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Aerobic and Anaerobic Biodigestion Assessment in the Production of Compost, Biol and Biogas from Restaurant Waste with Cattle Manure as Inoculum

Angel Villabona-Ortíz[1], Candelaria Tejada-Tovar*[2], Andrés Pernett-Gómez[3], Diofanor Acevedo[4]*, Ronald Tejada-Tovar[5]

[#]Faculty of Engineering, Chemical Engineering program, Research Group IDAB, University of Cartagena Av. El Consulado, 130015, St. 30 No. 48-152. Cartagena de Indias, D. T. y C.
[4]Research Group Nutrición, Salud y Calidad Alimentaria (NUSCA), Universidad de Cartagena, Campus of Piedra de Bolívar, 130015 Cartagena de Indias, D. T. y C., Colombia.

Abstract : The purpose of this research was to evaluate the production of compost, biol and biogas from organic solid waste using cattle manure as inoculum through aerobic and anaerobic biodigestion; two prototypes of biodigester were designed on a pilot scale. The monitored variables were pH and moisture in order to obtain good quality compost. Solid organic waste from a sample of restaurants in the city of Cartagena de Indias was used; cattle manure was also used for its production. The growth of mesophilic bacteria, fecal coliforms and fungi present in different stages of composting was monitored, using Brilla Broth and Mac Conkey and Brilla agar. The Most Probable Number method was used for counting microorganisms, and the successful collection of biological by-products and biogas was performed. The obtaining and quality of the compost from the experiments depended substantially on the use of inoculum, as evidenced by the aerobic/anaerobic experiments with inoculum, from which a greater quantity of by-products was obtained and complied with the optimum ranges for the chemical, physical and microbiological parameters for organic fertilizers.
Keywords : Composting, C/N ratio, aerobic biodigester, anaerobic biodigesters, biol, biogas.

1. Introduction

Accelerated population growth has caused a rise in consumption patterns, thus increasing the volume of solid urban waste generated. The mishandling or non-treatment of this waste produces bad smells and leachate, deteriorating the soil and the environment, also become home to disease vectors; until a few years ago, the final destination of food waste was disposal in landfills or incineration. Although this situation persists in many countries, the use of organic solid waste is an issue that has become of vital importance to the world in recent years. In this regard, many nations have considered more sustainable methods for waste management and have developed new legislation on solid waste disposal that involves the material recovery of these wastes. In addition, many studies propose alternatives for its use, with composting being one of the most widely applied and studied[1].(Bernstad et al., 2016).

Composting is considered a good alternative for recycling organic solid waste because of its aerobic microbial conversion capacity of the biodegradable fraction of solid waste into an oxidized and harmless product; it also reduces greenhouse gas (GHG) emissions and eutrophication of natural water bodies[2]. In Colombia, composting is a viable and necessary option, since there are many places that are sources of contamination, there is no control of these and no treatment is applied. The Colombia's industrial sector produces large quantities of waste, therefore many experiments have been carried out in this sector. In this sense, compost was obtained from agro-inputs from the sugar industry of good quality and complies with the parameters established in standard NTC 5167 of Colombia, which demonstrates that it is a viable alternative for the disposal of this waste[3].

The production of high quality compost requires that the process must be properly controlled and managed, since food waste is a heterogeneous material with high moisture content, high organic to ash ratio and an amorphous physical structure; in addition, it may contain a high percentage of inert materials such as glass or plastic depending on the collection system. These particular characteristics will affect some aspects of the process and therefore pH, C/N ratio, moisture content, aeration rate, particle size and porosity must be adjusted appropriately taking into account the characteristics of the raw material. Errors in initial preparation and adjustment of the mixture with typical loading agents or in process control will lead to odour emissions, increases in the environmental impact of the process and low quality compost[4].

