IMPROVING COMPOSTING BY CONTROL OF THE SOLID MATRIX STRUCTURE

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INTRODUCTION

Food processing is a major industry that is rapidly growing because of a demand for packaged foods in urban areas. In Atlanta, Georgia, several food processors are in the business of packaging fresh salads for grocery stores. These companies have large processing facilities where vegetables, such as lettuce, cabbage, carrots, onions etc. are cleaned, chopped, mixed and packaged. In a typical operation, the amount of wastes generated equal in quantity (by weight) to the amount of product shipped. Presently, these wastes are land disposed or landfilled. Vegetable wastes do not provide any known concerns relating to pathogens or human health issues, however, they are prone to potential odors during decomposition and are expensive to dispose because of of their high moisture content leading to high landfill tip fee and transportation cost. Composting vegetable wastes, McGuckin et al. (1999) reported that the sulfur content of lettuce and onion wastes were 0.2 and 0.7 %, respectively. Discarded components of lettuce and onions have an effective carbon to sulfur ratio of 215 and 63, moisture contents of 96.2 and 91.1% and carbon to nitrogen ratios of 10.3 and 11.5, respectively. The low C/S ratio of onions indicates that mixes with high fractions of onions can result in release of odorous sulfur compounds. High water content, most of which is bound within the vegetable fiber, results in significant leachate formation during composting and collapse of the composting matrix from initial height of e.g. 1.5 m to a lower value of e.g. 0.5 m resulting in reduction in air space and oxygen availability within the pile. Each of the phenomena discussed above potentially result in increasing the amount of odors released and therefore negatively affecting the composting process.

The physical properties of food wastes and the factors that affect their performance in composting require us to identify reliable methods to compost them. The standard method of composting with an organic amendment such as sawdust and an organic bulking agent such as bark may not be the most appropriate. In this project, we evaluated the use of synthetic (plastic) bulking agents while composting these food wastes. The presence of plastic bulking agents is expected to maintain the structure of the composting matrix, thereby preventing large reduction in porosity during composting. This is expected to provide a more rapid composting with relatively lower production of odors. In addition the synthetic bulking agents could be recovered and reused for subsequent composting trials thereby reducing the cost of bulking agents.

The objective of this work was to compare use of a plastic bulking agent with pine bark nuggets using three criteria: (1) Environment of composting, i.e. Oxygen level and temperature inside the compost pile; (2) Quality of final product and (3) Odor reduction.

MATERIALS AND METHODS

Food wastes were obtained from a commercial salad packing company. The salad packing wastes were previously characterized at the University of Georgia Bioconversion Research and Education Center (McGuckin et al., 1999) and some information on properties and behavior were known. Two bulking agents were evaluated, namely, (1)Pine bark with average size of 4.5 cm, void volume of 78% and bulk density of 136 kg/m^3 and (2)Synthetic packing media with the following characteristics, 5-cm saddles, void volume of 94% and bulk density of 50.5 kg/m^3.

Compost feedstock was brought to the research center, weighed and placed on a large concrete floor. Sawdust, obtained from a neighboring sawmill, and the two bulking agents were also weighed and placed on the concrete floor. Three samples of 3 L each were obtained from each of the feedstocks for analysis. Then, a portion of food waste was weighed and placed on a separate pile, followed by addition of sawdust and the bulking agent (Table 1). Once a pile was constructed, the materials were homogenized using a bucket loader for a period of 15 minutes and three samples of 3 L each were obtained from each mix. Thereafter a pile of homogenized materials was constructed such that it had a height of approximately 1.2 m (4 ft) and was covered using a Compostex® compost cover. The compost cover was used to prevent infiltration of the piles by rainwater. In this manner each of the piles were created. Two trials were conducted, trial 1 began on Jan 1999 and ended in April 1999 and trial 2 started and ended in April and July 1999. After the end of each trial, samples were obtained for analysis of physical and chemical properties of the product.

