

ARAŞTIRMA MAKALESİ / RESEARCH ARTICLE

CARBON MINERALIZATION OF VARIOUS COMPOSTS IN SOIL

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ABSTRACT

In this work, it was aimed to determine the degree of stabilization of various composts by determining their carbon mineralization in soil. The composts which originated from kitchen wastes, vegetable wastes and grass clippings were added to the soil. Then, these mixtures were incubated. During incubation period, CO₂-C evolution rates of controls were the lowest, and CO₂-C evolution rates of grass clippings were lower than both the CO₂-C evolution rates of kitchen wastes and vegetable wastes. Vegetable wastes had the highest CO₂-C evolution rates. After 9 days, CO₂ amounts of the soils amended with composts were close to the values of soil samples. It was seen that the maximum C mineralization in soil occurred at the initial stages of incubation. It can be said that composting would be useful to find a solution to environmental problems caused by raw wastes. As a result, it was determined that investigating carbon mineralization can be used for determining the degree of the stabilization of composts.

Keywords: Carbon, Compost, Mineralization, Waste, Soil, Stabilization, CO₂.

FARKLI KOMPOSTLARIN TOPRAKTAKİ KARBON MİNERALİZASYONU

ÖZ

Bu çalışmada, farklı kompostların topraktaki karbon mineralizasyonunun tespitiyle stabilizasyon derecelerinin belirlenmesi amaçlanmıştır. Mutfak atıkları, sebze atıkları ve çim kırpıntılarında elde edilmiş kompostlar toprağa eklenmiştir. Daha sonra bu karışımlar inkübe edilmiştir. Inkübasyon periyodu boyunca, kontrollerde CO₂-C oluşum hızları en düşük olmuş ve çim kırpıntılarında CO₂-C oluşum hızları hem mutfak atıklarındakinden hem de sebze atıklarındakinden düşük olmuştur. Sebze atıklarında CO₂-C oluşum hızları en yüksek olmuştur. 9 gün sonra, kompost eklenen toprakların CO₂ miktarları toprak numunelerinin değerlerine yakın olmuştur. Toprakta en yüksek C mineralizasyonunun inkübasyon başlangıcında meydana geldiği görülmüştür. Ham atıkların sebep oldukları çevre problemlerine bir çözüm bulmak için kompostlaştırmanın faydalı olacağı söylenebilir. Sonuç olarak, karbon mineralizasyonunun araştırılmasının kompostların stabilizasyon derecesini tespit etmekte kullanılacağı belirlenmiştir.

Anahtar Kelimeler: Karbon, Kompost, Mineralizasyon, Atık, Toprak, Stabilizasyon, CO₂.

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1. INTRODUCTION

Organic matter plays a key role to achieve sustainability in agricultural production because it possesses many desirable properties such as high water holding capacity, cation exchange capacity, ability to sequester contaminants (both organic and inorganic) and beneficial effects on the physical, chemical and biological characteristics of soil. The organic degradable refuse of plant and animal origin provides a good source of nutrients to improve soil productivity. With the increasing need to conserve natural resources and energy, recycling of organic wastes assumes major importance (Padmavathiamma et al., 2008).

Biological decomposition of the wastes depends on the degradation rate of a wide range of C compounds present in the sample (carbohydrates, amino acids, fatty acids, lignin, etc.), as well as on their nutrient content. The amount of CO₂-C released from organic wastes in soil has been shown to depend on the material used: plant residues, animal manures, sewage sludges, etc. (Ajwa and Tabatabai, 1994). The degradation of wastes that contain a high percentage of soluble organic carbon in the form of amino acids, carbohydrates, etc., leads to a flush of CO₂ production immediately after their addition to soil (Marstorp, 1996). This can cause a high CO₂ concentration, low O₂ levels, which can lead to O₂ deficiency in the rhizosphere, and therefore anaerobic and reducing conditions in the soil (Bernal et al., 1998a).

Composting is one of the most common treatment methods for organic solid waste, it uses the power of microorganisms to degrade waste into a more stable material. Composting dates back to antiquity, but in the past several decades it has gained importance as an industrial-scale process (Bongochgetsakul and Ishida, 2008). The process has many advantages including sanitation, mass and bulk reduction, and decrease of carbon to nitrogen ratio (C/N). The stabilized compost produced should benefit plant growth and be suitable for agricultural applications (Campbell et al., 1995; Charest and Bauchamp, 2002).

