BIODEGREDABILITY AND NUTRIENT ANALYSIS DURING CRAWFISH PROCESSING BY-PRODUCTS AND RICE HULL COMPOSTING

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ABSTRACT

Disposal of crawfish processing by-products poses a challenging problem to the rapidly expanding crawfish industry. Degradation of mass and nutrient content was determined during co-composting of different mixtures of rice hulls and crawfish by-products. This experiment was also undertaken to assess the suitability of recycling compost product with additional crawfish by-products. Mixtures containing high percentage of crawfish by-products had the highest degradability and nutrient content. The reuse of the recycled product induced higher degradation in the recycled product as well as complete degradation of the crawfish by-products.

INTRODUCTION

Crawfish processing by-products are highly organic and are typically rich in nitrogen (N) and readily-degradable organic carbon (C) compounds. These materials begin to decompose very soon after processing. Consequently, they become highly putrescent and could potentially create environmental problems if not handled and disposed of properly. By contrast, certain agro-industrial by-products are rich in less-readily-degradable C compounds. Examples are rice hulls, bagasse, bark, and yard wastes. These materials degrade slowly under normal conditions (Crawford, 1976).

By combining the N-rich crawfish by-products with materials high in C, such as rice hulls, the combination C:N ratio can be adjusted to within an acceptable range (20-40) to enhance composting without the associated odor problems. Earlier, Minkara et al. (1998) demonstrated that when composting crawfish by-products and rice hulls, most, if not all, of composting was attributed to the degradation of the crawfish by-products. It is because rice hulls contain more than 60 % lignocellulose and 20 % silica on a dry weight basis (Mizuki et al., 1993). These properties make rice hulls less susceptible to attack by microbes and consequently degrade very slowly. The slow degradation rate of rice hulls allows them to be reused as bulking material by simply adding raw crawfish by-products to the previously composted rice hull-crawfish by-products compost. A cost saving in bulk materials is thus realized by reusing the rice hulls.

When designing any compost process, knowledge of compost feedstock degradability is essential (Haug, 1993). In this study, dry mass and organic matter losses during composting were estimated in order to assess the degradability of different rice hull and crawfish by-products compost mixtures. Nitrogen losses and compost nutrient concentration were also analyzed to assess the nutrient value of the completed compost product.

The objectives of this research work were to characterize and compare the degradation rates and nutrient values of rice hull-crawfish by-products compost mixtures and to examine the efficacy of adding raw crawfish by-products to partially composted rice hulls. More specifically, the objectives were to 1) determine dry mass and organic matter losses, 2) measure N loss, and 3) estimate nutrient value of the final compost.

MATERIALS AND METHODS

Experimental Setup

Crawfish by-products were composted with rice hulls in 3-L beakers containing about 600 g of mixed material. Crawfish by-products were ground (5 mm) before mixing with rice hulls to facilitate sampling. Three replicates of four different mixing ratios of crawfish by-products and rice hulls, were used to obtain initial C:N ratios

of 14:1, 17:1, 25:1 and 42:1. The initial C: N ratio is used as the treatment in a 3x4 factorial experimental design. The 12 reactors were placed in an environmental chamber (Lab-Line Instruments, Melrose Park, IL) having the capacity to control temperature between 25 and 70 °C.

Three separate runs were performed. A new batch of crawfish by-products was added to the finished product of the first run identified as phase I. This second compost process was identified as phase II. As the degradation rate of phase II slowed, raw crawfish by-products were again added to begin phase III.

Sampling and Measurement Procedure

Samples were taken once weekly from each reactor to determine moisture, volatile solids, organic-C, and total-N concentrations. Water was added when necessary to maintain optimum moisture conditions in all reactors (40-65% wet basis). The compost was turned manually 3-4 times weekly to homogenize the mixture. Compost percent oxygen concentrations were measured four times weekly to confirm aerobic conditions.

Moisture content was determined gravimetricly at 60°C (APHA et al., 1992). After drying, samples were ground to 150-mesh size, thoroughly mixed and stored in air-tight containers for further analysis. Approximately 3 g sub-samples were combusted at 550 °C to determine volatile solids content. About 20 mg subsamples were used for organic C and total N determination using a Heraeus model CHN-O Rapid Analyzer. Elemental analysis of compost extract was determined for the initial mixture and the final product of each phase by the Inductively Coupled Plasma (ICP) method (APHA et al., 1992). Percent oxygen in the compost air space was measured using a model OT-21 oxygen probe (Demista Instruments, Wheeling, IL).

Determination of Organic Mass, Dry Mass, and N Losses

Degradation of organic matter is generally determined by a mass balance of the input and output materials. The mass lost during the process represents the total degradation. Dry mass degradability was determined to compare the degradability of rice hull-crawfish by-products compost during the three different phases of the experiment. Measuring total mass during the composting process is not always practical and cost-effective due to handling of different feedstock and the large volume produced. However, measurement of volatile solids concentration is feasible and a common practice, since aerobic biological activity decreases the volatile solids content by converting organic C to CO_2. Volatile solids concentration during composting is then used to estimate organic matter degradation.

