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Perspectives in anaerobic digestion of lipid-rich wastewater (No. IWA-522223)

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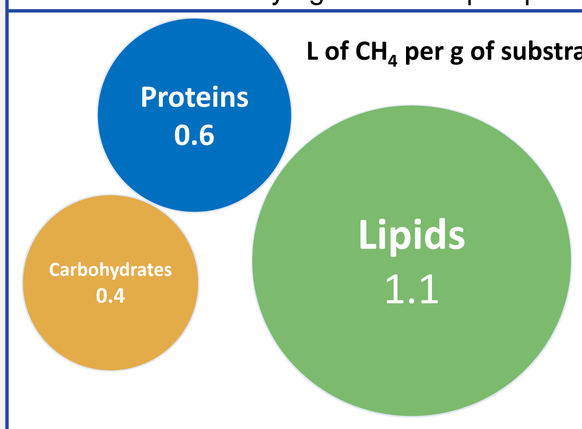
INTRODUCTION

Lipid-rich wastewaters are ideal sources for methane production, but lipids are generally separated and removed prior to anaerobic treatment to avoid sludge flotation and microbial inhibition. In this work, we review the major technological and microbiological advances in the anaerobic digestion (AD) of lipids, while highlighting the most important breakthroughs in the field and identifying the future perspectives.



Lipid-rich wastewater has high energy potential


Slaughterhouses
45 – 700 mg Lipids L^{-1}


Dairy industry
500 – 9500 mg Lipids L^{-1}


Edible oils production
2000 – 15000 mg Lipids L^{-1}

The most pioneering findings in the process of lipids AD

1981, Hanaki et al. LCFA inhibit essential reactions in AD due to their toxic effect towards anaerobic microorganisms.

1987, Koster & Cramer Lipids inhibition more correlated with LCFA concentration than with the amount of LCFA per unit of biomass.

1992, Angelidaki & Ahring LCFA exerts a permanent and irreversible toxic effect towards methanogens.

1993, Rinzema et al. Sludge flotation and washout cause treatment failure in UASB reactors treating lipids-containing wastewaters.

1994, Rinzema et al. LCFA were considered to be bactericidal to methanogens.

1997, Hwu et al. Usual operating parameters of EGSB reactors result in poor treatment of LCFA. Though, recirculation may improve the process.

2001, Alves et al. The LCFA adsorbed to biomass can be converted to methane. The contact with lipid-rich effluents improve the tolerance of the anaerobic sludge to the oleate toxicity.

2002, Lalman & Bagley LCFA chain length and the degree of saturation affects the level toxicity.

2002, Pereira et al. Palmitate identified as the main intermediate in oleate degradation.

2005, Pereira et al. Toxic effect of LCFA are related to accumulation onto the sludge, creating a physical barrier to the transfer of substrates/products.

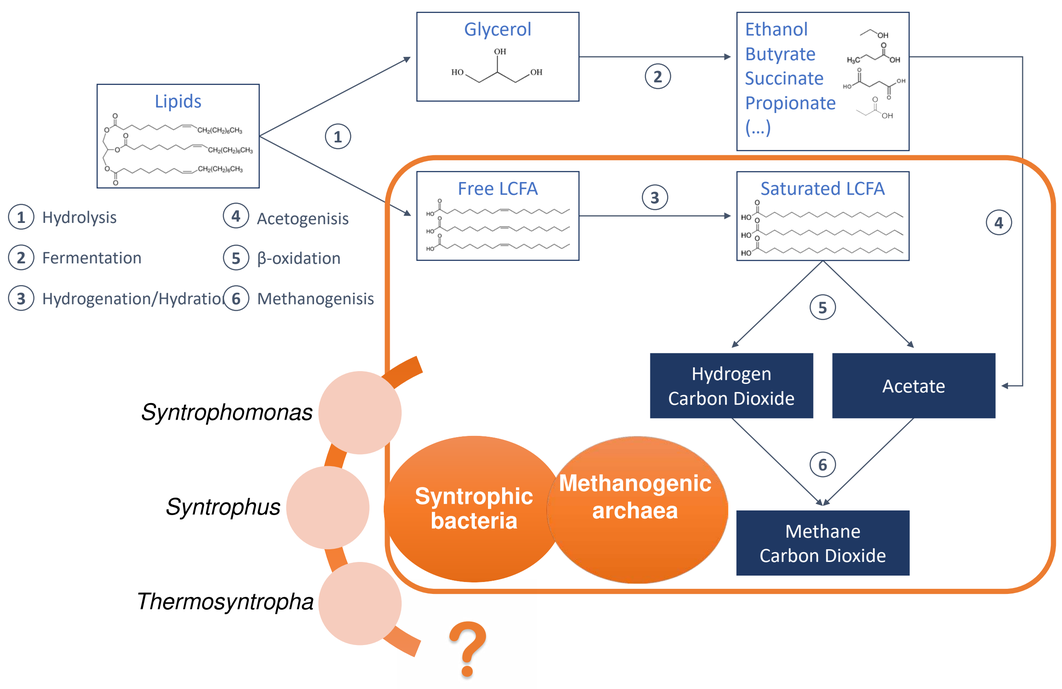
2007, Alves et al. New reactor was designed –IASB. This reactor optimizes the LCFA adsorption and uses the flotation to retain biomass.