During the composting trial, temperature of the pile was measured weekly using a 1.2 m long stainless steel cased thermometer (Reotemp® Inc.). Temperature was measured at a point that was visually located to be the center of the pile at a depth of 0.6 m from the surface. After the measurement of temperatures, a 1.2 m stainless steel gas-sampling probe was inserted to the same location and the oxygen concentrations of the gas within the pile were measured. The sampling probe was removed and reinserted to approximately the same location and a sample gas was extracted to measure the concentration of odorous gases, namely, ammonia, dimethyl sulfide, hydrogen sulfide and total mercaptans. Each of the gas measurements was conducted one after the other without removal of the probe. Measurements were performed using the field gas detection tubes manufactured by Drager Inc. After temperature, oxygen and gases were measured in the piles, the piles were homogenized using a bucket loader. After sufficient mixing, three samples 3-L each were removed from the center of the pile and placed in a plastic sealable bag. The samples were taken to the laboratory within a period of 4 hours.

Moisture content was evaluated by drying in a forced draft oven at 75°C until constant weight. After complete drying approximately 500 g was sampled and finely ground to an approximate diameter of 0.5 mm. A 50-g sub-sample from the ground dry sample was used for total carbon and nitrogen analysis using a Leco® Carbon-Nitrogen-Sulfur analyzer. The pH and soluble salt content (measured as electrical conductivity, EC) of the sample were measured using a 1:2 (v/v) sample to deionized water extract. The ground sample (20 ml) was mixed with 40 ml of deionized water, allowed to equilibrate for 30 minutes with occasional stirring with a glass rod. The resulting solution was filtered through a Whatman No 4 filter paper and used for direct measurement using an Acumet 50 pH/EC meter (U.S. Composting Council, 1997).

The stability index (SI) of the compost product was measured using the procedure described by Iannotti et al (1993). A sample of material was obtained and standardized for particle size (<9.5 mm) and moisture content (50%), and incubated (37°C) for 16 hours under aerobic conditions to build the microbial populations to an active standard level. A 60-g sample of the incubated material was placed in an aerated respirometric flask at constant temperature in a water bath (37°C) for one hour. The aeration source was removed and oxygen concentration inside the flask was monitored every five minutes for a period of one hour. The change in oxygen concentration in the flask was used to calculate a consumption rate in mg(O_2)/g(volatile solids)/hr. This rate of oxygen consumption under standard conditions of particle size, moisture, temperature, aeration and incubation depends only on the amount of substrate availability. Greater substrate availability results in higher oxygen demand indicating that the sample is biological unstable, i.e. the sample is continuing to degrade. Organic compost with a SI less than 1.0 mg/g/hr is considered stable and 1.0-1.5 mg/g/hr moderately stable. Unstable composts typically exhibit SI greater than 2.0 mg/g/hr (Epstein, 1997).

Two treatments were evaluated in trial-1, namely, vegetable waste, sawdust and bark as bulking agent in a mix of 28.5-27.2-44.3% (dry basis) and vegetable waste, sawdust and synthetic bulking agent in a mix of 40.4-39.1-20.5% (dry basis). Initially each treatment was replicated three times to provide six total windrows for monitoring. However, because of significant volume reductions resulting in very small size windrows, the three windrows of each treatment were combined to form one windrow per treatment toward the end of the trial (March 17). Trail 2 utilized similar treatments to Trial 1, with the amount of bulking agent reduced. The two treatments evaluated were vegetable waste, sawdust and bark as bulking agent in a mix of 36.7-44.3-19.0%(dry basis) and vegetable waste, sawdust and synthetic bulking agent in a mix of 41.9-50.7-7.4%(dry basis). Specific weight fractions in windrows are shown in Table 1.