Organic matter degradation, K_{OM} (%), was stated by Haug (1993) according to the conservation of ash. Total dry mass degradation, K_{dm} (%), is then calculated as a function of K_{OM} and initial volatile solids concentration (Minkara, 1998). Also, knowing the initial dry mass and K_{dm} at any time (t), the dry mass can be estimated at any time (t) during the composting period (Minkara, 1998).

Nitrogen mass balance is used to determine N loss during and after the composting process. Total N losses is estimated from the N concentration and dry mass after a time t of composting (Minkara, 1998).

RESULTS AND DISCUSSION

Changes in Organic Matter (Volatile Solids) and Total Dry Mass

During all three phases of the experiment, volatile solids content was reduced with the advancement of the biochemical reaction. Initial mixtures having higher C:N ratio tended to have higher volatile solids content as well. Initial volatile solids contents of 68.4, 72.6, 76.2, and 80.9 %, were obtained from mixtures having initial C:N ratios of 14, 17, 25, and 42, respectively. Raw rice hulls and crawfish by-products have volatile solids content of 81.3 and 62.1 %, respectively. During phase I, volatile solids content decreased to values of 63.0, 69.3, 73.5, and 79.3 % for the CN 14, CN 17, CN 25, and CN 42 treatments, respectively, by the end of the 40-day period (Figure 1).

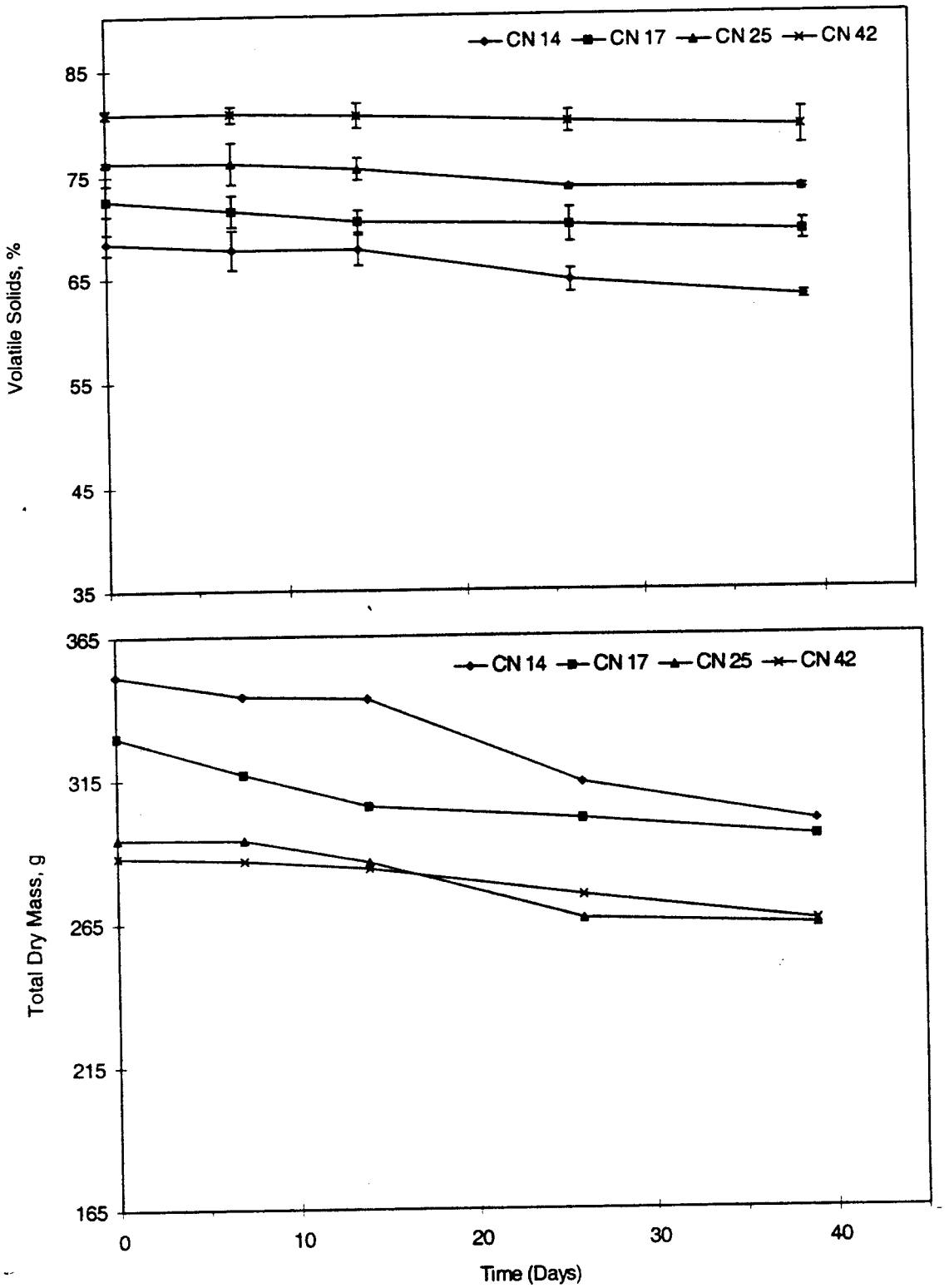

Figure 1. Volatile solids concentration (%) and total dry mass (g) versus time (Days) for the four treatments during phase I. Data are means of triplicate samples.

