Anaerobic digestion of the untreated food waste

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History, goals

Biofilter S.A. has a market leader position in Hungary in the field of collecting kitchen waste (EWC 190805), having a national-level collecting network. I received a request from Biofilter S. A. concerning the optimal technical solution needed for valorification of the energy content of the kitchen waste collected right at their site.
Basically, the waste can be digested easily biologically, therefore it can be considered as a good raw material for biogas when used together with other organic waste. At the moment, it is used for producing biogas mixing it with sewage sludge in the anaerobic digestors used for household waste. Given that at the site of the company there is no other organic raw material available, a solution was needed for digesting kitchen waste on its own.

Goals:

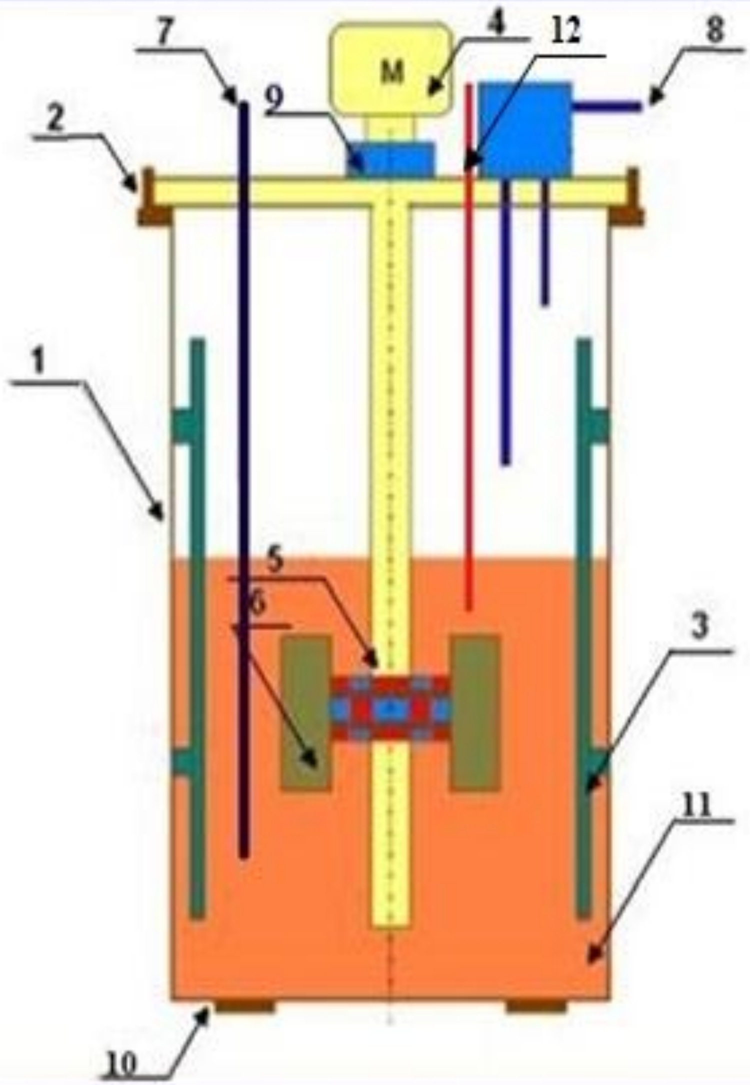
- Cost efficiency at Biofilter S. A. by decreasing the amount of waste (transport and storage costs).

- Electrical and thermal energy production which will reduce the energy demand of the site, where applicable, the excess amount can be fed to the electric service provider's network and may be sold.

Description of the present status

- Parallel pilot anaerobic digestor equipment were installed for analysing the following parameters:
  - Quantity and quality of the feed and removed material of the process (dry matter, loss on ignition, concentration of COD, ammonia content, etc..)
  - The amount and composition of biogas produced in reactors, (methane, carbon dioxide, carbon monoxide, hydrogen, oxygen, nitrogen, hydrogen sulphide content)
  - Physical and chemical parameters of reactors (reactor temperature, pH, concentration of volatile fatty acids, alkalinity, enzymes involved in anaerobic digestion (dehydrogenase, protease, lipase, cellulase) concentrations)

Structure of the experimental reactor



1. Stainless steel casing
2. Stainless steel fixer
3. Breakwater
4. Electric motor
5. Magnetic coupling
6. Mixer
7. Sampling and feeding
8. Gas exhausting pipe
9. Claw coupling
10. Positioning
11. Test
12. Thermometer

Main technical parameters of thesequentially feeded experimental anaerobic fermentor

Volume: 10.5 litres

Useful volume: 9 litres

Mixing of fermentor: vertical shaft mixer with two blades(6), with electric engine(4), the magnetic coupling (5) between the axes and the mixer enables a gastight realization of the reactor. Turn number is constant. Mixing is time-controlled, the duration of mixing and pause can be set.

