Biodegradation **10:** 35–41, 1999.

Accelerated coffee pulp composting

Gloria Sánchez, Eugenia J. Olguín & Gabriel Mercado
Department of Environmental Biotechnology, Institute of Ecology, Apdo. Postal 63, Xalapa, Ver. 91000 México

Accepted 15 October 1998

Key words: coffee pulp, composting, filter cake, organic accelerators, poultry litter

Abstract

The effect of two abundant, easily available and very low-cost agro-industrial organic residues, i.e., filter cake from the sugar industry and poultry litter, on the composting stabilization time of coffee pulp and on the quality of the produced compost, was evaluated. Piles of one cubic meter were built and monitored within the facilities of a coffee processing plant in the Coatepec region of the State of Veracruz, Mexico. Manual aeration was carried out once a week. A longer thermophilic period (28 days) and a much lower C/N ratio (in the range of 6.9–9.1) were observed in the piles containing the amendments, as compared to the control pile containing only coffee pulp (14 days and a C/N ratio of 14.4, respectively). The maximum assimilation rate of the reducing sugars was 1.6 g kg^{-1} d^{-1} (from 7.5 to 5.3%) during the first two weeks when accelerators were present in the proportion of 20% filter cake plus 20% poultry litter, while they accumulated at a rate of 1.2 g kg^{-1} d^{-1} (from 7.4 to 9.13%) during the same period in the control pile. The best combination of amendments was 30% filter cake with 20% poultry litter, resulting in a final nitrogen content as high as 4.81%. The second best combination was 20% filter cake with 10% poultry litter, resulting in a compost which also contained a high level of total nitrogen (4.54%). It was concluded that the use of these two residues enhanced the composting process of coffee pulp, promoting a shorter stabilization period and yielding a higher quality of compost.

Introduction

Coffee is one of the most important agro-industrial export products in tropical countries. In Mexico, coffee is the principal export product and generates the highest foreign revenue after oil (Olguín 1996). Forty percent of the wet weight of the currently utilized coffee is in the form of hard envelopes called pulp, which is removed and discharged as waste. In the State of Veracruz in Mexico, there are currently approximately 800 wet coffee processing units and from the production data for the 1996–1997 cycle it can be estimated that approximately 129 690 tons of wet coffee pulp were discharged.

Coffee pulp is usually disposed without any treatment and left to degrade naturally in heaps, with the uncontrolled liberation of noxious odors and nutrient-loaded leachates as a consequence. It may take 6 to 8 months to achieve a stabilization of the organic matter and moreover the nitrogen in the residue does not amount more than 2% of the dry weight. Efficient technologies for coffee pulp stabilization and transformation into a useful product are thus urgently required to control the continuous negative impact on the environment caused by these solid residues.

Composting represents a possible technology for dealing with coffee pulp recycling, since it may be carried out with a low capital investment and produces a high-quality organic fertilizer (Olguín 1996) in a shorter period than natural stabilization, i.e., 6–8 months for natural decay. Modern farms demand organic fertilizers to replace chemical ones in order to avoid the impoverishment of the soil, and to reduce operating costs (Anderson & Smith 1987). Moreover, there exists a greater demand for coffee grown on organically fertilized soils.

Although abundant information is available for small and commercial scale composting of several substrates (Canet & Pomares 1995; Brink 1995; Atallah et al. 1995; Iglesias & Pérez 1991), very little information has been published on coffee pulp composting. Calzada et al. (1989), in Guatemala, reported on the use of forced ventilation for coffee pulp composting in 6 m^3 piles. Stabilization was attained in 55 days and the nitrogen content in the compost was 3.5%. However, other technologies operating at lower costs are required in small and medium-sized coffee processing plants, especially in view of the fact that the coffee industry has been suffering from acute economic problems since 1988. Our research group investigated the use of organic residues as accelerators for composting food waste and attained good quality compost after short periods of stabilization, at low cost (Olguín et al. 1993). Other researchers have reported on the successful use of organic accelerators for the composting of various substrates, i.e., instant coffee residues (Tauk et al. 1982) and cotton residues (Pessarakli 1990).

