Combination of dry anaerobic digestion, composting and energy exploitation of biogas for innovative utilization in a pilot plant

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Summary

Introduction and objectives of the work

Description of the pilot plant and the methodology used

Main results and comments

Energy exploitation of the biogas

Conclusions

Introduction

The application of the anaerobic digestion technology for the treatment of the Organic Fraction of Municipal Solid Waste (OFMSW) is increasing in Europe because of the energy content, especially when it is source selected.

The digestate exit the process can be exploited by composting to stabilize the organic matter and produce a soil conditioner for agricultural use.

This paper presents the activities carried out at pilot plant scale with the aim to define a protocol for the management of **source selected food waste** by a first **anaerobic dry digestion**, followed by **aerobic composting** for the production of biogas and a soil conditioner of high quality.

The last part of the presentation deals with the research activities on the innovative **use of biogas to feed fuel cell for energy generation.**

Objectives of the work

1. Verify the reliability and efficiency of dry batch AD process
2. Define pre-treatments to assure process stability and high biogas production
3. Evaluate the incidence of the process conditions on the biogas rates
4. Define the behaviour of the digested biomass during composting
5. Monitor the quality of biogas produced by a new technique (PTR-MS)
6. Plan and test the biogas cleaning section before feed the fuel cell.

The FEM pilot plant: structure and components

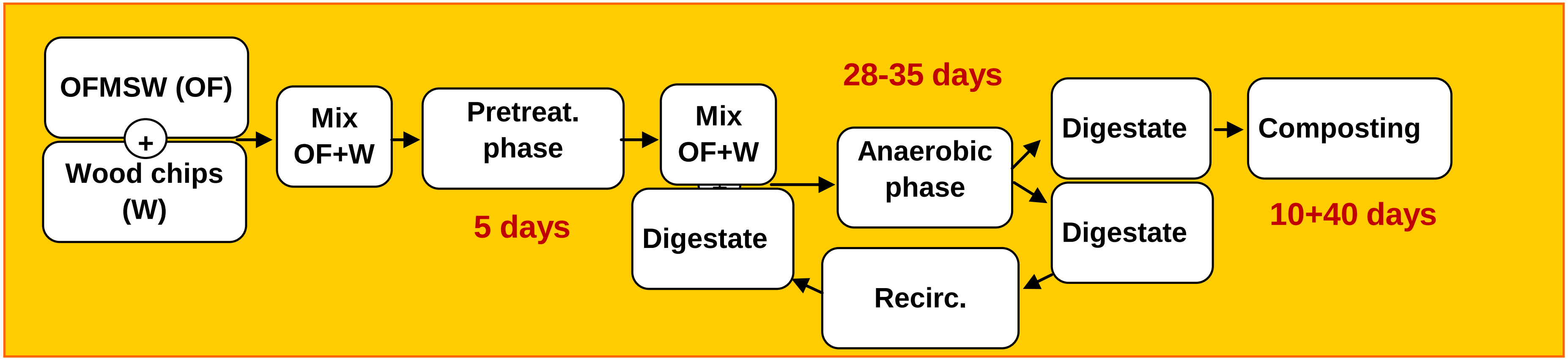
Dry batch anaerobic reactor

Compost curing in windrows

System for the biogas compression and storage

- Useful volume of the anaerobic reactor: 17 m3
- Insulated and heated to maintain mesophilic conditions
- System for the recovery, storage and heating of the leachate
- Irrigation plant using leachate
- Monitoring of inside pressure, mass temperature, leachate temperature, O_2, CO_2, CH_4, H_2S (4 measure points each one), gas flow rate
- Dedicated software and remote control of the process

Flow chart of the main steps of the developed protocol



The experimental activity started 3 years ago with more than 20 processes (150 tons of biomass treated) carried out on food waste as tested biomass under different conditions.