As regards to organic C conservation, the composting of organic wastes before addition to soil is a more effective way of reducing CO₂-C losses than the direct application of wastes which are either untreated, or slightly transformed during the thermophilic phase of composting. To protect the soil and conserve the organic carbon content, mature composts with a stabilized organic C are preferable to non-

transformed wastes, which may promote degradation of native soil organic matter (Bernal et al., 1998b).

It is necessary to know the degree of stabilization of the organic matter in composting organic wastes and its decomposition rate if maximum benefit is to be obtained from the compost after its addition to soil. This knowledge can be achieved by studying the C mineralization of organic wastes in incubation experiments with soil (Bernal et al., 1998b).

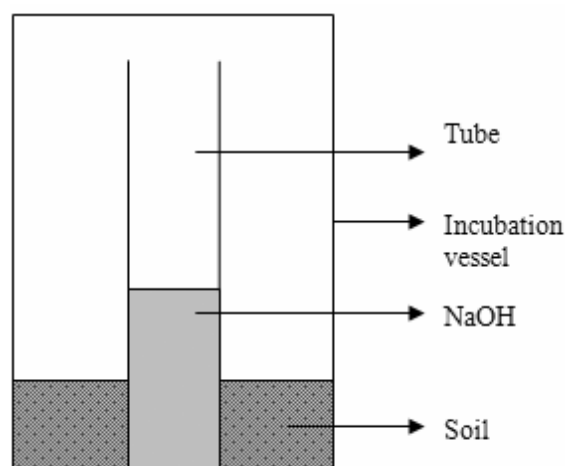
2. MATERIALS AND METHODS

The soil used in this study was taken from Firat University campus (Elazığ, TURKEY). The soil component was 25.2 % sand and 74.8 % clay + silt. The composts used in this study were obtained from the study of Arslan et al. (accepted). The characteristics of the composts originated from kitchen wastes (KW), vegetable wastes (VW) and grass clippings (GC) are given in Table 1. Organic C was calculated according to Adams et al. (1951). pH and EC were measured in the compost-water (1:10 w/v) extract by using a pH probe (WTW pH 330) and an EC probe (WTW LF 330), respectively. VS were determined according to the Standard Methods (AWWA et al., 1989). TKN was determined as described in Methods of Soil Analysis (SSSA, 1996). Cellulose were determined according to the AOAC methods (AOAC, 1990). Heavy metal determinations were done according to Hseu (2004) that partly modified from that of Zhejzakov and Nielson (1996). An ATI UNICAM Model 929 flame atomic absorption spectrophotometer equipped with ATI UNICAM hollow cathode lamp was used for the heavy metal determinations. Ca, Mg, Na and K were measured by flame spectrophotometry (Jenway PFP 7).

Carbon mineralization was studied in an aerobic incubation experiment with soil as described by Bernal et al. (1998b). 10 gram samples of soil (<2 mm) were thoroughly mixed with 200 mg portions of the composting samples (equivalent to 48 t ha⁻¹) and placed in 100 ml incubation vessels. Soil controls (CS) were run without any amendment. Each mixture content was adjusted to 70 % of its water-holding capacity with distilled water. The CO₂ evolved was trapped in 10 ml of 0.1 M NaOH in small tubes, which were placed on top of the soil in the incubation vessels. The incubation vessels were closed, but to maintain adequate O₂ levels they were occasionally opened during incubation. The CO₂ evolved was measured by titration of the NaOH solution with 0.1 M HCl in an excess of BaCl₂. The incubation was carried out in a dark, temperature-controlled incubator at 28°C for 28 days. The experimental set up design used for measurement of CO₂-C evolution rates is shown in Figure 1.

Table 1. Characteristics of the composts (KW, kitchen wastes; VW, vegetable wastes and GC, grass clippings).

Parameter	KW	VW	GC
pH	8.29	8.23	8.26
EC ($\mu\text{S}/\text{cm}$)	959	803	942
VS (%)	86.87	87.71	83.51
C (%)	48.26	48.73	46.39
N (%)	2.45	1.40	2.70
C/N	19.69	34.08	17.18
Cellulose (%)	37.3	30.3	29.8
Ca (mg/kg)	10290.8	19726.9	20584.8
Mg (mg/kg)	1563.5	1429.2	1126.2
Na (mg/kg)	558.75	357.55	830.975
K (mg/kg)	14112.9	15322.6	12096.8
Cr (mg/kg)	22.4	17.2	22.4
Mn (mg/kg)	94.3	86.575	169.725
Cd (mg/kg)	*	*	*
Ni (mg/kg)	15.525	14.8	17.35
Zn (mg/kg)	190.7	178.9	280.2
Cu (mg/kg)	35	18.9	34.45
Co (mg/kg)	7.7	7.45	9.05
Fe (mg/kg)	2641.75	2997.425	3092.775



*below detection limits

Figure 1. The design used for measurement of $\text{CO}_2\text{-C}$ evolution rates.