The objective of this work was to evaluate the effect of two abundant, easily available and very low cost agro-industrial organic residues, i.e., filter cake from the sugar industry and poultry litter, on the composting of coffee pulp. Manually aerated 1 m^3 piles, within the facilities of a coffee processing plant in the Coatepec region of the State of Veracruz, Mexico, were utilized.

Table 1. Physico-chemical characterization of utilized residues

Material	Coffee pulp	Filter cake	Poultry litter
Density kg/m^3	380	419	400
Dry matter %	13	20	84.5
pH	5.8	8.3	8.97
Organic carbon*	49	45	30
Organic matter*	85	78	52
Tot-N*	1.7	1	3.4
Reducing sugars as glucose*	7.4	12	6
C/N	28	45	8.7

* Percent of dry matter.

Table 2. Percentage (dry-weight basis) of each residue in different piles

Pile No./type	1-control	2	3	4	5
Coffee pulp %	90	60	50	50	40
Filter cake %	0	20	20	30	30
Poultry litter %	0	10	20	10	20
Wood chips %	10	10	10	10	10
C/N	28	19	25	21	20

Materials and methods

Residues

Coffee pulp (hard outer envelope) from a processing plant in the region of Coatepec was collected and processed from March to May 1995. Filter cake was obtained at no cost from the sugar factory ‘Mahuixtlan’. This residue is produced by the filtration of clarified cane juice and is rich in carbohydrates and minerals (Olguín et al. 1995). Poultry litter consisting of a mixture of chicken manure and rice husks was obtained at very low cost ($0.077 USD/kg) from a nearby area. A commonly used bulking agent consisting of wood chips (with a size of 0.5 × 1.5 cm and a density of 63 kg m^3) was obtained free of cost. Chemical characterization of all residues utilized, is presented in Table 1.

Residue mixtures

Mixtures were designed to keep an initial C/N ratio of around 20 to 30, as recommended by other researchers (Golueke 1977). Carbon from the wood chips incorporated as a bulking agent was not taken into account. Mixtures are defined in Table 2.

Piles

One cubic metre piles were established under a roofed structure on the premises of the coffee processing plant ‘El Fundador’ in the Coatepec region. Aeration by manual turning of the piles was carried out once a week.

Analytical methods

Samples were taken every week and consisted of a homogeneous mixture of 3 subsamples taken at 3 different heights of the pile. All analyses were performed after eliminating the wood chips incorporated as the bulking agent. Water content was determined by drying at 105 °C. The pH was determined with a solution of 5 g of the sample in 100 ml of distilled water. The organic carbon content was determined according to Allison (1965). Total nitrogen was determined by the Kjeldahl Method (Furman 1975) and reducing sugars were estimated according to Miller (1959), expressed as glucose.

Results

Temperature profile

During the first few days, the ambient temperature decreased from 25 °C to 20 °C, while the temperature in all piles rose to nearly 45 °C (Figure 1), as the result of microbial activity. After aeration on day 7, the temperature of all the piles increased by day 8, although those containing accelerators reached higher temperatures, in the range of 61 to 64 °C, than the control pile (only 55 °C). After this initial period, the temperature inside the control pile began to decrease until it reached a minimum of 28 °C by day 30. The thermophilic period (above 40 °C), lasted about 28 days for most piles containing accelerators, and only 14 days for the control pile. From day 30 to day 51, all piles remained at a temperature above 30 °C.

Decrease in the water content and pH profile

When piles are performing adequately, the heat liberated from metabolic activity helps to evaporate water from the substrate. In the piles containing accelerators, the liberated heat was higher than in the control pile and the water content decreased by about 20%, in contrast to a loss of only 6.5% from the control pile (Figure 2). The pH profile is also a good indicator of microbial activity and although some piles started at a very low pH of 4, as in the case of pile 4, they all reached a pH of 7.8 to 8.3 by day 13 (Figure 3). Subsequently the control pile remained more or less stable up to day 35, while the pH of the others continued to increase. Piles 2 and 3 reached a maximum pH of about 9.1, and piles 4 and 5 a maximum of about pH 8.7 by day 20. After this period, the pH of piles 2 and 3 tended to decrease more rapidly than that of piles 4 and 5.

