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# Use of the Organic Fraction of Solid Waste: Experimental evaluation in a market square in the city of Bogotá, Colombia

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**Abstract :** This paper presents the evaluation of the best biological treatment choice for harnessing the organic fraction to reduce in this way the difficult situation of waste management in that marketplace using reactors with molasses, manure and yeast. The volume reduction of composting obtained with molasses was 54%, followed by 52% of reduction in the reactor with yeast.
**Keywords :** Waste, composting, production.

## 1. Introduction

In the world about 1600 million tons of solid waste are produced per year (Skinner, 2000), which generate serious problems, not only by progressive deterioration of the environment, but also from the economic point of view since collection, transportation and disposal costs are increasing. It is estimated that disposal, treatment and utilization services of solid waste worldwide move an annual market of 100 billion dollars, of which 43 billion correspond to North America, 42 billion to the EU and only 6 billion to South America, being the waste production 250, 200 and 150 million tons per year respectively (Cardona, 2004).

Although health problems and environmental arising from improper handling of solid waste are widely known, it has not been given sufficient weight and the development of these public services it is still largely relegated in Latin America and the Caribbean (LAC). The urban centers of the region produced daily 361 tons of municipal solid waste, which is collected between 60 to 80% and of these only 23% have acceptable health and environmental disposal. The situation of waste management is worrying, about half of the waste generated in LAC is produced by medium and small centers that tend to have greater difficulty in waste management; with a considerably impact on the environment since the disposal of this waste it is generally low. (O.P.S., 2005).

In the case of Colombia as a nationwide,approximately 30,886 daily tons of waste are generated, of which 28,580 tons (92.54% of national production) are disposed in landfillssystems or integral treatment plants of solid waste and 2,305 tons (7.46% of total production) in inappropriate dumpsplaces open, burning, water bodies and burials. At present 758 municipalities are disposing their waste in 255 landfills (58 regional) and 34 integrated solid waste facilities. (SSPD, 2008).

Bogota has a population of 7 million inhabitants generating a daily average of 6,700 tons of waste of which 5,800 are arranged in the Doña Juana landfill and 900 tons are recovered for recycling or reuse (Alcaldia de Bogotá, 2006). Of the total generated, 65 percent are organic waste and 35 percent inorganic, being very similar to the trend in the country (Alcaldia de Bogota, 2006). Part of this volume of waste comes from the market places of the city. The country's capital market has 36 seats, 18 District - owned and 18 private. The waste generation in the market places has a high share of vegetables component (greater than 50%), followed by fruits (14% average) (Cardozo, 2007). The main component of the solid waste generated in the market places comes from the marketing of agricultural products such as vegetables, herbs, potatoes, banana and fruits; waste which by its nature have a high moisture content and easy degradation, a fact that defines a short - time storage to avoid problems of odor and appearance of insects, rodents and stray animals. Storage and collection of waste before the disposal is carried out in rooms that do not meet the standards set by the Health Code for the storage and presentation of waste to the entity responsible for the picking and transport system available to the District (Alcaldia de Bogota, 2001).

Due to the foregoing, it is necessary to experimentally evaluate an alternative use of the organic fraction of solid waste generated in the Kennedy`s Marketplace, in order to observe what is the best biological treatment choice for the use of the organic fraction to reduce the difficult situation of waste management in this important market square of the city. In this sense the question that will guide this study is **¿Which of the three biological treatmentsare optimal for stabilization of organic matter of solid waste generated in the Kennedy`smarketplace of Bogotá using composting?**

Aerobic composting is used in the biological conversion of the organic fraction of solid waste produced in the market places; this type of composting produces humus, carbon dioxide, reduces the volume of waste by 50% with a retention time of 20 to 30 days and it is a net consumer of energy (Tchobanoglous, 1998). Implementing composting using different activators such as beer yeast, molasses, manure and witness with a volume less than 1 $m^3$, ***it is assumed that the optimal alternative to the Kennedy`smarketplace is aerobic composting manure,*** which is a main component and also produces in the plants major improvements in their health and performance aspects.This hypothesis is based on criteria of economy, easy transformation mechanism and revenue forecast for actors problematic (Canovas, 1993).

