Aptitude for composting of the organic fraction selected by mechanical methods. Case study at “Serra do Barbanza” environmental facility (A Coruña, Spain)

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SUMMARY: The “Serra do Barbanza” Environmental Facility (A Coruña, Spain), in operation since 2003, receive origin-separated wastes from 7 municipalities, with different containers devoted to the organic fraction and inert matter. The organic fraction is subsequently submitted to a composting process. The inert matter is placed on a conveyor belt for hand and automated sorting of recyclable materials. Refuses of both fractions are destined for landfilling. In spite of the social motivation program, the amount of organic matter refused in the inorganic fraction involves 29.4% (wet basis) of the inert waste bag (much higher than the desirable limits). Sieving of this fraction through a 60 mm mesh size allows to obtain a material of about 80% fermentable fraction, suitable for composting. The purpose of this work is to compare the waste composition, composting process and compost quality obtained from separately collected organic household wastes, and the organic fraction refused by sieving the inert fraction container.

Municipal Solid Waste (MSW), compost quality, composting

1 INTRODUCTION

The “Serra do Barbanza” Environmental Facility (A Coruña, Spain), in operation since 2003, receive origin-separated wastes from 7 municipalities, with different containers devoted to the organic fraction and inert matter. Household wastes are sorted at home, collected separately and transported to the Environmental Facility. The organic fraction consisting mainly of wastes form vegetables, food, household paper and cardboard and green plants is initially sieved through a rotary drum screen provided with blades to open the plastic bags in which the material was collected and to remove any particle greater than 70 mm. The inert matter is placed in a bag opener, and then submitted to a conveyor belt for hand and automated sorting of recyclable materials, like plastics, glass, textile or metals. Refuses of both treatment lines are destined for landfilling.

Since the application of composting to municipal solid waste (MSW) is limited by the presence of large quantity of biologically non-degradable material, source separation was reported by many authors as the only satisfactory answer for complete separation (Chanyasak & Kubota, 1981, 1983). However, the concept of separate collection of organic waste relies entirely on the careful sorting by participating householders, who do not always collaborate as much as it would desirable. So, despite the social motivation program, the amount of organic matter refused in the inorganic fraction at the “Serra do Barbanza” Environmental Facility involve 29.4% of the inert waste bag (much higher than the desirable limits).

Previous studies performed by the Environmental Biotechnology Team (Department of Animal Ecology and Biology) at the University of Vigo have suggested that the composting value of inorganic waste could be significantly improved by simple trommel screening of incoming refuse. Sieving of this fraction through a 60 mm mesh size trommel allows to obtain a material of about 80% of fermentable fraction, suitable for composting.

The purpose of this work is to compare the waste composition, composting process and compost quality obtained from separately collected organic household wastes, and the organic fraction obtained by sieving the inert fraction container.

2 METHODS AND MATERIALS

2.1 Sample collection and sorting analysis

Waste A consists in separately collected organic household wastes sieved through a 70 mm mesh size. Waste B is the inert fraction sieved to <60 mm and submitted to a magnetic separation stage. The fractional composition of the crude materials was determined by hand-sorting analysis of 250 kg of each waste material. Wastes were screened into two fractions, one less than 20 mm and the other greater than 20 mm. The latter fraction was manually separated into paper/card, organic (food waste, branches, leaves, other yard waste fractions...) and non-fermentable. With the aim of obtain a representative sample for the composting process, approximately 1000 L of each material (waste A and waste B) were collected. After complete processing, compost samples were taken from waste A and B compost (compost A and compost B) by taking a composite sample of ten different depths during the unloading of the reactor. Those materials were sieved through a 20 mm mesh size.
The investigation was performed as a pilot study without replicates, not enabling any statistical evaluation and the representativity of the results may be limited.

2.2 Composting process

Both materials were processed, without any bulking agent addition, in a 1 m^3 Bioresor reactor, as described by Plana et al. (2001), equipped with: 1 centrifugal fan; 4 PT100 type temperature probes, three of them placed at different depths in the mass (20, 40, and 60 cm respectively), and other one for measuring ambient air temperature; and 1 electrochemical oxygen probe. The control and data logger system was carried out with a Eurotherm 5510 graphic recorder, switching the centrifugal fan when temperature exceeded 55 ºC or oxygen concentration declined below 5%. Both materials were processed until their thermal exhaustion, which took 27 days to fulfill.