Pre-treatments: 5 days of forced aeration

addition of calcium hydroxide (0.3-0,5% w/w)

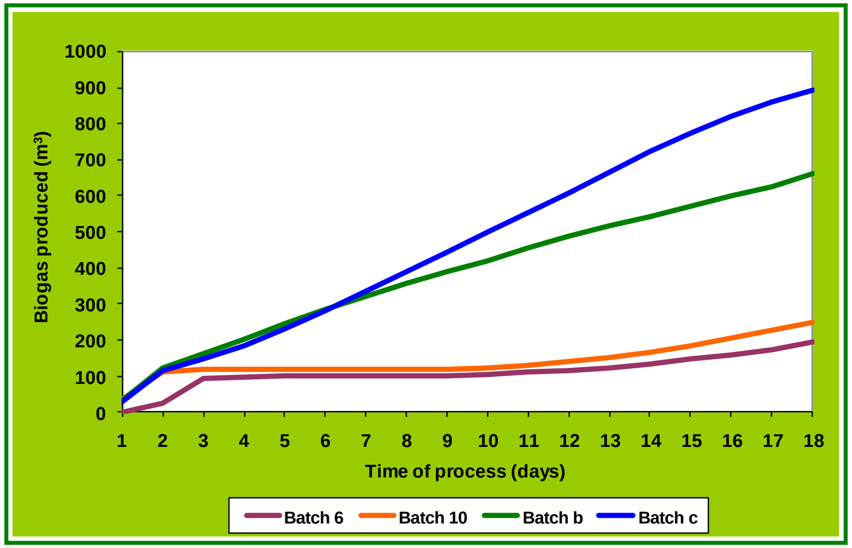
Mixture: 25-30% of food waste

20% yard waste

50-55% of digestate (recirculation)

Effects of pre-oxidation and pH correction

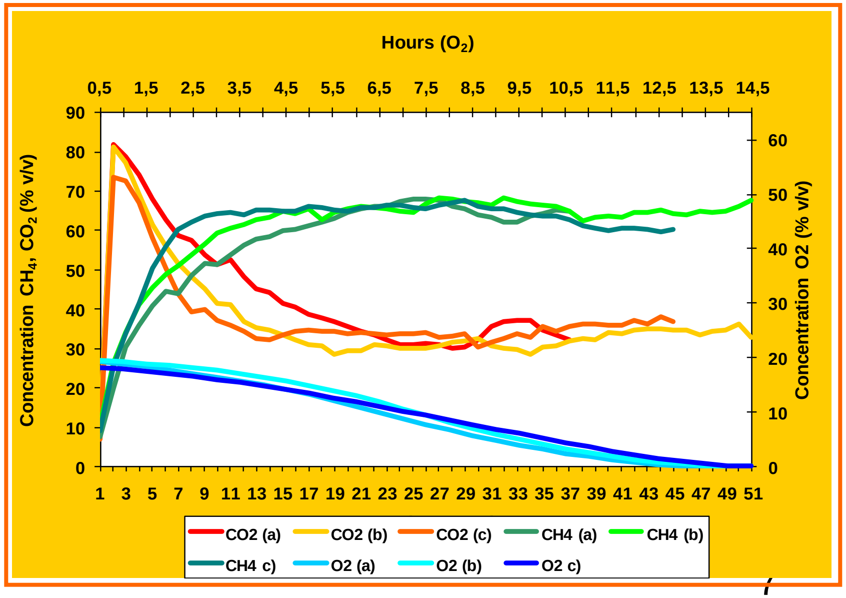
- increase of mass T° up to 45-55°C
- improve the biomass degradability
- rapid starting of the process
- reduction of sulfur compounds
- increase amount of biogas produced



Evolution of the anaerobic process

Similar behaviour in all the batches:

- CH_4 production starts after 15 hours
- CH_4 > 50% after 5 days
- CH_4 between 60-70%
- CO_2 between 30-40%