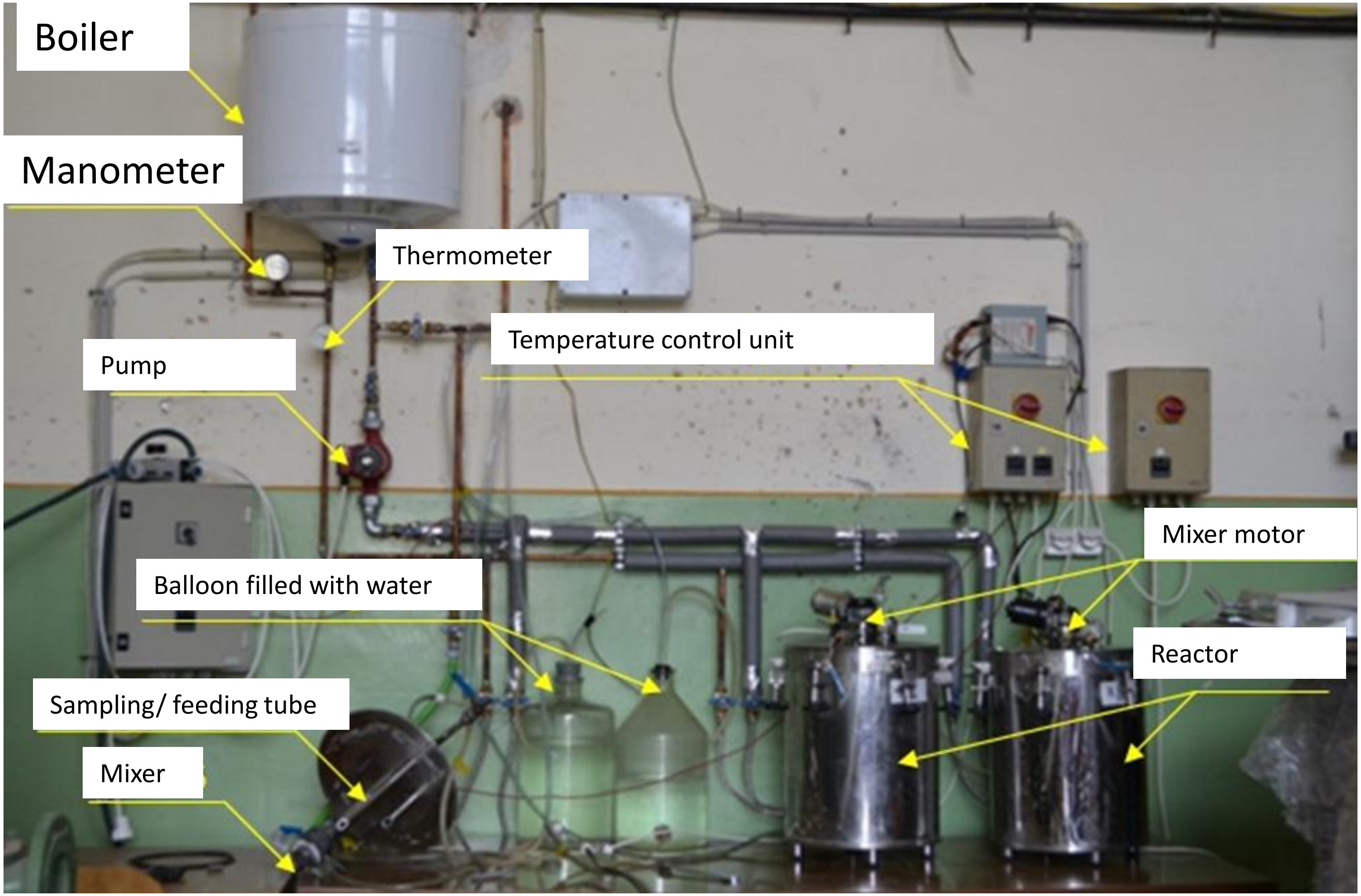
Measuring of temp.: PT 100 analog equipment (12), for measuring the temperature of the liquid in the reactor

Heating of fermentor: operating with water, recycled in the duplicated reactor walls, temperature controll is performed on the basis of the sludge temperature measured.

