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Physiochemical Parameters Analysis to Get an Upgraded Composting System

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Abstract: Physicochemical determinants parameters were analyzed in different stages of organic matter decomposition, using various chemical and biological treatments: Manure, Legumes, Mineral solution, and Vermicompost. Specifically, we studied the importance of decisive physicochemical parameters for obtaining an improved composting system. To do this, were used different techniques, such a C/N ratio, pH, organic matter content, atomic absorption to determining concentration of several mineral, ashes quantification for moisture content and temperature measurement. The vermicompost was the most effective treatment for decomposition of matter, achieving speed up the composting process just 35 days, accounting for 5 months the minimum estimated time to have a complete degradation using a conventional composting system, this represents a decrease of 23.3%, values obtained mainly from C/N ratio were close to 25:1 (25%), a final pH of 8.2, a percent of organic matter lower than 48%, and a concentration of minerals and heavy metals within the norm.

Keywords: Organic Matter, Mineral Solution, C/N ratio, Vermicompost, Manure, Organic Fertilizer, Conventional System

1. Introduction

Municipal Solid Waste represent a potential economic development to be possible to generate monetary resources from its use and, above all, achieving lower environmental movement of pollutants and greenhouse gases, which convey disease vectors and the accumulation in the disposal sites [1]. The generation of municipal solid waste has increased by 66.86% during the decade of 2001-2012, going from 31488.51 to 42102.75 (thousand tons), with a production of 1.12 Kg per capita/day. Composting is a viable option for solving the problem of municipal solid waste alternative, whereas the organic fraction covers between 48 and 55% of the total, approximately 22,584.4 tons [1]. That's the reason they have implemented various measures to counter the increasing fraction of the municipal solid waste. Methodologies such as those used by Amador et al., 2011, who used TiO_2 as a chemical agent for the degradation of organic matter in the effluent water [2]. As a result, there has been discussion about the advantages and disadvantages that come with using chemical treatments.

Compost is a fertilizer obtained from the bacterial degradation of organic matter, it is an odorless, stable humus-like material that does not pose a health risk to the natural and social environment. Currently a small percentage is recovered to 50% of potentially recyclable waste [3].

Within conventional composting processes various treatments have been applied to try to optimize the decomposition of organic matter not succeeding in most occasions. However, there are chemical and biological treatments that can greatly accelerate the rate at which waste is broken down, with the use of Californian red worms (Eisenia foetida) and legumes, especially alfalfa and lentils because of their high binding capacity nitrogen when performing interactions synergism with nitrogen-fixing microorganisms [4].

The aim of this study was to design a treatment process for the organic fraction of municipal solid waste by composting, which would reduce the processing time compared to conventional methods.

2. Materials and Methods

The research was conducted at the facilities of the Technological Institute José María Morelos y Pavón, located in the city of Morelia, Michoacán. In a land with an area of 63 m^2, with an approximate slope of 6° west (Source: Google Maps - ©2013 Google), allowing direct this leachate that occurred towards the pits intended for storage.

2.1. Selection of Treatments

Manure, legumes, mineral solution and vermicomposting: 4 different treatments for composting systems were used. These were selected because of the various antecedents are as to their use for the decomposition of organic matter. All were compared against a conventional composting system (A), which consists of a stack of layers of waste soil and plant debris, without the intervention of any outside treatment or benefits affecting microbial activity present. Identifying treatments: manure (B), legume (C) mineral solution (D) and vermicompost (E) (Mexican standard NMX-FF-109-SCFI-2008, which establishes the procedure for conducting a vermicompost).

2.2. Establishment and Fitness Site

Size beds estimated one third of the volume recommended by the Municipal Composting Manual [3], measures 0.8 meters were established long, 1 meter wide and 0.2 meters high. It also considered the volume detracting from the beds the polyethylene layer and other components of fitness, increasing about 5 centimeter in each direction. Site cleanup because it had plenty of waste building materials and excess vegetation was conducted and used to establish perimeters and stuff like coffee, respectively. Having cleaned the soil were measured and marked the areas allocated to the beds and lagoons, this according to a scaling in which took into account the volume of organic matter and the number of beds.

