INDUSTRIAL PROJECT FOR AUTOMATED AERATION OF ORGANIC COMPOST PILES

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Abstract. *Composting is a safe environmental alternative to reuse and treat organic wastes produced by human-beings. Although decomposition happens naturally, the handling of some factors such as oxygen levels, temperature, moisture content and pH, can improve the process' speed, accelerating microbial activity. Aeration is a crucial practice during the compost process, since it can ensure adequate oxygen supply, control the temperature and reduce the moisture content in the windrows. Therefore, this work aimed to develop an automated aeration process of organic compost piles in order to accelerate and optimize the production of bio fertilizers in a Brazilian industrial plant. Based on previous tests done in the company's standard ventilation, an automated aeration system called SAFA was projected. During system installation the moisture, oxygen levels and temperature were measured to verify the efficiency of the new aeration system. It was verified that SAFA provides a regular oxygenation of the compost piles, thereby reducing the moisture content, increasing the screening rate of the compost and finally reducing the production cycle. Based on these parameters, SAFA is shown as a promising tool for production of organic fertilizers.*

Keywords*: composting, automation, blower, oxygen and temperature.*

1. INTRODUCTION

The correct disposal of organic wastes from urban centers, industries and animal husbandry is the organic composting. In the last decades, organic waste used to be destined to dumps, landfills and controlled landfills, along with all the garbage produced, causing damage to the environment. Therefore, composting can be considered a sustainable solution to reduce organic wastes generated by humanity. This is an old process, performed by humans since the beginning of agriculture, taking advantage of organic wastes to improve soil quality. Nowadays this process has been associated with the organic waste treatment. Thus, human action is needed to accelerate the decomposition, by the handling of various organic materials and the automation of the compost process.

In developed countries composting is a very common practice. In the United States and Germany many companies invest in the compost plants automation, to accelerate and optimize the process. On the other hand, in Brazil, composting in an industrial scale is still an outdated practice and it is based on machines and technologies from agricultural sectors (Schalch et al., 2002). In other words, there are no specific machines for composting. Therefore, Brazilian composting plants should be better studied, since there are great expectations for the optimization of this process to assist the reduction of organic waste in the country.

Most of the studies reported in the literature focuses on the quality and management of the compost produced. Therefore, there is little technological information about the process optimization. Assuming that aeration is one of the main factors affecting the compost production and that its implementation usually involves the use of adapted equipments, researches concerning the dimensioning and optimization of aeration systems become necessary. Thus, improvements on aeration can ensure adequate air supplies and temperature control in the composting piles, resulting in better performance of the microorganisms responsible for decomposition.

In the 50s researchers from University of California showed the influence of parameters such as microorganisms, moisture, aeration and temperature on degradation of organic matter (Alves, 1998). Since then, studies have been intensified, allowing the development and improvement of various compost systems (Motter et al., 1987; Gómez, 1998; Bernabé, 2008).

Currently, the agriculture and food industry companies are major producers of organic waste, such as plant and animal remains that can cause serious environmental pollution problems. However, when handled properly, they can supply with advantages, a lot of demand for mineral inputs without affecting soil resources and the environment (Oliveira et al., 2004). In the literature, several authors comment about the use of organic fertilizers as an alternative to reduce the crops cost, saving of natural resources (Costa, 2005, Silva; Menezes, 2007, Araújo et al., 2007). In this sense, the practice of composting has been used by several agro-industrial sectors, proving the efficiency of the process. (Vitorino; Pereira Neto, 1994; Fortes Neto et al., 1997; Costa et al., 1997).

The composting occurs in three stages: fermentation, biostabilization and humification. Several factors may influence directly or indirectly in the composting process. Different communities of microorganisms (bacteria, actinomycetes, yeasts and fungi) predominate in different stages of composting, which is justified by changes in environmental conditions during the process (Miller, 1993). The speed of the composting process is related to the activity of bacterial microbiota (Mckinley; Vestal, 1985 cited by Tiquia; Tam, 2000; Mondini et al., 2004). The moisture is indispensable for microorganisms physiological and metabolic activity, the ideal range varies between 40 and 60% (Stentiford, 1996 cited by Tiquia et al. 1998a; Oliveira et al. 2004; Rodrigues et al ., 2006). The activity of the microorganisms during the decomposition process is exogenous and thus the heat is retained in the windrow composting because of the insulating property of the organic compost, resulting in temperature elevation. However, if the temperature exceeds 70°C biological activities and metabolism of microorganisms are reduced (Gomes; Pacheco, 1988). The windrow increase temperature is essential for the compost sanitize. (Fernandes, 1999). The oxygen content is the most important factor in composting because it makes the aerobic process, allowing respiration and metabolism of microorganisms (Diaz et al. 2002). The ideal range for the oxygen content varies from 14 to 17%, on the other hand, contents lower than 10% make aerobic composting impossible (Diaz et al. 1982). In addition to directly influence the activity of microorganisms, aeration allows control the humidity and temperature (Pereira Neto, 1989; KIEHL, 1998). Thus, the oxygen content is considered the main parameter in this process.