RESULTS AND DISCUSSIONS

Initial moisture contents in the mixes in trial 1 were 84.1 and 88.2 %. These levels are higher than typically encountered in composting (60-70%), however it would require a large amount of amendment (sawdust) to reduce this moisture and the physical structure of the windrow did not require this. As a result of leachate release and moisture reduction by drying, the final moisture contents were 65.2 and 56.3 % for bark and synthetic bulking mixes, respectively. Final compost had a stability index of 0.215 and 0.248 mg/g/hr (Table 2). These results suggest that end product at the 78th day of composting show no significant difference between the two treatments. After this period both the composts have reached the same level of stability and quality. The final nitrogen and phosphorus contents of the two products were also very comparable at approximately 1 and 0.2% (Table 2), respectively. The germination index, a measure of how well plants would grow in this compost indicates that the final compost product demonstrated very good plant growth characteristics.

The process of composting, however, followed a different path, especially in the first 30 days. The temperature (Figure 1-A) of the bark amended mix increased rapidly to over 45°C, whereas the synthetic amended mix only reached a maximum of 25°C. Moisture was not a limiting factor (data not shown) as both treatments had very similar moisture levels that decreased at similar rates. The lower temperatures in the synthetic amended mix were likely a result of addition of excessive bulking agent. In the month of January, the ambient outside temperature were typically in the 2-8°C range and having a pile with excess air space resulted in an inability to maintain a critical thermal mass. The rate of heat generation was almost equal to that being removed from the synthetic amended pile. The extremely high oxygen levels (over 18%) in synthetic amended piles also confirm this possibility during trial 1 (Figure 1-C).

Ammonia release from the two treatments was very comparable, with slightly higher levels seen in the synthetic amended windrows (Figure 2-A and B). Ammonia release was highest at about the 15th day, before which there was negligible release and after the 15th day the release steadily decreased till about the 45th day. In contrast, the release of dimethyl sulfide was clearly higher in the bark-amended mix. There appears to be an initial release in the first 15 days and a second release around the 35-40 day of composting in the bark treatment. In the synthetic treatment the concentrations were about three fold lower and was present only in the first 15 days. Only trace amount of hydrogen sulfide and mercaptans were measured. Possibly due to the sampling frequency adopted in this study being too sparse (once a week or less).

From the results of trial 1, it was concluded that the rate of bulking agent would have to be reduced to obtain more self-heating and better decomposition. Therefore trial 2 consisted of different ratios of mixing the vegetable waste-sawdust-amendment (Table 1). Initial moisture contents in the mixes (Table 2) were 81.5 and 84.6 % for bark amended and synthetic amended mixes, respectively. Over the period of composting, because of leachate release and moisture reduction by drying, the final moisture contents were 56.8 and 58.1 % for the two treatments, respectively. Final compost had a stability index of 0.175 and 0.172 mg/g/hr, indicating that better stabilization was achieved in approximately the same time (86 days vs. 78 days). As in trial-1, these results show that end product at the 86th day of composting show no significant variation between the two treatments. The final nitrogen and phosphorus contents of the two products were lower than in trail-1 at approximately 0.5 and 0.1%. The lower nitrogen levels were possibly a result of more nitrogen volatilizing because of higher temperatures in this trial compared to the previous.

Temperatures observed in trial 2 (Figure 1-B) were in the range expected for good composting (60-70°C). Both mixes followed a similar pattern with peak temperatures reached in the 10-20 day range. As earlier, the synthetic amended mix had a lower temperature because of higher porosity and better aeration. However, the temperature of 60°C reached can be considered acceptable and this amount of bulking agent addition can be recommended. Moisture content in both treatments were very similar and decreased at similar rates from initial values over 80% to final values around 60% at the 80th day. The temperature profile showing no significant change after the 30th day indicates that in this system of composting, most of the biological activity was completed in the first 30 days. The small increase of approximately 5°C (from 30 to 35°C) over the 40 to 60 day period is not significant to indicate that the material is unstable. Oxygen levels inside the windrows dropped to below 6% in the bark-amended mixes, indicating potential anaerobic conditions (Figure 1-D). In contrast, the synthetic amended mixes had a lowest measured oxygen level of over 12%. This indicates that the rate of bulking agent addition is within the range to achieve our goal of maintaining a solid matrix that remains porous while

