(193) AUTO-MANAGEMENT OF ORGANIC WASTE FROM A SMALL COMMUNITY BY COMPOSTING. THE EXPERIENCE OF VAL MIÑOR (GALICIA, SPAIN).

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EXECUTIVE SUMMARY

This project presents composting as a preferable option for the achievement of the integral treatment of the organic waste created in a small community. This waste comes from forest management (to reduce the risk of forest fires) during summer months. Other waste products like manures and agriculture remains that come from small farms in this area are included too. Such waste products lacked any type of management previously.
Composting makes easy the use of these waste products with a low cost and low technology solution. Resulting compost will be used in the recovery of areas damaged by forest fires.

The first step was analysis of different wastes produced in the Val Miñor community (Galicia, Spain): remains of vegetal material rejected by forest management, remains of seaweed from beach cleaning, mink manure, horse manure and exhausted growth substrate from *Pleurotus ostreatus* culture. These analysis are intended to detect potential pollutant recalcitrant elements which could affect the degradation process or the final compost quality.

The selected waste products were treated by composting through a dynamic biopile system in large proportions. Each biopile was built on that base, alternating layers of waste with layers of bulking agents (forestry remains). This biopiles-biofilter system allows the achievement of a large efficiency in the material oxygenation process, leachate control and pollutant gas emissions. All the process was carried out with non-specific machinery, so forest management groups can manage the process without high initial investments.

These biopiles were monitored by taking oxygen and temperature measurements in several places, and physic-chemical and biological parameters control while the biopile was turned over.

Up to date three piles have been built with different wastes (seaweed, green waste and horse manure), with the process lasting approximately 6 months.

Initial analysis detected wastes with a high heavy metal content. These levels of heavy metals allowed the reject of some wastes in order to prevent the final compost contamination.

Bearing in mind the results obtained up to now, we would like to emphasize the excellent results of the seaweed and manure co-composting with vegetal refuses. These show a better microbial activity rate, good mineralization level and overall quality of the final compost, superior to that of the composting of forestry remains.

Results obtained up to date suggest that co-composting is an optimal treatment solution for the waste products produced in this community since the mixing of different materials leads to the optimisation of the composting process, the improvement in microbial activity rates, as well as the optimisation of composting time and a better management costs when compared to treating the same wastes separately.

1 INTRODUCTION

Composting is a process where the organic matter is degraded and stabilized. With this process a volume and weight reduction of the initial waste is achieved, making much cheaper its transport and handling. The resulting material, "compost", is stable and valuable as an organic amendment for soils and cultures.
Scientifically, composting is defined as a bio oxidative and controlled process, where a heterogeneous organic material, on solid state, suffer a thermophilic stage with a transitory production of phytotoxins, having as a result products like carbon dioxide, water, minerals and stabilized organic matter denominated "compost". (Zucconi & de Bertoldi 1986)

Galicia is one of the most densely forested regions in Spain. The high frequency of forest fires in wood areas in the last years has destroyed an important part of the Galician forest area, and resulted in soil degradation.
In order to prevent forest fires risk and make a better management of forestry resources people make cleaning and maintenance jobs in woods of rural areas. This cleaning produce a high quantity of forest remains.
Rural areas have other waste products too, those from agricultural activities and cattle. Coastal areas have a lot of seaweed remains as a result of summer beach cleaning. Right now these waste products aren't subject to any treatment or management. They are directly applied to the soil juts to get rid of them.

To solve these problems we make an experimental experience in Val Miñor forestry community. This experience try to implement a management wastes system with wastes that not be treated until the moment with a simple and low-cost technical like composting. The final product of composting process, denominated "compost", is stable, moistured and with a high value as organic amendment and it will be apply on site to regenerate burned areas by forestry fires.