Phase II was initiated by recycling the product of phase I with a batch of crawfish by-products. Crawfish by-products were added at different amounts to each of the earlier treatments to obtain C:N ratios of : 11, 13, 15, and 20 and initial volatile solids content of 60.3, 64.1, 70.4, and 72.9 %, respectively. During phase II, volatile solids in the reactors were continuously decreasing to values of 50.2, 55.5, 65.7 and 67.9 %, for CN 11, CN 13, CN 15, and CN 20 treatments, respectively, at the end of the 40-day period (Figure 2).

Phase III was initiated by recycling the product of phase II with a new batch of crawfish by-products. Initial C:N ratios became as follow: 10, 12, 13, and 14 and initial volatile solids contents were 52.9, 55.2, 59.9, and 62.1 %, respectively. In this phase, although all four treatments had relatively similar initial C:N ratios, their initial volatile solids contents were significantly different. Volatile solids in the reactors continuously decreased and they reached values of 38.7, 40.0, 49.5 and 51.2 %, for CN 10, CN 12, CN 13, and CN 14 treatments, respectively, at the end of the experiment (Figure 3).

Total dry mass for phase I had a different trend than for phase II and III (figures 1, 2, and 3). In phase II and III, total dry mass experienced a sharp decline as commonly observed during the early stages of composting. This decline meant that substrate was readily available for microbial consumption. For phase I, acclimation of microbial population to the newly mixed feedstock delayed this phenomena. Total dry mass reached a steady state toward the end of each phase implying the exhaustion of the substrate.

The total dry mass loss and organic matter degradation for each treatment during each phase are shown in Table 1. In general, treatments with the lowest percentage of initial volatile solids had the highest loss of dry mass and organic matter. Although the percentage of crawfish by-products added was about the same at the beginning of phases I, II, and III, for treatment 1 (CN 14, CN 11, and CN 10) and for treatment 2 (CN 17, CN 13, and CN 12), the yield was higher for phase III than phase II or phase I (Table 1). Also, for treatments 3 (CN 25, CN 15, and CN 13) and 4 (CN 42, CN 20, and CN 14), the yield was higher during phase III than phase II, although a similar percentage of crawfish by-products was added. This implies that the degradability during phases II and III is not contributed to the added crawfish by-products alone, but also to the recycled materials. So the addition of crawfish by-products has provided an extra means for further degradation of the recycled product. In his model, Haug (1993) has considered that recycle product does not contribute any biodegradable fraction of volatile solids by assuming that the entire biodegradable fraction was consumed during the earlier cycle of composting. The results of this study seem to contradict his findings.

Changes in Total N

Initial N concentration varied in each mixture according to the ratio of crawfish by-products added to the amount of rice hulls or recycled compost. The initial N concentrations, for phase I were 28.7, 23.2, 16.4, and 10.1 mg/g (dry mass basis) for CN 14, CN 17, CN 25, and CN 42 treatments. During phase I, nitrogen concentration in all mixtures was continuously decreasing over the 40-day incubation period to final values of 10.5, 10.1, 8.2, and 6.7 mg/g, respectively (Figure 4). When the product of phase I was recycled with more crawfish by-products, N concentration became 28.0, 26.9, 23.7, and 19.5 mg/g corresponding to new C:N ratios of 11, 13, 15, and 20, respectively. Also, in phase II, N concentration for all treatments dropped simultaneously to final values of 12.0, 11.5, 10.1, and 8.5 g/kg for CN 11, CN 13, CN 15, and CN 20 treatments, respectively (Figure 5). The treatments in phase III having initial N concentrations of 29.4, 25.8, 26.0, and 25.0 mg/g corresponded to initial C:N ratios of 10, 12, 13, and 14, respectively. Final N concentration (dry mass basis) was observed for all treatments in phase III to be between 13.5 and 14.5 mg/g (Figure 6). Final N concentrations were the highest in phase III for treatment having similar initial N concentration.

Nitrogen content in each reactor was continuously decreasing through out the composting period (figures 4, 5, and 6 and tables 2, 3, and 4). Treatments with the highest N content observed the highest drop. This drop occured during the first 10 days due to high NH_3 volatilization. After the second week, N content tended to level off between 2 and 4 g N/reactor or a N concentration between 6 and 14 mg/g.

