Two-stage solid-state anaerobic digester optimisation for food waste valorisation in psychrophilic conditions

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Introduction

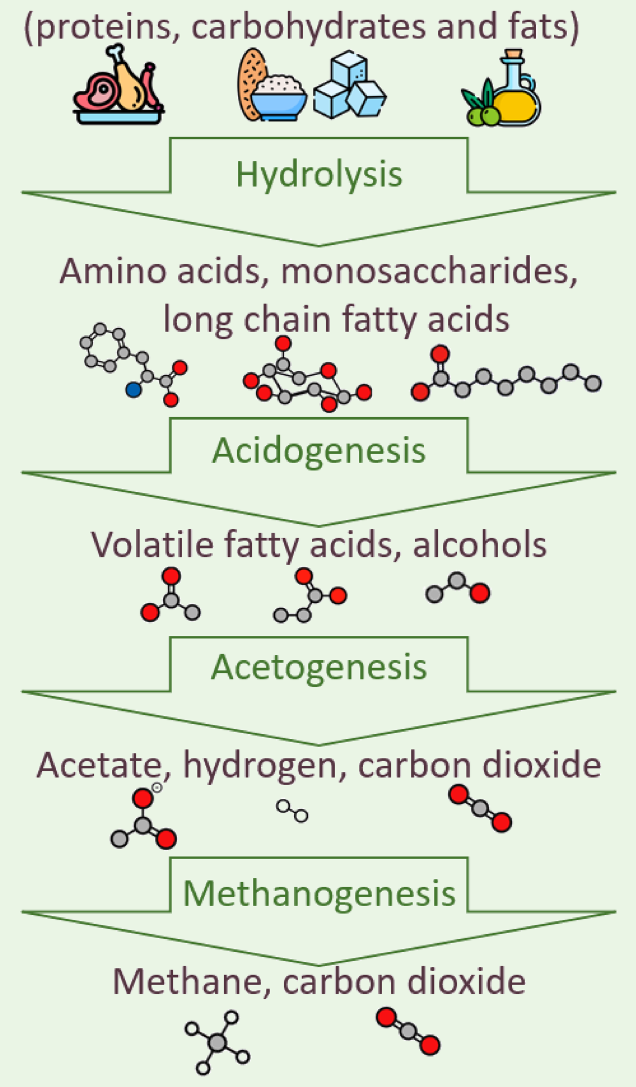

Figure 1 : Biomethanisation steps

Anaerobic digestion is a biological process in which a consortium of microorganisms decays organic matter to produce biogas and digestate. The first one, mainly composed of methane and carbon dioxide, can be converted into renewable energy while the second one can become a soil amendment. The biomethanisation consists of four biochemical phases: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Figure 1) [1]. Based on those reactions specificities, improved performance are achieved by dividing the system into two separate reactors, one for the two first reactions and another for the two remaining ones [2].

The WalBioPower project aims to achieve three advancements in this technology:

- Operation under psychrophilic conditions (< 20 °C) to reduce energy consumption and promote the development of decentralised installations by small producers [3] ;
- Use of food waste as feedstock, an emerging high-potential substrate for small-scale digesters ;
- Implementation of dry digestion processes (TS > 15%) to enhance sustainability by preserving freshwater resources [4].

To this end, a laboratory-scale, two-stage anaerobic digester was operated under psychrophilic conditions using a synthetic food-waste mixture mimicking real household biowaste (Figure 2). The system aims to be optimised for maximum methane production, with this study focusing specifically on the influence of feeding frequency, daily versus weekly, on both process stability and efficiency.

Figure 2 : Two-stage anaerobic digester characteristics

Results

The system was fed with a synthetic food waste blend with a TS of 21% and a VS of 20%, mimicking the complexity of real household biowaste. Performance of the reactor was evaluated based on the specific volume of biogas produced, its specific flow rate, methane content, the percentage of total solids (TS) remaining, the percentage of volatile solids (VS) remaining (Table 1), and the monitoring of biogas composition (Figure 4). On the other hand, the stability of the process was assessed by monitoring pH, fatty acid concentration (VFA), and alkalinity (TAC) of methanisation reactor (Figure 3).

	Daily feeding	Weekly feeding	p-value
Specific biogas production [Nml /gVS]	496 ± 28	329 ± 31	6,78 *10^{-5}
Specififc biogas production rate [Nml /gVS/h]	3 ± 0	2 ± 0	6,59 *10^{-5}
CH_4 content [%]	50 ± 3	53 ± 2	0,13
TS [%]	8,2 ± 0,2	7,8 ± 0,0	4,60 *10^{-4}
VS [%]	4,9 ± 0,2	4,9 ± 0,1	0,77

Table 1 : Performance characteristics of the reactor expressed as 95% confidence intervals