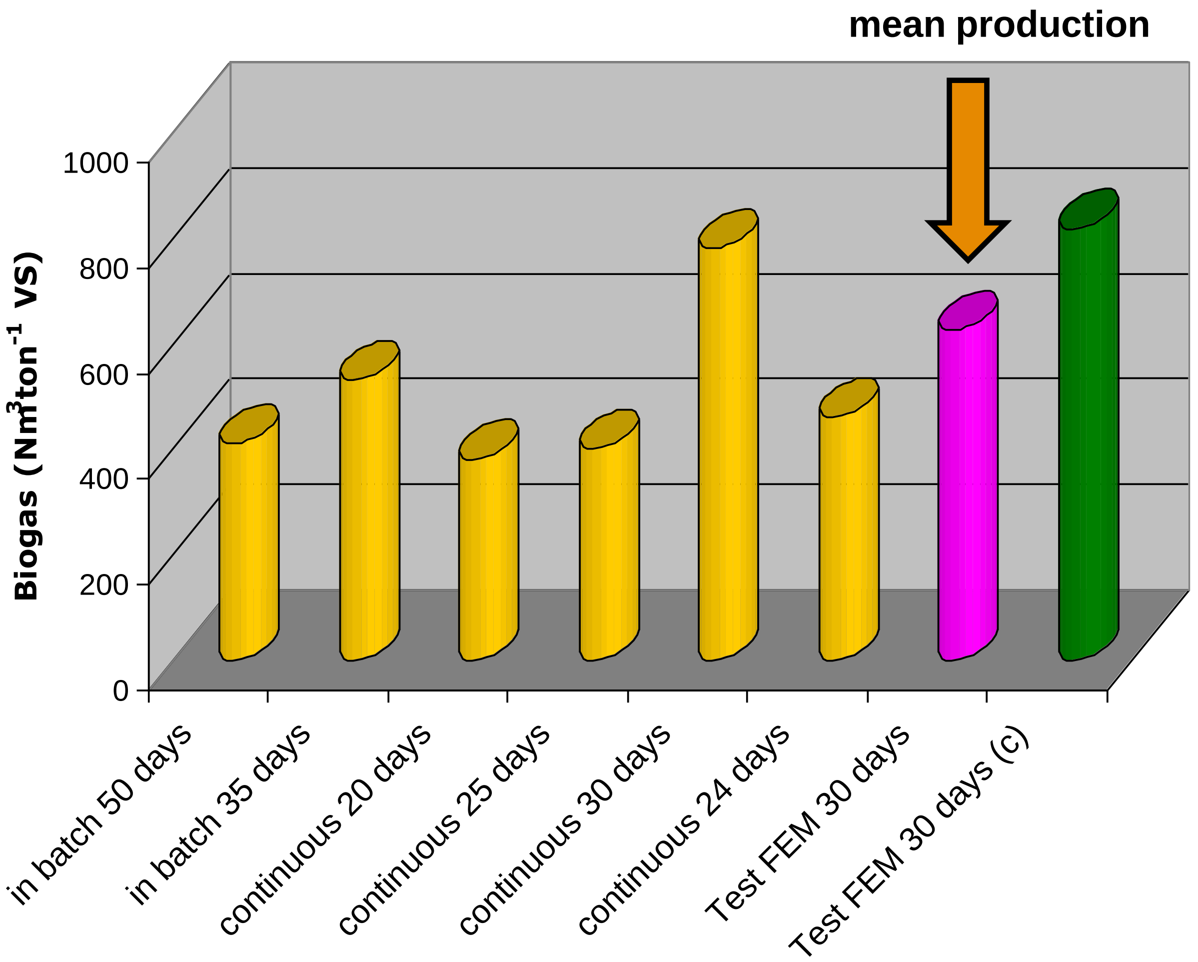


Main analytical data summarizing the evolution of the biological process (AD and composting) and the amount of biogas produced