Composting is a natural process and can take several weeks (Mota, 2000). Automation of the process makes it faster, reducing production time.

Nowadays, several researches have proposed automated plants to make bio fertilizers. A German company (COMPAG) developed a fully automated industrial plant for bio fertilizers production. The system control is performed according to data obtained by monitoring the temperature and oxygen content. This system renews the air by two methods: air insufflation and turning. Centrifugal blowers are used connected to a tube with four branches which are distributed over the compost. To revolving the compost are used a turner equipment installed on overhead crane. This equipment uses a 50 hp engine.

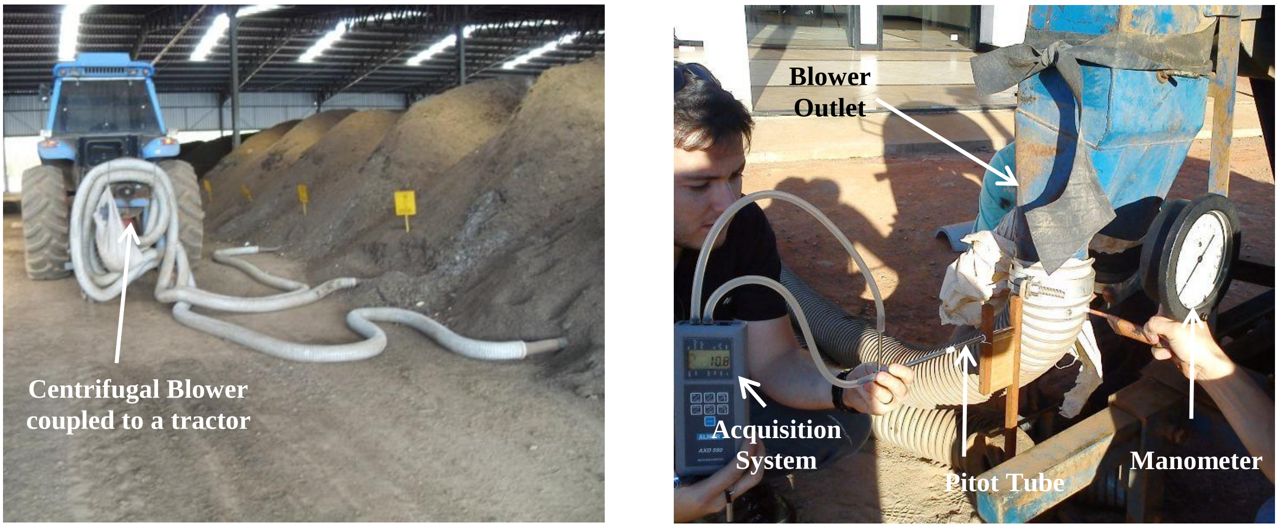
Another example of the composting process automation is developed by American Engineered Compost Systems (ECS). This company is responsible for design 15 industrial plants using aerated static piles. The aeration control is performed by software (comptroller monitoring system) that uses only temperature data to control the blowers. The system generates graphs of temperature throughout the composting cycle, and provides production data.

2. METHODOLOGY

This study was conducted by the College of Mechanical Engineering of Federal University of Uberlândia in partnership with a local company called Valoriza Agronegócios. Based on the company’s standard aeration practice, this work aims to scale, assemble and install an Automated Aeration System called SAFA (*Sistema de Aeração Forçada Automatizado*).

The industry currently has 48 compost piles that are aerated by a blower moved by the engine of a tractor. The standard practice is to aerate four windrows at a time as showed in Fig. (1a). The blower coupled to the tractor is turned on for 5 minutes and, after that, it is turned off and the tubes are unplugged and relocated to aerate other four compost piles. The aeration process is performed only during the day and depends on the employees to operate the tractor and relocate the tubes.