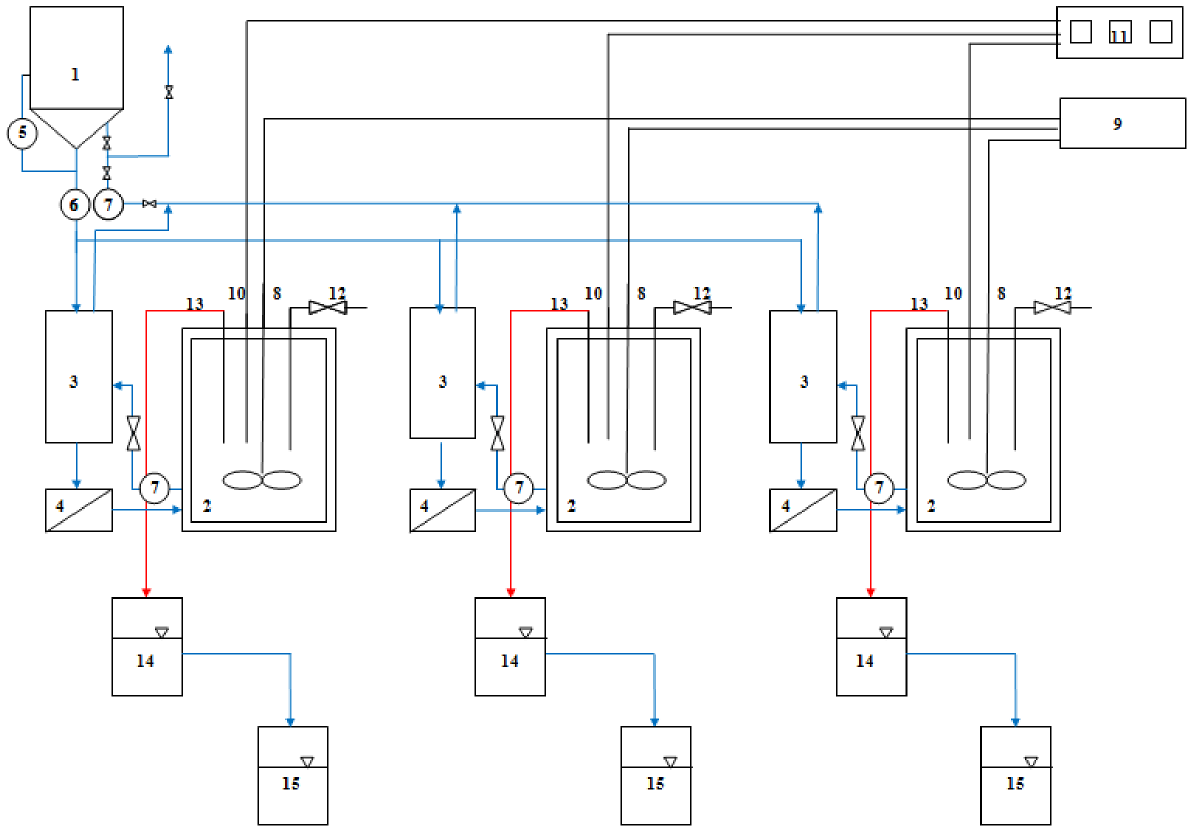
Common pipe for raw material input and end product output (7)

Biogas exhausting pipe (8)

Structure of the experimental reactor



Structure of the experimental reactor



1. boiler
2. reactor
3. heating water tank
4. heat exchanger
5. pressure meter
6. returned water temp. meter
7. pump
8. mixer
9. mixer regulation unit
10. temp. meter
11. Temp regulation unit
12. input/output pipe
13. biogas output pipe
14. water tank
15. collected water tank

Structure of experimental equipment

The heating water having the suitable temperature is provided by the heating equipment (1). The water heater is equipped with a manometer (5) and a thermometer (6), to follow the pressure and temperature of the recycled water. The heating water transfers the heat to the inner heating water cycle through a heat changer (4). The water circulating through the mantle of the reactor transfers its heat to the sludge. Water is circulated by a pump (7). The system is equipped with a temperature control unit (11). Sludge is circulated by the mixer with magnetic coupling as described above (8). Mixing parameters can be set by a control unit (9). The lid of the reactor is equipped with the following: thermometer (10), sampling/feeding tube (12), exhausting pipe (13). The inner thermometer serves for following the temperature of the sludge. Accuracy of thermostating is ± 0.2 °C. Samples are taken through the sampling/feeding tube and the same serves for adding fresh sludge and substrate. The biogas formed in the digestors is led to a water bottle (14) through the exhausting pipe. The gas pushes the water from the glass bottle to the water collecting bottle (15). The amount of biogas is measured by the mass difference measured on the water collecting bottle.