2.3 Chemical and physical analysis

The following analysis were made according to FCQAO (1994): moisture content (drying at 105 ºC until constant weight); organic matter content (ignition at 550 ºC in a muffle furnace until constant weight); pH value (determined electrometrically with a CRISON micro pH 2000 pH-meter in a suspension of 20 g of fresh material in 200 ml of 0.01 molar $CaCl_2$ solution for 1 hour); electrical conductivity (carried out with a CRISON CDTM 523 conductivity-meter after the extraction of 20 g fresh material with 200 ml distilled water for 2 hours); total carbon and nitrogen content (determined by combustion with subsequent infrared-spectrometry with a LECO CN 2000 elemental analyzer); NO_3-N and NH_4-N content (extraction of 20 g fresh compost sample with 200 ml 0.0125 M $CaCl_2$, shaken for 2 h, filtered and analysed with a SFA autoanalizer (BRAN+LUEBBE AutoAnalizer 3)); degree of rotting (self-heating capability of fresh compost in Dewar vessels).
Respirometric assay was performed during a 24 hours incubation period, by measuring the pressure drop in a incubator flask (WTW OXITOP-C), and calculating O_2 consumption. The germination index was assessed by a cress phytotoxicity bioassay, using a liquid extract from composts according to Zucconi et al (1981a, b). The presence of *Salmonella* spp was determined according to the ISO 6579 standard method (ISO 2002). *Clostridium perfringens* was determined according to CENAN (1982).

3 RESULTS AND DISCUSSION

3.1 Results

3.1.1 Crude waste composition

Despite the separate collection, waste A still contained unwanted impurities such as stones, metals, plastics and glass in various forms. Waste B contained significative amounts of fermentable matter, considered an impurity in this fraction.
As Table 1 shows, the sorting analysis showed that waste A contained 69.8% organic matter, 5.2% paper/cardboard, 10.7% inert matter, and 14.3% particles <20 mm, whereas waste B contained 39.7% organic matter, 6.9% paper/cardboard, 20.5% inert matter, and 32.9% particles <20 mm. A visual analysis showed that the fraction <20 mm was composed mainly by organic matter and paper/cardboard, in both A and B wastes.

Table 1 Crude waste composition (% wet basis)

Fraction	waste A	waste B
organic matter	69.8	39.7
paper/cardboard	5.2	6.9
inert matter	10.7	20.5
< 20 mm	14.3	32.9

3.1.2 Composting process

Temperature
During the composting process, the temperature evolution is considered to be a reflection of the metabolic activity of the microbial population involved in the process (Finstein & Morris, 1975). The temperature of the compost matrix increases during the first few days, remaining at thermophilic range for several days and then decreases gradually to a constant temperature (Golueke, 1972). Consequently this parameter may be considered a good indicative of the process evolution and of the end of the bio-oxidative phase in which the compost achieves some degree of maturity (Iglesias-Jiménez & Pérez-García, 1989).
Temperature in both compost reactors increased to 50-55 ºC within a few days after starting the experiment, and remained at thermophilic range over the following weeks to maximum temperatures of 66.3 and 70.3 ºC (mean of different depths) in waste A and waste B respectively. Rise and decline in temperature was somewhat faster in waste B than in waste A. Waste A was able to keep the mass in thermophilic conditions for 500 hours, against 264 hours of waste B. After twenty-two days temperature declined in both reactors.

3.1.3 Physical and chemical parameters

Table 2 shows the physical and chemical parameters analysed to crude wastes and derived composts.

- **Moisture content:** Moisture content is a limiting factor of composting process. If moisture content decline below 40%, the microbial activity becomes slower, whereas if it exceeds 65% the air circulation through the mass becomes difficult. Many authors state an optimal moisture content of about 55-65%, and consider values below 40% as hydric stress (Finstein & Miller 1985). Nevertheless, a low moisture content (30-40%) is desirable in the final product, since it avoid water transport and helps sieving and storaging. Waste A contained 55.9% moisture at the beginning of the process, and 37.3% in the final product whereas waste B declined from 54.0% to 33.7%.
- **Organic matter content:** Composting is a degradative process of organic matter by which complex organic compounds are transformed in water, CO_2, and humus-like substances. So, composting is a managed process in which mineralization and humification occur. Since organic matter losses is an

indicator of the degree o mineralization (decomposition rate) reached during the composting process, it can be said that the decomposition rate was greater in waste A than in waste B (31.5% instead of 1.3%).