## 2. Materials and Methods

In order to compare four treatments for composting of organic solid waste from Kennedy`s Marketplace, to evaluate the best alternative for the composting process with a volume less than 1 $m^3$. The procedure for each of the reactors is presented to their respective composting treatment that contains the following:

**Figure 1. Composting Process In Each Reactor.**

Source: Authors

Reactor 1: Organic waste witness. Material used: 20Kg of organic marketplace waste, 0.10Kg of lime and 8 Kg of sawdust. Process: the materials were placed in layers about 10cm high, except lime was a very thin layer, arranged as follows: organic solid waste - lime - saw dust and left for six days to make the mixture in the reactor.

**Figure 2. Witness Reactor**

Source: Authors

Reactor 2: organic waste with molasses. Material used: 20 Kg of organic waste, 0,10Kg of lime, 8 Kg layer of sawdust and 2 liters of water mixed with molasses. Process: the materials were placed in layers about 10cm high, except lime was a very thin layer, arranged as follows: organic solid waste - lime - sawdust and was added at the end of 2 liters of water with molasses, and they allowed for six days for makingthen the mixture into the reactor.

**Figure 3. Reactor with Molasses.**

Source: Authors

Reactor 3: Waste organic manure. Material used: 20 Kg of organic waste, manure 4.06 Kg, 0,10Kg lime, 8 Kg layer of sawdust. Process: the materials were placed in layers about 10cm high, except lime was a very thin layer, arranged as follows: organic solid waste - manure - lime and sawdust, allowed for six days for making thenthe mixture in the reactor.

**Figure. 4. Reactor with Compost.**
Source: Authors

Reactor 4: organic residue with beer yeast. Material used: 20Kg organic marketplace waste, 0.10 Kg lime, 8 Kg of sawdust and 1 liter of water mixed with 0,02kg of beeryeast. Process: the materials were placed in layers about 10cm high, except lime was a very thin layer, arranged as follows: organic solid waste - lime - sawdust and was added at the end of 1 liter of water with yeast beer, leaving for six days to start mixing all the materials arranged in the reactor.

**Figure 5. Reactor with Beeryeast.**
Source: Authors

For the three treatments (beer yeast, molasses, manure and one witness who is the guide) studied for aerobic composting in static pile, carried out the measurement of parameters such as temperature, humidity, pH, C/N ratio, percent organic matter, total nitrogen, total organic carbon. Before discussing the results it is necessary pin down on the additions did in each one of the reactors because it will be very useful in understanding the results.

**Table 1. Additions for Reactors.**

| **Reactor 1 Witness** | | | | |
|---|---|---|---|---|
| Organicwaste | 20 | kg | 20 | kg |
| Lime | 0.10 | kg | 0.10 | kg |
| Sawdust | 8 | kg | 8 | kg |

| **Reactor 2. Molasses** | | | | |
|---|---|---|---|---|
| Organicwaste | 20 | kg | 20 | kg |
| Molasses | 0.03 | kg | 0.03 | kg |
| Lime | 0.10 | kg | 0.10 | kg |
| Water | 2 | Lt | 8.5 | kg |
| Sawdust | 8 | kg | 8 | kg |
| | | | | |
| **Reactor 3. Manure** | | | | |
| Organicwaste | 20 | kg | 20 | kg |
| Manure | 4.06 | kg | 4.06 | kg |
| Lime | 0.10 | kg | 0.10 | kg |
| Sawdust | 8 | kg | 8 | kg |

| **Reactor 4. Beer Yeast** | | | | |
|---|---|---|---|---|
| Organicwaste | 20 | kg | 20 | kg |
| Beeryeast | 0.02 | kg | 0.02 | kg |
| Lime | 0.10 | kg | 0.10 | kg |
| Sugar | 0.0042 | kg | 0.0042 | kg |
| Water | 1 | Lt | 4.25 | kg |
| Sawdust | 8 | kg | 8 | kg |

Source: Authors

The data processing includes different parameters such as pH, temperature,% humidity, total nitrogen, % organic carbon,% organic matter and carbon – nitrogen relation, analyzed by the CIIA for three treatments (control, molasses, yeast beer and manure). Statistical analysis was performed using SPSS- 15, in order to find which of the three treatment options (beer yeast, molasses, manure and one witness who is the guide) is more efficient, using as an indicator volume reduction, quality compost and the possible use could be given to this material. An analysis of variance with an interval of confidence of 95% was used, the differences in treatment were assessed with a significance value of 5%, a test of multiple comparisons of group means was used by Sheffey, linking treatment with variables as temperature, humidity, pH,% organic carbon,% organic matter, total nitrogen and nitrogen-carbon ratio to evaluate the best treatment of the organic fraction of solid waste generated in this square.