Compost and biogas have been obtained from vegetable residues of carrot root and potato in different ratios of vegetable waste and cattle manure, obtaining products suitable for use[5]. Zhao et al.,[6]evaluated the dynamics of microbial communities and time maturation of two composting systems: suspension compost of biogas and compost with cattle manure, obtaining that the duration of the thermophilic phase (> 50 °C) for the biogas slurry compost was 8 days, less than the duration agreed for cow manure compost, and the maturation times of biogas slurry and cattle manure were 45 and 60 days, respectively. Using anaerobic digestion for the recovery of four products: Fiber, biogas, composting and pest repellent, obtaining that the recovery levels of dough obtained for plantain leaf were 20% fiber, biogas-70% (400 mL g^{-1} TS) and compost-10% For the shell of the areca recovery was 50% fiber, biogas-45% (250 mL g^{-1} TS) and compost 5%[7].

Therefore, the purpose of this research was to obtain compost, biol and biogas in two prototypes of aerobic and anaerobic pilot scale biodigester using the organic solid waste from a hotel in the city of Cartagena de Indias, evaluating its quality by means of physical and chemical parameters, establishing its characteristics. Similarly, the kinetic of microorganisms was monitored in order to guarantee the microbiological quality of the compost.

2. Experimental

The incidence of temperature, pH, moisture, aeration and the use of different amounts of inoculum on the quality and quantity of compost obtained was studied, following a 2^k experiment design, with two levels and two factors (quantity of inoculum and type of digestion) (See table 1). Measurements were made of variables throughout the process, physical (Color, odor and humidity)-chemical (%C, %N, %P and %K) analyses performed at the end of the process, and identification and counting of mesophilic bacteria, fungi and coliforms of samples from days 3,16,18 and 35 of aerobic composting.

Table 1. Design of experiments

Type of digestion	**Experiment**	**Inoculum ratio Orgánicmatter: Inoculum (g)**
Aerobic	1	1:0
	2	1:1
Anaerobic	3	1:0
	4	1:1

A total of 4 experiments were performed comparing the compost obtained with different types of digestion and different inoculum ratios. Where the influence of inoculum use and monitoring of temperature, pH and humidity variables is demonstrated, the aim was also to demonstrate that it was possible to obtain the biogas by-product using anaerobic biodigestion without inoculum[8].

2.1 Compost, biol and biogas production

Discontinuous flow acrylic biodigesters were used, at a pilot scale of 12 L, which had holes for the exit of leachates (biol) with diameter of 0.75 in with a pipe with valve for its collection. The anaerobic had holes in the walls with a diameter of 0.5 in, which was the value set for walls with a thickness of 3 in; on the other hand, the anaerobic had holes of 0.5 in at the top with a polymer hose connected to an inverted water bottle in a container with water, and thus measured the volume of biogas by displacement. Inside the biodigesters, 2 kg of raw material were placed for the production of compost and by-products. The turning in the anaerobic biodigester was done with blades.

2.2 Microbiological analysis

Brilla Broth was used, along with the Brilla and Mac Conkey agar types. Initially 400 mL of theBrilla broth was prepared in an autoclave for 1 h, then 10 mL of peptone broth was deposited in a test tube and 9 mL in 8 more tubes. A sample of 10 mg of compost was then taken and added to the first test tube, the mixture was stirred and after 30 s a serial dilution was performed where 1 mL was taken in each series until the ninth tube was reached. This procedure seeks the growth of mesophilic bacteria, fecal coliforms and fungi in the sample. After a 24 h incubation, microorganisms were observed and the two types of agar were prepared in an autoclave. Once ready, 5 mL of each agar were poured into 9 Petri boxes (9 for each agar), after 30 min samples were taken from the different test tubes and spread out in separate Petri boxes. Brilla agar was used to identify colonies of mesophilic bacteria and fungi, while Mac Conkey agar was used to identify colonies of fecal coliforms. The prepared petri boxes were taken to an incubator for 24 h for counting using the most likely number method[8].

2.3 Evaluation of the quality of compost and by-products

Initial experiments lasted 35 days, while aerobic/non-inoculum experiments lasted 10 days. During the performance of the aerobic experiments, daily temperature measurements were taken, with respect to the moisture and pH measurements, an average of two weekly measurements were taken. Biol was collected every 3 days in aerobic experiments to prevent the accumulation of leachate, which could generate bad smells and growth of unwanted bacteria[9]. In order to minimise the time that compost could be exposed to the outside in anaerobic experiments, the collection of biol and biogas was done on the same day, taking into account the volume displacement that was shown in the biogas collection bottles.