Assimilation of reducing sugars

In all accelerator-containing piles, especially in piles 3, 4 and 5, fast sugar assimilation was observed (Figure 4) during the first 14 days at rates of 1.6, 1.1 and 1.16 g sugar kg^{-1} d^{-1} respectively (i.e., from 7.5 to 5.3, from 8.5 to 7%, from 8.2 to 6.6%). By contrast, in the control pile, reducing sugars accumulated at a rate of 1.2 g kg^{-1} d^{-1} (from 7.4 to 9.13%), instead of being assimilated, during the same period of time. Such accumulation could reflect an active degradation of the complex sugars found in the coffee pulp, but also an inefficient assimilation from the present microbial population, most probably due to a lack of readily available nitrogen.

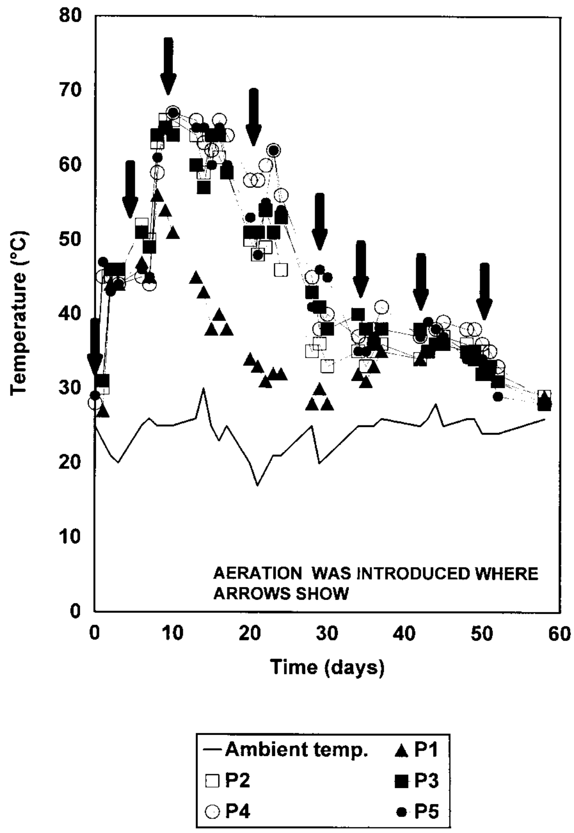

Figure 1. Temperature profile throughout coffee pulp composting with and without organic accelerators.

Decrease in organic carbon

The mixed microbial populations present in the coffee pulp were able to carry out a complete oxidation of such carbon sources and to transform them into CO_2 and other small molecular-weight carbon compounds, as reflected by the sharp decrease in organic carbon observed during the first 14 days (Figure 5). The consumption rate of organic carbon in accelerator-containing piles was twice that of the control pile (6.23 vs. 3.08 g kg^{-1} d^{-1}) during the same period. This profile of organic carbon decrease reflects the advantages of utilizing accelerators.

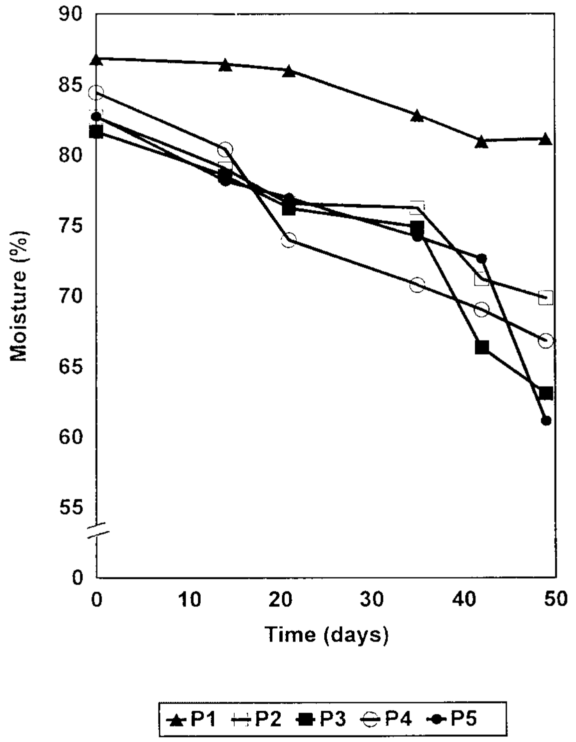

Figure 2. Changes in water content during coffee pulp composting with and without organic accelerators.

