INVESTIGATION OF THE N-DYNAMICS DURING COMPOSTING UNDER SPECIAL CONSIDERATION OF N_2-GENERATION

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ABSTRACT

The behaviour of N during composting was studied in 31 composting experiments. N-balances considering N-compounds in the substrate and the emissions were generated. N_2-formation could be detected in most experiments. Two different types of processes may be responsible. One probably occurred only at mesophilic temperatures and was only detectable under non-aerated conditions, the other took place at all relevant temperature zones and was measured also under aertion. N_2 can be generated by denitrification under anoxic conditions. NO_3^- is a needed substrate, which may be formed via nitrification. Autotrophic nitrification occurs commonly under oxic and mesophilic conditions. Heterotrophic nitrification may occur under a wide range of conditions and is more important. Oxic-anoxic interfaces may be very important in any case.

INTRODUCTION

N plays an important role during composting. On the one hand N in compost is a valuable plant nutrient; on the other N emissions during composting and compost application may have harmful effects on the environment. Significant processes of N-dynamics are ammonification, nitrification, denitrification and immobilization. Their intermediate and end products may be released via leachate and exhaust air. A lot of investigations regarding those processes and N-releases were allready described. However, mostly only one process or compound was considered and not the total N-dynamics or the direct formation of $N_{2.}$

MATERIALS AND METHODS

31 composting experiments with variable substrate and composting parameters were carried out using a laboratory composting unit (Körner et al., 2003). A sampling unit allowed gas samples to be taken. General and N-related parameters were measured (e.g. substrate - total N resp. Kjeldahl N, NH_4^+/NH_3-, NO_3-, NO_2-N; leachate - total N; condensed water – NH_4^+/NH_3-N; acidic solution - NH_4^+/NH_3-N; off-gas: N_2, N_2O). The substrates and the methods are described in more detail e.g. in Körner and Stegmann (2002). N_2 but also O_2, CO_2, H_2, $CH_{4,}$ N_2O was measured (~3 times/ week) by a gas chromatograph. Air has a N_2-content of 79.1 Vol.%. All measurements with N_2-concentrations higher than this were considered as examples where N_2-generation occurred. For the calculations of N_2-production the volume flow of the in gas was considered.

RESULTS AND DISCUSSION

In 7 experiments no N_2-concentrations above 79.1 Vol. % were found. Nevertheless, theoretically also a N_2-generation may have occurred. The O_2 contained in the fresh air will partly be transformed into CO_2 by aerobic metabolism. The volume of both (CO_2 + O_2) would stay constant in the exhaust gas. Anaerobic degradation with generation of CO_2, CH_4 and H_2 would result in an additional gas volume. This would lead to a shift in the distribution of the off-gas concentration. Although N_2 may be produced it may not be registrant since the total N_2-concentration resulting from the N_2 in the fresh air could fall below 79.1 Vol.%.

The experiments could be distinguished into the following groups regarding an increase of N_2-concentration: A) Not detected – 22.5 % of the experiments; B) Detected only in non-aerated phases – 16.1 %; C) Detected only in aerated phases – 35.5 %; D) Detected in not aerated as well as aerated phases – 25.8 %. N_2-generation could be detected in all phases of a composting process ranging from 0-150 days and from 23 to~80°C. The N_2-generation in on-aerated and aerated phases was evaluated separately (Figure 1). In *non aerated phases* a N_2-generation only was detected between temperatures from 23 to 45°C. In most of the non-aerated phases the temperatures were mesophilic since composting was in the maturation phase or the temperature decreased due to the stop of aeration. However, partly temperatures up to 66 °C were measured as well in non-aerated phases. In *aerated phases* a significant N_2-generation was detected for all temperature ranges investigated (23 to 78°C).

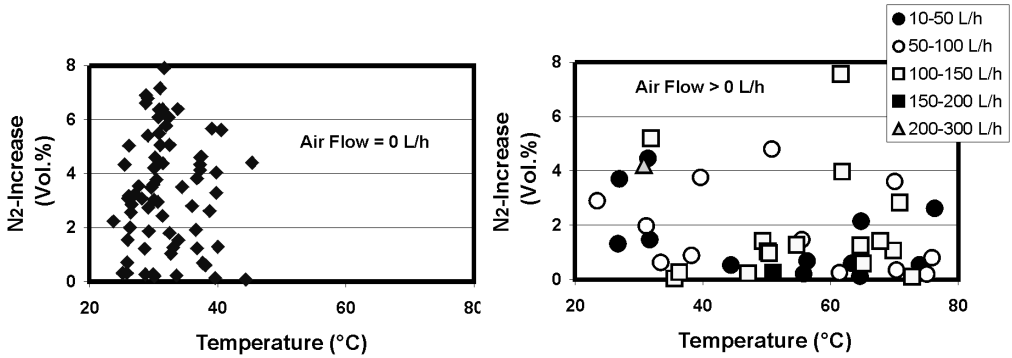

Figure 1*. Increase of N_2-concentration (over 79.1 %) in dependency of the temperature in non-aerated (left) and aerated (right) phases of 31 composting experiments*

Some of the experiments were selected to show the behaviour of N_2-generation in dependency of turning and aeration (Figure 2). N_2-formation became visible in some cases if aeration was switched off. This may mean, that O_2 limiting conditions favour the N_2-generation which corresponds with the anoxic conditions necessary for denitrification. It is as well possible, that a N_2-formation took already place but was not detectable due to the dilution with air. In some cases "anaerobic" CO_2 – production may also be responsible for a shift of the gas concentrations. A decrease of the N_2-concentration in phases were the N-amount would be constant or increasing would be the result (e.g. Figure 3 - R7b – 26-36d; R8e – 112-120d). In certain non-aerated phases (e.g. R8e) the exhaust air in the reactor was exchanged by fresh air. This change of milieu conditions had no negative impact on N_2-generation. The N_2-concentrations were re-established quickly after aeration was turned off again. Also turning of the substrate had no negative impact (e.g. R5b; R7b) on N_2-generation. It might be possible that N_2-generation was enhanced after turning, but it is also possible, that the removal of the gaseous anaerobic degradation products led to a shift in gas concentrations and N_2-generation only became better visible.