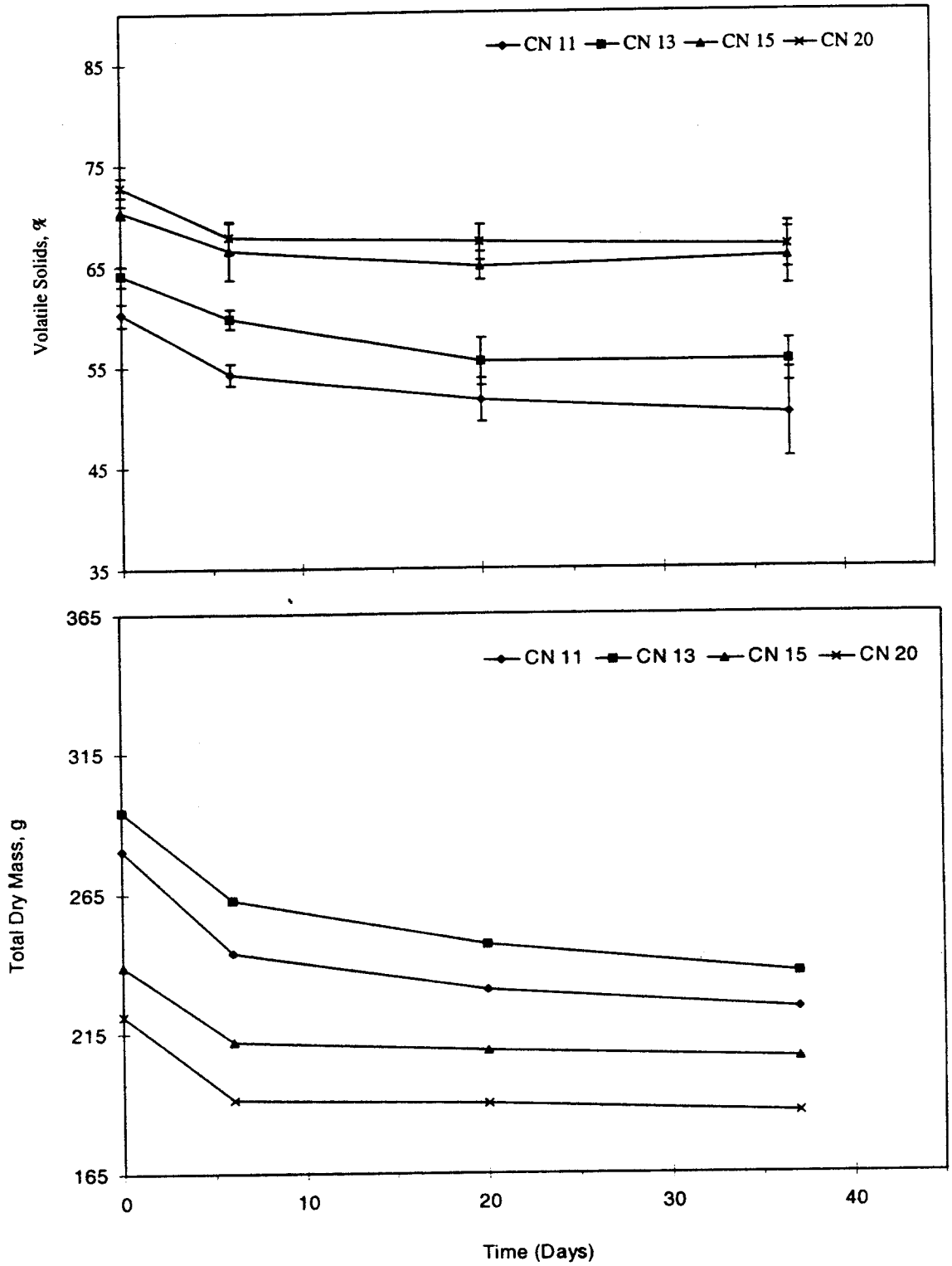

Figure 2. Volatile solids concentration (%) and total dry mass (g) versus time (Days) for the four treatments during phase II. Data are means of triplicate samples.