- **pH:** The compost pH is a good indicator of the development of MSW composts. During the first hours it descends slightly to values of about 5, and later rises as the material gradually decomposes and stabilizes, finally staying at values between 7 and 8 (Finstein & Morris, 1975; Cárdenas & Wang, 1980). Acid pH values indicate a lack of maturity due to short composting time or the occurrence of anaerobic processes in the mass. Large increases in pH were measured after composting process. In compost A, pH values increased from 5.3 to 8.2 and in waste B, from 5.9 to 7.81. Values observed in final products may be slightly high due to the lack of a maturation stage.
- **Electric conductivity:** Electric conductivity (EC) is an indicator of soluble salts content in composts. Composts may have considerable salinity which is attributed to extensive mineralization of organic substrates. The growth-limiting effects of salinity may be due to osmotic factors or to specific ion effects. Salinity in composts can vary with the sources of compost and can reach electrical conductivities of about 10 $mS \cdot cm^{-1}$ (Barker, 1997)**.** As Table 2 shows, EC in waste A increased from 0.45 to 1.17 $mS \cdot cm^{-1}$, and in waste B from 0.59 to 1.04.

Table 2 Physicochemical parameters of crude wastes and derived composts.

Parameter	Waste A		Compost A		Waste B		Compost B	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Moisture content (%)	55.9	1.2	37.3	1.23	54.0	0.80	33.7	1.93
Organic matter (% d.m.)	59.1	2.43	40.5	1.50	54.1	2.25	52.8	2.84
pH	5.3	0.01	8.2	0.01	5.9	0.02	7.8	0.01
Electrical conductivity ($mS \cdot cm^{-1}$)	0.45	0.03	1.17	0.02	0.59	0.00	1.04	0.04
Static Respiration Index (mg $O_2 \cdot kg^{-1}$ VS$\cdot h^{-1}$)			1381	37			1732	5.47
Degree of rotting			IV				II	
C (%)	27.24	0.13	17.93	0.88	26.58	0.08	24.66	1.48
N (%)	1.86	0.07	1.46	0.08	1.88	0.14	2.52	0.42
C:N	14.65		12.28		14.14		9.79	
NH_4-N ($mg \cdot kg^{-1}$ d.m.)	1221		2009		1431		2367	
NO_3-N ($mg \cdot kg^{-1}$ d.m.)	0.09		0.48		0.76		0.35	
Germination index			106.6				51.4	
***Salmonella* spp. ($\cdot 25\ g^{-1}$)**	n.d.		n.d.		n.d.		n.d.	
***Clostridium perfringens* ($CFU \cdot g^{-1}$)**	n.d.		n.d.		n.d.		1.3	

Figure 1 Evolution of temperature and oxygen concentration during the composting process of waste A