Experimental tests were performed to verify the mechanical characteristics of the blower used in the company’s standard practice (Fig. 1b). The goal is to replace the equipment for an equivalent electric blower that could be driving by an electronic system. In this case the mechanical characteristics are the flow rate (m³/min), pressure (mmca) and the power (CV). During the experimental procedure were used a Pitot tube, a pressure gauge, a caliper, an AXD 550 Micromanometer acquisition system, tube and a microcomputer to determine the mechanical characteristics of the blower moved by a tractor.



a) b)

Figure 1 – Aeration in organic compost piles a) Blower coupled to a tractor and organic compost piles; b) Experiment to determine the mechanical characteristics of the blower.

Based on experimental data, a computational algorithm was developed to determine the mechanical characteristics of the blower. It was based on fluid mechanical energy, Eq. (1), called modified Bernoulli's equation (Clezar and Nogueira, 1999).

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 + \Delta H_{gain} - \Delta H_{loss} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 \tag{1}$$

where, P is the fluid pressure, ρ is the density, g is the gravity, V is the velocity, z is the fluid elevation and ΔH_{gain} represents an increase of energy due to insertion of a blower in the network of ventilation and ΔH_{loss} is the losses due to the friction between the fluid and devices as tubes and fittings.

The ΔH_{loss} can also be written according to the Colebrook equation (Eq. 2) and the universal equation of Darcy and Weisbach (Eq. 3).

$$\frac{1}{\sqrt{f}} = -2{,}0\ log\left(\frac{\varepsilon/_D}{3{,}7} + \frac{2{,}51}{\frac{4\,Q}{\pi\, D\, \vartheta}\sqrt{f}}\right) \tag{2}$$

$$\Delta H_{loss} = f\,\frac{L}{D}\left(\frac{8\,Q^2}{\pi^2\, g\, D^4}\right) + \sum K\left(\frac{8\,Q^2}{\pi^2\, g\, D^4}\right) \tag{3}$$

where D is tube diameter, f is the friction factor, ϑ is kinematic viscosity, L is tube length, ε is absolute roughness, Q is the airflow and K is the drop pressure coefficient.

In the computational algorithm the drop pressure coefficient (K) was estimated using the Golden Section technique (Vanderplaats, 1999). It minimizes a square error function based on the difference between experimental airflow measured in the blower coupled to the tractor, Y, and calculated, Q, values of the airflow. Thus, the objective function, S_{mq}, to be minimized can be written as

$$S_{mq} = \sum_{i=1}^{nterm} \left(Y_i - Q_i\right)^2 \tag{4}$$

where $nterm$ represents the network of ventilation.

K was defined considering that the drop pressure is homogeneous into the windrow. In this case the value estimated was $K=159$.

Thus, with the centrifugal blower energy equation, the characteristics of the tubes and fittings and the drop pressure imposed by the organic compost, all information were inserted into the algorithm, which generates the distribution of airflow along the perforated tube into the windrow. It important to emphasize that the mathematical model considered the entire network of ventilation.

The commercial blower equations were obtained from manufacturer's catalogs.

Figure 2 presents a comparison between the airflow along the tube length under the windrow using the blower coupled to the tractor and a particular commercial electric blower.