supporting good composting. The steady level of windrow oxygen levels (15-18%) after the 30th day also shows that biological oxygen demand has reduced suggesting stability.
As in trial 1, almost no hydrogen sulfide or mercaptans were detected in this trial (Figure 2-C and D). The only measurable gas readings were ammonia and dimethyl sulfide. Ammonia release from the two treatments was very comparable, with bark amended mixes releasing ammonia at higher rates initially (10-20 days) and rapidly decreasing thereafter, whereas the synthetic amended mixes releasing maximum ammonia at the 10th day and then gradually decreasing till the 40th day. Following the 40th day there was almost no measurable ammonia. Peak levels of ammonia measured inside the pile were 450 ppm in the bark mixes and 320 ppm in the synthetic amended mixes. These are very high levels of ammonia and support the reason for the lower nitrogen content of these treatments compared to trial-1. The release of dimethyl sulfide was clearly higher in the bark-amended mix compared to the synthetic amended mixes. As in trial 1, there appears to be a bimodal release, with an initial release in the first 10-15 days and a second release around the 40th day of composting in the bark treatment. Although this phenomenon was observed in both trials, at this time we have no explanation for this. In the synthetic treatment the concentrations of dimethyl sulfide measured were about three to four fold lower than in the bark amended mixes.

EFFECT OF RATE OF BULKING AGENT ADDITION

In trial 1, we used a high rate of bulking agent addition, namely, 44.3% bark and 20.5% synthetic bulking agent in the corresponding treatments. This rate of bulking was found to be excessively high as the temperature profiles of the two treatments were significantly lower than that in trial 2 (Figure 1). In order to achieve good composting structure, a critical mass of material is required that will provide enough porosity that air will enter the pile through natural convection at a rate sufficient to replenish oxygen. In the case of trial 1, too much air entered the pile resulting in excessive cooling.

The addition of a lower amount of bulking agent in trial 2, namely 19% bark and 7.4% synthetic bulking agent resulted in a more favorable environment indicated by the higher temperatures. In both amounts of bulking agent addition, the bark amended mix reached oxygen levels of below 6%. This level is considered in the potentially anaerobic region, as pore space concentration of 6% oxygen results in a low gradient to provide sufficient mass transfer from the gas phase to the biofilm. Therefore a greater portion of the windrow would be under anaerobic conditions. The synthetic amended mix at the lower rate of addition (Figure 1-D) maintained over 12% oxygen levels in the pile at all times. This leads us to conclude that the rates of bulking in trial 2 can be recommended for these type mixes. Also, the use of synthetic amendment achieved its goal of maintaining an aerobic structure.

With regard to gases released during composting (Figures 2) there was an indication that the release of dimethyl sulfide and ammonia were higher in the bark amended treatment. The lower bulking agent rate (Trial 2) resulted in greater amounts to odor release, probably due to the higher levels of activity seen. The data also suggests that ammonia release was higher in the synthetic amended treatment and dimethyl sulfide release was higher in the bark amended treatment, however, this would have to be confirmed with more controlled testing.

KEY CONCLUSIONS

The following are a set of conclusions from this study. These can be used as recommendations or cautionary notes to persons who are designing food waste composting facilities in the future.