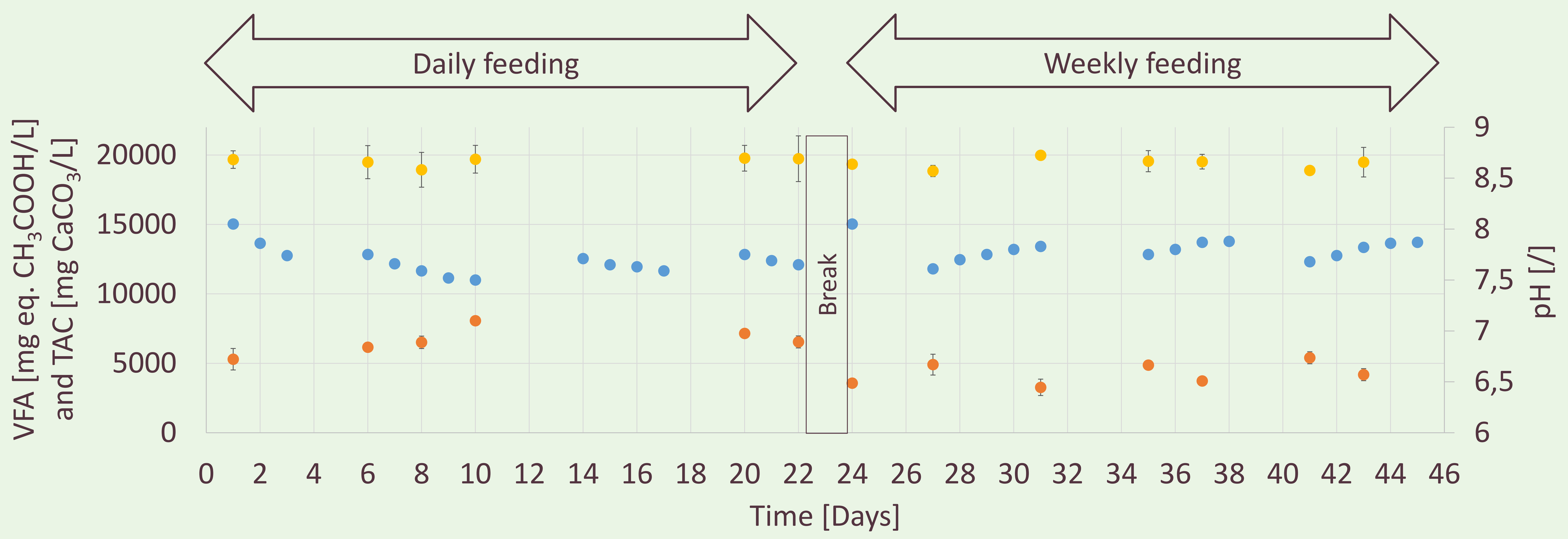

Figure 3 : Evolution of fatty acid concentration, total alkalinity and pH in methanisation digestate (● VFA, ● TAC and ● pH)

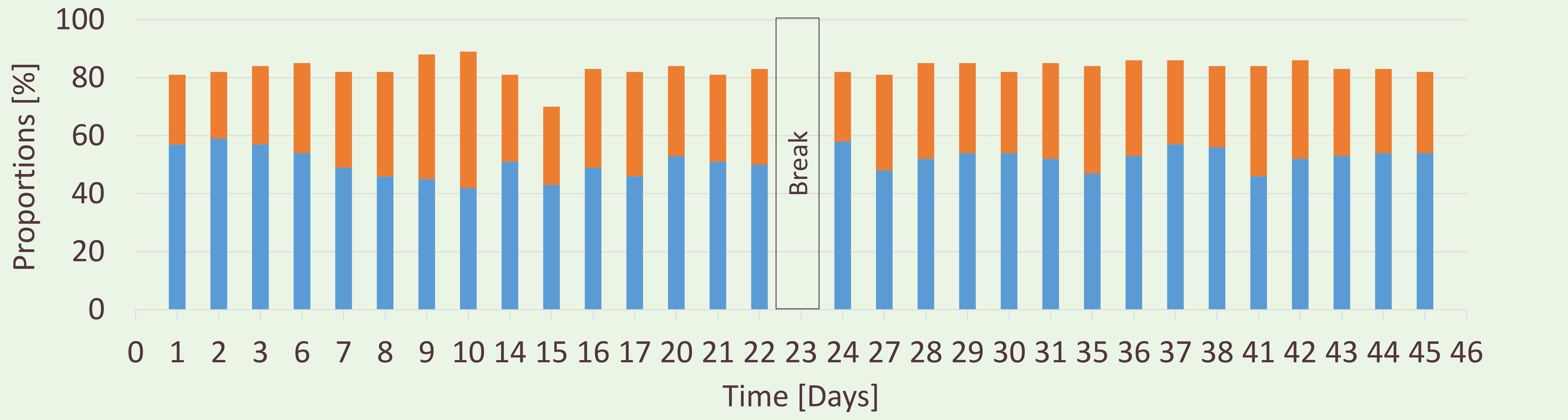

Figure 4 : Evolution of CH_4 and CO_2 proportions in the biogas produced by the methanogenesis stage (■ CH_4 and ■ CO_2)

Conclusion

- Process was quite stable for both feeding frequencies ;
- Significant better biogas productivity have been achieved with daily feeding for an equivalent methane content ;
- TS reduction is slightly better for weekly feeding but VS reduction is equivalent for both feeding frequencies ;
- Similar monitoring should be done with a higher organic feed load and on a longer period.

Acknowledgements

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References

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[5] Icons were made by Freepik from www.flaticon.com or came from www.sciencephotogallery.com