The pits were excavated in triplicate for treatments and white, for a total of 15 beds. Also the drainage system and leachate containment was installed, for which hoses introduced at the bottom of the pit and connected in series between the graves of the same treatment and directed towards their respective lagoon to contain the leachate were used there. Polyethylene impermeable layers are placed to prevent the leachate from leaking to the ground. This was done both in the pits for the beds to the leachate lagoons.

2.3. Collection, Sorting and Processing of Organic Matter

The organic fraction was used in this work was obtained from the municipal solid waste produced in the Supply Center in Morelia, Michoacán, Mexico. The first step was to characterize the waste according to the Mexican standard NMX-AA-022-1985, used for characterization of solid waste. Once the characterization is noted that only green waste containing organic matter, that is, food waste as tomatoes, lettuce, etc.

The residues were ground using a mill 5.5 HP® Central Machinery brand with certain amounts of organic coffee (garden waste) to achieve adequate homogeneity. A particle size of 10-50 mm suitable for the decomposition process was reached [5].

2.4. Armed Composting Beds

Plates were installed on the bed to facilitate aeration once the compostable material is placed. The beds were assembled in layers depending on the type of treatment at issue, differences exist only in the method of treatment when treated with earthworms and legumes (Table 2.1).

Table 2.1. *Establishment and armed of composting beds.*

Treatment	Layer					
Target	Ground	Organic matter*	Ground	Plastic layer		
Manure	Ground	Cow manure	Organic matter	Ground	Plastic layer	
Legumes	Ground	Organic matter*	Alfalfa and lentils	Ground	Plastic layer	
Mineral solution	Ground	Organic matter*	Ground	Mineral solution	Plastic layer	
Vermicomposting	Ground	Organic matter*	Earth worms	Organic matter*	Ground	Membrane

*Organic matter was composed by garden trash and wood, 50-50 proportion.

2.5. Determinations

Each determination was performed in triplicate to find significant statistical differences as well as their corresponding standard deviations. For matters relating to the analysis of the results obtained the statistical method of Tukey confidence intervals set at 95%, to thereby obtain statistically which of the 4 treatments the process of decomposition and mineralization are best performed organic matter to organic fertilizer. Parameters of temperature, pH, carbon-nitrogen ratio (C/N), and percentage of organic matter; mineral concentration and moisture content were measured at intervals of 4 days during the first 2 weeks after the samples were taken every 7 days up to a total of 5 samples over a period of 35 days. The values of these measurements were obtained by Mexican standards and technical methodologies: pH (NMX-AA-025-1984, with a range between 7.5-9), C/N (NMX-AA-067-1985, stablishing a 25% as a allowed value), percentage of organic matter (NMX-AA-021-1985), and moisture content (NMX-AA-016-1984, having an allowed range between 50-60%), the temperature measurement was performed with the use of a bayonet thermometer, likewise mineral quantification was performed with the use of equipment atomic absorption Perkin Elmer, model 400A Analyst in the Instituto Tecnológico de Estudios Superiores de Tacámbaro.

3. Results and Discussion

3.1. pH Determination

The initial pH value was 6.45, increased as the passage of time due to the formation of ammonia from the decomposition of organic matter, which causes an increase of the pH to between 8.5 and 9 during the first few days remaining in this range about twelve days, then begin to decrease due to the formation of organic acids from aliphatic molecules that are metabolized by microorganisms, mainly bacteria and fungi [6]. The optimum pH for the decomposition sort is developed in a range of 6.5-8.0, as a reference the results obtained in the present study were within those values [7]. Shown graphically that a significant difference in behavior of the pH in each composting systems depending on the treatment that was used. Was observed between the results obtained for the treatment with manure and those obtained for the mineral solution, in which case the pH values when they reached the stable value was between 8.5 and 9 had different changes (Fig. 1a). For the treatment with mineral solution pH drop was with a much stronger tendency than any of the other treatments including the "target" system. Statistical analysis showed that pH do not determinate which of 4 treatments is the best because there is no significant difference between theirs.