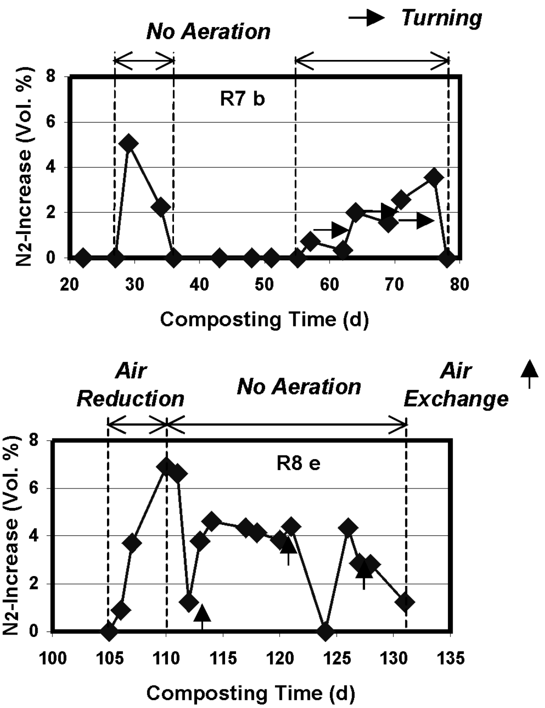

***Figure 2**. Increase of N_2-concentartion in the exhaust gas in dependencyof aeration and turning*

The N_2-formation in non-aerated phases was considered as not very significant for the N-balances. Due to the missing aeration only minimal releases may have occurred. In contrast, the N_2-generation in aerated phases might be significant (Figure 3). However, the shown N-balances are not complete, which may have the following reasons: 1) Measured N_2-generation is the minimum only. 2) Leakages may have led to N-losses. 3) Errors due to sample preparation, analytics and inhomogenities. 4) N-containing trace gases were not measured.

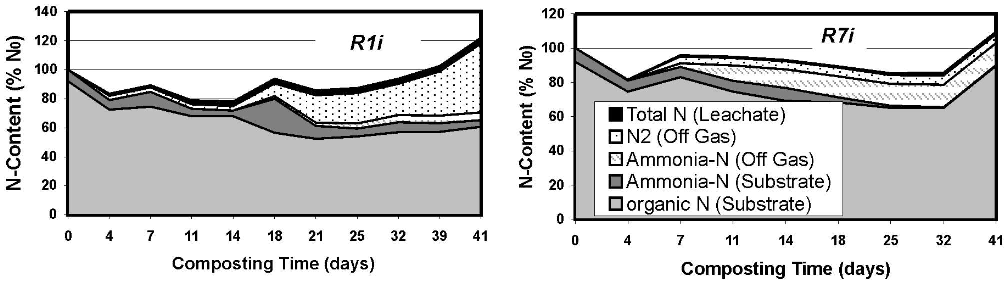

***Figure 3**. N-balances of selected composting experiments (N-content related to the N in the input)*

CONCLUSIONS

N_2 is generated by **denitrification** under a wide range of conditions using NO_3^- as a substrate. This process is considered to be carried out by heterotrophic, mostly facultatively anaerobic bacteria under anoxic conditions (Kuntze et al., 1994; Knowles, 1982). This paper shows that aerobic conditions do not inhibit denitrification. The classical pathway of **autotrophic nitrification** is commonly considerd as responsible for NO_3^- formation. The optimum temperature may range e.g. from 15 to 40 °C. Below 5 °C and above 40 °C it proceeds very slowly (Alexander, 1977; Kuntze et al., 1994). The process takes places commonly under aerobic conditions (Robertson and Kuenen, 1992). This process might be responsible for nitrification in the non-aerated phases (enough oxygen was still contained to ensured O_2-supply). The available NO_3^- was probably immediately transformed via denitrification. The **heterotrophic nitrification** was considered for a long time as unimportant. It can be carried out by a wide range of microorganisms and under a wide range of conditions. An inorganic as well as an organic degradation pathway may exist (Aleem, 1975; Doxtader, 1965). Robertson and Kuenen (1992) assume that heterotrophic nitrifiers may carry out denitrification in parallel inhibiting the accumulation of NO_3^- or NO_2^-. It may have occured in the aerated as well as in the non-aerated experimental phases.

The investigations show that N_2-releases may be significant in all stages of composting and that two different types of processes may lead to N_2-generation. One probably only occurs at mesophilic conditions and was detectable under non-aerated conditions. This process may be carried out by autotrophic as well as by heterotrophic nitrification in combination with denitrification. The other can take place in all temperature zones and is also detectable under aerated conditions. Here probably heterotrophic nitrification in combination with denitrification is important, but less the autotrophic due to its restricted temperature range. From the quantitative point of view, the heterotrophic nitrification in combination with denitrification seems to be most important for N_2-generation. In any case oxic-anoxic interfaces are needed.

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