1. A bulking agent rate of 6-7% by dry weight of synthetic bulking agent (or 17-19% bark) in the mix is sufficient for maintaining an aerobic solid matrix.
2. Addition of bulking agent in excess of rate noted in (1) results in reduction of biological activity. A lower rate (e.g. 5% by dry weight of synthetic bulking agent) may be acceptable as this rate provides for processing of larger amount of the composting feed stock.
3. Most of the biological activity (based on temperature) was completed in the first 40 days. Thereafter, the compost was cured to reach a high level of stability and maturity at the 78th-96th days. These time frames are recommendations that can be used in facility sizing.
4. In salad waste composting, moisture control was not an issue. The initial moisture was higher than desirable, however this did not retard the composting process. At the end of composting the moistures were in the acceptable ranges of 50-60% for a good product. No addition of water was required.
5. The final compost from the salad waste had C-N-P concentrations of 45-1-0.2 %(dry basis). The product can be considered biological stable (Respiration Index 0.175-0.2 mg/g/hr) and having no phytotoxic properties (Germination Index 87-100%).
6. Final soluble salt content and pH from all trial ranged was 1.7-2.9 dS/m and 7.4-8.5; these are within limits considered acceptable for use as a soil amendment.

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Table 1. Initial feedstock and mix properties during composting.

	Food waste	Sawdust	Bark	Synthetic
		Trial 1[1]		
Wet weight of each component, lbs	2691.7	270 .0	288.3	
Initial Moisture content, %	94.0	43.1	13.0	
Percentage in mix (wet basis)	82.8	8.3	8.9	
Percentage in mix (dry basis)	**28.5**	**27.2**	**44.3**	
Wet weight of each component, lbs	2578.3	263.3		78.3
Initial Moisture content, %	94.0	43.1		0.0
Percentage in mix (wet basis)	88.3	9.0		2.7
Percentage in mix (dry basis)	**40.4**	**39.1**		**20.5**
		Trial 2[2]		
Wet weight of each component, lbs	6613.3	995 .0	235 .0	
Initial Moisture content, %	94.1	53.0	14.6	
Percentage in mix (wet basis)	84.3	12.7	3.0	
Percentage in mix (dry basis)	**36.7**	**44.3**	**19.0**	
Wet weight of each component, lbs	6191.7	935.0		63.8
Initial Moisture content, %	94.1	53.0		0.0
Percentage in mix (wet basis)	86.1	13.0		0.9
Percentage in mix (dry basis)	**41.9**	**50.7**		**7.4**

[1] Trial 1 – Bulking amount = 214.2 lbs(pine bark)/ton(vegetable waste); 60.7 lbs(synthetic bulking)/ton(vegetable waste); Sawdust = 0.10 lbs(sawdust)/lbs(vegetable waste)

[2] Trial 2 – Bulking amount = Pine bark bulking agent rate = 71.1 lbs(pine bark)/ton(vegetable waste); 20.6 lbs(synthetic bulking)/ton(vegetable waste); 0.15 lbs(sawdust)/lbs(vegetable waste)

[3] Each treatment was replicated in three windrows of approximately similar sizes. All data reported in the table are averages of measurements from three different windrows.

Table 2. Changes observed during composting.

Initial properties (Day 0):	**Trial 1**		**Trial 2**	
	Bark	**Synthetic**	**Bark**	**Synthetic**
Moisture content, %	84.1	88.2	81.5	84.6
Carbon content, %	44.9	43.9	46.1	46.8
Nitrogen content, %	1.92	2.21	0.86	0.98
C/N ratio	23.4	19.9	54.3	48.6
Final properties	**(Day 78)**		**(Day 86)**	
Moisture content, %	65.2	56.3	56.8	58.1
Nitrogen content, %	0.98	1.07	0.51	0.51
Phosphorus content, %	0.18	0.22	0.13	0.16
Respiration Index, mg/g-VS/hr	0.215	0.248	0.175	0.172
Germination Index, %	100	100	87.4	90.7
pH	7.4	7.9	7.9	8.5
Soluble salts (EC), dS/m	1.8	2.3	1.7	2.9