		Batch a)	Batch b)	Batch c)
Process yields with respect to the fresh organic waste				
Biogas production	$m^3 ton^{-1}$	123.67	250.3	214.8
Specific biogas production	**m^3 kg VS^{-1}**	**0.479**	**1.025**	**0.864**
Specific methane production	m^3kg VS^{-1}	0.285	0.586	0.496
CH_4 (mean)	%	59.5	57.1	57.5
Digestate				
TS	%	41.77	44.52	44.46
VS	% TS	55.90	40.71	47.27
Respiration index	**mg O_2kgVS^{-1} *h**	**952**	**1095**	**538**
Odour unit (1 sample)	OU m^3 h^{-1}	1000		
Composting				
Respiration index - 45 days	**mg O_2 kgVS^{-1} *h**	**311**	**246**	**262**
Odour unit (1 sample)	OU m^3 h^{-1}	97 (after 17 days)		

Comparison among the results of the FEM tests and the literature data referred to dry biogas technologies.

(source: Trockenfermentation – Brücke zwischen Abfallbehandlung und Landwirtschaft ? Kraft, 2004).

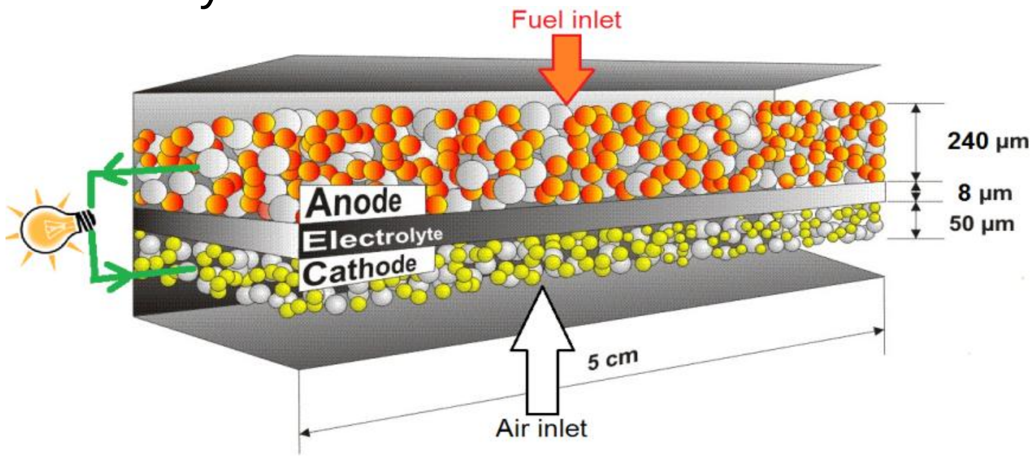


Energy exploitation of biogas in fuel cells [1]

Fuel cells are alternative systems for energy generation based on redox reactions. In particular **Solid Oxide Fuel Cell** (SOFC) is a promising technology that couples the use of renewable fuels as biogas with high electrical efficiency (55%).

This option could be a valid solution for small biogas plants where the limited amount of biogas produced can be directly used.

Structure of one single fuel cell



(1) This is part of the activities of the VEGA project carried out by SOFCPower Spa in cooperation with FEM and Torino University. It was co-funded by Trento Province.

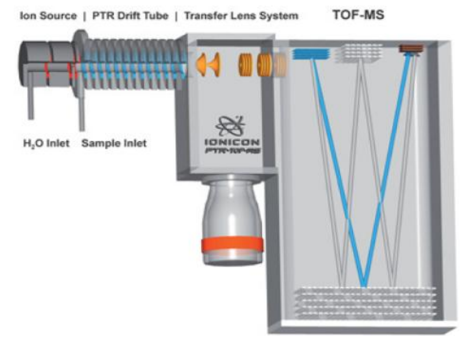
SOFC operate with high CO_2 content in the gas fuel, but the presence of VOCs and can damage the cell anode (carbon deposition).
Sulfur compound >1 ppmv have severe poisoning effects.

