Basics of Anaerobic Digestion

Article contributed by
Bruno de Wilde
Organic Waste Systems nv, Ghent, Belgium

Anaerobic digestion: another way of biological solid waste treatment

Within biological solid waste treatment a distinction can be made between two major categories, one being aerobic composting and the other being anaerobic digestion (AD) or biogasification.

In composting, organic matter is degraded by a microbial population consisting of bacteria and fungi, that consume the organic matter together with oxygen and produce CO₂, water, biomass (compost or humus) and a lot of heat. Due to this exothermic process, the temperature in a composting pile increases significantly. In anaerobic digestion, organic matter is degraded by a microbial population consisting of bacteria in the absence of oxygen and producing CH₄ (methane) and CO₂, this mixture often being referred to as ‘biogas’ and compost with practically no exothermic heat. When collected properly this biogas can be exploited in a CHP (Combined Heat and Power) system, producing electricity and heat, or can be upgraded to biomethane. To put it simply, the energy present in wet organic waste is released as biogas instead of heat as in composting. Typically from 1 tonne of biowaste 120 m³ of biogas can be produced, with a total electricity yield of 250 kWh and a net electricity yield of 200 kWh.

In industrial composting the different technologies are rather similar and the differences lie in relatively minor aspects e.g. aeration by over-pressure or under-pressure, the form of the waste heaps, etc. with little or no consequence for the treatment of bioplastics. In contrast, rather different technologies can be distinguished in anaerobic digestion. One distinction between different technologies is the temperature at which the anaerobic digestion is operated. Temperature is externally controlled and digesters are run either at mesophilic temperature (35–40°C), or at thermophilic temperature (50–55°C). These are two distinct temperature zones at which different types of anaerobic bacteria show maximum activity (namely mesophilic and thermophilic bacterial). The rate of activity is higher at thermophilic temperature. Further, anaerobic digestion can be a single-phase or a two-phase process. In a single-phase process the complete digestion takes place in one unit or digester. In two-phase fermentation the first phase (hydrolysis and acidification) and the subsequent methanogenic phase are run in separate tanks. The distinction between single-phase and two-phase is referred to as a distinction between dry and wet fermentation systems. In dry anaerobic digestion the process is run at a moisture content of < 85%, while in wet systems the process is run at a moisture level of > 85%.

These technical differences have rather far-reaching consequences with regard to the treatment of bioplastics. For example, certain bioplastics (e.g. PLA) need an elevated temperature (50–60°C) to start biodegrading. In thermophilic anaerobic digestion this temperature is met and these bioplastics will degrade. However, in mesophilic anaerobic digestion where the temperature is lower, these bioplastics will not readily biodegrade.

Practically all commercial anaerobic digestion systems feature a combination of an anaerobic fermentation first step, and a subsequent, aerobic composting, stabilisation second step. Since fermentation is something of a mixed process the output is not fully stabilised or fermented (note: mixing can be done in the reactor or outside the reactor by blending residue output with new feedstock input). In order to reduce the residual biological activity and to obtain complete maturity of the compost end product, the residue from the anaerobic digestion phase is therefore aerobically composted for a short time (typically for 2-4 weeks).
Even though anaerobic digestion can be applied to very different types of waste streams, it is particularly suited to organic waste with a high moisture content such as kitchen waste and food waste. Anaerobic digestion plants have been built and have been operational for many years for the treatment of mixed, municipal solid waste, for biowaste (obtained after source separated waste collection), for residual waste and for many types of industrial waste.

The major differences from aerobic composting include the production of energy, less odour production, less health risk (i.e. killing off of pathogens, typical for thermophilic digestion), less need for surface area (smaller footprint), and a higher level of technology. Consequently, anaerobic digestion is often the preferred biological waste treatment option in densely populated areas such as big cities or countries such as Japan or Korea.

Recently, anaerobic digestion has also become an important player in the area of renewable energy production from energy crops (e.g. corn). The net energy yield per hectare is higher compared to the production of bio-diesel or bio-ethanol. Also, in bio-refineries, anaerobic digestion could play an important role with high-value plant parts being used for green chemistry and residual vegetable matter (after processing of low-value plant parts, such as stems and leaves or straw) being treated in anaerobic digestion for production of energy and compost.

Current distribution and prospective of technology

Figure 1 below gives an overview of the development of biogasification capacity in Europe in the last two decades. From just three plants in Europe with a total capacity of 87,000 tonnes per year in 1990, European anaerobic digestion facilities have now grown to a total of 171 plants with a digestion capacity of more than 5 million tonnes per year in 2010. Figure 2 gives an overview of the AD capacities in different European countries. Both the total capacity per country is quoted as well as the average capacity per plant. As can be seen, some countries tend to have smaller plants (e.g. Germany, Switzerland, Austria, ...) while others have larger installations (e.g. Spain, France).