3. Results and discussions

3.1 Evaluation of the quality of the compost obtained

The composting process was carried out in a series of different microorganisms with the aim of degrading organic matter. Therefore, the monitoring of these microorganisms in succession is key to the effective management of the composting process, the rate of biodegradation and the quality of the compost given that the appearance of some microorganisms reflects the maturity of the compost[10]. In the initial experiments, there was a composting time of 35 days, except for the aerobic/non-inoculum (ANI) experiment, which lasted 10 days. In conducting the aerobic experiments, daily temperature measurements were taken and recorded in Figures 1 and 2, with respect to moisture and pH measurements two weekly measurements were taken on average.

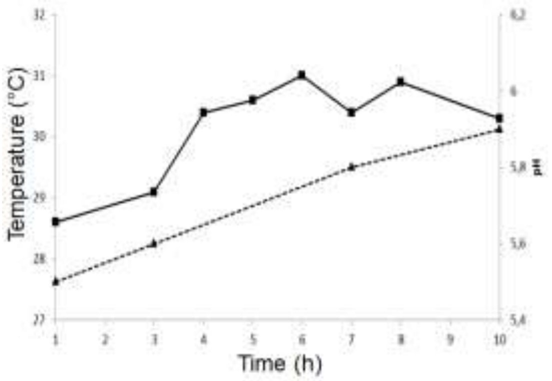

Figure 1.Temperature (—■—) and pH (--▲--) in composting time ANI.

The aerobic experiment without inoculum ended earlier because it had a very rapid putrefaction; on the fifth day a white layer appeared which spread all over the compost as the days passed. Its initial temperature was 28.6°C and the highest temperature recorded 31°C on day 6, the pH showed a constant increase starting at 5.5 and ending at 5.9 as shown in Figure 1. The little increase in temperature caused the early proliferation of fungi and the formation of sludge, which prevented the correct exit of leachate from the experiment, which caused accelerated putrefaction of the experiment.

The aerobic experiment with inoculum (AWI) ended in the expected time and reached temperatures similar to those reported by Eljaiek-Uzola and Quiñonez-Bolaños[9], showing that despite not reaching the thermophilic stage (60°C - 70°C) it is possible to obtain good compost using biodigesters, always remaining in the mesophilic range (<45 ºC). There was an increase in temperature between days 1 and 12 (from 30.1°C to 39.2°C), and a decrease between days 13 and 35 (from 38°C to 26.1°C), while the pH showed an increase from the beginning (6), ending at a basic pH of 7.8 as shown in Figure 2. The other experiments were carried out at the desired time and yielded favorable results in terms of the physical and chemical characteristics of the compost.

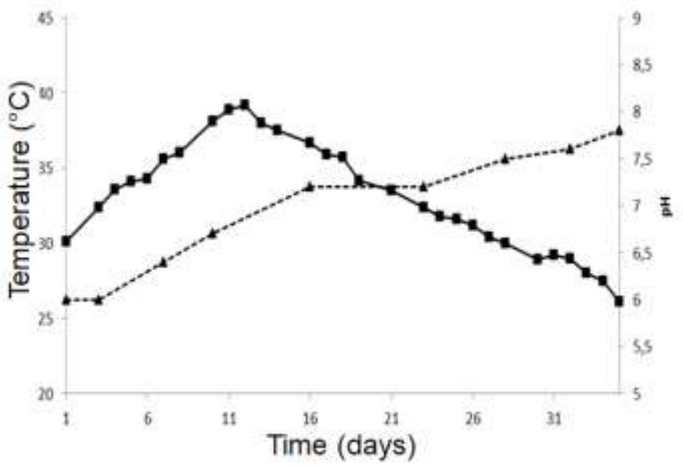

Figure 2.Temperature (—■—) and pH (--▲--) in AWI composting time.

Microbial activities are strongly influenced by pH, and it is suggested that a neutral pH is optimal for the composting process. The progressive increase in pH during experimentation is possibly due to the degradation of acids and alcohols together with organic content and production of humic substances[8, 11].