To design an experimental composting trial in large proportions, we carried out an organic waste search in the Val Miñor area. These waste products have been analysed to check they were suitable for the composting process.
Available wastes were: horse manure, mink manure, exhausted growth substrate from *Pleurotus ostreatus* culture (straw), seaweed and green wastes.
The most abundant waste was green waste, because it contains rests of prune and gardens community management. Green waste includes branches, dead leaves, bark, etc. This vegetal waste has a long composting time because it has a high content of lignocellulose compounds. We try to reduce composting time by mixing this with other organic wastes to favour optimization process and time length reduction.
To make a different time composting study it suggest an experimental prove based on a open composting system with three dynamic biopiles with different waste composition.

Piles were monitored with regular measurements of oxygen and temperature rates at several points. The evolution of these parameters determines the moment to "turn over". Turn over operations were perfomed with the aide of non specific machinery (like a bulldozer, for instance). This fact reduces initial economic investment in the experimental test, but increases the time to be invested in such operations. Cost reduction is very important so that small forestry communities with low budgets are capable of investing in this type of experiences.

Turning over the piles with this machinery is a simple process where the biopile structure is destroyed and built again. It produces a waste round movement, from inside to outside and vice versa. This process is also used to control the evolution of the temperatures and oxygen rate inside the material, to achieve its correct evolution during the process. This practice allows a better mixing of the waste materials and a homogeneous composting matrix.
During the turn over operations we accessed the inner of the pile, and samples were taken in several points. The following analysis in the laboratory allows for the monitoring of physic-chemical parameters, like moisture content, volatile solids, C/N, pH, respiration index, etc.

Research objectives:

- Composting capability of the vegetal waste products, both alone and mixed with more labile waste products
- Possibilities of developing the process employing the means at the disposal of the forest management communities and groups
- Evaluation of the developed composting process

2 METHODOLOGY:

Previous analysis:

The first step was to conduct a search for available organic waste in this area that could be used like co-substrate in green waste composting (green waste coming from forestry activities). Green waste was analysed to detect any possible recalcitrant pollutant element (like heavy metals) that could affect the degradation process and final compost quality.

The available waste products were: seaweed, horse manure, mink manure, exhausted growth substrate of *Pleurotus ostreatus* culture. Out of these, the most appropriate waste products were selected to be included in the composting trials.

Experimental design and biopiles assembly:

It proposed an experimental design based on three dynamic biopiles in large proportions to compare the potential of chosen wastes to composting process.

The co-substrates chosen were:

- Horse and cow manure mix
- Seaweed remains collected in beach cleaning

The final dimensions of the biopiles change according to the quantity of waste available at the moment of the test. The mixing proportions of waste: bulking agent were made in volume and changed according to waste composition.

Final volume and final proportions biopiles were:

- Pile ALG: green waste and seaweed (2:1) (65 m^3)
- Pile EST: green waste and manure (1:1) (44 m^3)
- Pile VERD: green waste (100 m^3)

Air flow is one of the most important control parameters of the composting process because it ensures the correct evolution of microbial aerobic population and the good evolution of the temperature. To make air flow easier, a bed of branches (one for each pile) with a plastic below was prepared, the latter in order to prevent soil leachate filtration. This base of branches forms ducts to favour convective airflow created by the temperature differential between the compost and the ambient air to make easy passive ventilation (Barrington et al., 2003).
Due to lack of specific machinery to make mixing wastes were disposed over that base alternating layers of bulking agent (green waste) and layers of waste. The system employed for the construction of the biopiles is called biopile-biofilter (figure 1). The first layer is always built with bulking agent. It acted like a moisture stock and helping to keep a correct moisture level all along the process because it receives possible leachate produced during the first composting stage. This stage is characterized by a strong hydrolysis of the organic matter with a water and CO_2 production. The final cover with bulking agent gave thermal isolation to the biopile and acted as a biofilter agent retaining organic volatile compounds and avoiding undesirable smell.

Figure 1: The bed of branches to be set as the base of the pile and the layer assembly.

