QUALITY CONTROL AND MANAGEMENT

TREATMENT METHOD-SOLID WASTE

Introduction

The agri-food industry produces a large variety of wastes which must be handled in an environmental and sustainable way. Depending on the type of waste, various waste handling alternatives are available; including fermentation, separation, biofuel conversion, composting, extraction and more. Choosing the right waste handling process can help to meet environmental regulations and provide a saleable by-product for further processing, recovery or animal consumption.

In this episode we are discussing solid waste management under following topics

1. Solid waste generated from different food industry
2. Dewatering of solid waste
3. Fermentation, biogas and ethanol production from solid food processing
4. Composting, food waste drying systems and landfill
5. Incineration

1. SOLID WASTE GENERATED FROM DIFFERENT FOOD INDUSTRIES

The amount of solid waste is highly variable across the food industry sector. As wastewater, its amount may depend on a number of factors, including the raw material being processed, the technology employed and the season.

Meat and poultry

Very little solid waste comes from meat and poultry processing plants. Generally, this includes bones, fat and skin. Some of it may be used, e.g. for production of glue, detergents and gelatine. However, EU, Regulation 1774/2002/EC (EC, 2002), for example, states explicitly that some animal byproducts must be disposed of as waste. The major options for the stabilization and re-use or disposal of organic solid waste from meat processing and rendering operations are composting (aerobic digestion) and vermicomposting, anaerobic digestion, disposal to landfill and incineration. Incineration has recently been adopted by the meat industry as a viable option as it is considered among the most effective methods for destroying potentially infectious agents.

Fish and shellfish

The amount of waste material resulting from fish and shellfish processing is relatively high, up to 60 % of the catch. However, nearly all of it can be reused – the range of byproducts thus produced is very large, with animal feed at the top of the list. Therefore, final solid waste output is typically non-existent.

Fruit and vegetables

The amount of solid waste in the fruit and vegetables processing sector is significant as up to 50 % of the raw material is wasted. Most of this waste is reused for the production of various by-products (animal feed is again one of the major ones), but there still remains a significant quantity of waste that needs to be disposed of. Some may be used for land spreading, though this is limited by the possibility of soil contamination by salts and organics. Therefore, the remaining waste requires waste treatment technologies such as thermal on other treatments.

Vegetable oils and fats

The amount of residual waste in this sector is very small, as there are multiple ways of reusing virtually everything that is not a product. Solid waste specification is, therefore, not meaningful.

Dairy products

A relatively low amount of solid waste is produced in the dairy sector, mainly comprising waste sludge from on-site wastewater treatment plants. Landfilling is the typical means of disposal at present.

Sugar

The solid outputs from sugar beet processing include soil, beet pulp, weeds and lime. All may be sold or re-used, so there is virtually no solid waste output in this sector.

2. DEWATERING OF SOILD WASTE

A lower moisture content of the waste material has benefits for transport costs with reduced volume and reduced weight. The reduction of moisture content offers flexibility in terms of handling, shelf life and subsequent use of the waste. Common dewatering processes use mechanical means of separation such as screens, screw presses, belt presses, vacuum filters and centrifuges, which can all be combined with additional forces to remove the water – such as using an electric field, ultrasonics, vibrations, chemical treatments, etc. In any dewatering application there is a definite advantage in combining multiple dewatering fields to promote the synergy of separation forces.

There are several dewatering methods such as Belt filter press, Screw press dewatering, Rotary and centrifugal presses, Membrane filter press, Electro-osmotic dewatering, Dissolved air flotation separation and even combined dewatering methods such as Electro-osmotic belt filter, Ultrasonic vibrations, Electro-acoustic dewatering, Vapour pressure dewatering are considered to be more effective.

Food Waste Drying SystemS (FWDS)

It can provide a fast, simple and user friendly onsite process for decomposing and dehydrating food scraps into rich soil sediments. Another benefit of FWDS is that they do not require any microorganisms, enzymes, fresh water or other additives. In addition, they can be configured to extract animal oil for high quality biodiesel refinement. Throughput capabilities range from 60 pounds to 100+ tons per day. The size of a 60 lb per day system only requires a footprint of approximately 9 square feet and a system capable of processing 2,400 lbs per day requires roughly 72 square feet of floor space (12' x 6').