Table 1. Physical and chemical quality parameters

Parameters	Experiment			
	ANI	**AWI**	**ANI**	**AWI**
C/N	-	24	37	21
%N	-	2.05	1.05	2.14
%P	-	0.73	0.49	0.65
%K	-	1.21	0.74	1.03
% Moisture	73	56	75	64
pH	5.9	7.8	8	7.5
Colour	Brown – Yellow	Darkbrown	Darkbrown	Darkbrown
Odour	Putrid	ground	Wetground	Wetground

Some of the raw materials used to produce compost are rich in nitrogen, but there are restrictions on retaining it. During the first stages of composting, nitrogen is volatile and therefore cannot be absorbed by plants when the compost is finally applied to crops. Several factors contribute to nitrogen volatilization as ammonia: temperature, C/N ratio, mixing, aeration and pH[12, 13, 14].It was observed that the inoculum experiments reached a C/N ratio that is within the optimal levels, while the non-inoculum anaerobic had a C/N ratio that exceeded the optimal levels due to its low nitrogen content. As for the percentages of phosphorus and potassium, it can be seen in Table 2 that in experiments with inoculum use the percentage of nutrients is higher and that the moisture values were higher in anaerobic experiments due to the lack of aeration and flipping, causing a characteristic smell of wet soil.

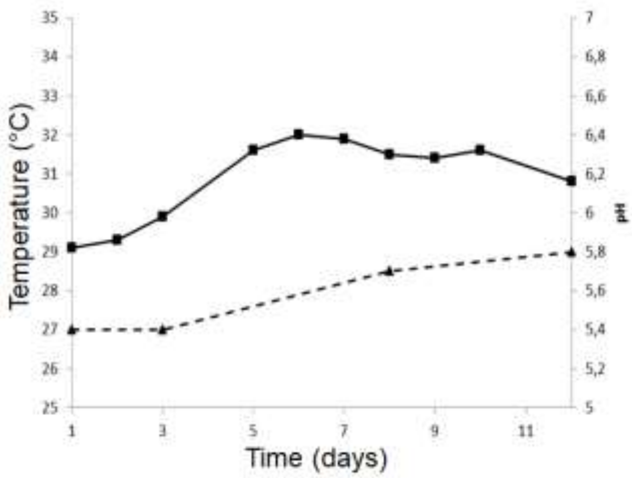

Figure 3.Temperature (—■—) and pH (--▲--) in the composting time AWI (replica).

The replicas were carried out at the same time as the previous experiments (35 days), except for the aerobic experiment without inoculum, which had a composting time of 12 days, little increase in temperature (Ti=29.1°C and Tm=32°C) and the appearance of fungi on day 3, as shown in Figure 3.

The behavior of the replicas shown in Figure 4 was similar to that of the initial experiments, since it presented the behavior in the form of a temperature bell and an increase of pH until ending in a basic pH. Showing that the use of inoculum potentially influences the production of quality compost. As for the aerobic experiment without inoculum, the need for a significant increase in temperature along with pH is clear, to avoid the early appearance of fungi, which generated the appearance of sludge that makes it difficult to leave leachate and generate nutrient decomposition at the beginning of the process[15].

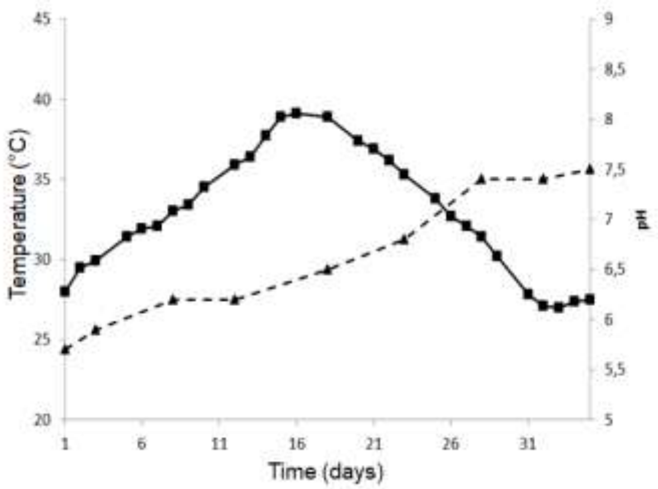

Figure 4. Temperature (—■—) and pH (--▲--) over AWI composting time (replica)

When performing a statistical analysis of the temperatures obtained in the aerobic experiments with inoculum, it is observed that they showed a behavior in the form of bell as reported in the literature. On days 19 and 21, the largest standard deviation (1.6 and 1.7 respectively) occurred due to the addition of 50 ml of water on day 18 in the first experiment, which caused a drop in temperature of 1.5°C for day 19 and 1.8°C on day 21.