Monitoring and sampling:

Once built the biopile the control process started. Several measurement points were chosen depending on the biopile's shape and size to take oxygen and temperature measurements. The number of sampling points change depending on

final shape and size of biopiles to detect possible gradients and it assure a correct control of the thermal and aerobic conditions into the material and a good monitoring process.
Composting causes a waste mass reduction in volume and weight, so each turn over operation must be adjusted to the morphology of the pile to minimize the surface/volume proportion and decrease the border-effect and so favour the performance of the process.
Each point was analyzed at two depths, 1 and 1.5 metres. These measures could be changed depending on the final biopile height. During the first stages of the process we controlled the temperature and oxygen rates weekly. This time interval rises from a week to two weeks, as the materials degradation progresses, since the speed of the process drops due to the lack of easily degradable organic matter. This leads to temperature changes happening more slowly.
The monitoring process is kept until the biopile temperature falls and remains stabile. This indicates the maturing stage has begun.

Figure 2: taking samplings during the turn over operation of pile (2a). Measuring temperature and oxygen (2b).

Samples were taken at the beginning of the process, during each turn over operation, and at the end (figure 2a). Each biopile was sampled in three different places: north, middle and south, to obtain representative measures of the total material.
The turn over operations were determined by the temperature and oxygen evolution inside the biopile. With each turning over the whole biopile was destroyed and mixed again. This caused a re-oxygenation of the materials and helped to cool higher temperature zones. The cooling prevented the mass from achieving high temperatures that could cause the death of micro organisms and the stop process.
Turning over also helped to maintain aerobic conditions inside the biopile, but this increase of oxygen rate is momentary, since its values decrease quickly. The number of turn over operations depends on the evolution of the process in each biopile.
When the process ends, a sample of the final material is taken to evaluate the compost final quality.

Figure 3: Turning over the piles with a bulldozer

Moisture is one of most important parameters to make a correct composting process. In this case it changes depending on environmental conditions because biopiles were place in open systems. Low initial moisture levels on certain waste products caused the piles to be irrigated at the start of the composting process.

3 RESULTS AND DISCUSSION

Previous analysis:

The results of the analysis of the available waste products used in the composting experience were the following:

Table 1:

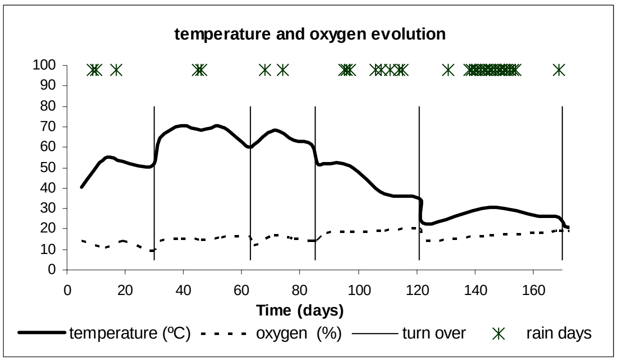
	P. ostreatus substrate	mink manure	seaweed	vegetal biomass	horse manure	units
ph	5.59	7.03	5.56	5.99	8.27	
moisture	67.24	58.54	83.90	40.20	75.43	%
organic matter	91.73	52.57	75.64	95.08	75.43	%
Nitrógeno nítrico ($N\text{-}NO_3^-$+ $N\text{-}NO_2^-$)	249.31	388.99	ND	48.42	76.92	mg N * Kg^{-1} s.m.s
Nitrógeno amoniacal ($N\text{-}NH_4^+$)	468.70	7966.15	2014.69	661.44	737.52	mg N * Kg^{-1} s.m.s
Nitrógeno total Kjedahl (NTK)	4494.63	39250.00	29570.01	8869.30	10560.39	mg N * Kg^{-1} s.m.s
Total nitrogen	0.70	4.14	3.07	0.94	1.64	%
Total carbon	35.30	17.30	31.96	23.35	37.70	%
C/N	50.43	4.18	10.41	24.84	22.99	
Organic carbon	1.54	11.55	11.48	10.71	7.44	%
Zn	14.90	2200.00	48.15	29.98	84.10	mg Zn * Kg^{-1} s.m.s
Cu	6.47	189.00	3.27	3.33	10.34	mg Cu * Kg^{-1} s.m.s
Ni	1.19	4.22	4.47	32.31	12.26	mg Ni * Kg^{-1} s.m.s
Cd	0.17	0.55	2.06	0.75	0.26	mg Cd * Kg^{-1} s.m.s
Pb	2.76	335.00	2.58	3.00	2.89	mg Pb * Kg^{-1} s.m.s
Hg	0.02	0.15	0.02	0.02	0.04	mg Hg * Kg^{-1} s.m.s
Cr_{total}	4.54	7.00	4.56	63.79	23.74	mg Cr * Kg^{-1} s.m.s
respiration index	150.13	291.23	755.68	15.00	369.68	mg O_2 * Kg^{-1} VV.SS h^{-1}