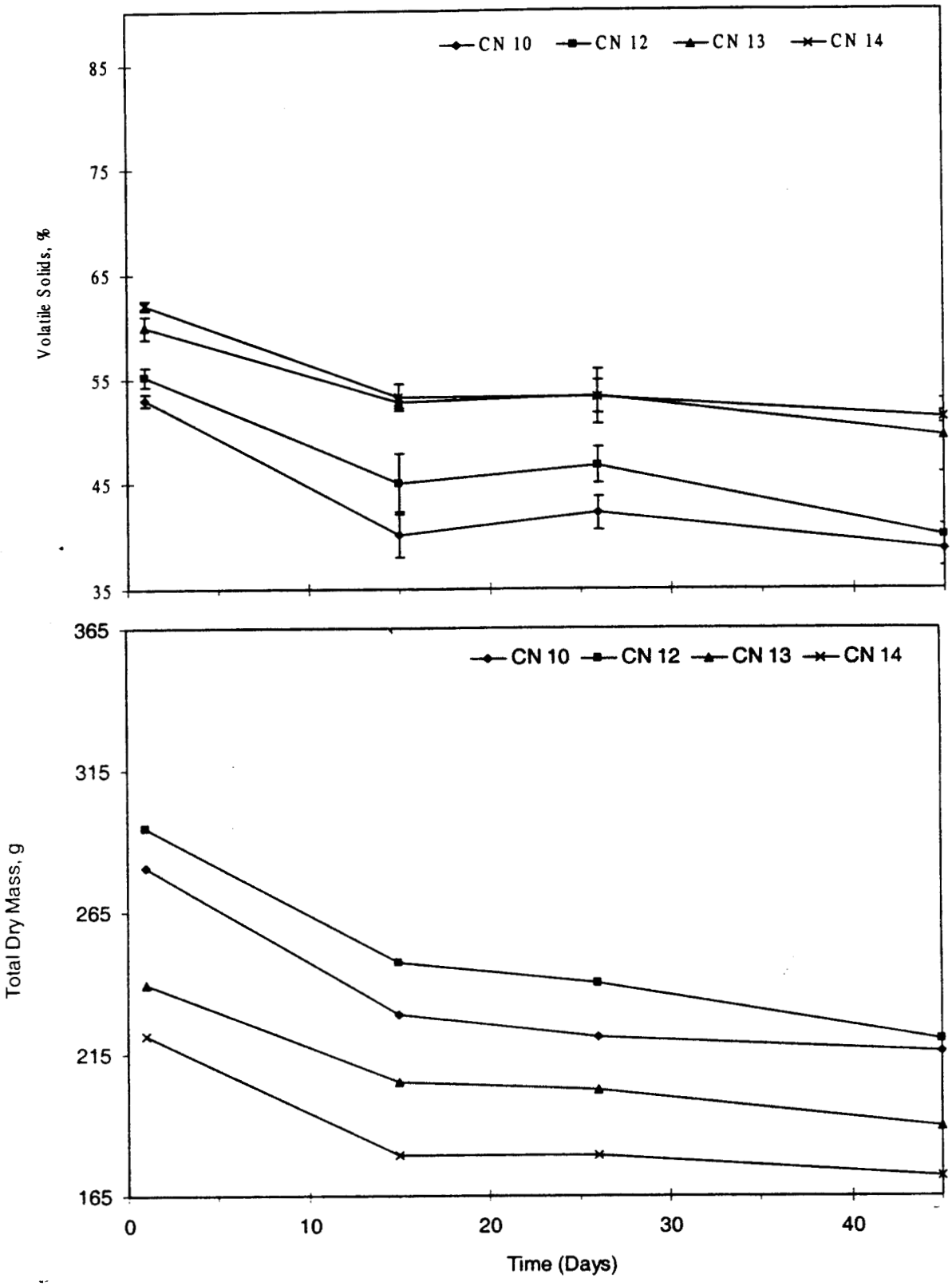

Figure 3. Volatile solids concentration (%) and total dry mass (g) versus time (Days) for the four treatments during phase III. Data are means of triplicate samples.

Table 1. Final organic matter degradation (K_{OM},%), dry mass loss (K_{dm}%), and percent distribution (dry mass basis) of crawfish by-products, rice hulls or recycled compost in feedstock having initial volatile solids, VS_i (%), for phases I, II, and III. Values are means of triplicate samples.

Phase I					
Treatment	VS (%)	Rice Hulls (%)	Crawfish By-Products (%)	K_{OM}(%)	K_{dm}(%)
CN 14	68.4	47	53	21.3	14.6
CN 17	72.6	57	43	14.8	10.8
CN 25	76.2	73	27	13.6	10.3
CN 42	80.9	84	16	9.6	7.8
Phase II					
Treatment	VS (%)	Recycled Compost (%)	Crawfish By-Products (%)	K_{OM} (%)	K_{dm} (%)
CN 11	60.3	50	50	33.4	20.2
CN 13	64.1	56	45	30.4	19.5
CN 15	70.4	57	43	19.5	13.7
CN 20	72.9	62	38	21.5	15.7
Phase III					
Treatment	VS (%)	Recycled Compost (%)	Crawfish By-Products (%)	K_{OM}(%)	K_{dm} (%)
CN 10	52.9	53	47	43.8	23.2
CN 12	55.2	59	41	46.0	25.4
CN 13	59.9	60	40	34.5	20.7
CN 14	62.1	63	37	35.9	22.3