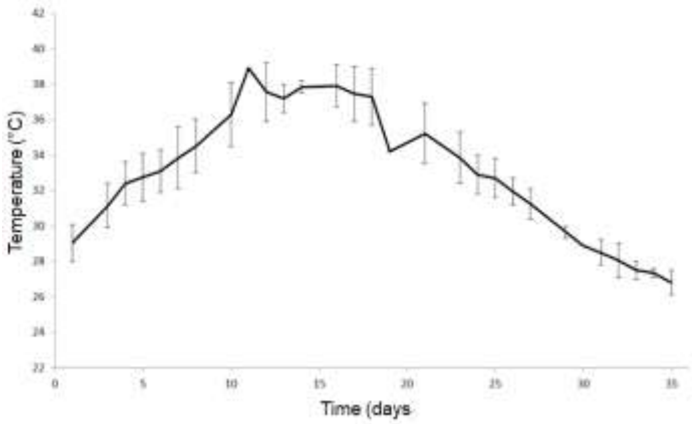

Figure 5.Statistical analysis of temperature.

It can be affirmed that at the end of the process, the temperature tends to be between 26 and 28 degrees Celsius, as can be seen in Figure 5, where it is observed that from day 30 to day 35, the smallest variations of the standard deviation are present. Based on the results of carbon/nitrogen ratio, %P, %K, odor and color shown in Table 2, it can be concluded that the composting process tends to stabilize the temperature range from 26 °C to 28 ºC, which serves as an indication for the completion of the process.

The process is maintained in the thermophilic temperature range, the values recorded for C/N are among the values allowed by Solid Waste Management (SWM) rules[16], in addition, they are consistent with results obtained in other studies, evidencing that the loss of nitrogen in ammonium form during composting, indicating that mature compost was obtained with a high nitrogen content as nutrient and a high fertilizing value[17, 18, 19].

2.3 Evaluation of the microbiological quality of prepared compost

For the analysis of process microbiology, samples were taken from aerobic experiments on days 3,16 and 35, the data of which were recorded in tables 2 and 3.

Table 2. Quantities of microorganisms in organic fertilizers

Microorganismo	Mínimum	Maximum
Mesophiles (UFC mL^{-1})	0,1	0,35
Fecal coliforms (UFC mL^{-1})	3	10
Mushroom	No presence	No presence

According to Table 3, at the beginning of the process there are coliforms that are contributed in greater quantity by the inoculum, also seen the early growth of mesophilic bacteria that are responsible for starting the degradation of organic matter simpler. In the middle of the process, fungi are present, which take care of the carbohydrate degradation. The values shown in Table 3 were obtained by the final compost, and are within the permitted ranges of microorganisms for organic fertilizers[20].

Table 3. Microorganism monitoring for AWI experiment

Microorganism	AWI			AWI Replica		
	Day 3	Day 16	Day 35	Day 3	Day 18	Day 35
Mesophiles (UFC mL^{-1})	4.3	1.46	0.26	2.56	1.25	0.14
Fecal coliforms (UFC mL^{-1})	13.5	11.2	8.75	12.4	11.8	9.47
Mushroom	-	No presence	-	-	No presence	-

Similar behaviour was observed in the replica experiment. The notable difference is found in the number of mesophilic bacteria and the reduction of faecal coliforms, which are below the values shown by the initial experiment, from which it can be concluded that by promoting a significant growth of mesophilic bacteria at the beginning of the process, a greater reduction in the number of coliforms in compost can be guaranteed, 2015)[21].