## 3. Results and Discussion

### 3.1. Statistics Analysis.

The comparison of the temperature, pH, moisture, organic carbon, organic matter, total nitrogen and carbon/nitrogen ratio averagesis based on the following hypotheses:

Ho: $\square_{witness} = \square_{molasses} = \square_{yeast} = \square_{manure}$

Against the alternative that a couple of treatments presents difference. The variance analysis table obtained for the temperature is:

**Table 2. Anova for Temperature.**

| | Sum of Squares | fd | Mean square | fc | Significance |
|---|---|---|---|---|---|
| Treatment | 16.037 | 3 | 5,346 | 0.459 | 0.712 |
| Error | 885.450 | 76 | 11,651 | | |
| **Total** | **901.488** | **79** | | | |

It can be concluded that no statistically significant difference in average temperature levels are presented in the four treatments considered ($f_c$= 0.459, p-value = 0.712).

Against the alternative that a couple of treatments presents difference. The variance analysis table obtained for pH is:

**Table 3. Anova for pH**

| | Sum of squares | fd | Mean square | fc | Significance |
|---|---|---|---|---|---|
| Treatment | 0.733 | 3 | 0.244 | 5,652 | 0,001 |
| Error | 3,457 | 80 | 0.043 | | |
| **Total** | **4,190** | **83** | | | |

It can be concluded that statistically significant differences in mean pH levels in the four treatments considered ($f_c$ = 5,652, p-value = 0.001) are presented. To detect which averages are different is used Scheffe test, finding that the average pH obtained in the control is significantly lower than obtained with molasses (p-value = 0.006).

Against the alternative that a couple of treatments presents difference. The variance analysis table obtained for moisture is:

**Table 4. Anova for Moisture**

| | Sum of squares | fd | Mean square | fc | Significance |
|---|---|---|---|---|---|
| Treatment | 251.789 | 3 | 83.930 | 1,632 | 0,189 |
| Error | 4115.142 | 80 | 51.439 | | |
| **Total** | **4366.930** | **83** | | | |

It can be concluded that no statistically significant differences occur in the average moisture levels in the four treatments considered ($f_c$ = 1.632, p-value = 0.189).

Against the alternative that a couple of treatments presents difference. The analysis of variance table obtained for the C/N ratio is:

**Table 5. Anova for the relationC/N**

| | Sum of squares | fd | Mean square | fc | Significance |
|---|---|---|---|---|---|
| Treatment | 158.447 | 3 | 52,816 | 0.864 | 0.463 |
| Error | 4887.729 | 80 | 61.097 | | |
| **Total** | 5046.176 | 83 | | | |

It can be concluded that no statistically significant differences occur in the average levels of the relation C/N in the four treatments considered ($f_c$ = 0.864, p-value = 0.463).

Against the alternative that a couple of treatments presents difference. The variance analysis table that was obtained for total nitrogen is:

**Table 6. Anova for Total Nitrogen**

| | Sum of squares | fd | Mean square | fc | Significance |
|---|---|---|---|---|---|
| Treatment | 0.080 | 3 | 0.027 | 1,335 | 0,269 |
| Error | 1,593 | 80 | 0,020 | | |
| **Total** | 1,673 | 83 | | | |

It can be concluded that no statistically significant differences occur in the average levels of total nitrogen in the four treatments considered ($f_c$= 1.335, p-value = 0.269).

