Research Note

EVALUATION OF THREE COFFEE PULP COMPOSTING FEEDSTOCKS[1]

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When coffee pulp is properly composted it becomes mature, stable and usable organic matter. Stable organic matter, compost, can provide environmental benefits such as reduced water and air pollution. Mature compost could improve the soils' chemical, physical and biological characteristics (Bernal et al., 1998) thereby reducing the need for inorganic input and thus providing economic benefits. Coffee pulp (CoP), a major by-product from the processing of coffee beans, contains up to 90% water by weight; it is considered a wet composting material or feedstock, and it contains easily degradable organic matter. Improper handling of this material typically starts when the coffee bean is removed from the coffee berry and the CoP is deposited in large piles where it becomes anaerobic. The CoP high water content, low porosity and high bulk density are the main factors that reduce the oxygen content, thus creating anaerobic conditions. These anaerobic conditions result in malodorous compound production. This problem is exacerbated when the pile collapses because of decomposition of organic matter and increased weight of feedstock, thus decreasing pile porosity.

Coffee pulp left in piles or under water degrades anaerobically, generating obnoxious odors. This anaerobic degradation is passive, lengthy and renders the material unstable, all of which can result in nutrient lixiviates. On the contrary, aerobic-controlled compost decomposition methods render mature-stable material. Proper composting of CoP requires the addition of bulking agents that reduce water, and bulk density, and increase air porosity. If bulking agents are not used the coffee pulp compost pile collapses, thus arresting the process. Generally, composting has two phases, a thermophile microbial phase, followed by a curing process that stabilizes the organic matter. During this process the liable organic matter is consumed by microorganisms reducing the material, and producing heat. Upon microorganism death and reduced activity, much of the organic matter becomes non-liable or harder to decompose, thereby rendering mature stable compost.

Aerobic composting methods facilitate the contact between organic matter particles, air and aerobic microorganisms so that the latter can function and consume the organic matter. The relatively low maintenance and management of aerobic composting methods allows ease of implementation on small farms. Aerobic composting methods for coffee pulp include mechanically turned piles and passively or actively aerated compost piles (Chong and Dumas, 2011). Selection among compost methods depends on the type of

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feedstock, on economic and environmental considerations (Spellman et al., 2007) as well as on available feedstock on the farm where coffee pulp is produced. The mechanical method uses a tractor bucket or similar equipment to move and turn the compost pile. This method is easy to manage, but requires periodical compost handling. The pile is handled as required by temperature, oxygen or by schedule. Contrary to the mechanical method, the passively aerated method has the advantage that the organic matter-air-microorganism contact is promoted by a chimney effect requiring no further handling until the compost is mature. The passively aerated method consists either of embedding aeration pipes at the base of the compost pile to promote airflow through a chimney effect, or of the use of wood chunks or chips at the base to replace the pipes. Maintaining adequate moisture and porosity is necessary for either method. Improving porosity and humidity in feedstock materials with high bulk density, such as coffee pulp, requires the addition of bulky agents to the feedstock piles.

Our hypothesis is that mature compost could be a good alternative as bulking agent for the compost of coffee pulp feedstocks, thus reducing the need to transport wood chips to remote farm locations. Mixing the CoP with bulky agents such as wood chips increases the porosity of the mix and reduces bulk density in the pile. The transportation cost and availability of bulky agents, such as wood chips, is the major drawback for coffee pulp compost.

The objective of this study was to evaluate three passively aerated static composting treatments for coffee pulp: CoP pile (CP); CoP mixed with screened mature CoP compost (CPCP); and CoP mixed with wood chips (CPWC). During the evaluation we used the CoP as control, the CPCP as comparison for the replacement of CPWC mix, with the purpose of avoiding the need to source and transport bulking agents to farms. The quality parameters included specific oxygen uptake rate (SOUR); total organic carbon (TOC); nitrogen (N) and phosphorus (P) content; carbon to nitrogen ratio (C/N); nitrate (N-NO_3^-) and ammonium (N-NH_4) content; pH; and electrical conductivity (EC).

Compost preparation and assays

The materials used for the compost were coffee pulp (CoP), composted CoP, and wood chips. The CoP was relatively fresh, less than one month after having been extracted from the coffee berry. The composted CoP, a mature composted coffee pulp, was passed through a 0.95-cm screen (Orbit model 62, Delhi, IA)[4]. The wood chips, obtained from shredded shipping crates, varied between 2.5- and 5-cm long. Table 1 shows the physicochemical properties of the mature CoP compost. The three treatments were by volume CoP piles (CP); a 1:1 mixture of CoP and screened mature CoP compost (CPCP); and a 1:1 mixture of CoP and wood chips (CPWC).

