Data acquisition during composting experiments with usage of 4-chamber bioreactor for modeling of biological processes

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Abstract. The paper presents the system for data acquisition from composting process in 4-chamber bioreactor. This system lets to create the model for decomposition process for different biowaste, especially including ammonia and GHG emissions.

Keywords: bioreactor, composting process, data acquisition, modeling.

1 Introduction

The problem of environmental friendly biowaste management has become one of the most important areas of scientific activities within last 20 years in Europe. The strong increase of research concerned on recycling and re-utilization of organic wastes from agricultural, municipal and industrial origin has been observed (Gomez, 1998; Raghavarao et al, 2003). This fact was related with the tendencies in suitable law regulations according to the strict ecological norms implemented after 1992 in EU. One of the most environmental promising technologies is composting of biowaste.

Composting is a process creating a closed ring of circulation of organic substances in the environment. It consists of the microbiological decomposition of organic substances in oxygenic conditions under the influence of thermophilic microorganisms and moulds. The composting process can run in the piles or open containers on a free air, in closed chambers or barrels with controlled oxygen supply (Dach et al., 2003; Raghavarao et al., 2003). The very important condition for the correct execution of this process is a suitable oxygen content in the delivered air (above 8-10%) as well as the proper moisture degree (remaining on a level of 55-75%) for the whole duration period.

However, in some cases, the composting process can be a source of ammonia and GHG (greenhouse gases) emissions. It happens while bad, insufficient porosity of composted material (emission of CH_4 and H_2S) or high nitrogen content

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(emission of NH_3). That is why during the last years different scientific teams carried on the research concerning an estimation of ammonia and greenhouse gases emissions from composting of different biowaste and the factors influencing on this emission. These activities are focused around national projects and international concerted actions where the different models of gaseous emissions are developed for many countries under different conditions.

However, the fieldworks related with composting process of organic materials require an extreme labor and financial input. The weather conditions variability does not ensure the guarantee of repeatability. Moreover during the fieldworks it is difficult or sometimes completely impossible to use so complex measuring apparatus as it is in case of laboratory experiments. Usage of bioreactor eliminates some part of fieldwork, considerably decreases the costs and accelerates the final results.

In 2002 scientific team from Institute of Agricultural Engineering (Poznań University of Life Sciences) worked out the idea and built isolated 2-chamber bioreactor for model research on the processes of organic matter decay (in the frame of Ministry of Science and Higher Education grant concerning the study of gaseous emissions from different technologies of manure management (Dach et al, 2003). On the basis of many investigations it has been stated that during the experiments bioreactor ensures the run of decomposition similar like in real conditions during heap composting with usage of tractor aerator. Simultaneously allows to control very precisely changes running during the process (Czekała et al, 2006; Dach et al, 2004).

Numerous experiments explored with usage of bioreactor resulted in new conceptions of solutions. In 2006 (under the CleanCompost 6 FP UE project) 4-chamber bioreactor was designed. Completely new idea of gaseous measurement was introduced, the tightness level and thermal isolation were raised, control and measurement of aeration level were improved.

The aim of this study is to check the possibility of data collecting from aerobic and/or anaerobic decomposition of organic wastes in order to create the ammonia and greenhouse gases emissions prognostic model. Technologies of reduction of methane emission from animal production and manure management in the context of GHG taxation" (*research project financed by the Polish Ministry of Science and Higher Education, Contract number: N N313 271338*).

2 Material and methods

4-chambers bioreactor set-up

Scheme of bioreactor construction and working is presented on Fig.1. The capacity of one bioreactor chamber amounts 165 dm^3. Thermal isolation consists of hermetic 10 cm tight polystyrene layer. It ensures the run of composting process under exact control without any disturbances from the outside.

The air pressed by the air pomp flows through the biomass placed in bioreactor chamber. Chambers are made of metal sheet and components from stainless steel. It is conditioned with highly aggressive environment occurring during composting, in particular sewage sludge composting process (Harrison et al, 2006). Chambers have second bottom with openings of ø 2,5 mm placed every 50 mm on the whole surface.

It allows to distribute evenly the delivered air in the entire mass volume, as well as to obtain wholeness of drains leaking out from the biomass while composting.