### 3.2 Test Results Analysis

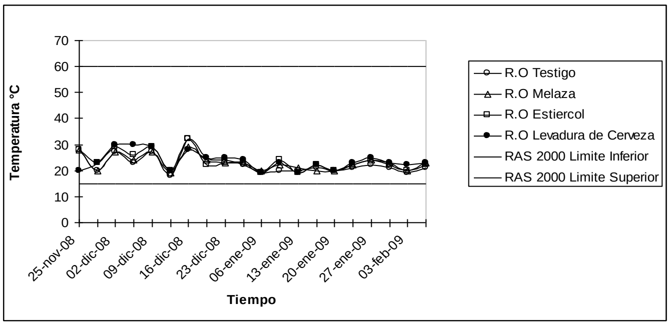


**Figure 6. Variability Temperature in Function Time for the Four Reactors.**

Figure 6 shows that the experimental design did not exceed 40 °C for any of the treatments which evidence that in the experimental composting process have not developed thermophilic microorganisms phase. The next step was to create a model that would predict which values for variables embedded in the experimental process, could reach this stage. The reasons why the three treatments and the witness did not show a further increase to 40 °C temperature could be given for the following reasons: When the temperature did not exceed 40 °C since the beginning of the process is indicating that probably there is not enough nitrogen in the cell to activate the process (INTEC, 2000), the average total nitrogen reported in the four reactors was 0.92%, this being a low value on total nitrogen content. In the period when composting developed it was rainy, prompting a decline in environment temperature and a relative humidity increase, resulting in a decrease in the substrate temperature in composting. Another reason is that the outside of a composting mass will be cold temperature and the temperature will vary between room temperature and the surface temperature at the core of the mass to 15cm from the surface. So in the way as the mass in the cell is higher, higher will be the volume in the central core reaching suitable temperatures for destroying pathogens and weed seeds. (Porras, 1999). The lowest temperature values recorded after performing the re - aeration of the system and adding water to maintain the humidity, and thenthe temperature increased due to homogenization of the material in each of the reactors.

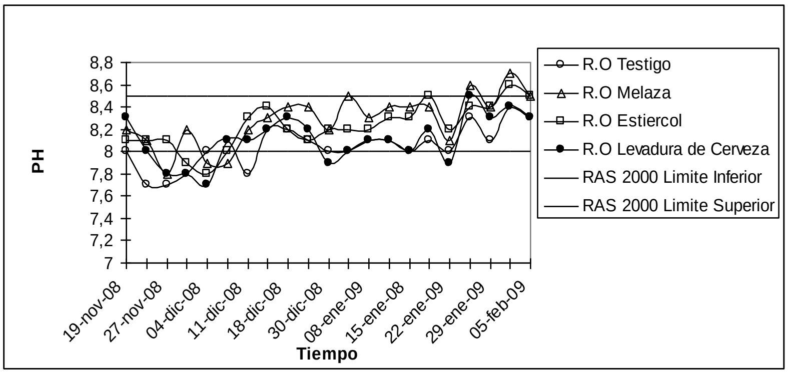


**Figure 7.PH Variability in Function of the Time for the Four Reactors.**

According to some authors pH evolution in composting has three phases. During the initial mesophilicphase a decrease in pH is observed (Figure 7) due to the action of microorganisms on the labile organic matter, producing a release of organic acids. Eventually, this initial decrease in pH can be very pronounced if anaerobic conditions exist, due of the amount of organic acids that will be form. In a second phase a progressive alkalinization of the medium occurs due to the loss of the organic acids and the generation of ammonia from the breakdown of proteins (Sánchez –Monedero2001). And in the third stage the pH tends to neutrality due to the formation of humic compounds having buffer properties. The data obtained in the pH for four reactors can be analyzed as follows: At the beginning of the composting process in each reactor, the pH dropped below 8 approaching a neutral pH. This is because early in the process turning is performed in each of the reactors allowing aeration in the mixture, because if anaerobic conditions are created at some point, the released of organic acids cause lowering the pH below 7, but that condition did not happen. pH evolution in each of the reactors presented three phases. In the initial mesophilicphase was observed a pH decreased corresponding to the first four weeks of starting the process because of the action of microorganisms on the most labile organic matter resulting in a release of organic acids. This decrease in pH was not very pronounced since the system conditions were aerobic because the whirls made early in the process. In the second phase a progressive alkalinization of the medium was presented, due to loss of organic acids and generating of ammonia from the decomposition of proteins. And in the third phase where pH tend come to be neutral, it didn`t occurred, otherwise the pH raised further due to an increase in the moisture content in the reactors. The decrease in pH in the third phase at neutral pH was not made in this investigation because there was an increase in moisture and pH levels were above 7.5 and with this value can only survive mushrooms. In each of the reactors the pH did not fall below 7 and can be analyzed that the aeration in the four reactors was adequate, preventing the generation of anaerobic processes in the reactors.