Vasquez Diaz reported in 2010 composting systems optimized by using native microbial consortia, for pH values between 8.6 and 9.6 for systems where minerals also were obtained solutions were added, these values reported as stable at a time of 40 days approximately, being similar to those obtained in this investigation for the system in which the mineral solution used values [8].

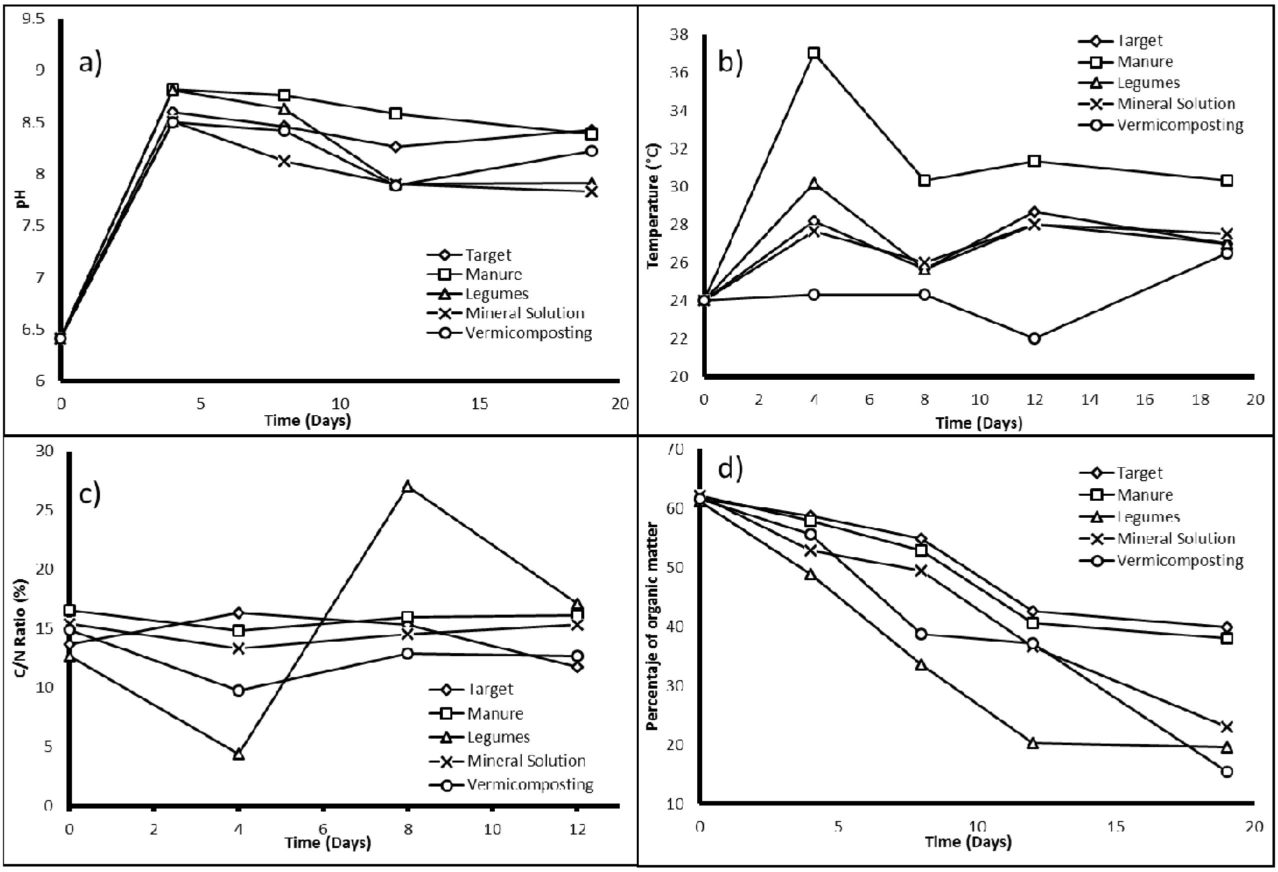

Figure 1. *a) pH behavior during the composting period. Representative sampling every 4 days. Ex-situ measurements on a wet basis; b) Temperature variation. In- situ measurements using thermometers with bayonet; c) Study of the C/N ratio in each of the systems through decomposition time. Measurements from the fourth day for proper homogenization of nutrients; d) Determination of the reduction of organic matter. Acid digestions aerobic digester using phosphoric acid as the agent. White (◊), legumes (Δ), Vermicompost (○), manure (□), mineral solution (×). Data are representative of 3 experiments per sample.*

3.2. Temperature

Temperature control was difficult, due to high ambient temperatures developed during the course of the experiment, reaching values of up to 30 °C. These temperatures affected the moisture retention in the soil. An initial value in the range of 24 to 30 °C for vermicomposting systems, legume and mineral solution was obtained, while for the system with manure the initial temperature was 38 °C (Fig. 1b). Rink (1992) reported an optimal temperature range for proper decomposition of organic matter comprising values between 65-75 °C, also in giving a range which can still be considered as acceptable temperature, 55-75 °C [6]. An important factor to be considered is the use of appropriate thermometers, in this case two types, and one laboratory conventional bayonet used. Martinez et al., 2013, reported an analysis of the relationship between the size of the pits used for composting systems and temperatures that can be achieved, explained that the size of a compost pile will influence the duration and intensity thermophilic phase, and therefore the duration of the bioprocess. His research is the ideal dimensions were obtained to reach thermophilic temperatures within the range, these dimensions were only in relation to the height of the pits, 0.5m and 1m being the most suitable [9]. The decrease of the temperature range, compared with that shown in the Manual composting of Secretary of Environment and Natural Resources (SEMARNAT), is possible due to the scaling of composting systems and the concentration of organic matter was used.