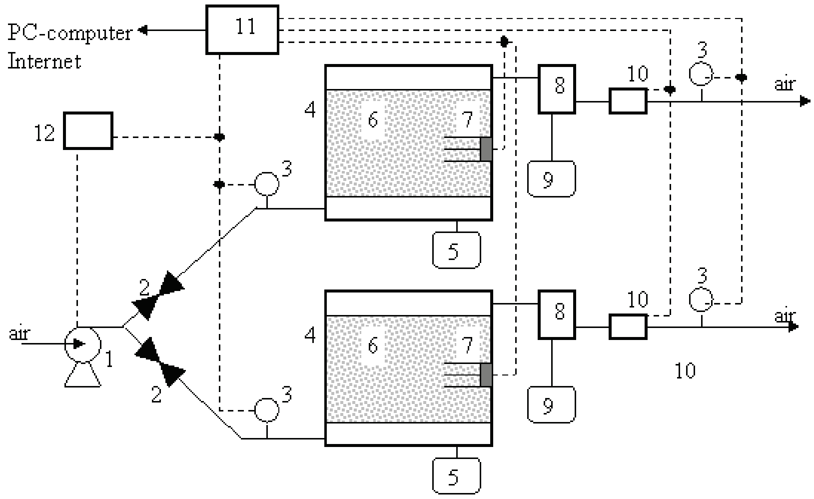

Fig. 1. Schematic diagram of the bioreactor: 1. pump, 2. flow regulator, 3. flow meter 4. isolated chamber, 5. drained liquids container, 6. composted mass, 7. sensors set, 8. air cooling system, 9. condensates container, 10. column of gases content analysis (NH_3, O_2/CO_2, CH_4), 11. 16-channel recorder, 12. air pump steering system

Between the chamber and the cover specialistic seals were used. In connection with 60 kg charge it is a hermetic set-up empowering the chemical analysis of the air leaving the chamber. Between the air pomp and chamber inlet there is an air flow regulator integrated with a flow sensor (produced in IAE by own idea of dr. A Jędruś), processed according to the individual solution. This system allows to precise control and constant registry of the air amount delivered into the chamber (in the range 0,5-6 l/min).In every bioreactor chamber there are at least 2 temperature sensors in special acid-resistant covers. The air leaving the chamber at first gets to the cooler cooperating with condensers system. The cooler target is to chill the air to the temperature below 40^{o}C (maximal working temperature for gases sensors).

Integrated sensors and systems for signals measuring and recording

Selected parameters of bioreactor measuring system are shown in Tab. 1. Parent part of this measuring system are simultaneously working two microprocessor recorders of measuring signals. Main parameters are presented in Tab. 2. In case of a breakdown of one of the recorders the data continuity is ensured by working of the second one. In case of voltage fading of feed net system automatically passes on a battery power supply. It allows to save the data already recorded in the memory and to register further measurements. The system is constantly connected with a computer. In any moment the measurements results can be forward to the computer with usage of standard output RS 232C.

Table 1. Selected parameters of bioreactor measuring system.

Measured parameter	Sensor type	Measuring range	Output signal
Temperature	LM35DZ	0-100^{o}C	0-1 V
Air flow	Electronic flowmeter	0.5-6 l/min	0-5 V
NH_3	MG-724AM	0-100 ppm	4-20 mA
NH_3	MG-724AM	0-1000 ppm	4-20 mA
O_2	MG-724OX	0-25 %	20-4 mA
CH_4	MG-724P-90	0-5 %	4-20 mA
CO_2	MG-724CF	0-100 %	4-20 mA

Table 2. Selected parameters of bioreactor measuring system.

Parameter	Type 1	Type 2
Maximum amount of measurement	168	2011
Measurement frequency	1 measurement/h	≤ 4 measurements/s
Supply voltage	12 V DC	12 V DC
Amount of measuring channels	16	32

Applied measurement heads MG-72 of Alter S.A. firm are designed to measure the gasses concentration and to forward this information to the central measuring unit. Tab.3 shows the basic technical parameters of gaseous heads.

Table 3. Basic technical parameters of gaseous heads MG-72.

Delivery time of metrologic ability	≤ 20 sec.
Nominal supply parameters	5,6V DC/30 mA
Maximum termination resistance of current loop	50Ω
Temperature working range	-20 - +40^{o}C
Humidity working range	10 – 90%Rh (without condensation)

Electro-chemical sensor is the main part of this head. It turns the changes of concentration magnitude of measured gas onto adequate changes of electric parameters. Output signal is the most essential information from the recorder point of view. Gasses measuring system consists of the following heads: NH_3 (0-1000 ppm), CH_4 (0-5%), O_2 (0-25%), CO_2 (0-25%). It cooperates with an original system of electro valves which empower to use one set of heads for 4-chamber bioreactor.