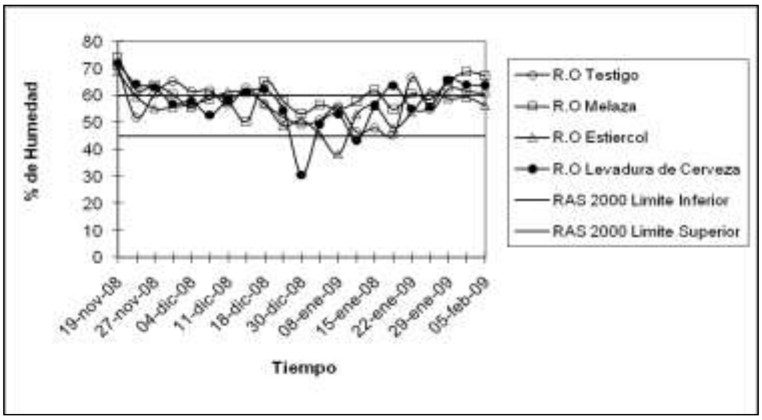


**Figure 8. Variability Moisture % In Function of Time for the Four Reactors.**

Figure 8 shows that the percentage of moisture remained most of the time within the limits given by the RAS 2000, except for the last days were the moistureincreased. Also the figure shows a significant drop in the percentage of moisture in the reactor with yeast due to the decrease in moisture could be responsible for the suspension of microbial activity and the decreased of the assimilable organic matter. In this study it remained adequate moisture level because is important for microbial activity, humidity values below 20% causes a decrease in microbial activity. According to the above can be discussed: The optimal value for the moisture in compost as the RAS 2000, should be between 40% - 60%, can be seen in Figure 8 that most of the data is within the range settled down. The ratio of moisture left with 71.5% of a substrate with the passage of time, the moisture content was decreasing, as the weight; this weight loss is assumed, for the production of compounds such as carbon dioxide and water evaporation (Castrillon, 2008). When making the chopped waste to begin the process of composting organic waste from the Kennedy`smarket square we can observed a high percentage of humidity,which involved extending the chopped material in thin layers to lose moisture by natural evaporation, allowed spread on a plastic for five days and then placed in each reactorwell by mixing with dry materials such as sawdust, always trying to maintain an adequate C/N ratio. The osmotrophynature of the vast majority of physiological groups means that less than 20% moisture, pass populations stationary phases or in extreme conditions to death phase, slowing or stopping the composting process. Adequate moisture for each stage depends on the nature, compaction and texture of materials in the cell. Fine and fibrous materials retain more moisture and increase the contact surface area (OMS, 1999).

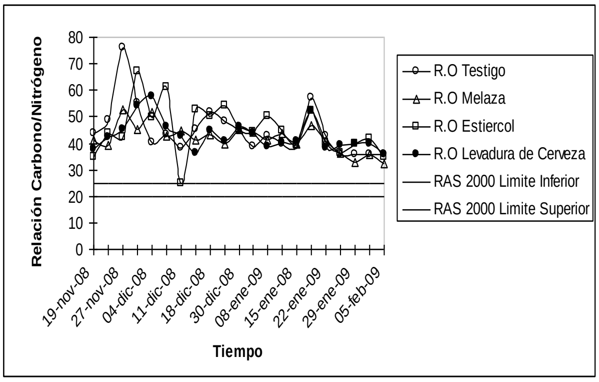


**Figure. 9. Variability of Relation C/N for the Four Reactors.**

In Figure 9, the relation C/N decreases during composting because the carbon is lost as $CO_2$ by microbial respiration, while most of the nitrogen is recycled. A C/N ratio too high limits the amount of nitrogen available for cell growth at the expense of organic matter, which leads to inactivation process, otherwise initially accelerates microbial growth and decay of organic matter (Moreno, 2009). On the other hand, the value of C/N ratio cannot be taken as an absolute indicator of maturity, due to the relatively large variation between 5 and 20, which depends among other factors on the nature and the origin of the material range. In this research as of other authors (Hirai et al., 1983; Seekins, 1996; Jimenez and Garcia, 1989;Zuccuni et al., 1987) final value near 15 is appropriate and is in the accepted quality range for the end product of compost (Pino, 2005). The C/N of the mass ratio is an important factor to control for proper degradation; in the composting process it is important to avoid high values of this relationship that prevent extensive microbial activity develops, slowing the process. However, ratios C/N low lead to volatilization of $NH_3$, which causes loss of N and odors (Zhu, 2006).