3.3. Determination of the C/N Ratio

This is one of the most important factors in determining the degree of maturity of compost; Soto (2002) reported optimum values of this ratio, with the optimum range of 25-30% [7]. In this case determinations began the fourth day to allow it to begin to consume the carbon and nitrogen, for every four days to perform the sampling. After this time it was found that the systems had a lower ratio of 16%, this represented a loss of nitrogen we lack carbon. Espinoza (2013) reported a systems research reactors using aerobic composting diapers outpatient treatment, obtaining values of C/N in the range 10 to 12, with an average value of 20 as optimal [10], according to standard NMX-FF-109-SCFI-2008, which stablished optimal C/N ratio values. The only system that showed good ratio C/N in which alfalfa was used, with a value of over 25% (Fig. 1c), a value that is between the average required for the degradation of organic matter, this is thanks to that legumes have a symbiotic relationship with nitrogen-fixing microorganisms [4]. After 15 days, the C/N ratios stabilized up to values between 20 and 12% giving this results in a stable system and a partially complete decomposition, but statistically, there is no difference between the four treatments and all are grouped within the same range due to the proximity of their respective mean values (Table 3.1).

Table 3.1. *C/N ratio, Statistical analysis.*

Treatment	N	Media	Group
Legumes	3	16.211	A
Manure	3	15.660	A
Target	3	14.450	A
Mineral solution	3	14.416	A
Vermicomposting	3	11.777	A

Simultaneous confidence intervals of 95% Tukey
All comparisons paired-levels between treatments
Individual confidence level = 99.18%

3.4. Determination of the Percentage of Organic Matter

Percentage of composted organic matter refers to the amount of substrate that exists to be consumed by the microorganisms present. In this investigation the average initial percentage organic matter, obtained by a random sampling of 3 of the 15 beds, was 61.7, almost starting to decrease steadily. Legume systems were those with a more rapid decline. However, vermicomposting treatment achieved the highest reduction in the percentage reaching a value of 15% (Fig. 1d), this representing a reduction of almost 47% over a period of 20 days. Statistical comparison shows a similarity between the four treatments (Table 3.2), however, according to the trend following treatments with vermicompost and manure system, these are considered the most effective treatments.