The stability and nutrient composition of the three examined feedstock mixes were determined after 70 days from mixing the materials and after building two piles per treatment with two PVC pipes at the bottom of each pile. Each PVC pipe was 10.16 cm in diameter and 3.05-m long, placed parallel to each other and separated by 61 cm. The PVC pipes were drilled longitudinally every 30 cm, thus creating a 5-cm hole in two straight lines, one at 120° and another at 240° in the circumference of the pipe. The pipe was placed with the holes facing downward to prevent the feedstock from clogging the air conduits. Samples were collected in polyethylene bags and shipped the same day to the laboratory. These were ground to pass through a 5-mm sieve for physicochemical analysis; they were stored at 4° C until extraction and analysis.

[4]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

TABLE 1. *Chemical and physical properties of mature coffee pulp (CoP) compost chunks (bulky agent).*

Property	Composted Coffee pulp
N (%)	4.89
P (%)	0.46
TOC (%)	33.64
C/N	6.91
pH	6.77
EC (mS/cm)	3.33
$N\text{-}NO_3$ (%)	0.35
$N\text{-}NH_4$ (mg/kg)	9.8

Compost samples were analyzed for moisture, pH, and electrical conductivity (saturated paste method). Organic carbon (OC) was estimated by loss upon ignition at 500° C for 2 h. Total Kjeldalj nitrogen (N_T) and total Kjeldalj phosphorus (P_T) were analyzed by using a Technicon II Autoanalyzer. Inorganic N was extracted by shaking 1 g (dry base) of the compost with 10 mL of 2 M KCl for 1 h. The supernatant was filtered through a 0.45-µm Whatman Nylon syringe filter and analyzed for ammonium N, and for nitrate N, by using USEPA Methods 350.1 and 353.2, respectively. The specific oxygen uptake rate was measured according to the method described by Lasaridi and Stentiford (1998). A 30-g aliquot of wet compost was mixed with 500 mL of distilled water, $CaCl_2$, $MgSO_4$, $FeCl_3$, and phosphate buffer (pH 7.2). The mixture was incubated in a water bath held at 30° C for 24 to 36 hours. During this time, the suspension was alternately aerated for 15 min and allowed to stand for 20 min. During resting time, the oxygen concentration was measured continuously and the SOUR was calculated.

Analyses of variance and least significant difference (LSD, $p \leq 0.05$) were used to compare the chemical and physical data (pH, EC, NO_3, NH_4, N_T, OC) among the different composting treatments (CP, CPCP and CPWC).

Treatment effects are presented in Table 2. The organic carbon (OC) ranged from 38.4 to 27.3%, in the order of CP > CPWC = CPCP. During the composting processes

TABLE 2. *Chemical and physical properties of 70-day-old compost end-products achieved by three composting treatments.*

Treatment[1]	OC-LOI[2] %	N_T[3] %	P_T[4] g/kg	$N\text{-}NO_3$[5] mg/kg	$N\text{-}NH_4$[6] mg/kg	N_i[7] mg/kg	C/N[8]	N_i/OC[9] mg/kg
CP	38.4 a[10]	2.63 b	120 c	37 b	23 c	60 c	14.61 a	167 c
CPCP	27.3 b	3.14 a	210 a	675 a	167 b	842 a	8.88 b	3,112 a
CPWC	30.4 b	1.93 c	150 b	31 b	412 a	443 b	16.32 a	1,468 b

[1] CP = coffee pulp (CoP) pile; CPCP = CoP mixed with screened mature CoP compost; and CPWC = CoP mixed with wood chips.

[2]Organic carbon.

[3]Total nitrogen.

[4]Total phosphorus.

[5]Nitrate-nitrogen.

[6]Ammonium -nitrogen.

[7]Inorganic nitrogen.

[8]Carbon to nitrogen ratio.

[9]Inorganic nitrogen to organic carbon ratio.

[10]Values followed by the same letter within a column are not significantly different, using Fisher ANOVA on rank test.

the microbial activities reduced the organic carbon content (Epstein, 1997). The CPWC and CPCP treatment had less OC thus suggesting less available OC to degrade when compared with that of the control CP. Lower OC is a reflection of reduced liable organic carbon, hence greater compost stability.

Total nitrogen content ranged from 3.14 to 1.93%, statistically decreasing in the order CPCP > CP > CPWC. Because of the nitrogen contribution of the composted CoP used as feedstock (4.89% N, Table 1) greater nitrogen was measured in CPCP. Total phosphorus decreased in the order CPCP > CPWC > CP. These results indicate that CPCP treatment has the highest potential for nutritional benefits as an organic soil amendment.

The highest nitrate content was observed in the CPCP treatment (Table 2). Table 2 also shows that both CPCP and CPWC treatments had higher amounts of ammonium than the CP treatment. The total inorganic nitrogen (N_i) varied from 60 to 842 mg/kg, in the decreasing order of CPCP > CPWC > CP. Both the N_i content and N_i to OC ratio decreased in the order of CPCP > CPWC > CP, all of which indicates that the CPCP treatment had the highest mineralization in comparison with that of the other two treatments in this study. The electrical conductivity ranged from 3.01 to 5.38 mS/cm (Table 3), decreasing in the order of CPCP > CPWC > CP. The results indicate that the physicochemical properties evaluated were affected by the composting treatment (Table 2).