The Proton Transfer -Mass Spectrometry (PTR-MS*) is a direct injection MS technique particularly suitable to this use because of the rapid and on-line analysis of the gas.
It was used to detect the biogas composition and to define the cleaning system before feed SOFC.

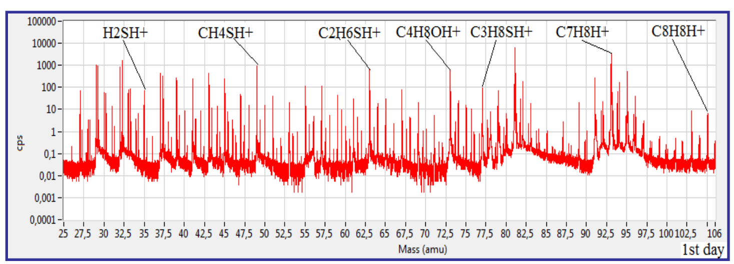

Bioresource Technology

Monitoring of volatile compound emissions during dry anaerobic digestion of the Organic Fraction of Municipal Solid Waste by Proton Transfer Reaction Time-of-Flight Mass Spectrometry

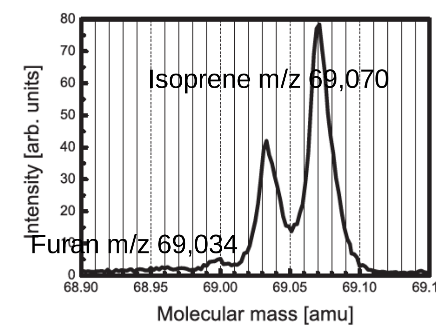
Davide Papurello, Christos Soukoulis, Erna Schuhfried, Luca Cappellin, Flavia Gasperi, Silvia Silvestri, Massimo Santarelli, Franco Biasioli