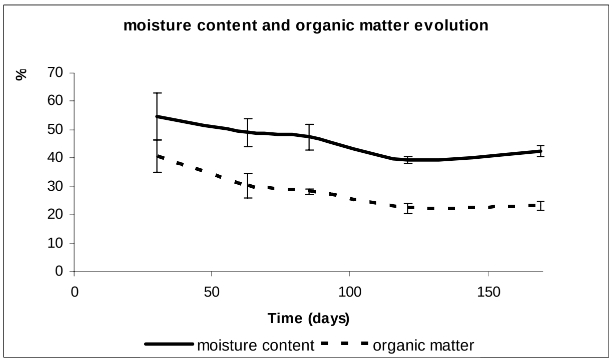
Mink manure and exhausted growth substrate from *Pleurotus ostreatus* culture were excluded from the trial. Mink manure has very high heavy metal content levels that could endanger the final quality of the compost. On top of that, the content of organic matter is low and so is the nitrogenous – carbon proportion if compared to that of horse manure.
The exhausted growth substrate from mushroom culture is here essentially composed by straw, and due to its bidimensional configuration and the presence of silicon crystals in the composition of its cell walls makes a recalcitrant waste product. That is, it requires longer to compost.

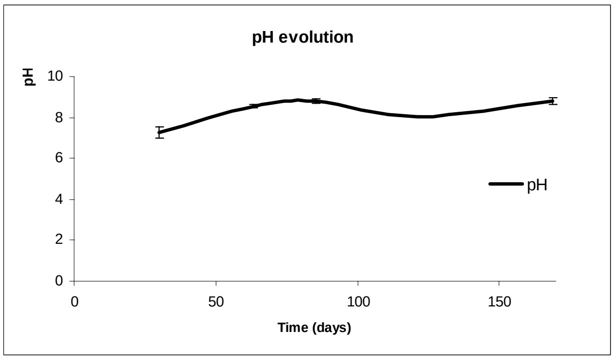
Seaweed and vegetal biomass pile:

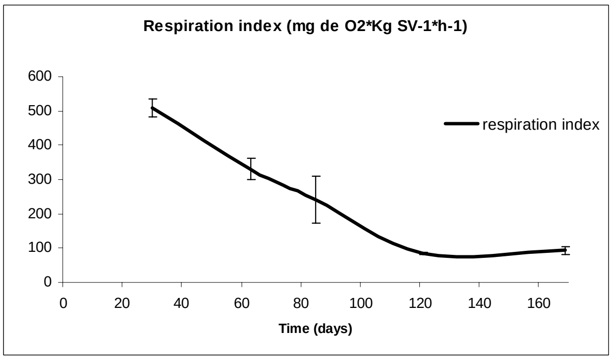
Seaweed has an initial moisture rate of 83.90% and a 75.60% content of organic matter (Table 1). The high concentration of organic matter leads to the quick increase of the temperature to thermophilic levels already from the first day. This increase is produced by the metabolic heat generated by the degradative activity of micro organisms (figure 4a). Such intense microbial activity is also reflected in the decrease of oxygen levels below 10%. This caused a small decrease of the temperature due to the micro organisms' inactivity, caused by the lack of oxygen. To reactivate this process, a first turn over operation was scheduled on day 30th. This favoured the mixing of the different materials, which had been distributed in layers up to that time, leading to a more homogeneous mixture. This in turn produced a second increase of the temperature, which rose to 70 ºC on the 39th day. After a second and third turn over, which caused a small decrease in the temperature due to the cooling of the mass, the temperature falls to mesophile levels, while the oxygen levels rise up to 20%. This tells that the process is entering a mature stage. In these conditions one last turn over is executed on day 170th to re-homogenise the material and ensure degradation of the complete waste mass.