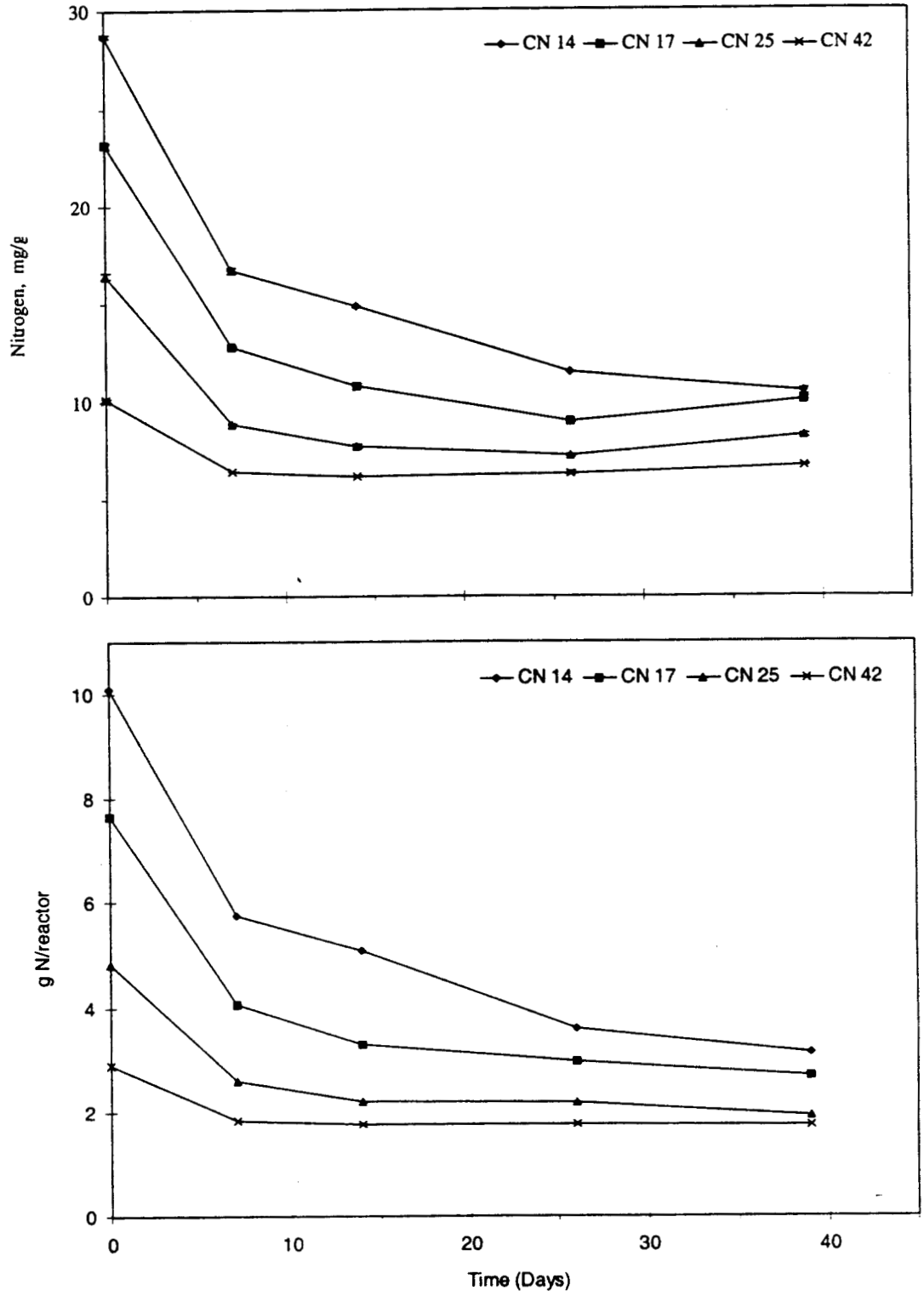

Figure 4. Mean total N concentration (mg/g) and content (g N) per reactor versus time for the four treatments during phase I.