3. FERMENTATION, BIOGAS AND ETHANOL PRODUCTION FROM SOLID FOOD PROCESSING

The anaerobic process is accomplished through biological conversion of organics to methane and carbon dioxide in an oxygen-free environment. The overall conversion process is often described as a three-stage process which may occur simultaneously in an anaerobic digester. These stages are: (1) hydrolysis of insoluble biodegradable organic matter; (2) production of acid from smaller soluble organic molecules; (3) methane generation. The three-stage scheme involving various microbial species can be described as follows: (1) hydrolysis and liquefaction; (2) acidogenesis; (3) methane fermentation.

Biowaste to ethanol

Around half of the total dry matter in plant origin biomass is cellulose, and since this makes up the majority of the biowaste component in MSW, it represents a huge potential source of renewable energy. As is widely appreciated, sugars can be broken down by certain micro-organisms to produce alcohols, of which ethanol (C_2H_5OH) is the most common. This is, of course, a well-known application for the production of alcoholic beverages across the world, typically using fermentative yeasts.

In the mid-1990s, various researchers began to investigate the potential of genetically modified bacteria, by inserting appropriate sequences from a variety of naturally occurring wood-rotting organisms. In the following years, a number of technologies have emerged, based both on whole-organism and isolated-enzyme techniques, and the commercial processing of cellulose to alcohol now appears to be about to become a mainstream reality.

A number of countries have begun to show an interest in the potential gains to be had from developing a biowaste-based ethanol industry. Within the USA, many individual states have started to undertake feasibility studies for their own areas. A recent California Energy

Commission Report, for example, has established that the state-wide annual generation of biowaste exceeds 51 million dry tonnes, comprising forestry residue, MSW and agricultural waste. The same document estimates the resultant maximum ethanol yield at more than 3 billion gallons (US).

4. COMPOSTING, FOOD WASTE DRYING SYSTEMS AND LANDFILL

For centuries, gardeners and horticulturalists have encouraged biodegradable waste to break down to produce stable, nutrient-rich compost for use in pots or directly for improving the soil. This application of the natural, exothermic process of aerobic decomposition, is familiar and time-honoured. More recently, however, composting has been the recipient of increased attention as a potential means of treating biowaste.

When considering On-Site composting or Food Waste Drying Systems there are several questions that are important, such as a) Space Availability, b) Staff Resource for separating food scraps from trash as well as operating the equipment etc; c) Infrastructure availability (whether it is just electrical requirements or sewer considerations); d) End Use for the finished product; e) local support and cooperation or obstacles from nearby businesses or residences and; f) approvals from local enforcement agencies. Of course, approvals and permit requirements from local agencies will depend upon the type and volume of food being composted. The most common on-site methods are in-vessel composting; vermicomposting and anaerobic digestion.

In-Vessel Composting

This process involves temperature, moisture and aeration controlled systems where organic materials are fed into equipment which has mechanisms for turning or agitating the material for proper aeration. This type of system can generally process large amounts of waste without taking up too much space and can accommodate almost any type of organic waste (meat, biosolids, food scraps etc). It can also be used year round in almost all climates (including extremely cold weather) since the internal environment is controlled, usually by electronic means. The process is fairly quick and can take as little as a few weeks (however for the microbial activity to stabilize into finished compost it can take several more weeks or months). Available land space, as well as haulers and end users in your area will help you decide which is better for you. Some in-vessel systems are fully automated with sensors to monitor temperature, oxygen, and moisture. They use biofilters to reduce or eliminate odors. This is a good method for institutions with large amounts of compostable materials and limited space.

Vermicomposting

With this process, worms are used to break down the organic materials. Animal products or grease cannot be composted using this method but (when applicable) this process can break down organic materials into high value compost faster than In-Vessel composting.