Figure 4: temperature (ºC) and oxygen (%) evolution (4a), moisture content evolution (%) and organic matter concentration (%) (4b), pH evolution (4c), evolution of the microbial breath rate (mg de O_2*Kg SV^{-1}*h^{-1}) (4d).









Organic matter concentration alter 30 days reaches 41%, this decrease from initial levels is caused by the mixing with the green waste products used as a bulking agent (figure 4b) and the high initial degradation rates. The reduction of organic matter is progressive along the 170 days of the process, down to a 23.26%. Moisture levels alter the first turnover were established at 54.55%, falling to 42.51% during the mature stages. This indicates the materials had appropriate moisture levels along the whole process. An important fact is the absence of leachate products in the first stages of the degradation, in spite of the high initial moisture content presented by seaweed. This reflects the good performance of the biopile-biofilter system, where the lower bulking layer holds and maintains moisture and avoids the loss of leachates.

Initial pH for seaweed is 7.93 and it falls to 7.2 during the first turn over as a result of the liberation of organic acids, caused by the intense degradation of organic matter in the first composting stages (figure 4c). High pH values in the last samplings could be the result of salt concentration, coming from the cell content of seaweed and liberated during its degradation.

Seaweed initially presents a very high respiration index (table 1). This rate is proportional to the intensity of the microbial activity, which in turn depends on the amount of organic matter available for degradation. Thus, a progressive decrease in the microbial activity during the first 100 days is observed (figure 4d). From that moment on, the respiration index is stabilized. Such stabilization takes place simultaneously with the temperature falling to mesophile levels (figure 4a) and the entering the maturation stage by the materials due to the reduction of organic matter concentration easily degradable by micro-organisms.

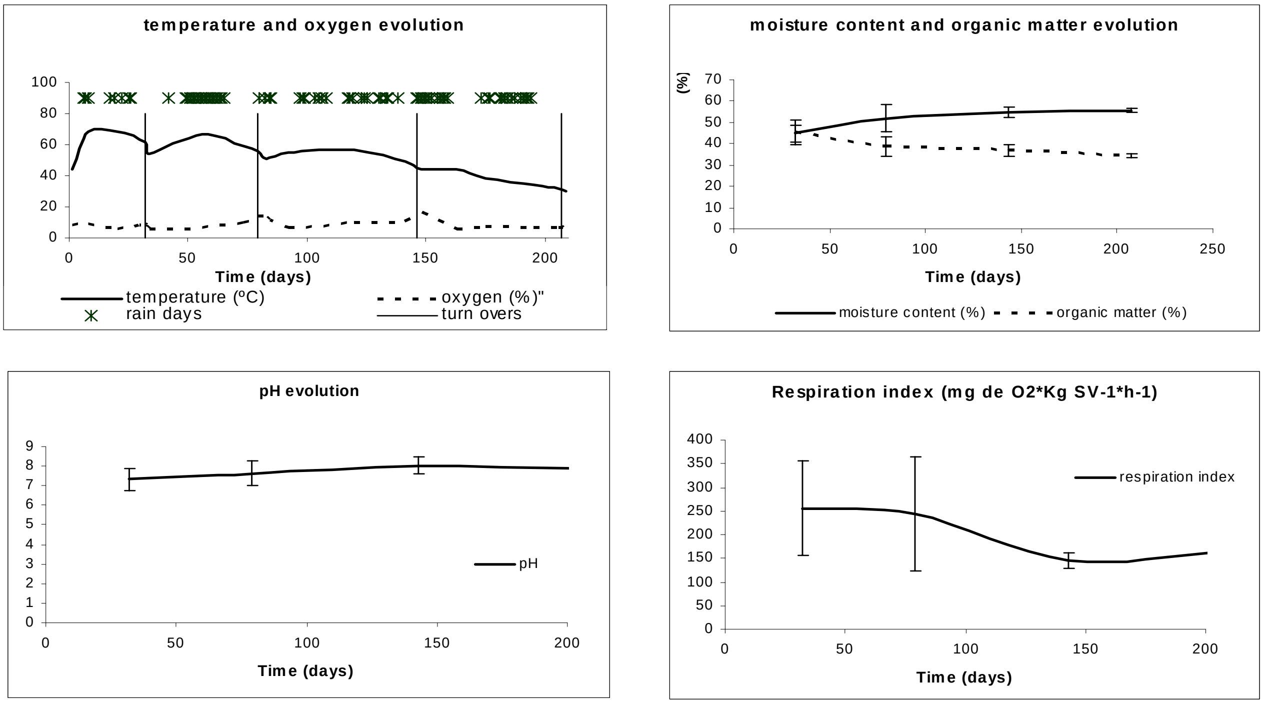
Manure and vegetal biomass pile:

Initial concentration of organic matter for horse manure is 75.43%, and moisture rates 60.69% (table 1), both appropriate values for temperature to rise to thermophilic levels in the first days of the process, reaching 68 ºC on day 8th. Quick temperature rise cause the oxygen levels to fall lower than 10% during these first days, reaching minimum values of 5% on day 20th (figure 5a). This indicates the need of a first turn over to homogenise the materials. After a temperature surge (up to 65 ºC) followed by e 5a). This causes the need of a first turn over operation to homogenise the pile materials. After this, the temperature is observed rising to 65 ºC, and then a slight decrease happens, while the oxygen levels rise. The following turn over operations try to re-homogenize the materials to make its complete degradation possible. But the decrease of the easily degradable organic matter has a repercussion: less microbial activity and a lower respiration index (Figure 5a and 5b). Consequently, on day 175th the temperature falls to mesophile levels and the pile materials enter the maturing stage.

The progressive increase of the moisture levels measured in the waste products during the whole process is remarkable: from a 45% value registered in the first turn over operation to a 65% registered in the last samplings taken (figure 5b). The reason behind this is the heavy rainfall received during the experiment (figure 5a). This increase of the moisture levels causes also the oxygen levels to stay close to 10% during almost the whole process.

Same as in the case of the seaweed pile, a slight decrease of the manure's initial pH levels (Table 1) was recorded: from 8.27 to 7.4 at the time of the first samplings, due to the liberation of organic acids during the degradation of the organic matter. (figure 5c). As the process continues, pH level rises due to the growing concentration of ammonium ion (Polo, A. et al.)

Figure 5: temperature (ºC) and oxygen (%) evolution (5b), moisture content and organic matter concentration (5b), pH evolution, respiration index evolution (mg de O_2*Kg SV^{-1}*h^{-1}) (5d).