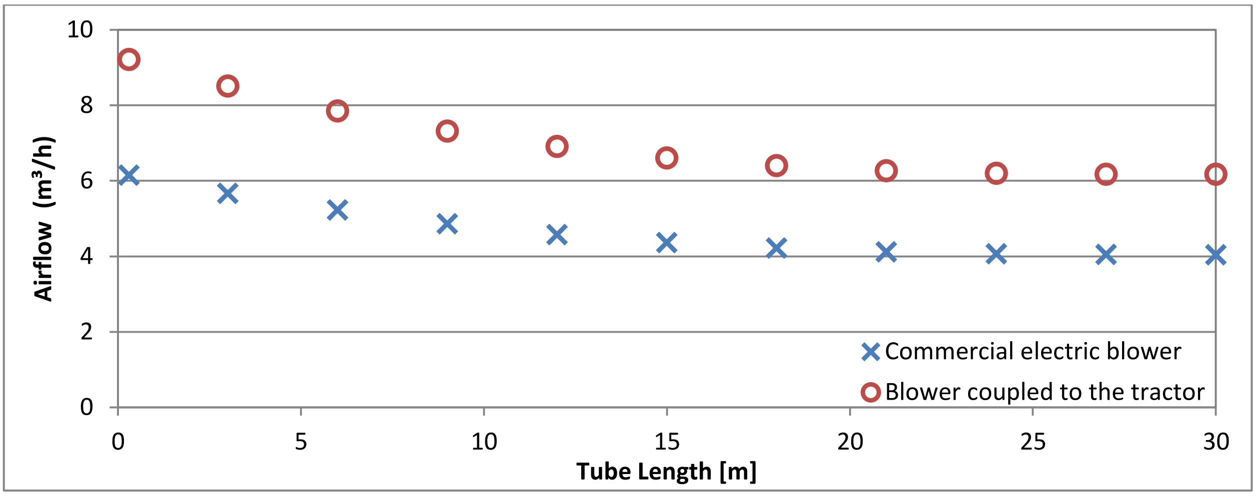


Figure 2 - Comparison between the airflow along the tube length using the blower coupled to the tractor and a particular commercial electric blower.

It is worth emphasizing that the commercial electric blower was chosen considering its engine power, low cost and proximity to the airflow provide by the blower coupled to the tractor.

3. RESULTS AND DISCUSSION

Four blowers were installed in order to aerate eight compost piles. Only a blower is turned on each time and in the first test it stays on for ten minutes. Considering eight compost piles, a complete cycle of aeration lasts forty minutes. After this time, the aeration cycle restarts. It works twenty-four hours a day and the blower operation time can be adjusted according to the compost, levels of temperature and oxygen in the compost piles.

Figure 3 - SAFA installed in the compost shed.

Thus, to identify the correct time of aeration of the piles, this work proposes an analysis of the oxygen and temperature levels during three compost cycles. It was considered the same compound and each cycle lasted thirty days on average. Eight compost piles have been aerated and each one had thirty meters long and three meters high.

The blowers were turned on sequentially, one by one, for a period of time set in the electronic system. In the first cycle a blower is turned on for 5 minutes, after that time, it turns off and remains in standby mode for 5 minutes, then when the next blower is turned on. A complete aeration cycle was standardized in 40 minutes. In the second cycle it was set an aeration time of 7 minutes and 3 minutes in standby mode. In the last one, 10 minutes of aeration and 2 seconds in standby mode.

The oxygen and temperature levels were measured in the middle of the pile, two meters above the ground. The gas analyzer Testo 350S was used in the experiments. The maximum and minimum values of oxygen and temperature measured in each cycle are shown in Table 1.

Table 1 – Maximum and minimum levels of oxygen and temperature measured during each compost cycles.

Aeration Time (minutes)	**Levels of Oxygen and Temperature**	
	Maximum	**Minimum**
5	12.2% of O_2 and 65.1°C	8.52% of O_2 and 61.1°C
7	16.1% of O_2 and 69.3°C	11.7% of O_2 and 60.4°C
10	19.6% of O_2 and 78.8°C	14.7% of O_2 and 77.0°C

In first cycle it can be seen that 5 minutes of aeration was insufficient. The oxygen level was less than 10%, which may lead to an anaerobic compost process, considered undesirable for some researchers as Diaz et al., (1982), Gomes and Pacheco (1988) and Fernandez (1999).

Meanwhile, when the blowers were turned on during 7 and 10 minutes, the oxygen levels are presented in a range recommended for the composting of organic waste that varies from 14 to 17% according to Diaz et al. (1982). Some authors state that the temperature should not exceed 70°C because it could cause the death of microorganisms. Thus, 10 minutes of aeration could not be considered an appropriated time for composting. It was expected that the excess of oxygen could decrease the temperature of the windrow due to death of microorganisms. However, it did not happen. Therefore, during this research, it was concluded that 7 or even 10 minutes of aeration could be applied to accelerate the compost process, reducing the production time.

Another parameter analyzed during all cycles was the methane emission. However, it did not exceed 0.5% in all of the experimental tests.

Figure 4 shows the levels of temperature and oxygen over a full cycle considering 7 minutes of aeration. The Chauvenet statistical method was used to treat experimental data and to define the mean and the standard deviation from measured values.