COV - ppmv

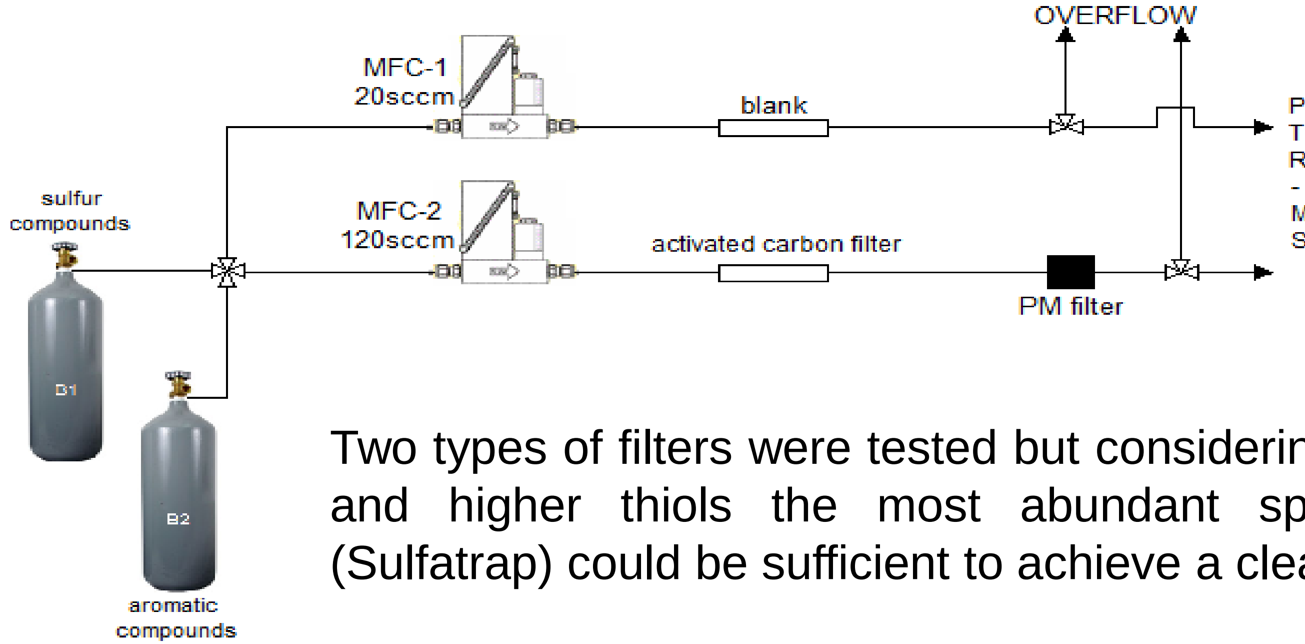


Identification VOCs having the same uma



* Ionicon Analytik GmbH, Innsbruck (A)