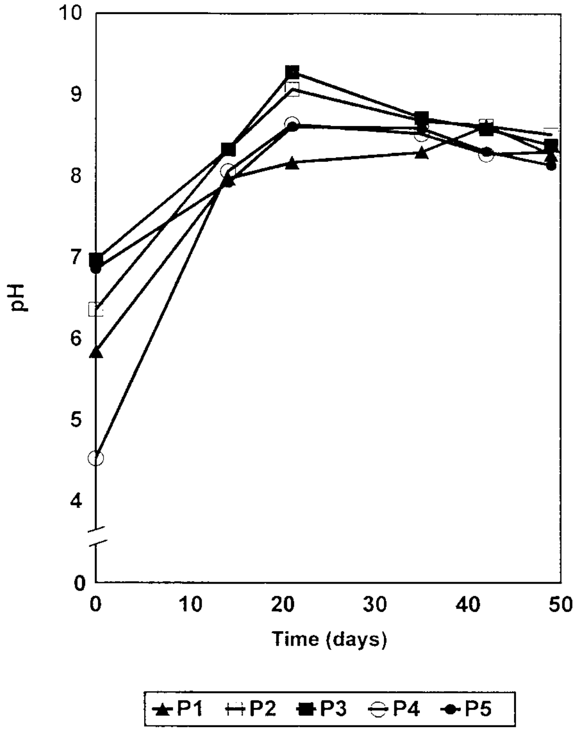

Figure 3. pH changes throughout coffee pulp composting with and without organic accelerators.

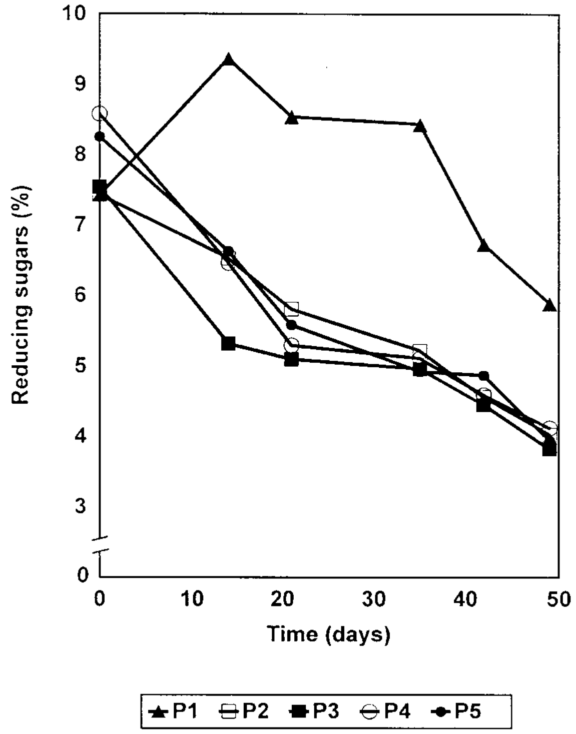

Figure 4. Reducing sugars assimilation throughout coffee pulp composting with and without organic accelerators.

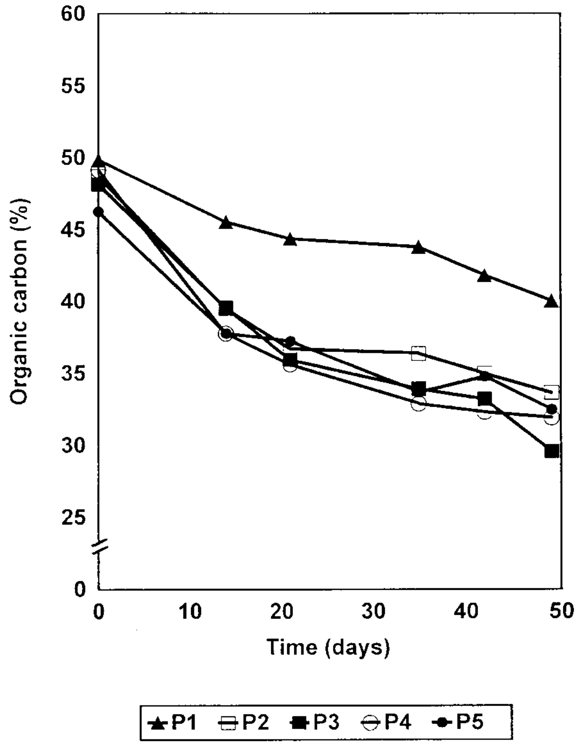

Figure 5. Organic carbon degradation throughout coffee pulp composting with and without organic accelerators.

