DAIRY PROCESSING WASTES ANAEROBIC DIGESTION

The main wastes generated from dairy process industries are whey, dairy sludges and wastewater (processing, cleaning and sanitary). Such wastes tend to have a high nutrient concentration, an elevated biological oxygen demand (BOD) and chemical oxygen demand (COD), as well as appreciable organic and inorganic contents.

Reducing and utilising such waste streams is a priority for dairy processors, as a means of reducing costs and mitigating environmental impacts. A wide range of potential technologies may be used to biologically convert wastes into energy and products but the complex and varied nature of dairy wastes makes an assessment of the best strategy for the utilisation of each specific waste stream a challenge.

With the rapid industrialisation of dairy processing observed in the last century, and the growing rate of milk production, dairy processing is usually considered one of the largest, if not the largest, industrial food wastewater source. Around 50% of the world's whey production, and especially acid whey, remains untreated at the point of disposal.

Anaerobic digestion facilities are more suitable for the direct utilisation of high-strength dairy wastewater than chemical or mechanical processing options. They are also more cost-effective than aerobic processes. Where properly operated, such systems do not produce unpleasant odours.

The major problems of anaerobic dairy wastewater treatment include long start-up times, due to complex substrate degradation, preliminary biomass adaptation prior to protein and fat utilisation, and rapid reductions in pH leading to a resultant inhibition of methane production. This latter difficulty occurs as a consequence of the high concentration of easily fermentable lactose and low substrate alkalinity. Further issues are sludge disintegration by fats in the form of triglyceride emulsions and subsequent biomass flotation, the presence of inhibitory compounds, e.g. long-chain fatty acids, K^+ and Na^+ ions, problems with ammonia and phosphorus removal, and an increased sensitivity to shock loadings.

COMPONENTS INVOLVED IN A DAIRY WASTE-TO-ENERGY SYSTEM

Pre-treatment

Anaerobic digestion

Ammonia control

Hydrogen sulphide control

Biogas pumping equipment

Biogas processing systems

Burners and/or power generation equipment

Compressed biomethane preparation and dispensing

All of the above items are available directly from Organics using project-proven proprietary technology

ISO 9001 REGISTERED FIRM

ISO 14001

PROJECT ROUTE

Organics has developed a project delivery structure for dairy processing waste anaerobic digestion projects over many years that ensures reliable completion and quality control whilst maintaining specification requirements, and time-schedules.

WASTE STREAM CHARACTERISATION

Waste stream characterisation involves two primary subject areas: (1) rate and composition of waste arisings; (2) analysis of waste biodegradability. The first is achieved with an on-site sampling campaign, the second with laboratory analyses and Bio-Methane Potential (BMP) testing.

SITE ASSESSMENT AND SPECIFICATION

Establishing a clear statement of the practical design parameters is the first step in determining scope. This will require a detailed study of each specific situation.

DESIGN

Each project is designed as a unique entity to ensure that all details are fully addressed.

PROCUREMENT

The procurement function takes full responsibility for maintaining delivery schedules. Their remit is from drawings and component specification through to all parts ready for final fit-out and commissioning.

MANUFACTURE

Manufacture may either be completed to “good engineering practice” or, where specifically requested, under the supervision of a Third Party Inspector, such as Lloyds.

INSTALLATION

Installation can be a complex process and requires careful planning.

COMMISSION AND HANDOVER

Established procedures are followed to ensure that equipment is fully operational at the point of handover.

PRE-TREATMENT REQUIREMENTS

In dairy plants, the great fluctuations in wastewater quality and quantity are problematic as each milk product needs a separate technological line.

A major factor in the volumetric loading of dairy wastewater treatment plants is the immediate discharge produced in the cleaning of tank trucks, pipelines or equipment at the end of each cycle. In such cases, the effluent volumes are higher than those of manufactured milk. On average, wastewater discharge is 70% of the amount of the fresh water used in the plant.

Pre-treatment is necessary to equalise volumetric and mass flow changes. It can also reduce elements of suspended solids. Given the fact that the wastewater is largely washdown water, from the cleaning of cleaning of tank trucks, pipelines or equipment at the end of each cycle, it will normally be necessary to assess the buffering capacity required on a case-by-case basis. This will be developed out of an audit of the processes involved and the timings of activities executed in the factory.

Where possible fresh water should be separated out of the feed to the anaerobic digester, to avoid excessive dilution. Feedstock should be monitored for pH, COD, volatile solids and alkalinity with a view to ensuring that there are no excessive shocks passed into the anaerobic digester. Chemical dosing may be required to bring monitored parameters into line.

Clearly, this will be a challenging feedstock to address, being distinguished by its relatively increased temperature, high organic content, and wide pH range, but, on the other hand, the nature of such dairy wastes are highly conducive to the production of biogas. Such biogas can result in difficult wastes becoming an additional source of revenue.