3 Results

Within last 5 years, described bioreactor set-up was used in many projects. The integrated sensors and systems for signals measuring and recording let to collect during all experiments many valuable data separately for each bioreactor's chamber. This let to compare the process parameters in each moment of the experiments and help to create the database for gases emission model (Fig. 2).

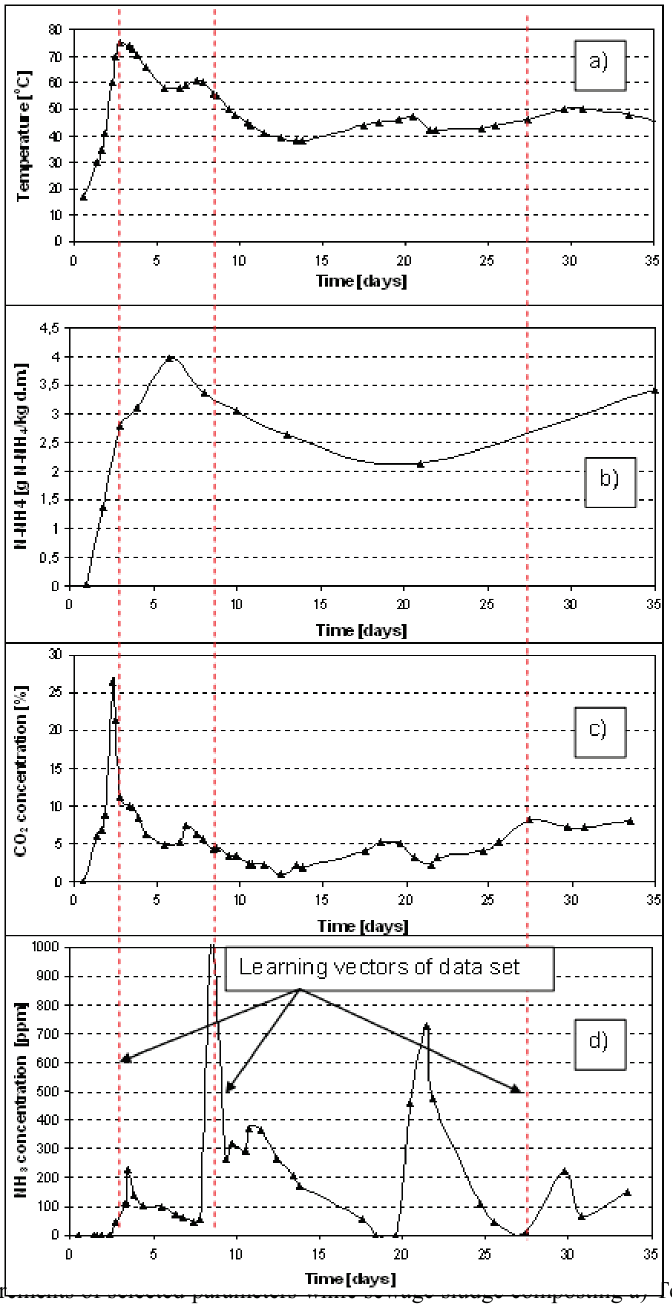

Fig. 2. Measurements of selected parameters while sewage sludge composting a) Temperature changes b) Changes of ammonia nitrogen c) Carbon dioxide concentration d) Ammonia concentration; Three vertical lines are the examples of learning data vectors.

4 Conclusions

Measuring systems and measuring signal recorders used in bioreactor are the source of wide amount of data. Large measuring frequency reflects the real dynamics of physical and chemical changes of composted mass. Moreover, it is very helpful in gaining the representative data indispensable in modeling of occurring processes. This is an essential for usage of bioreactor as a tool for prediction of aerobic and anaerobic decomposition process with usage of artificial neural network.
Usage of bioreactor eliminates some part of fieldworks, considerably decreasing costs and accelerates the obtainment of final results. Laboratory conditions give an opportunity of usage of more developed measuring apparatus in comparison with fieldworks ones.
Constant control of oxygen content allows to avoid the presence of anaerobic conditions, unfavorably influencing on the quality of compost.

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