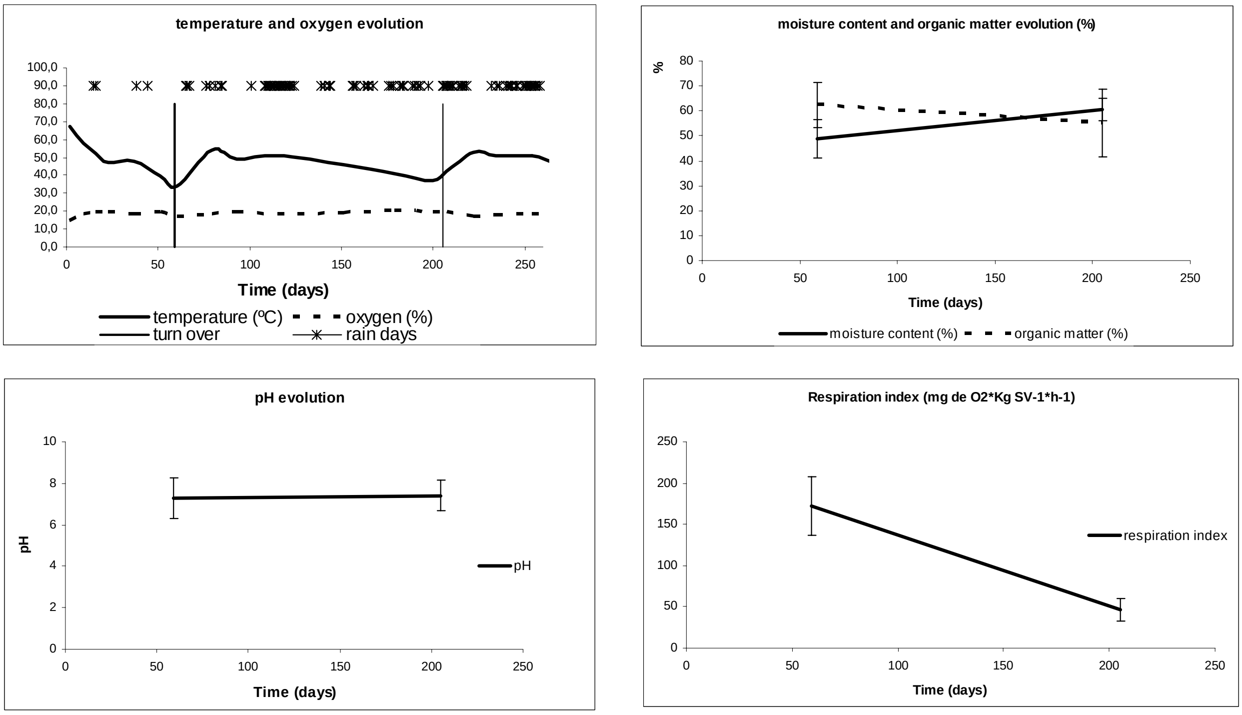


Green waste pile:

The green waste pile evolution was marked by a significant temperature drop during the process' first days.
The high initial waste activity makes possible to reach 62 ºC on the second day of the process. These values are due to the high quantity of dead leaves and grass (figure 6). Moreover, part of the waste products used in this pile had already started its degradation process during the three months needed to collect enough materials to start assembling the piles.

The changing of the place for the waste materials and piles assembly causes the materials re-oxygenation, that causes unusual temperature values for green composting (figure 6a).
Fifteen years later a progressive temperature drop was observed, it fall continue until 30 day reaching at 41 ºC. After a first turn over operation the temperature rises to 54 ºC. These values were kept until the 115th day when it produces a new temperature drop.
The second turn over operation re-activated the materials, keeping temperature values between 45 and 50ºC.
Oxygen level was constant during the experience, ranging about 18% values. These values were caused by the high waste porosity. Porosity was favoured by a high content of branches, which make air circulation easier.

Figure 6: temperature (ºc) and oxygen rate (%) evolution (6a), moisture content and organic matter evolution (6b), pH evolution (6c), respiration index evolution (mg de O_2*Kg SV^{-1}*h^{-1}) (6d).



4 DISCUSSION

Initial organic matter of the three types of waste was bigger than 75% (table 1). Respiration index and organic matter content comparison shows that green waste respiration index is lower than that of seaweed and manure, in spite of green waste organic matter content being higher than in the other types of waste. Lignocellulose composition and a low easily degradable organic matter content make difficult the micro organism action and causes the composting process to require longer.

Figure 7: initial organic matter content of waste (7a), initial waste respiration index (7b).