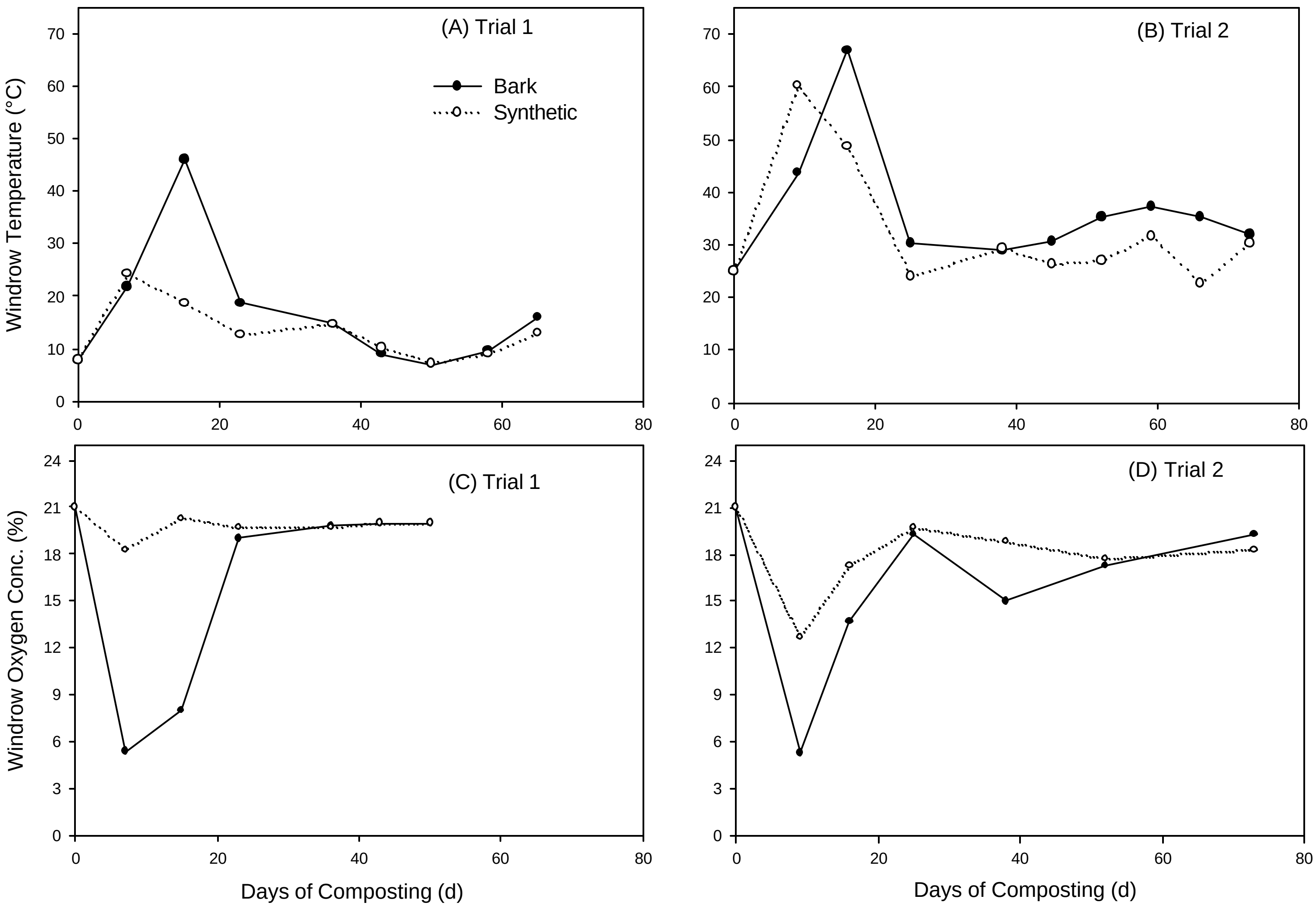

Figure 1. Comparision of composting performance when using bark and synthetic bulking agents. Response based on temperature (A, B) and oxygen concentration (C, D).