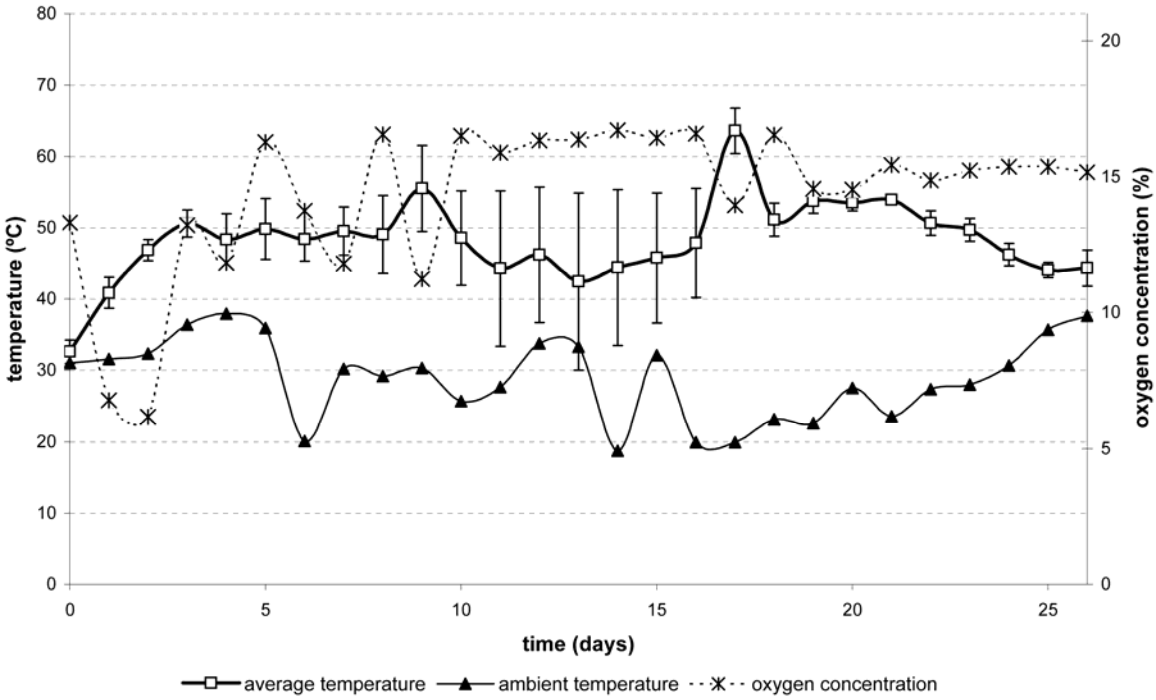
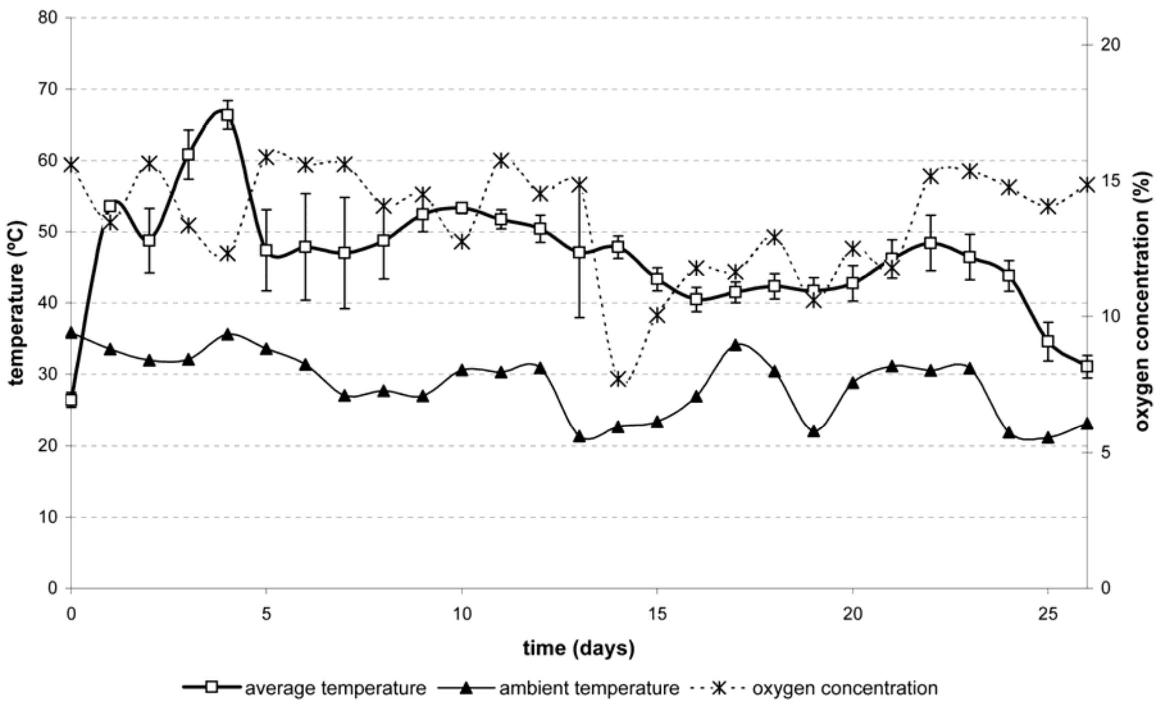


Figure 2 Evolution of temperature and oxygen concentration during the composting process of waste B



3.1.4 Compost maturity and hygienization

Evaluation of the maturity of MSW compost has been widely recognized as one of the most important problems concerning the composting process and its land application. The most notable effect of immature compost is the biological blockage of soil-available nitrogen which may give rise to serious N-deficiencies in crops with consequent depressive effects. Other effects are: decrease of O_2 concentration and soil Eh, creation of an anaerobic and strongly-reducing environment at the level of the root system, increase of solubility of heavy metals, and inhibition of plant seed germination by the production of phytotoxic substances, fundamentally ammonium, ethylene oxide and organic acids (Iglesias-Jiménez & Pérez-García, 1989).