3. RESULTS AND DISCUSSION

As seen from Figure 2, VW which had the highest C/N ratio had the highest evolution rates during the incubation period. GC which had the lowest C/N ratio had lower evolution rates than both the KW and VW. $\text{CO}_2\text{-C}$ evolution rates of CS were the lowest. Similar to our results, Parnaudeau et al. (2004) studied C mineralization of different wastewater sludges in soil reported that the important criteria that may help to predict C mineralization of wastewater sludges in

soil is the sludge C/N ratio. Their data showed that high C mineralization did not strictly correspond to sludges having a high C/N ratio, while low C mineralization was always associated with a low C/N ratio.

The type of compost added to soil effected C mineralization (Figure 2). The effect of the type of residue on C mineralization agrees with several similar studies. In the study of Janzen and Kucey (1988), the mineralization of C from residues of wheat, lentil, and rape was measured over a 12-week incubation period. The rate of decomposition, as measured by CO_2 evolution, varied considerably in these treatments. Kabonka et al. (1997) conducted an incubation study for 30 days in silt loam soils to evaluate C mineralization from soybean, corn, and wheat residues. Decomposition ranged from 39% for wheat to 67% for soybean. Thuriès et al. (2001) added various organic matters to a Mediterranean sandy soil. Most of added organic matters from animal origins were rapidly mineralized. Mineralization from plant origin-added organic matter was less intensive. Some added organic matter have uncommon patterns. On one hand the kokoa mineralization curve looks like a fertilizer or an animal-originated added organic matter with a large very labile fraction. On the other hand, native fine feather was less susceptible to microbial degradation, and behaved like a recalcitrant plant material. Kruse et al. (2004) who measured the rates of C mineralization in soils treated with cotton leaves and compost (compost mixture: grass clipping, hardwood leaves and pine needles) reported that residue type affected rates of C mineralization in accordance with those seen in our study. In their study, cumulative $\text{CO}_2\text{-C}$ were higher for treatment of cotton leaves than treatment of compost. Pedra et al. (2005) studied the C mineralization on soils amended with two different amounts of sewage sludge and municipal solid waste compost. The treatments were significantly different among themselves and the highest C mineralization occurred with higher amount of sewage sludge. Sewage sludge showed a tendency to introduce a higher C mineralization than the compost. Bipfubusa et al. (2005) evaluated the effects of fresh paper mill sludges and their composts on the carbon mineralization and reported that on average, carbon mineralization was highest in soils with paper mill sludges, than for their composts, which suggests that paper mill sludge C was more labile than compost C.

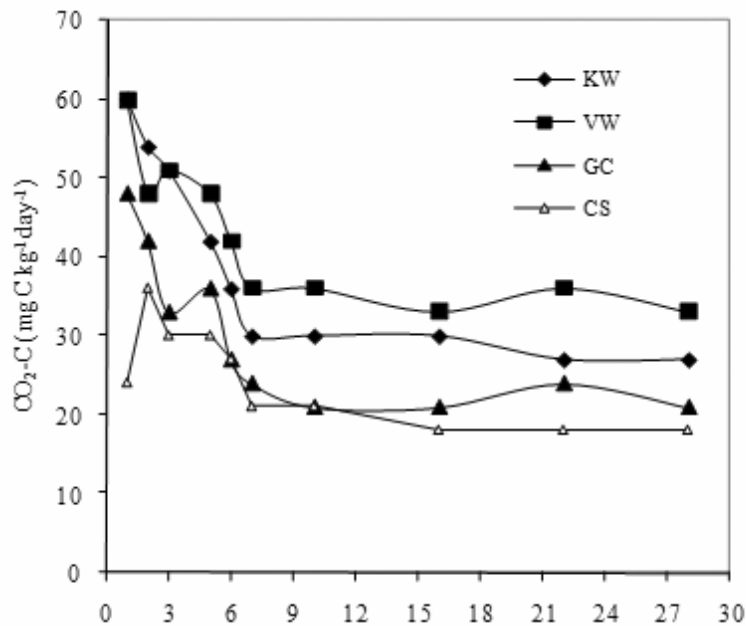


Figure 2. CO₂-C evolution rates with the incubation of composts in soil (KW, kitchen wastes; VW, vegetable wastes and GC, grass clippings).