Table 3.2. *Organic matter percentage, Statistical analysis.*

Treatment	N	Media	Group
Manure	4	15.886	A
Legumes	4	15.340	A
Mineral solution	4	14.662	A
Target	4	14.255	A
Vermicomposting	4	12.560	A

Simultaneous confidence intervals of 95% Tukey
All comparisons paired-levels between treatments
Individual confidence level = 99.18%

3.5. Concentration of Minerals

During the process of decomposition and mineralization of organic matter in compost piles study the concentration of different minerals that are present during this process, phosphorus, sodium, calcium, and potassium, was performed, as well as other nutrients that rather than are considered pollutants, including zinc, iron, copper, and manganese were found. In the case of the concentration of phosphorus, which is one of the most representative nutrients found in the soil naturally allowing correct growth of vegetable organisms. Analyses were performed by atomic absorption using samples taken only at the end of the composting process to assess the quality of the end product and analyze the possibility of marketing it. Table 3.3 shows the concentrations obtained; was observed that fall within the ranges reported by several authors in similar investigations, e.g. Meneses (2012) reported values of concentrations for potassium (0.793 mg/L), sodium (0.217 mg/L), zinc (77.29 mg/Kg, with a concentration of 200 mg/Kg the maximum allowable) [11], being within the limits established in the Mexican standard NMX-FF-109-SCFI-2007. Paul and Clark (1996) report phosphorus values in a range of 0.15-1.6% [12]. While the concentrations reported in Table 5 within that range. Soto (2002) reports different concentrations in a study using composting systems with coffee pulp and mucilage, obtaining values of 0.27% and 0.25%, respectively [7]. In the same investigation concentrations of some heavy metals such as iron (3413.53 ppm) and manganese (155.17 ppm), close to those obtained for the 57260 ppm Fe and 500 ppm Mn values are reported.

Table 3.3. *Mineral concentrations.*

		Units: mg/g (dry basis)								
Treatments	**Samples (g)**	**Zn***	**Ca**	**Mg**	**Mn***	**K**	**Na**	**Cu***	**Fe***	**P****
A1	0.50	0.06	1.74***	4.55	0.63	18.75	1.81	0.04	58.30	0.24
A2	0.50	0.05	5.18	4.32	0.42	16.52	1.96	0.04	56.11	0.36
A3	0.50	0.06	6.57	3.80	0.46	18.81	1.69	0.04	57.38	0.31
Media		0.06	5.88	4.22	0.50	18.03	1.82	0.04	57.26	0.30
B1	0.50	0.10	1.52	3.77	0.70	14.72	1.88	0.05	60.30	0.51
B2	0.50	0.16	6.84***	6.73	0.47	28.84	3.21	0.09	56.52	1.66
B3	0.50	0.14	2.47	6.30	0.71	24.40	3.00	0.08	58.72	1.63
Media		0.13	2.00	5.60	0.63	22.65	2.70	0.07	58.51	1.27
C1	0.50	0.06	1.73	5.05	0.62	19.83	1.41	0.04	60.36	0.35
C2	0.50	0.06	2.79	4.96	0.49	22.33	1.79	0.04	57.55	0.48
C3	0.50	0.08	8.72***	7.06	0.49	25.28	1.93	0.04	55.73	0.58
Media		0.067	2.260	5.690	0.534	22.480	1.710	0.040	57.880	0.471
D1	0.50	0.06	1.32	5.21	0.59	19.78	1.71	0.04	61.27	0.98
D2	0.50	0.09	2.60	5.82	0.57	21.62	1.72	0.06	59.10	1.18
D3	0.50	0.09	2.59	4.67	0.61	19.70	1.47	0.06	60.63	1.04
Media		0.08	2.17	5.23	0.59	20.37	1.63	0.05	60.33	1.07
E1	0.50	0.09	8.97***	4.68	0.47	10.47	2.20	0.04	58.44	0.29
E2	0.50	0.08	1.37	4.49	0.77	9.40	1.92	0.04	61.52	0.45
E3	0.50	0.09	0.80	4.41	0.69	7.89	1.90	0.04	63.19	0.32
Media		0.09	1.09	4.53	0.64	9.25	2.01	0.04	61.05	0.36