The use of a variety of annelid worm species is one alternative approach that has received fairly regular reawakenings of interest over the years, having been variously termed worm composting, vermicomposting, vermiculture or our preferred annelidic conversion, a term first attributed to H. Carl Klauck of Newgate, Ontario. The description worm composting and its like is somewhat misleading, since the process from both biological and operational criteria is quite distinct from true compost production in two significant ways.

Firstly, as we have seen, in traditional composting, breakdown is brought about by the direct actions of a thriving microbial community. Within a worm based system, while micro-organisms may contribute in some way to the overall biodegradation, their role in this respect is very much incidental to that of the worms themselves.

Secondly, in worm systems, biowaste is typically laid in much shallower layers than is the case for windrows or static piles, frequently being deposited on thesurface of an underlying soil bed. This is a major difference, principally because it reduces the natural self-heating tendency within the decomposing matrix.

Worms of various species can be present in traditional compost heaps, even in thermophilic piles, but they avoid the genuinely thermophilic core, being found at the significantly cooler edges of the heap. In addition, under such conditions the resident annelid population is, in any case, many magnitudes smaller than in the deliberately high-biomass levels of AC systems. While in common with all poikilothermic organisms, worms do require some warmth to remain active, which for most species means a lower limit of 10 ºC, they do not generally tolerate temperatures in excess of 30 ºC and death occurs above 35 ºC. Most species have an optimum range of 18–25 ºC, which makes the point very clearly that the highly exothermic conditions encountered as part of the ‘true’ composting process would be impossible for them to survive, and certainly not in any sizeable numbers.

Anaerobic Digestion

Although composting certainly accounts for the majority of biowaste treatment applications around the world, anaerobic digestion (AD) is an alternative option which has been receiving increasing interest over recent years. In many respects, it is a regulated version of the natural events of landfill, in that it results in the controlled release of methane-rich biogas, which offers the potential for a very real form of energy from waste. This technology is viewed in certain circles as rather novel, but this is not really the case. It has been used in the water industry for around a hundred years to treat sewage and, more recently, been successfully applied to the processing of agricultural and household wastes, most notably in Germany and the Netherlands. However, waste management tends to be a naturally cautious field and the relative lack of a proven track record with MSW-derived biowaste compared to composting has made the uptake of this approach slow.

The key to effective practical applications of AD technology lies in regulating and optimising the internal environment of an enclosed bioreactor vessel such that the ideal conditions for the process are produced and maintained. Under these circumstances, in the absence of free oxygen, anaerobic bacteria convert the large organic molecules mainly into methane CH_4 and carbon dioxide CO_2. The actual progression of this breakdown is chemically very complex, potentially involving hundreds of intermediary reactions and compounds, many of which have their own additional requirements in terms of catalysts, enzymes or synergistic chemicals. Unlike composting, AD occurs at one of three distinct temperature ranges, namely:

- Cryophilic (<20 ºC).
- Mesophilic (20–45 ºC).
- Thermophilic (>45 ºC).

Since AD is very much less exothermic than composting, within a landfill or in bogs and swamps, it proceeds under cryophilic conditions. This largely accounts for the relatively protracted timescale and the irregular progress of breakdown typically encountered in these examples. In order to overcome these drawbacks, engineered anaerobic bioreactors are usually run at one or other of the higher ranges, with additional heat supplied by external means to elevate the temperature to the required level. A variety of technology vendors have developed commercial systems based around either thermophilic or mesophilic digestion, which have their own particular characteristics. Without entering into a lengthy discussion of the relative merits of these approaches, it is important to note that the internal conditions favour different bacterial complements and that certain aspects of the reaction details also differ. Consequently, for any given application, one or other may be particularly suited, dependent on the specifics of the material to be processed and the overall requirements for treatment.

There are four main groups of bacteria involved in AD, as shown below, with some typical examples of each:

• Hydrolytic fermentative bacteria – *Clostridium* and *Peptococcus*.

• Acetogenic bacteria – *Syntrophobacter* and *Syntrophomonas*.