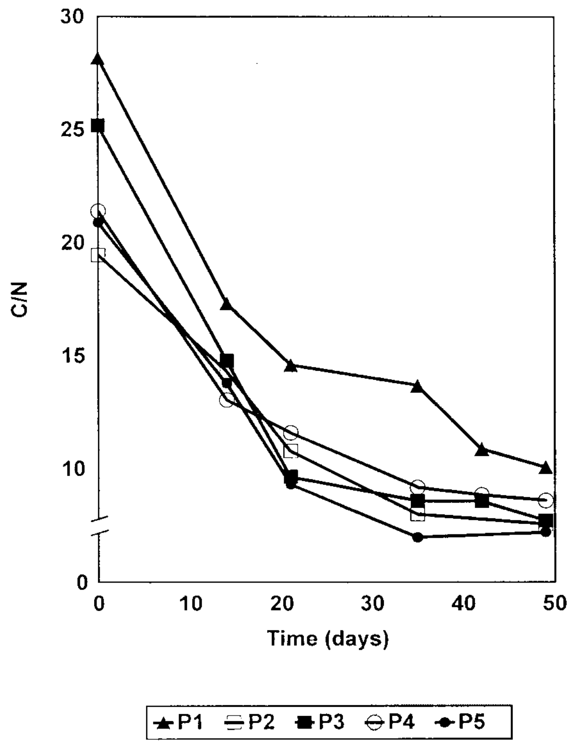

Figure 6. Changes in the C/N ratio throughout coffee pulp composting with and without organic accelerators.

C/N profile and general quality of the produced compost

Decrease of the C/N ratio reflects the organic matter mineralization and an adequate evolution of the microbial composting process (Schwab et al. 1994). The C/N ratio is expected to reach minimum values when mineralization of organic matter has finished. In case of the work presented here (Figure 6), pile 5, which contained the highest percentage of each accelerator (30% of filter cake and 20% of poultry litter), showed a C/N ratio of 6.9 after 35 days, while the control had a corresponding value of 14.4. The rest of the accelerator-containing piles (P2, P3 and P4) showed values in the range of 8.0 to 9.1, also after 35 days.

The general quality of the produced compost in piles with amendments is superior to the quality found in the control pile after 35 and 49 days (Table 3), especially in terms of total nitrogen content, C/N ratio and phosphorus content. The pile 5 with the lowest C/N ratio (6.9), also had the highest total nitrogen content (4.81%). Furthermore, all piles with amendments showed a much higher content of phosphorus compared to the control pile. Further research is required to evaluate the quality of the produced compost. In fact, research to evaluate maturity in terms of degree of humification, cation exchange capacity, C/N in the water-soluble phase, etc. is in progress.

Discussion

Composting is an effective organic-matter degrading process when the appropriate conditions for microbial activity are given. It is well known (Golueke 1977; Crawford 1983) that different types of microorganisms dominate as degradation proceeds. Mesophilic populations start fermenting available simple sugars if enough nitrogen is present. When metabolic energy is dissipated as heat, temperature increases up to the thermophilic range (from 40 to 70 °C). A second group of organisms, capable of degrading polymers and utilizing intermediate fermentation products, becomes active during this thermophilic period. The final result of a proper composting process, in which conditions are provided for adequate transfer of oxygen inside the piles, is a good quality compost (Inbar et al. 1990).

