Biological waste treatment

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Waste management continues to be a topic of increasing importance. The origins of organic waste are diverse. For instance, in European countries such as Austria around 560 kg of municipal solid waste (MSW) are produced per capita per year1. Waste generation in Asian countries ranges from 73 to 821 kg MSW capita^{-1}year $^{-1}$ (Shekdar, 2009), with constant growth rates of 8 to 10% per year as in China (Cheng and Hu, 2010). In these countries at least 25% and up to 80% of this waste stream are biodegradable (Shekdar, 2009). Taking all these numbers into account it is of no surprise that biological waste treatment has become a major biotechnological and engineering sector not only in developed but also in developing countries. Apart from the municipal and industrial sector, agriculture is among the main sources. Every year 1.5 billion tonnes of animal manure are already produced in the European union (Faostat (2003), cited in Holm-Nielsen et al. (2009)).

The introduction of appropriate management technologies is of paramount importance to promote waste resource efficiency and to open up new avenues for entrepreneurship in the waste management sector. Waste-to-energy processes have been widely used for the recycling and recovery of waste components through either direct combustion or the production of combustible fuels. In recent years, anaerobic digestion (AD) has become increasingly popular as a treatment process. This is primarily due to the production of biogas that can be used as an eco-friendly energy source, which is crucial in times of decreasing fossil fuel supplies. The substrates for AD range from manure to agricultural residues, as well as from sewage sludge to domestic organic wastes. Potential organic substrates for AD are generally combined with co-substrates to increase the overall biogas yield. However, there are also other additives that can improve the process performance, even in low amounts (e.g. trace elements). The development of AD technologies is further encouraged by efforts to reduce greenhouse gas emissions in the agricultural sector. This process has other direct advantages, which are related to the production of digestate, applicable as an organic amendment to agricultural land thereby closing the nutrient cycling. In developing countries AD is still an emerging sector and MSW is generally treated by a combination of incineration, composting and landfilling. This later technology enables the utilization of landfill gas for household and industrial purposes (Cheng and Hu, 2010).

Composting and vermicomposting have also been used for processing a wide variety of solid organic waste materials, either separately or in combination with each other, under aerobic conditions. Unlike composting, vermicomposting depends on the joint between earthworms and micro-organisms and does not involve a thermophilic phase. During these biological processes organic wastes are transformed into a safer and more stabilised product, with benefits for both agriculture and the environment, thereby resulting in a more balanced nutrient mix and increased nutrient bioavailability for plants in comparison with the untreated waste. Certain chemical characteristics of the waste can limit the efficiency of these processes, such as an excess of moisture, low porosity, a high N concentration in relation to the organic C content or high pH values. Therefore, different aeration strategies, substrate conditioning–feedstock formulation, bulking agents and process control options should be considered so as to reduce the time and costs of both processes and enhance the quality of the end-products.

Biological waste treatment processes are based on the conversion of organic matter through the chemical reactions performed by micro-organisms. They are the key players in the degradation and conversion of organic matter and are responsible for the functioning of nutrient cycling in ecosystems. Microbial communities in organic wastes are diverse and dynamic and often metabolically closely linked to each other (Insam et al., 2010). By knowing the optimal physiological and environmental needs of the micro-organisms involved in the processing of organic wastes, engineers can adapt the process conditions of full-scale plants to ideally support the work of the microbes. In the same way, adjusting environmental factors in a certain direction can inhibit undesired groups of micro-organisms or reactions. Therefore, a consolidated knowledge of microbial communities and their interactions is crucial to attain the successful treatment of the organic fraction of wastes. Recently, new bioprocessing strategies have opened a door to untended possibilities of nutrient recovery (e.g. phosphorus), a research field that will gain more and more importance when looking at the future shortages in natural resources and inefficient consumption during past decades.

Considering the recent advances in biological waste management and the implementation of novel operation strategies, it is now time to evaluate these processes, not only from an engineering perspective, but also from microbiological and economic points of view. A holistic approach to each new strategy is crucial to plan further steps. This implies the monitoring of general process parameters together with the analysis of the different microbial consortia involved in these processes. Furthermore, standardised measurement and sampling strategies would facilitate a direct comparison of results found by various researchers and accelerate methodological and operational innovations.

Ultimately, the major challenge facing professionals in our field is to create a more comprehensive framework of waste management, taking into account environmental, socio-political, economical, and legal aspects. Although economics is ultimately the major driving force other aspects such as sustainability and environmental stewardship should also be considered in order to pave the way to an integrated, forward-looking and global waste management.

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