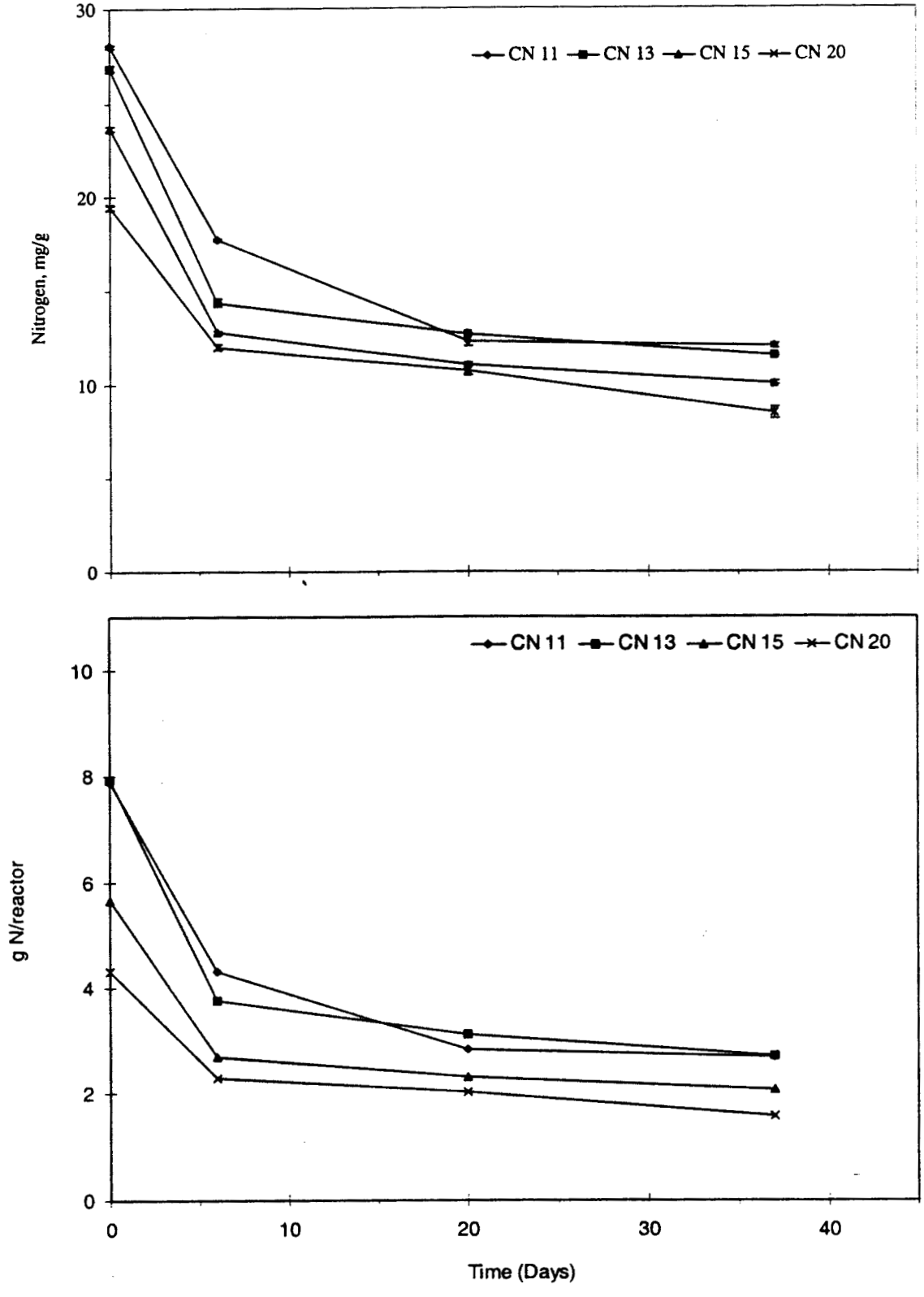

Figure 5. Mean total N concentration (mg/g) and content (g N) per reactor versus time for the four treatments during phase II.

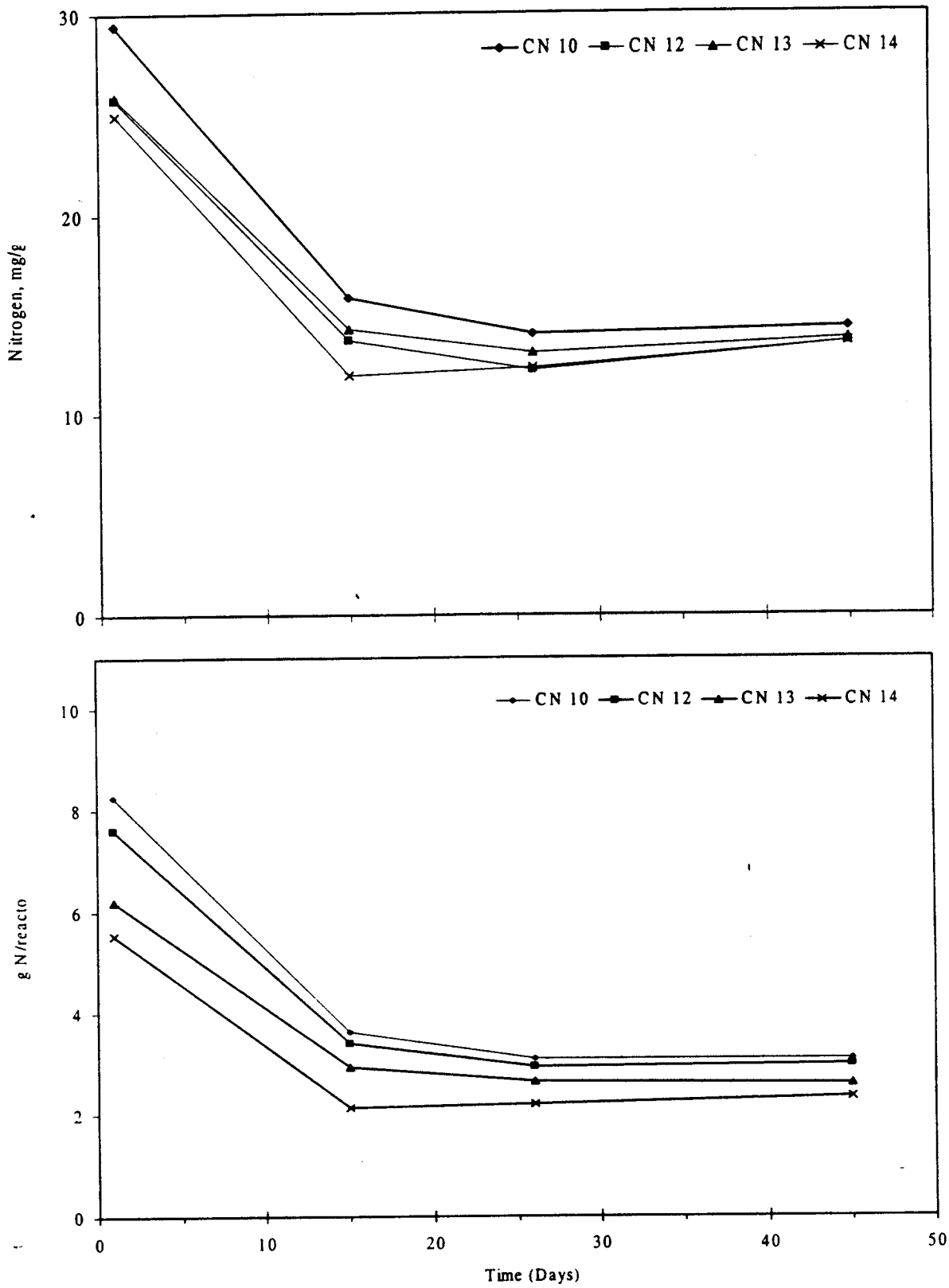

Figure 6. Mean total N concentration (mg/g) and content (g N) per reactor versus time for the four treatments during phase III.

Table 2. Average N loss from each treatment, for phase I, expressed as the cumulative mass loss and percentage loss from initial amount.

