# Anaerobic Co-digestion of Fat, Oil and Grease (FOG) with Sewage Sludge

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Sewage sludge anaerobic digesters

## Background

- Large quantities of fat, oil, and grease (FOG), generated from households and food service establishments (FSEs), are discharged into sewers and react with other constituents (e.g., calcium ($Ca^{2+}$) ions from concrete) to form insoluble and hardened FOG deposits that frequently block sewerage networks and cause sanitary sewer overflows (SSOs).
- FOG accumulation can also cause operational problems including blockages and fouling at wastewater treatment plants (WWTPs).
- In the UK, 50% of total annual SSOs are caused by FOG deposits.
- The estimated annual cost of removing FOG deposits from sewers in the UK is £15-50 million, and 130 t of “fatberg” were removed from sewer lines in London in 2017.
- Whilst FOG normally represents one of the smallest fractions of organic matter in sludge (10-15% dry solids (DS)), it is the most digestible (80%) and has by far the largest contribution to the overall biogas yield, equivalent to more than 40%, compared to other major substrate types (protein, carbohydrate and fibre) present in sludge (Liu & Smith, 2022). Significant advantages could therefore be gained by increasing the biogas yield of sewage sludge anaerobic digestion (AD) by co-digesting sludge with FOG collected from sewers or grease separators at FSEs or at WWTPs.

Image of FOG deposit on a sewer pipe wall (Wilkinson Environmental, 2018)

## Effect of FOG on the AD process

Table 1. Examples of studies from literature

| | Primary Substrate | Co-substrate | Mixing Ratio (on a volatile solids basis) | Process Temperature | Methane yield increase | Reference |
|---|---|---|---|---|---|---|
| 1 | Mixed sewage sludge (SS) | Grease trap sludge (GTS) | 70% SS + 30% GTS | Mesophilic | 27% | Davidsson et al. (2008) |
| 2 | Mix of primary sludge (PS)and thickened waste activated sludge (TWAS) | FOG | 21%PS+31%TWAS+48%FOG | Mesophilic | 198% | Kabouris et al. (2009b) |
| 3 | Waste activated sludge (WAS) | Greasy sludge (GS) | 60% WAS + 40% GS | Mesophilic | 76% | Girault et al. (2012) |
| 4 | Waste activated sludge (WAS) | Greasy sludge (GS) | 48% WAS + 52% GS | Mesophilic | 106% | Girault et al. (2012) |
| 5 | Mixed sewage sludge (SS) | Greasy sludge (GS) | 40% SS + 60% GS | Mesophilic | 70% | Noutsopoulos et al. (2013) |
| 6 | Mixed sewage sludge (SS) | Grease trap sludge (GTS) | 88% SS + 12% GTS | Mesophilic | 93% | Grosser and Neczaj (2016) |
| 7 | Mixed sewage sludge (SS) | Grease trap sludge (GTS) | 54% SS + 46% GTS | Mesophilic | 66% | Luostarinen et al. (2009) |
| 8 | Mixed sewage sludge (SS) | FOG | 35% TWAS + 65% FOG | Thermophilic | 87% | Alqaralleh et al. ( 2018) |
| 9 | Mixed sewage sludge (SS) | FOG | 30% TWAS + 70% FOG | Hyper-Thermophilic | 145% | Alqaralleh et al. ( 2018) |

## Research Gaps

- Significant differences have been observed in increase in biogas yield with various types of FOG content added to sewage sludge (Table 1). These differences are possibly due to different sources of FOG and different characteristics of fatty co-substrates. Despite the significant potential benefits of FOG on the AD process and biogas yield (BY), the extent of the effects of the wide variation in different sources and types of FOG on the process have not been quantified.
- More information is required on the role of fundamental physico-chemical properties of different sources of FOG that influence the AD process.
- Comprehensive characterisation of FOG and FOG deposits is also required to determine how FOG properties and saponification reactions in sewer systems may improve biogas yield.