According to the standardized effect Pareto diagram in Figure 6 for the C/N ratio, it can be inferred that the most incident variable in the composting process is the amount of inoculum incorporated, which is because the C/N ratio is crucial for the development of microorganisms during composting because it provides the source of carbon and nitrogen needed for growth[22]. In this context, the C/N ratio is a measure of the degree of decomposition due to carbon to CO2 degradation during the high-speed degradation stage, leading to a decrease during the composting process because the degradation rate C is higher than the mineralization rate of N[23]. Thus, an excessive C/N is associated with a nutrient deficiency for the microbiota and a low C/N implies the release of several undesirable compounds such as odours or salts, which are unfavourable for plant growth[24].

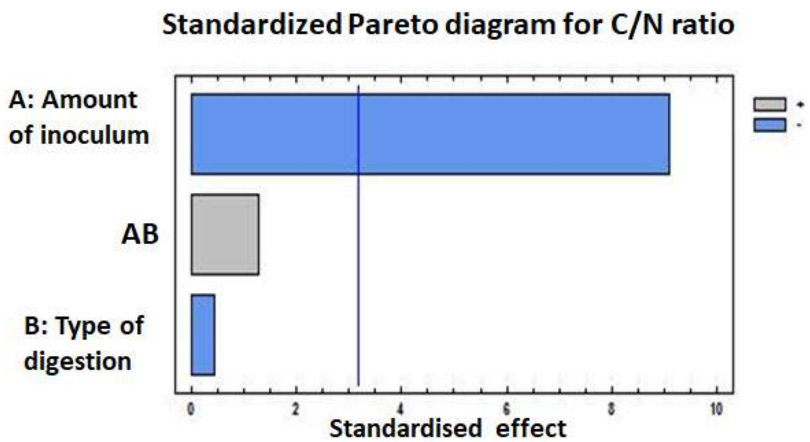

Figure 6.Standardised effect Pareto diagram for the C/N ratio in compost production.

2.4 Biol and biogas produced evaluation

Biol and biogas are by-products of anaerobic digestion of organic compounds and their composition, which depends on the digested substrate, operating conditions and the type of technology used, can be as follows: 50-70% methane (CH4). 30-40% carbon dioxide (CO2). ? 5% hydrogen (H2), sulfuric acid (H2S), and other gases[25].The number of by-products obtained was monitored by monitoring the volume produced; the results are reported in Table 4:

Table 4. Quantity of by-products

By-producto	Experiment				Replicates			
	ANI	AWI	ANI	AWI	ANI	AWI	ANI	AWI
Biol (mL)	20.4	351.3	164.6	192	25.9	381.15	141.5	223.2
Biogás (mL)	-	-	6	549	-	.	10	447.1

The data collected from Table 4 shows that the presence of inoculum generates a higher production of by-products, also depending on the aerobic experiment on the moisture content and type of organic matter used, since initially there was a high content of potato and vegetable peel, while the replica had a high content of fruit peel. With regard to biogas production, it was demonstrated that the generation of gases is largely due to the use of inoculum and different quantities can be obtained by the use of another type of inoculum, since cow manure contains mostly grasses and grasses which provide high nitrogen content[26]. The composting process to which the raw material was subjected makes the substrate more likely to be degraded; therefore, in both treatments there is greater degradation of organic matter which was reflected in the amount of by-products obtained when the process is carried out in the presence of inoculum[27].

3 Conclusions

The temperatures reported by the experiments show that composting in biodigesters does not reach the thermophilic stage (60°C to 70°C), but mesophilic bacteria and fungi growth was sufficient to degrade most of the organic compounds present, since a compost with C/N ratios of 22 to 25 and acceptable nutrients was obtained; indicators that allow us to consider it as of good quality. The obtaining and quality of the compost from the experiments depended very much on the use of inoculum, being evidenced in the aerobic/anaerobic experiments with inoculum, from which a greater quantity of by-products was obtained and they complied with the optimal ranges for the chemical, physical and microbiological parameters for organic fertilizers. The collected quantities of by-products were satisfactory, demonstrating that the presence of inoculum in the anaerobic process favors the generation of biogas and in the aerobic the generation of biol.

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