Lalande et al. (2003) examined the effects of a co-composted papermill sludge and hog manure, applied alone or in combination with mineral fertilizers, on the C mineralization potential. The potential was low, indicating that the composted material was relatively stable. Yang et al. (2002) evaluated food waste compost, yard waste compost, liquid pig manure, liquid pig manure + yard waste compost, liquid pig manure + wheat straw compost, red clover and an unamended control soil. CO₂ emissions were increased relative to the control soil for all treatments except liquid pig manure + yard waste compost. In our study, CO₂ emissions were lower than the values of total CO₂ emissions result from the study of Yang et al. (2002). This situation shows that our composts were more stable than the composts which were used by Yang et al. (2002).

In the study of Saison et al. (2006), maximum CO₂ rates were 0.34, 0.70 and 2.90 μg C g⁻¹ soil h⁻¹ for treatments control soil, soil amended with a low level of compost and soil amended with a high level of compost, respectively. The values of maximum CO₂ emissions, except the soil amended with a high level of compost, were lower than our results.

Contrary to compost treatments, CS showed an increase on the first days (Fig. 2) similar to the result obtained by Zhang et al. (2007). They studied the topsoil organic carbon mineralization and CO₂ evolution of soils. C mineralization underwent an increasing

stage after the initiation of the incubation followed by a decreasing one after 23 d.

In our study after day 9, CO₂ amounts of the soils amended with composts were close to the values of soil samples. It was shown that the maximum C mineralization in soil occurred at initial stages of incubation. Similar to our findings, in the study of Kaboneka et al. (1997), CO₂ evolution peaked on the third day, and 30 to 50% of residue C was decomposed during the first six days of incubation. Similarly, in the study of Bernal et al. (1998b) the maximum C mineralization rate in the composted samples occurred during the first day of incubation and in the untransformed initial samples the maximum occurred between days 1 and 3 of incubation. This was because of the presence of a high concentration of easily degradable organic carbon in the wastes, which led to a large growth in the microbial population in the soil. In the study of Fierer et al. (2001), who examined the effects of four poplar condensed tannin fractions on carbon dynamics in alder and poplar soils, the effect of the tannins on CO₂ flux was most apparent during the first 2 to 3 weeks of the 4 week incubation period. This time was longer than time obtained in our study. In the study of Parnaudeau et al. (2004), two phases of mineralization were observed during all soil incubations: fast and substantial mineralization during the first days followed by slowing down and low mineralization during the rest of incubation that agreed well with result from our

study. Also in the study of Benito et al. (2005) which was about the C mineralization of four compost samples originated from pruning waste, C mineralization occurred in two phases: a first rapid phase (corresponding to the decomposition of the most labile products by microorganisms) and a second, slower phase, during which the most resistant organic products mineralized. Similarly, in the study of Pedra et al. (2005), it seemed that the C mineralization occurred in two distinct phases, being faster during the first week of incubation, comparing to the following ones. Similarly, Saison et al. (2006) reported that actual C mineralization rates were maximal around 4 days after incubation start for compost treatments. After 1 month and until the end of the incubation period, C mineralization rates remained roughly constant. Longer time was reported by Griffin and Hutchinson (2007). When they evaluated compost carbon during a 130 d aerobic incubation in a sandy loam soil after compost was applied at 200 mg total/kg soil, there were few differences in C mineralization between composts after 48 d in soil.

Contrary to our results, in the study of Bernal et al. (1998b) some samples showed a second maximum in the C mineralization rate which occurred because of the great variety of compounds they contained with different degrees of degradability. After the initially high mineralization rate there was a gradual decrease in all cases before it became fairly constant. In our study, mineralization rate was nearly stable for all composts and CS after day 9.

4. CONCLUSION

- (i) Compost types effected CO_2 -C evolution rates.
- (ii) VW which had the highest C/N ratio also had the highest evolution rates during the incubation period.
- (iii) GC which had the lowest C/N ratio, had lower evolution rate than both the KW and VW.
- (iv) As a result it could be said that GC is more stable than VW and KW, because it caused lower C mineralization. So, when the GC compost is used in agriculture it would not cause higher CO_2 -C evolution rates and consume more oxygen in soil than KW and VW composts.

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