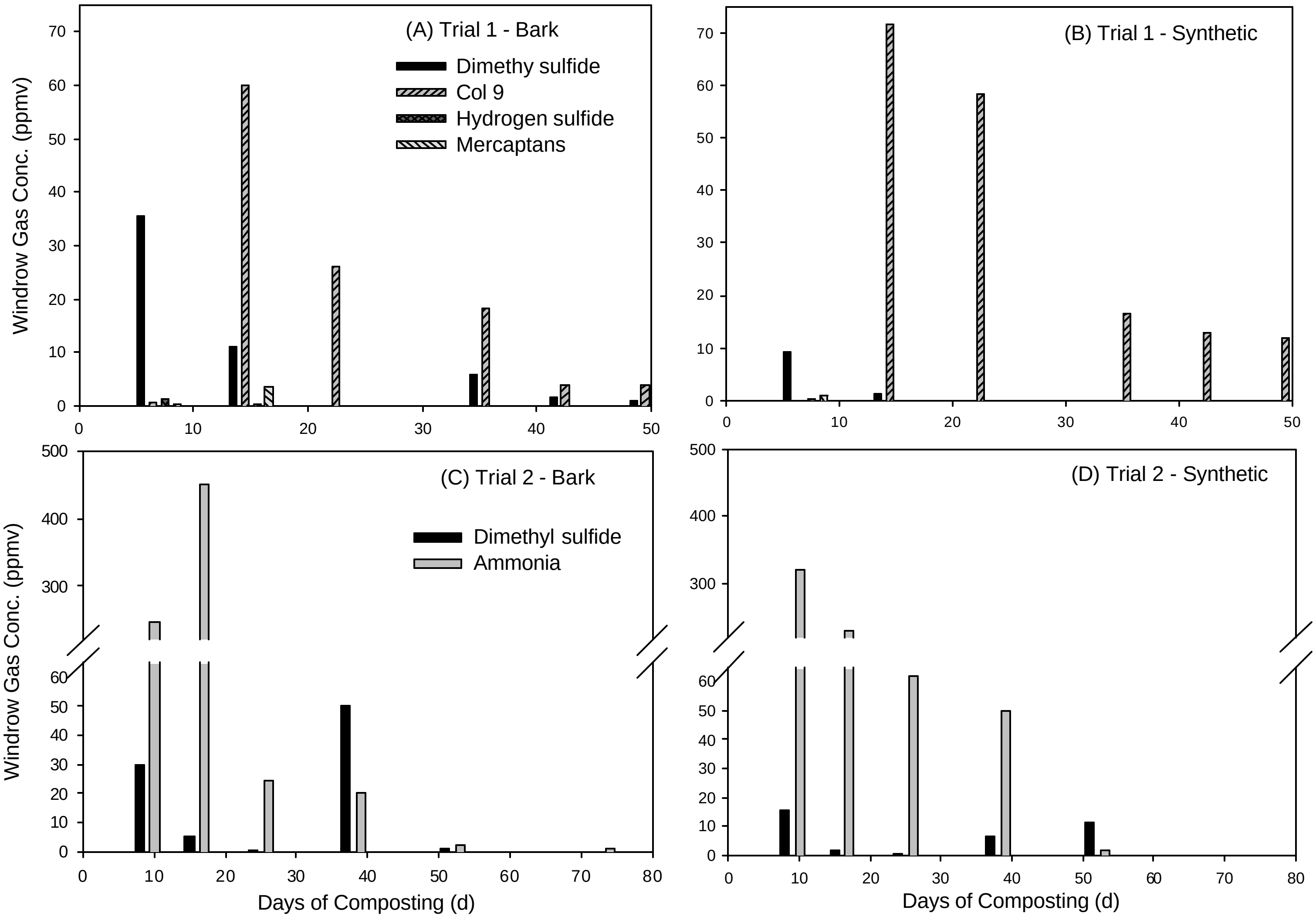

Figure 2. Comparison of composting performance when using bark and synthetic bulking agents. Response based on odorous gases. All data are averages of three readings in each of three windrows.