Characteristic parameters of the food waste (Different values published in the literature)

Table 3
Elemental composition of food waste examined in this study

Components	Unit	Average value (standard deviation)
Total solids (TS)	% (w.b.)	30.90 (0.07)
Volatile solids (VS)	% (w.b.)	26.35 (0.14)
Fixed solids (FS)	% (w.b.)	4.54 (0.21)
VS/TS	%	85.30 (0.65)
C (Total)	% (d.b.)	46.78 (1.15)
N (Total)	% (d.b.)	3.16 (0.22)
P (Total)	% (d.b.)	0.52 (0.08)
K	% (d.b.)	0.90 (0.11)
Ca (Total)	% (d.b.)	2.16 (0.29)
Mg (Total)	% (d.b.)	0.14 (0.01)
S (Total)	ppm[a]	2508 (87)
NH_4-N	ppm	973 (571)
NO_3-N	ppm	118 (80)
Al	ppm	1202 (396)
Fe (Total)	ppm	766 (402)
B (Total)	ppm	12 (1)
Zn (Total)	ppm	76 (22)
Mn (Total)	ppm	60 (30)
Cu (Total)	ppm	31 (1)
Cd	ppm	<1
Cr	ppm	3 (1)
Pb	ppm	4 (3)
Ni	ppm	2 (1)

[a] *Note*: Based on wet base.

Table 3
Characteristics of FW reported in literatures

Parameters	Zhang et al. [2]	Zhang et al. [3]	Zhang et al. [4]	Li et al. [5]
TS (%, w.b.)	18.1 (0.6)	23.1 (0.3)	30.90 (0.07)	24
VS (%, w.b.)	17.1 (0.6)	21.0 (0.3)	26.35 (0.14)	232
VS/TS (%)	0.94 (0.01)	90.9 (0.2)	85.30 (0.65)	94.1
pH	6.5 (0.2)	4.2 (0.2)	–	–
Carbohydrate (%, d.b.)	61.9	–	–	55.2
Protein (%, d.b.)		–	–	15
Fat (%, d.b.)	23.3 (0.45)	–	–	23.9
Oil (%, d.b.)	–	4.6 (0.5)	–	–
C (%, d.b.)	46.67	56.3 (1.1)	46.78 (1.15)	54
N (%, d.b.)	3.54	2.3 (0.3)	3.16 (0.22)	2.4
C/N	13.2	24.5 (1.1)	14.8	22.5
S (ppm, w.b.)	0.33	–	2508 (87)	8.6
P (ppm, w.b.)	1.49 (0.09)	–	–	88
Na (%, d.b.)	0.84	3.45 (0.2)	–	2.24
K (%, d.b.)	0.3	2.30 (0.04)	0.90 (0.11)	–
Ca (%, d.b.)	0.07	0.4 (0.01)	2.16 (0.29)	2.44
Mg (%, d.b.)	0.03	0.16 (0.01)	0.14 (0.01)	–
Fe (ppm, w.b.)	3.17	100 (23)	766 (402)	–
Cu (ppm, w.b.)	3.06	–	31 (1)	–
Zn (ppm, w.b.)	8.27	160 (30)	76 (22)	–
Al (ppm, w.b.)	4.31	–	1202 (396)	–
Mn (ppm, w.b.)	0.96	110 (95)	60 (30)	–
Cr (ppm, w.b.)	0.17	–	< 1	–
Ni (ppm, w.b.)	0.19	–	2 (1)	–

Table 4
Characteristics of the inoculum digestate at the start of the semi-continuous fed trial and the average composition of the food waste used over the trial period.