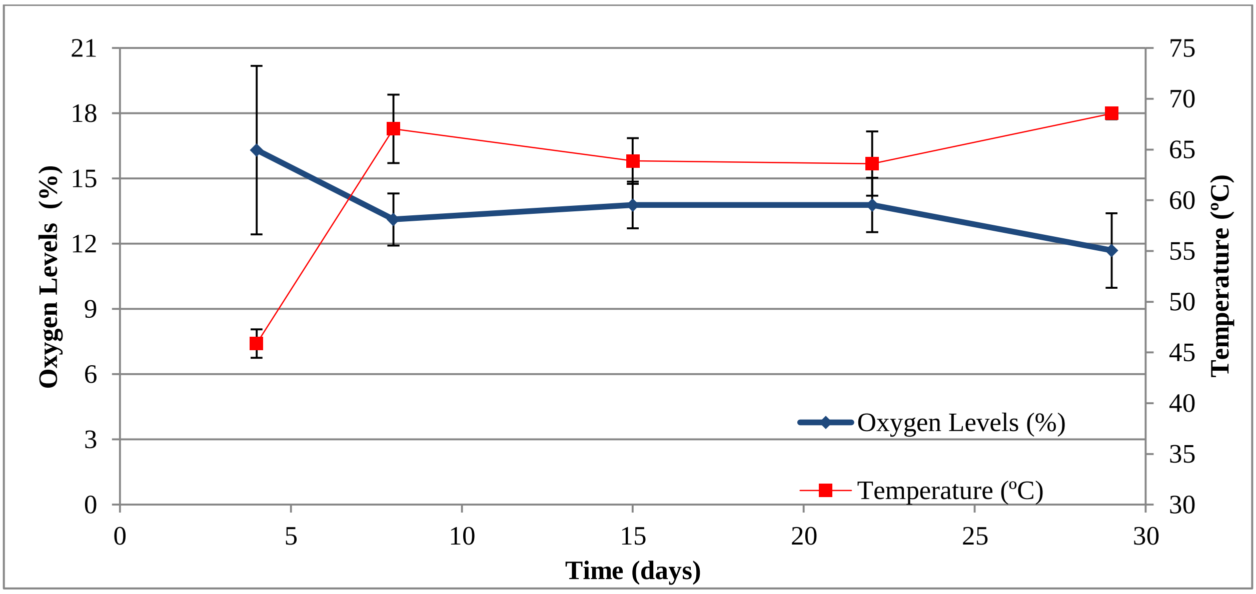


Figure 4 – Temperature and oxygen levels evolution during the organic composting cycle.

It can be seen that at the beginning of the cycle the temperature of the windrow is low due to low activity of the microorganisms. However, after a week, oxygen levels and temperature are stabilized, remaining practically constant during over 20 days of composting, within a range expected for organic compost process, which proves the efficiency of SAFA. It is worth emphasizing that the tests were performed for only one type of compound (basically leftover ham, turkey and poultry litter). Other studies should be conducted to adjust the SAFA for another kind of compound.

According to the company rules, the compost process ends when the cycle reach 30 days and the compost humidity is around 30%. Therefore, the moisture content of the windrows was evaluated after 30 days to compare the performance of the blower coupled to the tractor and the electronic system proposed in this work called SAFA. The results are shown in Table 2.

Table 2 - Moisture content of windrows using the blower coupled to the tractor and SAFA

	Moisture Content (Old Sys)	**Moisture Content (SAFA)**
Mean	32,26%	27,64%

It can be seen that the moisture measurement in windrows with SAFA is fairly less than that identified in standard practice. This means that the composting cycle could have been stopped before 30 days provided by standard practice. Thus, SAFA provides a regular oxygenation of the compost piles, thereby reducing the moisture content, increasing the screening rate of the compost and finally reducing the production cycle. Based on these parameters, SAFA is shown as a promising tool for production of organic fertilizers.

4. CONCLUSIONS

According to the results, it was concluded that SAFA tends to reduce the time demanded for the organic compost production in at least three days, since promotes a faster pile drying. It represents an 8% increase in the company’s annual production. Furthermore, the system increased oxygen levels in the compost windrows, favoring aerobiosis. Therefore, the continuous aeration cycle (24 hours per day) allows faster reduction in the moisture content of the compost and higher levels of oxygen and temperature into the windrows. Furthermore, the automated aeration system (SAFA) provides a lower operating cost when compared with the old ventilation system.

It can be stated that SAFA developed in LTCM/FEMEC - UFU in partnership with Valoriza Fertilizantes Ltda and Government Agencies was satisfactory, because replaced the old ventilation system and improves the compost cycles.

5. ACKNOWLEDGEMENTS

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