginea* (CHPMf) and cow dung was significantly high but not significantly different from the control. The pH of the compost at 45 days of composting was significantly high than the other days of composting (Table 4).

### Cation exchange capacity (CEC)

Variation in CEC was significantly affected by organic amendments and time of composting. Treatments containing cow dung and combination of cow dung (Cd) and *Millettia ferruginea* (Mf), and that treated with effective microorganism had more CEC than the other treatments. Cation exchange capacity of the residue amended with Cd, Mf, effective microorganisms and the control was 3.9, 9.5, 5.3 and 20.7% less than the residue treated with both Cd and Mf together, respectively (Table 3). On the other hand, extending time of composting from 25 to 70 days linearly raised cation exchange capacity of the compost (Table 4).
Nitrogen content of coffee residue significantly increased from the addition of organic materials/additives. Coffee residue amended with Cd and combination of Cd and Mf had more N than the control and that treated with effective microorganisms. Nitrogen content of coffee residue alone or combined with Cd, Mf or effective microorganisms was 25.9, 12.6 and 13.3% less than the compost of the residue amended with both cow dung and *Millettia ferruginea* together, respectively (Table 3). On the other hand, nitrogen content was significantly reduced as time of composting extended, and there was a 16.6 and 20.7% decrease in N content as time of composting extended to 45 and 70 days, respectively (Table 4).

### Available P.

Availability of phosphorus was significantly variable among the different composting treatments. Coffee residue amended with cow dung and its combination with cow dung and *Millettia ferruginea* was significantly...
high compared with other treatments, but the control without any additives had low N content (Table 3). Phosphorus availability at 45 and 70 days of composting was significantly high compared with the 25 days of compost (Table 4).

Exchangeable K.

Coffee by-product amended with either *Millettia ferruginea* or cow dung plus *Millettia ferruginea* had significantly higher exchangeable potassium compared with the other treatments (Table 3). The control had very low exchangeable K even that treated with effective microorganism. Exchangeable potassium was significantly high when time of compost was extended to 45 days beyond which there was a decrease (Table 4).

DISCUSSION

Increase in temperature in coffee residue compost amended with additives/organic materials/ was due to the heat generated as activities of microorganisms decompose organic material. Variation in temperature is one of the most important parameters that reflect the microbiological activity in the composting process (Epstein, 1997; Strom, 1985). The studies of Vashi and Shah (2003) on co-composting of municipal solid waste (MSW) with sewage Sludge; Taiwo and Oso (2004) on composting of MSW and Anandavalli et al. (1998) on recycling of banana pseudo stem compost also indicated reduced temperature as composting proceeded.

The high pH in some of the treatments and days of composting was because of production of ammonia during ammonification and mineralization of organic nitrogen as the result of microbial activity. The release of basic cations from the mineralization of organic matter resulted in higher pH. Similarly, the report of Bishop and Godfrey (1983) showed rise in pH due to ammonia production during ammonification and mineralization of organic.

The high CEC in some of the treatments with time might be attributed to the release of elements (humification) from organic material as composting process proceeded. Increase in CEC was also attributed to increase in the materials bearing a negative charge as maturity progressed (Harada and Inoko, 1980). The greater ability of the particles to retain cations was because of more CEC in the compost (Harada and Inoko, 1980).

The presence of additives (Cow dung, *Millettia ferruginea*, and effective microorganisms) reduced OM content and C/N ratio compared to the control, and created conducive condition for microbial activity, which resulted in accelerated decomposition and conversion of organic matter into carbon dioxide, energy and stable compounds. All the composts had values greater than 20, which is comparable with the quality compost (OM > 20%) used in some countries such as Dutch, Belgium and Italy. Similarly, Anandavalli et al. (1998); FFTC (2007); Greenway and Song (2002) confirmed the reduction of organic matter content as composting process proceeds/ progresses.

C: N ratio is an indicator of compost quality and N availability and the compost with low C: N ratio (<20) will release organic N making it available to plant. Addition of different additives reduced C: N ratio (Mashayekhi et al., 2012). The low C: N ratio in coffee residue amended with additives except the control may be attributed to creation of favorable conditions and nutrient balance for microbial activity. Chane (1999) in his study indicated that rate of mineralization of organic carbon and nitrogen varied widely among the coffee husk and pulp composts examined. Amount and composition of organic matter in the compost influenced the variation. The finding of this study was in agreement with the compost quality standards used in countries such as Dutch, Belgium and Italy. Similarly, the mean C: N ratio of all the composts was within the range of the Ethiopian Federal EPA guidelines that recommended C/N ratio of 29:1 or less (EFEPA, 2004). Lower C:N ratio with time has been observed, which was accompanied by a decrease in C/N ratio in which the purpose of composting is to reduce or narrow down the ratio.

Variation in N content in some of the composts was due to the difference in nitrogen content of the additives like *Millettia ferruginea* that contains more N content. This result is in agreement with compost quality standards for compost used in agriculture in Switzerland (>1%) and India (>0.8%). Besides, Barker (1997) reported the total N content of the compost more than 1% on dry weight basis to use as fertilizer. The decrease in nitrogen content might also be volatilization of gaseous ammonia as composting process progressed/proceeded. Mahimairaja et al. (1994) noted reduced N content in his study of losses and transformation of nitrogen during composting of poultry manure with different amendments.

The low availability of phosphorus in coffee residue alone or treated with *Millettia ferruginea* or effective microorganism could be the release of available phosphorous during decomposition of organic phosphorous. Most of the P in organic material is held in organic complex (Rechogil and Mackinnon 1997). An increase in availability of P might be decomposition of organic phosphorous when composting process was extended. Study by Warman and Termeer (1996) on racetrack manure, grass clippings and sewage sludge reported that P is not lost by volatilization during the composting process, but P concentration might increase as composting proceeds.

Decomposition of the compost increased exchangeable K with time (time for active composting
(thermophilic) period), and this was in line with the work of Chane (1999) that indicated increase in K content due to decomposition

CONCLUSIONS

Compost of coffee residue that contained additives/organic amendments showed higher temperature, pH, CEC, total nitrogen, available P and exchangeable potassium but lower organic matter and C/N ratio. The decrease to ambient temperature at the later stage of composting indicates reduction in availability of biodegradable substrates. Amending coffee residue with some additives would increase pH, CEC, total N, available P and exchangeable K but reduced organic matter and C/N ratio. The longer active composting time (thermophilic period) indicates high decomposition of organic matter. Composting coffee residue up to 70 days was important to acquire quality compost because of ambient temperature, medium moisture, low pH, high CEC, medium N, high available phosphorous, medium exchangeable K, low organic matter and low C/N ratio. Since the pH of the various compost was >8, use of this compost to amend acid soils is crucial rather than using chemicals/ lime for amending the acidity. Composting coffee residue with either Millettia ferruginea (CHPMf) or combinations of cow dung and Millettia ferruginea together (CHPComDf) with their respective proportion could be exploited for compost quality preparation

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