Gas cleaning by filter adsorption

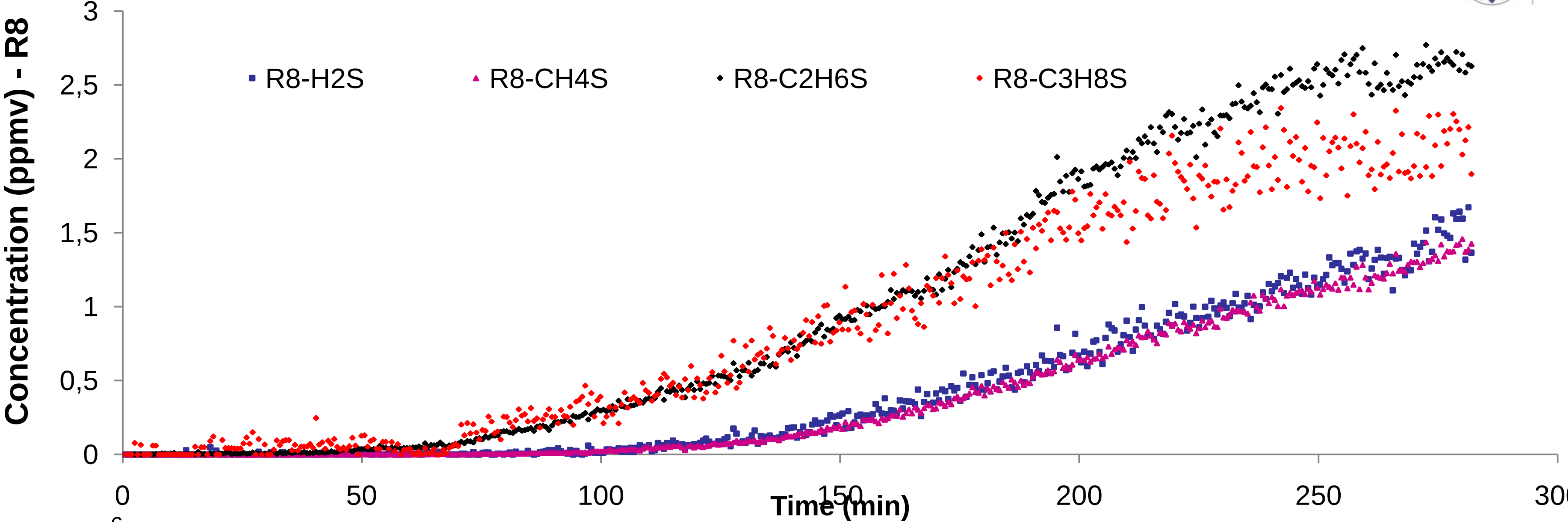


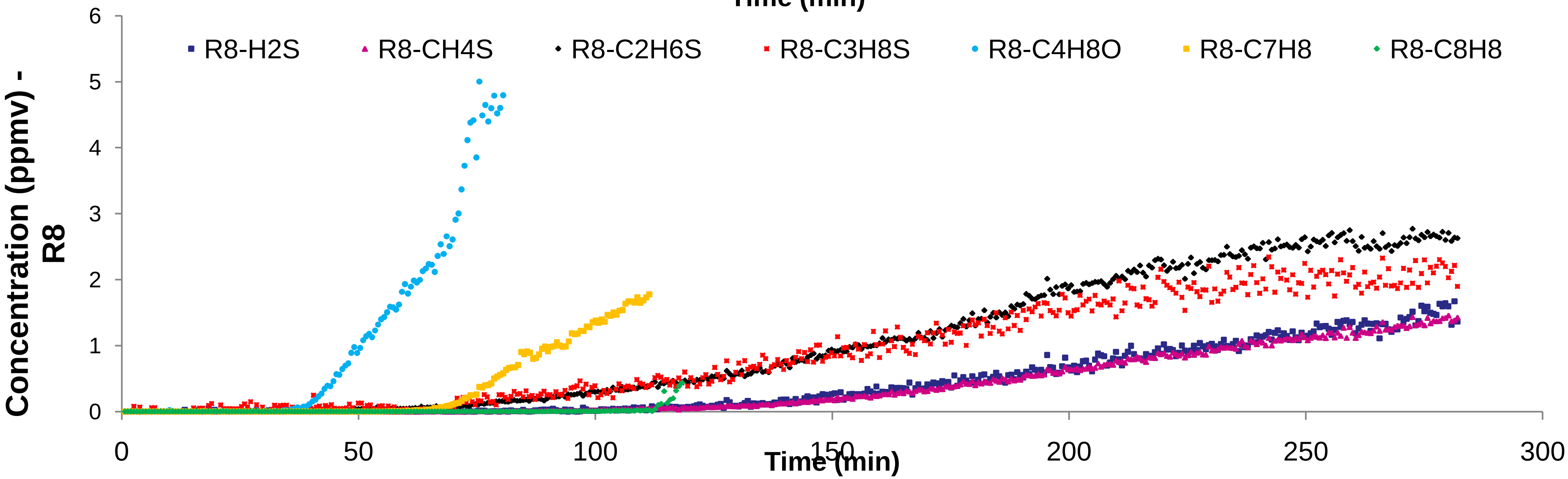
Two types of filters were tested but considering the H_2S and higher thiols the most abundant species R8 (Sulfatrap) could be sufficient to achieve a clean gas.

Compound	ppmv	Protonated Molecular Weight +
C_3H_8S	6,01	77,042
C_2H_6S	5,84	63,026
CH_4S	4,75	49,011
H_2S	5,51	34,995
C_8H_8	5,29	105,070
C_7H_8	4,83	93,070
C_4H_8O	5,1	73,065

Sulfatrap R8 (%)	
Carbon	<85
Copper (I) oxide	<10
Copper (II) oxide	<10
Iron (III) oxide	<10
Chromium salts	-

Monitoring VOCs – performances of R8 filter





(Sulfatrap R8 TDA inc.)

Conclusions

The study was aimed at finding a proper way of managing the dry anaerobic process in order to support the plants adopting this kind of technology.

The double pre-treatment consisting in a preliminary aerobic step (5 days) and subsequently an addition of calcium hydroxide allows the improvement of the biomass degradability, the increase of mass temperature (45 - 56 °C) and the reduction of lag-phase.

Among the different batches the “c” one resulted the best one in terms of evolution of the process and amount of biogas produced (0,8 $m^3 kg\ VS^{-1}$) comparable with literature data.

The composting phase happens in about 50 days and gives a product with a very high stability level showed by very low values of the respiration index and odour unit.

The PTR-MS technique is particularly useful for optimization of filter applications and directly monitoring of biogas volatile organic compounds due to the rapid measurements and multistream unit setup.

Thank you for your attention !

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