• Acetoclastic methanogens – *Methanosarcina* and *Methanothrix*.

• Hydrogenotrophic methanogens – *Methanobacterium* and *Methanobrevibacterium*.

Ananerobic digestion can be carried out in several systems such as Anaerobic baffled reactor (ABR), Anaerobic fixed film reactor (AFFR), Completely mixed contact reactor (CMCR), Continuously stirred tank reactor (CSTR), Fluidised bed reactor (FBR), Multi-phasic processes (MPP) and Upflow anaerobic sludge blanket (UASB).

This process involves breaking down organic matter in an oxygen-free environment in order to generate biogas, which is a combination of methane and carbon dioxide. The methane can then be burned for energy. The material that remains after digestion (digestate) should then be composted aerobically to complete the process and produce a valuable soil amendment. In addition to energy production, another benefit of anaerobic digestion, is that these systems require less space than many other large-scale composting methods, which means they are easier to locate in urban areas.

Efficient AD requires the development and maintenance of an optimised internal environment to facilitate biological activity. This is of particular importance in the commercial setting and a number of both physical and chemical factors must be taken into account to achieve it, of which the most important are:

• Temperature

• Retention period

• Agitation

• Wetness

• Feedstock

• Loading rate

• pH and volatile fatty acids concentration.

Landfill

Another natural process of solid waste management is landfill. All discarded biological waste gradually undergoes a natural process of biodegradation, typically beginning with autolysis and culminating in putrefaction. The speed at which this progresses is governed by a number of factors such as the nature and freshness of the material, the temperature, moisture and so on. When this happens in the open air, or in the upper levels of the soil, decomposition is aerobic, the organic material being mineralised and carbon dioxide (CO_2) released as the major gaseous product. However, though biowaste awaiting collection in dustbins and even, to some extent, when only recently delivered to landfill, initially begins to break down in this way, older putrescible material, buried deeper, experiences conditions effectively starved of oxygen. In this environment, the degradation process is anaerobic and mineralization continues with broadly equal amounts of methane (CH_4) and carbon dioxide being produced. This resultant mix is known as landfill gas and typically contains a number of trace gases of varying chemical composition. At the functional level, the mechanism of this reaction is very complex, with hundreds of intermediary reactions and products potentially involved and many requiring additional synergistic substances, enzymes or other catalysts.

$$\text{Organic material} \longrightarrow CH_4 + CO_2 + H_2 + NH_3 + H_2S$$

5. INCINERATION

Incineration as a disposal method involves burning the trash. Sometimes this is simply referred to as thermal treatment, as a general category of high temperature treatment of trash material. This method can be used to transform waste into heat, gas, steam and ash. One of the advantages of incineration is that with this method, refuse volume can be reduced by half or more and it requires little usage of land. An incineration facility can be built in a small area to process huge amounts of waste. It definitely saves a lot of space compared with using a landfill only. This method is popular in countries like Japan where space is limited.

Incineration of waste materials converts the waste into ash, flue gas, and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas. Some Incinerators generate energy from the burning of waste; these plants are called waste-to-energy plants. Incinerators reduce the volume of waste by about 90 percent and weight by 75 percent. There are eight types of incinerators, fixed-hearth incinerators, rotary kiln, plasma arc, liquid injection, fluidized bed, multiple hearth, catalytic combustors, and static heart incinerator. In 1885 the U.S. Army created the first garbage incinerator in New York Harbour.

Incinerators can have a harmful effect on the environment. Incinerators can release up to 190 different chemicals into the sky such as lead, mercury, and arsenic. Incinerators liquefy materials which may end up in watersheds causing water pollution. Incineration can leave behind dangerous materials that need to be put into special landfills.

Conclusion

For facilities generating large percentages of food waste it is important to initiate an analysis of the waste stream and existing circumstances so that various alternatives can be properly evaluated. Due to the growing pressures towards food waste, the above practices are becoming more and more commonplace and the trend is expected to accelerate at an even faster pace in the near future.