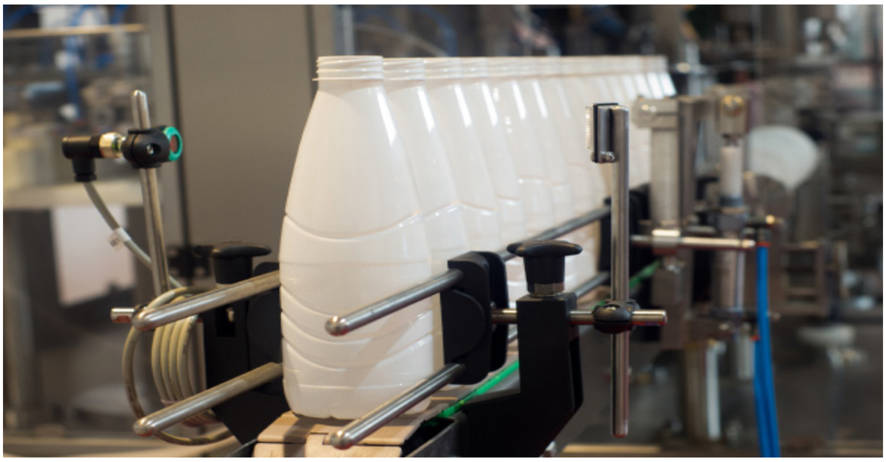
ANAEROBIC DIGESTION

Anaerobic systems are suitable for the direct utilisation of high-strength dairy wastewater and are more cost-effective than aerobic processes. Milk processing effluents are predominantly treated in conventional single-phase systems: upflow anaerobic sludge blanket (UASB) reactors and anaerobic filters (AF). UASB reactors have been used in industrial dairy wastewater treatment for more than twenty years.

Dairy effluents with low Total Suspended Solids can be successfully utilised in AFs. A large specific surface of the filter media creates a pre-condition for higher biomass accumulation which is less affected by shear stress. A five-times higher load than with the non-porous filler under the same conditions can be achieved.

Other types of anaerobic digester which may be suitable for specific situations include the anaerobic baffled reactor (ABR) and the continuously stirred tank reactor (CSTR). The CSTR can be combined with membrane filtration, to minimise biomass losses at shorter hydraulic retention times.

Similarly, separated-phase systems may often be preferred from a technological point of view. They have the highest organic loading rates and shortest hydraulic retention times compared to other anaerobic digesters. The consecutive acidogenic-methanogenic phase division of anaerobic digestion is suitable for the treatment of dairy wastewater with an unbalanced composition (high C:N ratios which acidify very quickly). In such separated-phase systems, the acidogenic reactor has a major role as it supplies short-chain volatile fatty acids which can be readily fermented to methane in the methanogenic reactor. The easily utilisable lactose requires a shorter hydraulic retention time and a smaller volume of the acidogenic reactor than the methanogenic digester



BIOGAS FEED TRAIN

A typical biogas feed train will consist of a prime mover, to drive the biogas through the various items of equipment involved and deliver it at the correct pressure to the point of use, as well as gas cleaning equipment, typically for hydrogen sulphide reduction and/or siloxanes, gas filtration and gas dewatering facilities.

Gas dewatering may be accomplished to acceptable levels with a simple air-blast cooling system, although to prevent condensation it may often be necessary to employ a chiller. This unit can drop the dewpoint to below ambient conditions. As well as the general difficulty of having water condensing in gas burners or gas engines, the condensate can also pick up trace gases in the biogas, leading to highly corrosive acids, such as sulphuric acid, coming from hydrogen sulphide combined with water.

Organics has considerable experience with building biogas feed trains. Each application and each type of biogas needs to be assessed in its own right. Pressure losses through the system, temperatures and relative humidity all need to be taken into account when optimising design. As much as is possible, Organics specialises in mounting equipment onto factory-built skids, or into ISO containers, thereby simplifying installation.

As well as standard packages there is often a requirement to address specific issues and specific requirements. Removal of carbon dioxide, in whole or in part, will be necessary for the use of biogas as a vehicle fuel. Removal of oxygen and nitrogen may be necessary where these gases are found to be entrained and cannot be removed by means of prevention.

BIOGAS UTILISATION

Biogas may be used in several ways to recover both energy and greenhouse gas credits. Where methane is destroyed and fossil fuel is offset, credits may also be available.

The simplest route for biogas utilisation is to pipe gas to a boiler or a kiln. As with all green-house destruction, it is essential that the actual destruction of methane is proven beyond any doubt.

Should such an option not be available at a specific location, as is often the case at food waste facilities, the next option is to generate electrical energy, either for in-house use or for sale to the national electricity grid. In either case, the electricity produced should preferably be used to offset fossil fuel electricity, such as power from diesel engines.

One further option is that of converting biogas into bio-methane. This involves the removal of carbon dioxide from biogas and the compression of the balance-methane to approximately 3600 psig (250 bar). This technology draws upon global experience with CNG in vehicles. Compressed Bio-Methane (CBM) may be suitable for vehicle use and creation of carbon credits but careful attention must be paid to the problem of destruction-verification. Simply put, it is difficult to prove methane destruction in a vehicle that is travelling around, although the environmental benefit is clear.