There are many criterions or methods proposed in the literature for the evaluation of MSW compost maturity. However, most of the methods at present in use are not conclusive and complementary one to another.

- **Static Respiration Index (SRI):** Chrometza (1968) shows that O_2 consumption (and CO_2 emission) increases quickly at the beginning of composting, decreases midway through the process and continue to decrease to the end, falling to values lower than those of arable soils. It can be said that an insufficient mature compost is a compost with a strong O_2 demand (Adani et al., 2003). Compost A showed a SRI of 1381 mg $O_2 \cdot kg^{-1}$ $VS \cdot h^{-1}$, and compost B has a SRI of 1732 mg $O_2 \cdot kg^{-1}$ $VS \cdot h^{-1}$. According to this authors, it can be said that both A and B composts are immature, probably due the lack of a maturation stage.
- **Degree of rotting:** degree of rotting is a shelf-heating test related with the exothermal capability of a immature organic material which is not completely stabilized. Compost B showed a greater shelf-heating capability than compost A (Rotting degree II instead of Rotting degree IV).
- **Carbon to nitrogen (C:N) ratio:** Carbon (C) and nitrogen (N) are the two most important elements in the composting process. Carbon is the main source of energy for the microorganisms involved in the composting process. The C concentration in compost gives an indication of the amount of organic matter and the effects that compost will have on soil fertility; and ratios of C to other plant nutrients indicate the bioavailability of nutrients and govern the value of compost as a slow-release fertilizer. Nitrogen, a constituent of proteins and generic matter, is critical for microbial growth. Nitrogen may be considered a more critical factor in composting than C. If N is limiting, microbial populations will remain small, and composting will proceed slowly (Barker, 1997). The C:N ratio is the criterion traditionally used to determine the degree of maturity and define compost's agronomic quality. Many authors report that a C:N ratio below 20 is indicative of an acceptable maturity (Iglesias-Jiménez & Pérez-García, 1989; Cárdenas & Wang, 1980). However, the C:N ratio of compost cannot be used as an absolute indicator of the state of maturation since the C:N ratio found in well-composted materials presents great variability. So, a C:N ratio less than 20 can only be considered a necessary, but not sufficient condition for establishing the degree of maturity. Both wastes A and B started with a C to N ratio of about 14, and their derived composts showed a C to N ratio less than 20, but significatively lower for compost B.
- **Presence of nitrates and nitrites:** Finstein & Miller (1985) define the concept of "maturity" in terms of nitrification: when during the composting process, appreciable quantities of NO_2^- and/or NO_3^- appear, the compost may be considered acceptably mature. Different trials of composting processes show that the appearance of oxidized forms of N takes place between the third and fourth month of composting (Iglesias-Jiménez & Pérez-García, 1989). During the composting process, ammonium concentrations increased from 1221 to 2009 $mg \cdot kg^{-1}$ d.m. for waste A, and from 1431 to 2367 $mg \cdot kg^{-1}$ d.m. for waste B. Relatively low concentrations of nitrate, 0.35-0.48 $mg \cdot kg^{-1}$ d.m. were measured.
- **Germination index:** Germination index was performed by a cress phytotoxicity bioassay, using a water extract prepared from composts according to Zucconi et al. (1981a, b). Compost B showed phytotoxicity (Germination index of 51.4%) respect to the control extract, whereas compost A acted like a soil fertility improver (Germination index of 106.6%).
- **Presence of micropathogens:** during a correct composting process, a hygienization phase must occur. When relatively high temperature is reached for a certain time interval, most of micropathogens present in the material die (different combinations time-temperature are avaliable). If the hygienization temperature is not reached, or its duration time is very short, the effect could be the opposite, and the material may be converted in a micropathogen incubator. Both wastes A and B started free of micropathogens (*Salmonella spp* and *Clostridium perfringens*). Compost A showed a good hygienization, whereas compost B showed a little load of *Clostridium perfringens* (1.3 $CFU \cdot g^{-1}$).