* Heavy metals
** P is in weight percentage already
*** Values untaken because they are out of ratio

3.6. Moisture

The initial values of moisture that had been over 50% (Fig. 2) because this type of waste that were used were mainly tomato, lettuce. Which present water concentrations of up to 95% (FAO, 2008). However, after 4 days the values decreased approximately 15% to values below the optimum values of 50-60% [6], remaining all the time how hard the decomposition process, reaching values above 40% for the system with legumes, but not to exceed that range. The system in which manure is used as a treatment provided a humidity value below 35% due to the high temperatures developed, which were the highest of the 5 systems, this combined with high ambient temperatures provided the percentages of moisture less stable. Soto et al., 2001 obtained values greater humidity of 85%, however, showed that a system of volts programmed it is possible to reduce these optimal values of 60%, approximately, being this close to the value obtained from the first show for all treatments [13].

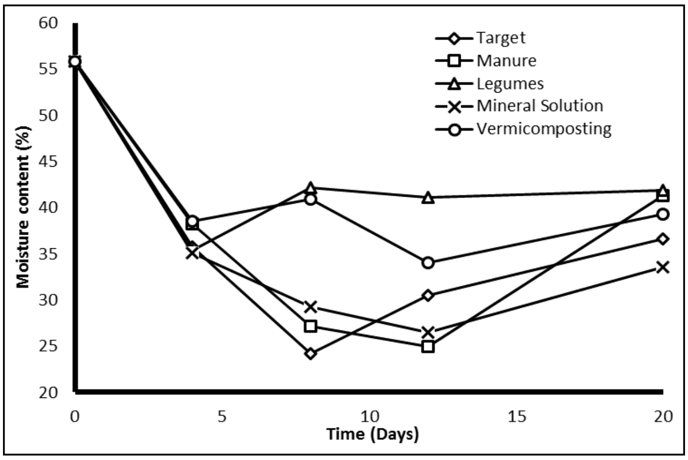

Figure 2. *Comparison of changes in moisture between individual treatments. Method for determination of ash porcelain capsules. White (◊), legumes (Δ), Vermicompost (○), manure (□), mineral solution (×). Data are representative of 3 experiments per sample.*

4. Conclusions

Applying conventional treatments composting systems results in decomposition of the organic matter and efficient desirable physicochemical characteristics. Characterization of composting systems identifies registered common compliance requirements in various investigations that allow control of product quality is sought offer. In this paper conducted a series of test methods recommended by different regulations, locating parameters that are outside the recommended range, as in the case of the presence of moisture above the regulated rate and temperature. From which we conclude that aeration and moisture are critical for proper decomposition of organic matter in a compost system factors, however, are not the only ones that determine the speed with which this process takes place. It is therefore not considered when making the decision on what was the most effective treatment.

The atomic absorption method allowed to study the concentration of minerals and heavy metals. The coexistence of these was more dependent on the treatment used to natural soil conditions. High concentrations of cations such as manganese (Mn) and iron (Fe) suggest that the quality of the compost obtained depends on the conditions established in composting systems.

The pH of composting systems was studied by use of potentiometers. The shape of the curves of each treatment pH of said ammonia formation is accelerated and is maintained constant for a period of time, then triggering a decrease in the values due to the mineralization of the nitrogen fraction. Therefore, the design of conventional composting systems using physicochemical treatments can reduce the time of mineralization of nitrogen fractions and suitable carbon, but without reaching pH values higher than those reported.

We conclude that the establishment of the beds composting conditions size and organic matter content allows a correct decomposition, yielding values of physicochemical parameters ideal for the process, also reducing composting time by 24%. These conditions were achieved first by vermicompost systems, can be say that this was the most effective treatment.

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