These graphs also show that the anaerobic digestion capacity in Europe is increasing rapidly. Many digesters are being built in Mediterranean countries such as Spain and France. Most plants are dry and single-phase, and run at mesophilic temperatures.

The evolution for the coming years can be deduced from the two graphs, the data for which are based on the bids for proposals published in the European Journal.

Bioplastics and anaerobic digestion

First of all, just as with aerobic composting, since anaerobic digestion is a biological waste treatment process, bioplastics
should be biodegradable in order to be compatible. Whether bioplastics are produced from renewable resources or not, doesn’t matter. The key element is that they must be biodegradable under anaerobic conditions or at least be compatible with an anaerobic digestion process.

Concerning technical preconditions of treating bioplastics in anaerobic digestion plants, a distinction must be made between wet and dry technologies. In general, wet technologies, especially in the pretreatment phase, cannot treat bioplastics easily: in the first pulping and hydrolysis phase they are removed either by flotation or by sedimentation and therefore are not really entering the digestion (except when bioplastics are quickly soluble or dispersible, which is rarely the case). A solution could be to add the bioplastics directly to the second step, the aerobic composting step (considering the retention time in this second step is much shorter than the residence time in a typical composting process). Another solution might be new developments in the pretreatment phase. In most dry systems, bioplastics can be added when some random conditions are fulfilled: they should be shredded (to reduce the particle size) before entering the digestion just like biowaste itself and sieving is better located at the end of the process in order to enable as much biodegradation and disintegration as possible in both the anaerobic digestion and the aerobic composting step.

The major underlying reason why several bioplastics show a different biodegradation behavior in aerobic composting from their behavior in anaerobic digestion is the influence of fungi. Fungi are abundantly available and very active in aerobic composting while in anaerobic fermentation no fungi are active. Some polymers are mainly (or even only) degraded by fungi and not by bacteria and will therefore biodegrade in aerobic composting and not in anaerobic digestion - or only much slower. As a matter of fact, this is also the case for the natural polymer lignin which can be found in wood, straw, shells, etc.

On the other hand, when bioplastics do also biodegrade in anaerobic fermentation there is a double benefit. First of all, energy is produced from the bioplastics in the form of biogas that can be converted to electricity. Secondly, as most bioplastics are very rich in carbon and do not contain nitrogen (or very little), the addition of bioplastics to biowaste will improve the C/N ratio of the mixture. Biowaste tends to be low in C/N, which is sometimes a problem in anaerobic digestion, by adding a carbon-rich substrate the C/N ratio is increased.

So far, the knowledge of anaerobic biodegradation and treatability of bioplastics is limited and further research would be welcome. Ideally, bioplastics would biodegrade and also disintegrate during the anaerobic phase in an anaerobic digestion plant, just as the major part of natural biowaste does. However, if the bioplastic disintegrates during the anaerobic phase and then afterwards biodegrades completely during the aerobic stabilization phase or during the use of digestate or compost in soil, it can also considered to be compatible with anaerobic digestion.
Event Calender

December 2-3, 2009
Dritte Deutsche WPC-Kongress
Maritim Hotel, Cologne, Germany
www.wpc-kongress.de

December 2-3, 2009
Sustainable Plastics Packaging
Sheraton Hotel, Brussels, Belgium
http://sustainableplasticspackaging.com

March 8-10, 2010
GPEC 2010
Global Plastics Environmental Conference
The Florida Hotel & Conference Center
Orlando, Florida, USA
www.4spe.org

March 15-17, 2010
4th annual Sustainability in Packaging Conference & Exhibition
Rosen Plaza Hotel, Orlando, Florida, USA
www.sustainability-in-packaging.com

March 16-17, 2010
EnviroPlas 2010
Brussels, Belgium
www.ismithers.net

April 13-15, 2010
Innovation Takes Root 2010
The Four Seasons - Dallas, Texas, USA
www.InnovationTakesRoot.com

June 22-23, 2010
8th Global WPC and Natural Fibre Composites Congress an Exhibition
Fellbach (near Stuttgart), Germany
www.wpc-nfk.de

Editorial Planner 2010

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Further topics to be covered in 2010:

- Beauty and Healthcare
- Lignin
- Paper-Coating
- Non-Food Bioplastics
- Printing inks
- and much more...