	Digestate	Food waste
pH	8.0	4.71 ± 0.01 (1:5)
TS (% of fresh matter)	6.34	23.74 ± 0.08
VS (% of fresh matter)	4.59	21.71 ± 0.09
VS (% of TS)	72.4	91.44 ± 0.39
Trace elements (mg kg^{-1} fresh matter)		
Aluminum (Al)	63.3	
Boron (B)	2.5	
Cobalt (Co)	0.083	<0.060
Copper (Cu)	5.75	1.7 ± 0.2
Iron (Fe)	173.7	54
Manganese (Mn)	18.5	20 ± 3
Molybdenum (Mo)	0.29	0.11 ± 0.01
Nickel (Ni)	2.9	1.7 ± 0.7
Selenium (Se)	0.050	<0.070
Tungsten (W)	<0.035	<0.25
Zinc (Zn)	8.11	7.8 ± 2.6
Potentially toxic element (mg kg^{-1} fresh matter)		
Cadmium (Cd)	0.038	<0.25
Chromium (Cr)	5.25	6.9 ± 0.3
Lead (Pb)	0.63	<2.5
Mercury (Hg)	<0.010	<0.003
Macro nutrients (g kg^{-1} fresh matter)		
Calcium (Ca)	2.16	
Magnesium (Mg)	0.168	
Potassium (K)	2.63	3.39 ± 0.19
Sodium (Na)	1.13	
Phosphorus (P)	0.700	1.28 ± 0.08
Total Kjeldahl Nitrogen (N)	8.47	8.12 ± 0.01
Other digestate parameters (g kg^{-1} fresh matter)		
Total ammoniacal nitrogen (NH_3-N)	4.7	
Total volatile fatty acid	4.4	
Acetic acid	4.1	
Propionic acid	0.1	

The composition and chemical parameters of the food waste, so that the biodegradability (usable energy content) significantly depending on the country's culinary culture.

Characteristic parameters of the food waste (Different values published in the literature)

Minta jellege (type of the sample)	Moslék (food waste)	
DP mintaazonosító (sampe identification)	5153	
KL mintaazonosító	10293	
Vizsgált komponens (analised components)	Mértékegység (unit)	
Összes szárazanyag (Total DS)	g/kg	585
izzítási maradék (inorganics)	g/kg	25
izzítási veszteség (organics)	g/kg	560
Összes szén (total carbon)	g/kg sz.a.	603
Összes nitrogén (total nitrogen)	g/kg sz.a.	5,69
Összes kén (total sulphur)	g/kg sz.a.	1,04
Összes foszfor (total phosphorus)	mg/kg sz.a.	1 427
Összes szelén (total Se)	mg/kg sz.a.	<1
Összes bárium (total Ba)	mg/kg sz.a.	2,67
Összes nikkel (total Ni)	mg/kg sz.a.	3,50
Összes ólom (total Pb)	mg/kg sz.a.	<5
Összes króm (total Cr)	mg/kg sz.a.	5,43
Összes kadmium (total Cd)	mg/kg sz.a.	<0,2
Összes réz (total Cu)	mg/kg sz.a.	1,26
Összes mangán (total Mn)	mg/kg sz.a.	2,56
Összes cink (total Zn)	mg/kg sz.a.	26,5
Összes bór (total B)	mg/kg sz.a.	5,73
Összes vas (total Fe)	mg/kg sz.a.	1 363
Összes alumínium (total Al)	mg/kg sz.a.	59,2
Összes kalcium (total Ca)	mg/kg sz.a.	1 395
Összes magnézium (total Mg)	mg/kg sz.a.	224
Összes kálium (total K)	mg/kg sz.a.	2 520

According to our analytical results, it can be seen that the main difference consists in the carbon/nitrogen ratio, which is higher than the values reported in the literature. It is expected that this will be reflected in the stability of the anaerobic processes as well, therefore the technological changes should be supported by digestion experiments as well. The aim of these experiments will be to find the limits of the optimal values of the process parameters. It should be aimed to optimalize the digestion efficiency, the biogas production and the economical efficiency.

Further plans

- Further specification of qualitative parameters of kitchen waste based on a significant number of representative samplings and laboratory analyses.

- Search of the literature regarding the anaerobic biological digestivity of kitchen wastes, exploration of technological possibilities, especially those regarding separate treatment of kitchen waste.

- Finding more technological solutions for the technical problems arisen.

- Feasibility analysis of the technological solutions found using the pilot anaerobic digestors, evaluation of the results, technical decisions.

- Application of the technology selected on larger scale, technological and energetical (electrical, heat) calculations.

- Evaluation of economical feasibility

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