According to the above can discussed: Bacteria and microorganisms responsible for aerobic decomposition require greater presence of carbon than nitrogen to create an optimal environment for growth and development (OMS, 1999). According to this the four reactors had high carbon content and low nitrogen content, making the ratio C/N being in some texts in Table 27?above ranges except for the ranges established by Infoagro and George Tchobanoglous. In the four reactors is seen that the ratio C/N decreased at the 12 week and remains, Nitrogen begins to increase above one, because there is an increase in microbial activity by raising the temperature two degrees higher than normal in previous days. The material to be composted presented a C/N ratio above 30, indicating that required for biodegradation more generations of microorganism and a necessary time to achieve a C/N ratio of 12-15 ends (considered appropriate for agronomic use). Figure 9 shows the evolution of the ratio C/N during the experimental work of the four reactors, where a gradual decline was presented during composting, this may be due to % carbon decreasedand to % nitrogen increasedalong the process; although it should be noted that at the beginning of the process the nitrogen content is very low, so these ratios C/N are high. According to the optimal ranges as RAS 2000, the ratio C/N should be between 20-25, compared to experimental data this ratio is above the set range, so it can be presumed that the product obtained at the end of the process requires more time to mature and with this manner obtain an acceptable range of quality for the final product of compost.

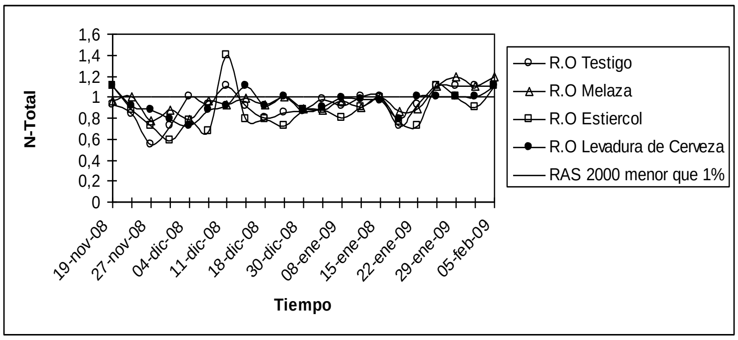


**Figure. 10. Variability of Total Nitrogen for the Four Reactors.**

In Figure 10, Total Nitrogen can be discussed as follows: According to the RAS 2000 Total Nitrogen for stable compost should not be greater than 1%, indicating that the total nitrogen was maintained in most of time within range (Figure 10). Manure and yeast presented an increase in total nitrogen at 1.1% in the first sampling, one might think that is the heterogeneity of the waste in the reactor with yeast, which could contain green plant debris with presence nitrogen and manure is due to its composition which is characteristic, the presence of nitrogen. In the seventh and eighth week increased nitrogen could be given by the biological activity of the process, as they promote higher values of biomass carbon and respiration was also presented, (Burbano, 1989) and in the last four weeks showed an increased of nitrogen above one, associating it to the use of nitrogen by microorganisms to synthesize cell protoplasm and the fact that when microorganisms die increase the concentration of recyclable nitrogen during the process. Among the last four weeks we found an increased of total nitrogen which correlates with an increased with organic carbon; however theratio C/N is very high which would imply nor presence of microorganisms activity, then the hypothesis that may arise is that due to the death of microorganisms these break down, which would justify the increase in carbon and nitrogen.