Time (Days)	CN 14 g N Lost per Reactor	CN 14 % N Lost of Initial Amount	CN 17 g N Lost per Reactor	CN 17 % N Lost Initial Amount	CN 25 g N Lost per Reactor	CN 25 % N Lost Initial Amount	CN 42 g N Lost per Reactor	CN 42 % N Lost Initial Amount
0	0	0	0	0	0	0	0	0
7	4.35	43.1	3.60	47.0	2.22	46.0	1.56	36.7
14	5.00	49.6	4.35	56.8	2.62	54.2	1.14	39.1
26	6.49	64.3	4.68	61.2	2.66	55.1	1.15	39.5
39	6.96	68.9	4.95	64.7	2.91	60.2	1.18	40.5

Table 3. Average N loss from each treatment, for phase II, expressed as the cumulative mass loss and percentage loss from initial amount.

Time (Days)	CN 11 g N Lost per Reactor	CN 11 % N Lost of Initial Amount	CN 13 g N Lost per Reactor	CN 13 % N Lost Initial Amount	CN 15 g N Lost per Reactor	CN 15 % N Lost Initial Amount	CN 20 g N Lost per Reactor	CN 20 % N Lost Initial Amount
0	0	0	0	0	0	0	0	0
6	3.55	45.1	4.14	52.3	2.96	52.2	2.01	46.7
20	5.03	63.9	4.79	60.5	3.35	59.2	2.27	52.7
37	5.18	65.7	5.19	65.5	3.59	63.4	2.73	63.3

Table 4. Average N loss from each treatment, for phase III, expressed as the cumulative mass loss and percentage loss from initial amount.

Time (Days)	CN 10 g N Lost per Reactor	CN 10 % N Lost of Initial Amount	CN 12 g N Lost per Reactor	CN 12 % N Lost Initial Amount	CN 13 g N Lost per Reactor	CN 13 % N Lost Initial Amount	CN 14 g N Lost per Reactor	CN 14 % N Lost Initial Amount
0	0	0	0	0	0	0	0	0
15	4.64	56.2	4.20	55.3	3.28	52.9	3.38	61.2
26	5.16	62.5	4.66	61.4	3.55	57.2	3.32	60.1
45	5.16	62.6	4.61	60.7	3.59	58.0	3.19	57.8

Characterization of Final Product

Nutrient analysis of compost samples showed that repetitive addition of crawfish by-products increases the concentration of important nutrients like P, K, Mg, Mn, S, and Ca (tables 5 and 6). These high concentrations provide plant nutrients and improve soil quality. Although high concentration of Na may cause damage to crop, the concentration of Na in crawfish compost remains lower than poultry litter compost (Lu et al., 1997). It was noted earlier that multiple addition of crawfish by-products reduces the volatile solids concentration (i.e. increases ash concentration). Since Ca is a major constituent of ash, the increase of ash concentration led to an increase in Ca concentration as well. This is why final Ca concentration ranged between 110-150 mg/g. At the end of the experiment, the treatments receiving the highest amount of crawfish by-products have the highest final nutrient concentration. The concentration of Si did not vary significantly among treatments

CONCLUSIONS

Biodegradability analysis conducted in this experiment showed that rice hulls and crawfish by-products can be composted when initial C:N ratio is within 10-42; however, mixtures containing a higher percentage of crawfish by-products to rice hulls or recycled product, tend to degrade at a faster rate. The results also showed that the initial

Table 5.

Table 5. Selected properties of initial compost mixture for all treatments (mg/g).

Treatment	K	P	Na	Mg	Mn	Ca	S	Si
CN 10	3.3	3.6	2.6	0.88	0.17	50.5	1.9	0.09
CN 12	3.1	3.0	2.1	0.78	0.17	41.3	1.5	0.11
CN 13	2.7	2.1	1.6	0.64	0.18	26.6	1.2	0.12
CN 14	2.1	1.2	0.9	0.49	0.18	12.8	0.9	0.13
$LSD_{0.05}$*	0.1	0.5	0.2	0.08	0.01	7.9	0.3	0.02

* Least significance difference

Table 6. Selected properties of final compost product for all treatments (mg/g).

Treatment	K	P	Na	Mg	Mn	Ca	S	Si
CN 21	6.3	10.2	5.5	2.4	0.34	150.6	3.6	0.068
CN 20	5.9	9.4	5.0	2.3	0.33	138.9	3.4	0.075
CN 17	5.6	8.0	4.5	2.0	0.32	118.4	3.0	0.064
CN 18	5.3	7.5	4.1	1.9	0.30	111.0	2.9	0.065
$LSD_{0.05}$*	0.3	0.4	0.2	0.1	0.01	6.1	0.1	0.02

* Least significance difference

C:N ratio is not a good indicator of the subsequent composting of feedstock. In addition to N availability, the extent of C degradability must also be taken into account. The addition of a nitrogenous feedstock, such as crawfish by-products, to recycled compost had a positive effect in improving the degradability of the recycled compost and the nutrient concentration of the final compost product. Rice hulls, having good structural property (i.e. high porosity, low bulking density), proved to be an excellent bulking agent for composting crawfish by-products which in turn provided readily available substrate for microorganisms. Further research is needed to quantify the degradation of different lignocellulotic materials during repetitive composting with nitrogenous feedstock.

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