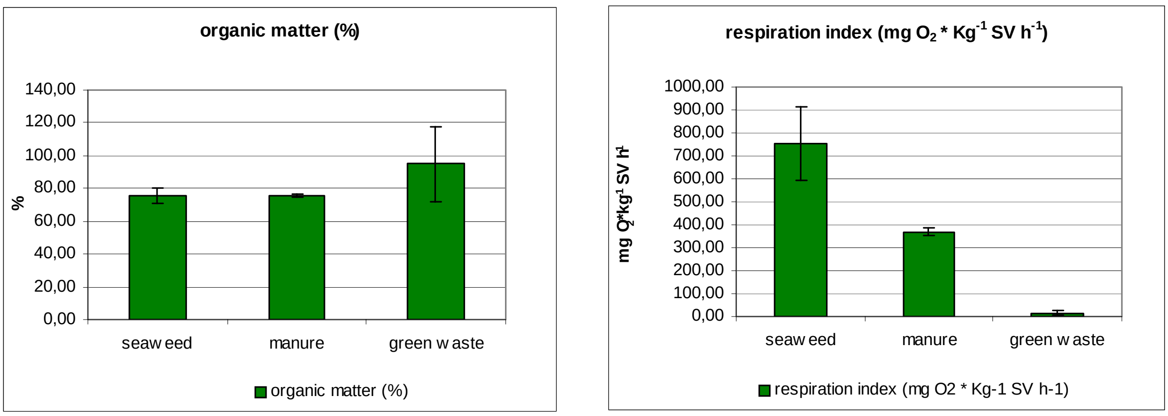
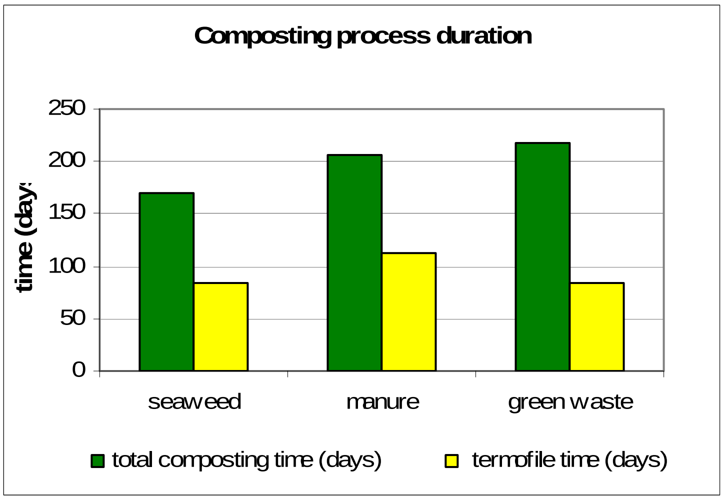


Figure 8: composting process duration.



Seaweed biopile composting time is lower (107 days) than manure biopile (207 days). Up to now the moment the green waste biopile of green waste has accumulated 217 process days and the temperatures kept over 45 ºC. Because of that we cannot consider the process as finished (figure8). If we compare the energy efficiency of the three piles, we can see that the manure pile shows the longest period of thermophilic stage (112 days), making it the most energetic. Second comes the seaweed pile (84) days. The green pile shows a shorter thermophilic stage when taking into account the total process time. This is due to the nature of the organic matter from vegetal waste.

With these results we can say that the mixture of green waste products with seaweed and manure paves the way for a better efficiency of the composting process, through a significant reduction of the total time consumed by the process. The reason behind this is that they make a bigger proportion of organic matter which is easily degradable, thus increasing microbial activity which in turn leads to reach thermophilic temperature levels already in the first days of the process. Most of the degradation of organic matter takes place below this temperature range.

Composting of the green waste all by itself is much slower, due to the high proportion of lignin and cellulose in its organic matter composition: these are recalcitrant materials which take longer to compost since their degradation process is difficult.

Composting time reduction through the addition of co-substrates like seaweed or manure ensures composting of several materials together has advantages over green waste composting alone. This means that forest managing communities, agencies or groups interested in composting should add some more materials to the mixture along with the green waste obtained from forestry cleaning to optimise the composting process.

5 CONCLUSIONS

Co-composting of seaweed and manure with green waste products increases composting efficiency because it reduces the amount of time needed for waste products to reach complete degradation.

Composting appears as a good solution for the integral management of different waste products for small forestry management communities and groups. It is a low cost technology and easy technique.

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