As with anaerobic digestion, each technology has its own optimum point of application. The decision as to which route to take is a function of cost, opportunity, technology and practicality. Organics can assist in such decisions from a perspective of knowledge, experience and familiarity with all relevant costs.

KEY FEATURES

TURNKEY DESIGN, MANUFACTURE AND INSTALLATION OR COMPONENT SUPPLY ONLY

FINANCE AVAILABLE THROUGH AFFILIATED COMPANIES FOR BUILD, OWN, OPERATE AND TRANSFER PROJECTS

OPERATION AND MAINTENANCE SERVICES PROVIDED

A ONE-STOP SOLUTION FOR A COMPLETE SERVICE RELATING TO THE DEVELOPMENT OF RENEWABLE ENERGY PROJECTS

The objectives of a project designed to recover energy from food waste are:

- The installation of an anaerobic digester which will generate biogas and reduce waste flows to landfill
- Reduction of odours and harnessing energy in the form of methane
- Generation of renewable electricity to offset the use of fossil-fuels
- Production of compost
- Where applicable, reduction of greenhouse gas emissions and creation of Certified Emission Reductions (CERs) by reducing greenhouse gas emissions

Organics is equipped to supply individual components within a complete system or all of the components required to make up a complete system. Organics has been active in this sector since 2002 and has a wide experience with all elements of such systems, from equipment design, instrumentation set-up for CDM compliance and CDM compliant gas flaring to gas production technologies as well as energy generation using engines operating with biogas.

TYPES OF WASTE

Two main by-products are obtained from the dairy industry: effluents, including washing and pasteurisation water, and cheese whey.

Effluents are mostly mixed with detergents and have low organic loads. By way of contrast, cheese whey is highly polluting. Up to ten litres of cheese whey are obtained per kilogram of cheese produced.

On a dry matter basis, cheese whey is composed mainly of lactose (~70%), proteins (~10%), and minerals (~15%). Its pH ranges between 3.3 and 9.0; it contains between 0.01 to 1.7 g/L of Total Kjeldahl Nitrogen (TKN); its Chemical Oxygen Demand (COD) is in the range of 50–102 g/L; and its Biological Oxygen Demand (BOD) ranges between 27–60 g/L. For these characteristics, cheese whey may, therefore, be considered an attractive substrate for biological treatment through anaerobic digestion, leading to bioenergy production

The implementation of many such processing alternatives is a part of the transition taking place in dairy companies, from the traditional linear economy model (take-make-use-dispose) to the new paradigm of the circular economy, which proposes the reincorporation of biological and technical waste into production chains. Both biogas and digestate can help to achieve this objective.

PROCESS REQUIREMENTS

There are three primary variables which must be addressed when designing an anaerobic digestion facility for dairy industry wastes. These are: type of inoculum, the substrate mix, and the reactor configuration.

Some of the inoculum characteristics, such as being granular or flocculent, determine the biogas production. It is noted that granules have greater microbial activity, which stimulates the substrate degradation, obtaining higher biogas productions rates, so leading to smaller footprint requirements. Inoculum may come from existing operational facilities or from other agro-industrial waste treatment plants, such as chicken litter digesters, cattle and pig farms.

The substrate to be deployed is the key factor for the development of an anaerobic degradation process. Characteristics such as pH, alkalinity, volatile fatty acids, nutrients, and the carbon/nitrogen ratio, amongst other variables, influence the production of biogas. It may often be desirable to use a substrate-mix to improve the performance of anaerobic digestion. There are many suitable co-digestion wastes.

The configuration and operation of the reactor has a major influence on biogas production. The options range from the Upflow Anaerobic Sludge Blanket (UASB), to the Completely Stirred Tank Reactor (CSTR) and the inground, covered lagoon anaerobic reactor (CLAR). The organic loading rate (OLR), the number of separate stages and the hydraulic retention time (HRT) should provide a balance between cost, performance and footprint. An increased OLR or a reduced HRT usually comes at a cost. Separating out the biological stages may improve performance. Each situation will be judged by Organics on its merits.

SPECIAL CONSIDERATIONS

Effective management of ammonia within an anaerobic digester can lead to many performance improvements, such as reduced water and chemical requirements, as well as increased gas production. Ammonia is an inhibitor to methanogenesis at relatively low concentrations. Organics owns several proprietary technologies requiring no chemical additions, which can be used for the control of ammonia in anaerobic digestors, both within the anaerobic digestion process as well as in the effluent line.

Mixing within an anaerobic reactor is also substrate specific. The options range from occasional to continuous mixing. It is important to maintain the correct degree of mixing in the anaerobic digestion tank in order to avoid the build-up of a scum on the surface or prevent the separation of elements within the substrate.

Organics

Organics Group plc

Sovereign Court II
University of Warwick Science Park
Coventry CV4 7EZ,
United Kingdom
T: +44 (0) 24 7669 2141
F: +44 (0) 24 7669 2238
E: comms@organics.co.uk
W: www.organics.co.uk