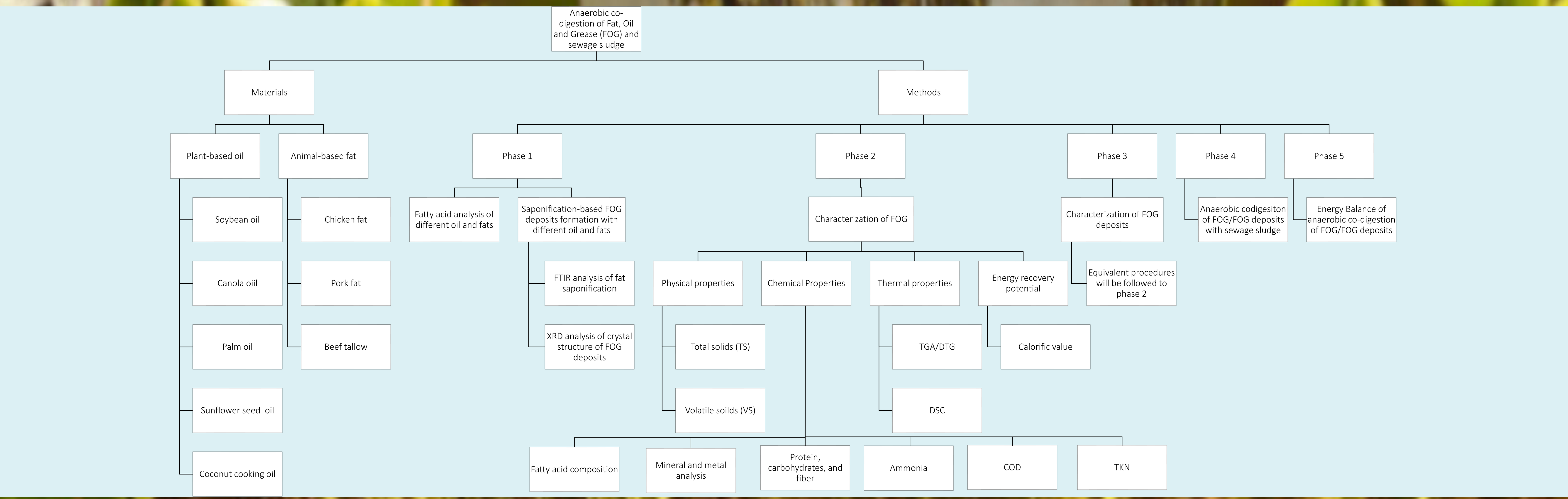
## Inhibitory Effect of FOG on the AD process

- High rates of FOG/grease trap waste addition, greater than 60% on a VS basis, to sewage sludge may cause AD operational instability and reduce biogas yield because of long chain fatty acids (LCFAs) accumulation.
- Saponification with Ca can reduce the inhibitory effects of LCFAs on the AD process and significantly improve the biogas yield.
- Moreover, FOG deposits form in sewers through the saponification reaction between Ca and LCFAs.
- Indeed, Hao et al. (2020) showed that FOG deposits increase higher biogas yield compared to freshly collected sources of FOG because saponification reactions reduce inhibition by LCFAs.

## Research Plan

- A programme of research has begun at Imperial College London to complete a comprehensive characterization of FOG and FOG deposits to understand the effects on anaerobic co-digestion (ACD) of sewage sludge. This research aims to provide insight into how FOG behavior and saponification reactions in the sewer system may improve biomethane yield. Objectives include:
  - ➢ Determination of the physical, chemical and thermal properties of FOG and FOG deposits.
  - ➢ Investigation of the changes in physical, chemical and thermal properties of FOG sources and corresponding FOG deposits that result from saponification.
  - ➢ Assessment of the effects of these changes on ACD performance by comparing the bioenergy recovery potential of FOG and FOG deposits.
- Batch chemostat experiments will be performed to examine the anaerobic co-digestion of FOG/FOG deposits with sewage sludge, and to determine the effects of FOG properties on the process energy balance.

## Experimental Framework




Experimental flow chart for the research investigation of the effects of FOG properties on anaerobic co-digestion of sewage sludge

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