2009, Cavaleiro et al. A step feeding start-up promoted the development of a community able to mineralize LCFA, in continuous, with OLR up to 21 kgCOD m^{-3} d^{-1}.

1981 | 1981 | 1984 | 1987 | 1990 | 1993 | 1996 | 1999 | 2002 | 2005 | 2008 | 2016

MOST PIONEERING FINDINGS IN AD OF LIPIDS

Microbiology of AD of lipids: opening the black box



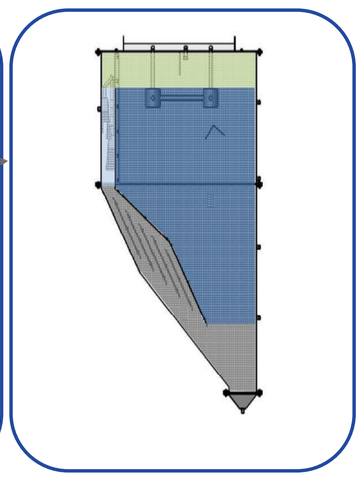
β-oxidation: the suggested route for Lipid degradation

- Thermodynamically feasible (Low hydrogen partial pressure)
- This generally accomplished through syntrophic cooperation with hydrogenotrophic archaea.

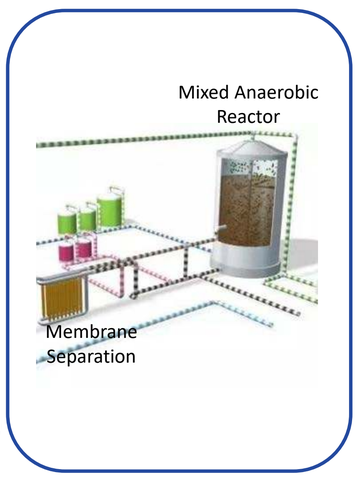
Nevertheless, Cavaleiro *et. al* (2016) proved that the initial steps of unsaturated LCFA degradation may proceed **uncoupled from methanogenesis**, and that palmitate production may involve the activity of facultative anaerobic bacteria.

Full-scale reactors designed for AD of lipids

BIOPAQ®AFR, by Paques, utilises an integrated flotation unit where solids and fats are floated using biogas, and are recirculated back into the reactor for further digestion.



IASB, reactor operated in downflow mode, utilises the flotation as sludge retaining mechanism, and promotes the contact between feed and settled biomass for improving biodegradation



MEMTHANE®, by Veolia, retains the biomass inside the reactor by using a membrane coupled to the anaerobic digester/ reactor.

Full-scale application of these bioreactor configurations is recent and promise future possibilities for energy recovery from lipids wastewater.

FUTURE PERSPECTIVES IN AD OF LIPIDS

Further expansion to solve the basic issues is needed.

- Experiments should be more focused to specific and comparable (synthetic) wastewaters prior to moving toward 'real' WW –both with industry & academia.
- A solution for to solve the issues for UASB and EGSB style reactors would be a large leap for the field.

Knowledge Gaps remain in the understanding of microbial communities and microbial interactions in anaerobic lipid digestions:

- Specific and targeted experiments are needed across the field
- Further targeted use of new and expanding Omic and Analytical technologies
- A strong link between industrial and academic sectors within these experiments will yield greater leaps for the field.

Alves, M.M. et al., 2001. Water Research, 35(1), pp.264–270.;**Alves, M.M. et al., 2007**. International Patent 2007, [WO2007058557]; **Angelidaki, I. & Ahring, B.K., 1992**.. Applied Microbiology and Biotechnology, 37, pp.808–812.;**Cavaleiro, A.J. et al., 2009** Environmental science & technology, 43(8), pp.2931–2936.; **Cavaleiro, A.J. et al., 2016**. Environmental Science & Technology, 50(6), pp.3082–3090.;**Hanaki, K. et al., M., 1981**. Biotechnology and Bioengineering, 23(1), pp.1591–1610; **Hwu, C. et al., 1997**. Biotechnology Letters, 19(5), pp.447–451.;**Koster, I.W. & Cramer, A., 1987**. Applied and environmental microbiology, 53(2), pp.403–409.;**Lalman, J. & Bagley, D.M., 2002**. Water Research, 36(13), pp.3307–3313; **Pereira, M.A. et al., 2002**. Water science and technology, 45(10), pp.139–144.; **Pereira, M.A. et al., 2005**. Biotechnology and bioengineering, 92(1), pp.15–23.

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