The carbon to nitrogen ratio (C/N) is considered an important parameter for determining compost maturity (Keller, 1961). Generally, decreasing C/N ratios suggest increasing maturity. However, C/N ratios are feedstock-dependent; thus immature compost with low C/N is possible (Hirai, 1983; Mathur, 1991). Data in Table 2 show that the C/N values ranged from 8.88 to 16.32, statistically decreasing in the order of CPWC = CP > CPCP. The CPCP had the lowest C/N value because of the influence of the already stable added compost (Table 1). In treatment CPWC any non-decomposed wood chips were removed from the samples prior to the analysis, but after screening wood sticks smaller than 0.5 cm remained in the samples. The wood chips are rich in lignocellulose, resistant to degradation; thus the wood chips were not degraded during the length of time of this study. This finding explains the high C/N value of the CPWC treatment, and also explains why in this case the C/N ratio is not a good criterion for determining stability.

The compost maturity and stability were assessed by measuring the SOUR of the three 70-day old composts that resulted from the methods assayed in this study. The SOUR ranged from 0.23 to 1.96 mg O_2/g VS-h (Table 3), decreasing in the order of CP > CPWC = CPCP. The SOUR varied significantly among composting treatments because of the bulky agents (composted coffee pulp chunks and wood chips), which increased porosity in the piles of CPCP and CPWC. The SOUR for stable organic matter is below 1 mg O_2/g VS-h (Lasaridi et al., 1998). Thus, results showed that after 70 days of composting mature-stable organic matter compost is obtained from the CPCP and CPWC treatments

TABLE 3. *Maturity data of 70-day-old compost achieved by three composting treatments.*

Treatment[1]	SOUR[2] mg O_2/g VS-h	pH	EC[3] mS/cm	Moisture %
CP	1.96 a[4]	7.58 b	3.01 c	80.2 a
CPCP	0.23 b	7.55 b	5.38 a	63.7 b
CPWC	0.39 b	8.00 a	3.63 b	48.9 c

[1]CP = coffee pulp (CoP) pile; CPCP = CoP mixed with screened mature CoP compost; and CPWC = CoP mixed with wood chips.

[2]SOUR =specific oxygen uptake.

[3]EC= electrical conductivity.

[4]Values followed by the same letter within a column are not significantly different, using Fisher ANOVA on rank test.

TABLE 4. *Standard errors for SOUR, C/N and N_i/OC ratios for each composting treatment.*

Treatment[1]	SOUR[2]	C/N[3]	N_i/OC[4]
CP	50	14	95
CPCP	43	13	34
CPWC	20	16	7

[1]CP = coffee pulp (CoP) pile; CPCP= CoP mixed with screened mature CoP compost; and CPWC = CoP mixed with wood chips.
[2]SOUR =specific oxygen uptake.
[3]Carbon to nitrogen ratio.
[4]Inorganic nitrogen to organic carbon ratio.

(Table 3). The 1.96 SOUR value for the CP treatment indicates that a longer period of time is needed in order to obtain mature-stable compost from this composting treatment.

Samples from the CPCP treatment showed the highest N_i/OC ratio, as well as the lowest C/N ratio; this finding indicates that the CPCP treatment had the highest mature-stable conditions (Table 2). Table 4 shows that the standard errors in SOUR, C/N ratio and N_i/OC ratio were higher in CP than in CPCP and CPWC composts. The high values in standard error in the CP treatment are typical of non-uniform composting, indicated by CP pile collapse that affects airflow even with the use of composting passively aerated PVC pipes with humidity levels of 80.2%. The collapse of piles in the CP treatment was due to this treatment's having no bulky agent. Thus, in the CP treatment the maturation process was slower in the deeper parts of the pile. This finding explains the standard error of SOUR, and why N_i/OC decreased in the order of CP > CPCP > CPWC.

In conclusion, both CPCP and CPWC are faster composting treatments for CoP feedstocks than the CP control, and these feedstock mixes can be used interchangeably. The percentage of OC and N_i, EC and SOUR indicated that the CPCP composting treatment was faster than CPWC and CP. However, the composting treatment with lower standard error was CPWC. A more uniform product is obtained by using CPWC. The more uniform product obtained with the CPWC treatment was probably due to the fact that the wood chips mainly provided structure, but the chunks of mature CoP as bulky agent for CPCP treatment provided both structure and nutrients, although in a non-uniform way. This study indicates that reusing the larger fractions of already composted material as an alternative feedstock can be feasible both for reducing the need to bring wood residues to the farm, and thus for reducing the cost of importing materials for coffee pulp composting.

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