3.2 Discussion

Due to the lack of a maturation stage, both composts A and B result immature (high Static Respiration Index, lack of oxidized forms of nitrogen, relatively high self-heating...). However there are some interesting differences between the behaviour of each waste during the composting process, and consequently in the final product obtained. The composting process shows that Waste A, separated at source, resulted to be more energic than Waste B, and it was able to keep the mass in thermophilic conditions for a longer time (500 hours against 264). On the other side, Waste B had difficulties to guide de process to achieve a good digestion and hygienization of the product. Also, compost derived from Waste A, shows a higher maturity index, a lower pathogenic microorganisms content, and a higher germination index than Waste B.

4 CONCLUSIONS

Waste A, consisting in separately collected organic household, developed the composting process in a more accurate way than waste B, obtaining a better compost with higher quality parameters and more suitable for vegetable growing.

The results showed that little improvements regarding the separation efficiency of inert materials becomes of great significance, showing that a good selection at the origin of the organic matter is a key aspect to achieve a good quality end product.

References

Adani, F., Ubbiali, C, Tambone, F., Scaglia, B., Centemero, M., and Genevini, P.L. (2003). Static and Dynamic Respirometric Indexes - Italian research and studies. In *H. Langenkamp and L. Marmo (ed.) Biological treatment of biodegradable waste - Technical Aspects*. European Commission Joint Res. Centre, Brussels. pp. 126–144.

Allison, F.E. (1973). *Soil Organic Matter and its Role in Crop Production*; Elsevier: New York, NY, 1973.

Barker, A.V. (1997). Composition and Uses of Compost. In: *Rechling, J.E., Mackinnon, H.C. (Eds.), Agricultural uses of by-products and wastes*. ACS Symposium Series No. 668, vol. 10. American Chemical Society, Washington, DC, pp. 140–162.

Cárdenas, R.R. & Wang, L.K. (1980). Composting process. In *Handbook of environmental Engineering, vol. II.* The Human Press, New York, pp. 269-327.

CENAN. (1982). *Técnicas para el examen microbiológico de alimentos y bebidas*. Centro Nacional de Alimentación y Nutrición. Madrid.

Chanyasak, V. Kubota, H. (1981). Carbon/organic nitrogen ratio in water extract as measure of composting degradation. *J. Ferment. Technol.*, 59, pp. 215-19.

Chanyasak, V. & Kubota. (1983). Source Separation of Garbage for Composting. *Biocycle*, vol. 24, no. 2, pp. 56-58.

Chrometza, P. (1968). Determination de la consommation d’oxigène des composts en voie de maturation. *Bull. Inf. GIROM.*, 33, pp. 253-256.

FCQAO (1994). *Methods Book for the Analysis of Compost*. Federal Compost Quality Assurance Organization. Cologne, Germany.

Finstein, M.S. & Miller, F.C. (1985). Principles of composting leading to maximization of decomposition rate, odor control, and cost effectiveness. *In Composting of Agricultural and Other Wastes, ed. J.K.R. Gasser*. Elsevier Applied Science Publishers, London & New York, pp. 13-26.

Finstein, M.S. & Morris, M.L. (1975). Microbiology of municipal solid waste composting. *Adv. appl. Microbiol.*, 19, pp. 113-151.

Golueke, C.G. (1972). *Composting. A Study of the Process and its Principles.* Rodale Press, Emmaus, USA

Iglesias-Jiménez, E. & Pérez-García, V. (1989). Evaluation of City Refuse Compost Maturity: A Review. *Biological Wastes* 27, pp. 115-142.

ISO. (2002). *Microbiology of food and animal feeding stuffs. Horizontal method for the detection of Salmonella spp*. International Organization for Standarization.

Plana, R.; Pérez, C.; Domínguez, J. & Mato, S. (2001). Development of a Semi-Industrial Escale Experimental Organic Wastes Biodegradation Reactor. *In Recycling and Reuse of Sewage Sludge*. 351-360. Thomas Telford Ltd. London.

Zucconi, F., Forte, M., Monaco, A. & De Bertoldi, M. (1981a). Biological evaluation of compost maturity. *Biocycle*, 22, pp. 27-29.

Zucconi, F., Pera, A., Forte, M. & De Bertoldi, M. (1981b). Evaluating toxicity of immature compost. *Biocycle*, 22, pp. 54-57.