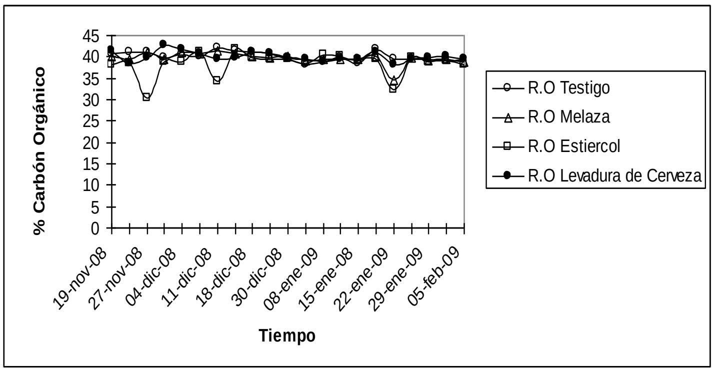


**Figure. 11. Variability Percentage of Total Organic Carbon for the Four Reactors.**

In Figure 11, for the analysis of organic carbon could wediscuss the following: The rate of decrease of the percentage of organic carbon in the four guiding is very low, because in the composting process in the four reactors cannot reach the thermophilic phase, because in a longer thermophilic phase the activity of the microorganisms is greater. (Iglesias, 1992). For this reason the percentage of organic carbon did not change much since the experiment failed to reach thermophilic phase but instead remained in the mesophilic phase. In the three reactors (white, molasses and yeast) since day twenty seven (27) organic carbon content stabilizes near 40% values and around 39%for manure. Behavior variation of organic carbon through the process can be attributed to the higher consumption of the carbon source in the first few weeks, when microorganisms used sugars and other readily degradable substances; then the decrease is less as they start using cellulose and hemicellulose (Melgarejo, 1997).

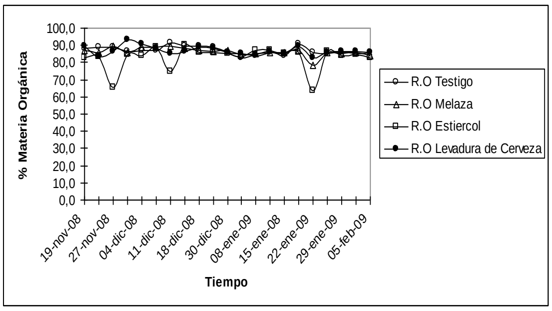


**Figure. 12. Total Percentage Variability of Organic Matter tor the Four Reactors.**

In Figure 12, for the analysis of organic material we could discuss the following: a quick distribution of available organic matter is presented as aresult of temperature increase during composting and nitrogen compounds by microorganisms. As organic matter is stabilized, microbial activity and decomposition of organic matter gradually decreases with temperature to ambient levels, which marks the end of the thermophilic phase (Raut, 2007). Levels in the percentage of organic matter not decreased because in the four reactors did not reach temperatures above 40 °C, where initiates the thermophilic phase, which could cause an inhibition of the microorganisms and the not decreased of the decomposition of the organic matter. In Figure 12, variations occurred in the four reactors. If there was a loss of organic matter data would decrease because it is caused by microorganisms that initially consume readily degradable or water - soluble carbon source of energy and the transformation of carbon in $CO_2$. This do not happen in the reactors. Heterogeneity of organic matter is transformed, after a composting period including bio-oxidative and maturation phases, it stabilized in a partial final product through mineralization and humification (Gray, 1971). From this we can analyze the experimental work also showed heterogeneity of organic matter to be composted in the reactors which should create stabilization in the maturation phase which it took him to the four reactors.

## 4. Conclusions

According to the experimental results presented, the working hypothesis of manure as best biological treatment is rejected. In contrast, as relevant scientific result, it is found that the process with molasses was the most efficient treatment followed by yeast. This follows by reduction and volume obtained by measuring variables fluctuated within the range set by the RAS 2000 as moisture, pH, total nitrogen and temperature. The data obtained for the ration C/N for molasses, were more stable compared to other treatments, however, it did not reach the values suggested in RAS 2000. The volume reduction composting for molasses was 54%, followed by a 52% reduction in the reactor with yeast.

Significantly, nitrogen is a good indicator of the mature compost necessary for protein synthesis and the development of beneficial microorganisms. The more you approach the value of one, it means that you are not wasting nitrogen leaching (nitrate) or gases (ammonia) or production of odors. In our case, nitrogen levels were close to the value of one. Biodegradation of materials during composting depends on microbial activity and this in turn is related to the moisture content in each of the reactors, according to the results this variable was kept in a range of 50% and 70%, and these values are adequate to carry out biodegradation.

Variables such as temperature, total nitrogen, ratio C/N, organic matter and organic carbon for treatment with manure have a higher standard deviation than the other treatments being this more changeable than the average. Therefore it can be concluded that appeared less stable compared to the other treatments. The development of composting in the four reactors requires more time to achieve compost maturation so that it can be used as organic fertilizer or soil conditioner. This is because the results of the ratio of carbon nitrogen not lower than 30 (Figure 15?) indicating that it requires more time for such a ratio C/N of 20, this being indicative of maturity acceptable compost according to RAS2000.

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