The organic residues rich in reducing sugars (filter cake) and nitrogen (poultry litter) utilized as accelerators for coffee pulp composting in this study (Table 1) promoted an increase in the rate of composting, as evidenced by some key parameters shown in the above results. The temperature profile showed a much longer thermophilic period in piles containing accelerators, as compared to piles containing only coffee pulp and bulking agent (28 days vs 14 days). This may be considered as a major indication of composting acceleration. These results are in agreement with previous reports, in which a higher initial concentration of ready available or degradable carbon substances (Crawford 1985) or a higher initial nitrogen content (Dabyshire et al. 1989) resulted in longer thermophilic periods. A second key indicator of the role of the utilized accelerators was reflected in the lower C/N ratios at the end of the composting period, for the piles containing the amendments. Such lower C/N ratios were the result of the changes of other parameters, such as faster assimilation of reducing sugars, a faster organic carbon mineralization and an increase in total nitrogen. In the piles containing accelerators, the C/N ratio decreased to much lower values than in the control pile after 35 days. Filter cake as a source of reducing sugars and poultry litter as a source of nitrogen and active microbial biomass were found to be complementary.

Table 3. General quality of the produced compost in piles with different residue mixtures after 35 and 49 days

Parameter	Coffee pulp (P1)		Coffee pulp + 20% filter cake				Coffee pulp + 30% filter cake			
			10% pol (P2)		20% pol (P3)		10% pol (P4)		20% pol (P5)	
	35d	49d	35d	49d	35d	49d	35d	49d	35d	49d
Moisture %	82.8	81	76	69.8	74.8	63	70.5	66.7	74	61
pH	8.3	8.2	8.6	8.5	8.7	8.3	8.5	8.2	8.6	8.3
Tot-N *	3.2	3.8	4.5	4.4	3.9	3.8	3.5	3.7	4.8	4.5
Reducing sugars as glucose*	8	5.8	5.2	4	4.9	3.8	5	4	5.5	3.9
Organic carbon*	43.7	40	36	33.6	33.9	29	32	31.9	33.6	32
C/N	14	10	8	7.5	8.5	7.7	9	8.6	6.9	7.2
Phosphorus		0.38		3.0		2.8		3.4		2.5

pol: poultry litter.
* Percent in dry wt basis.

Poultry litter has a high nitrogen content (3.47%) and although some volatilization of ammonia might have taken place when the pH was in the alkaline range (8–9), the final nitrogen content in some piles was higher by about a factor of 2 than that of the coffee pulp alone. Others have shown that alternative sources of nitrogen, such as cow blood, increased the final nitrogen content of composted sweet sorghum by 67% (Rodríguez et al. 1995). One of the major reasons which could explain the effect of the accelerators utilized in this work is that they helped to provide a proper balance of nutrients to the microbial population responsible for degradation, especially at the beginning of the process. Piles 2 and 5 gave a higher nitrogen content after 35 days and a lower C/N ratio. In both piles, the initial C/N ratio was around 20. By contrast, coffee pulp alone had an initial C/N ratio of 28 and reducing sugars were accumulated instead of assimilated during the first 14 days, most probably because of a lack of readily available nitrogen. In fact, this pile only contained 1.76% of initial total nitrogen while piles P2 and P5 contained 2.5% and 2.2% of total nitrogen, respectively.

Other parameters, such as final pH and water content, were also adequate in the piles containing accelerators. An alkaline pH in the range of 7.7–8.8 has been found adequate for composts utilized in red and calcareous soils for ryegrass cultivation (Murillo et al. 1995). The water content decreased faster in the piles containing the accelerators than in the control pile and reached a minimum in a range of 61% to 66%, which reflects a higher amount of dissipated metabolic heat in these piles.

All these changes in the major parameters needed to monitor composting performance (i.e., temperature, humidity, reducing sugars, organic carbon, C/N ratio), were similar to those found in previous experiments we did utilizing 0.5 m^3 piles and the same proportion of amendments (Sánchez 1997). There was a significant difference between the control and the various treatments, especially in the reducing sugars profile and the organic carbon during the first two monitoring points at 7 and 14 days. Manual aeration proved to be effective.

Conclusions

Addition of filter cake and poultry litter to the coffee pulp accelerated the composting process, promoting a shorter stabilization period and a higher quality of compost compared to coffee pulp alone. It appears that the use of a mixture of both accelerators provided a proper balance of easily degradable carbohydrates and readily available nitrogen, especially at the beginning of the process. Mixtures starting with a C/N ratio of about 20 were the most effective in terms of higher nitrogen content and lower C/N ratios after 35 days of degradation.

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