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TECHNICAL NOTE 51.2

Biodegradation of non edible parts of higher plants

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1	0	13/04/2000	Draft version
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1. Introduction

It is generally accepted that an Advanced Life Support System based only on the biomass production of *Spirulina* and *Rhodospirillum* and/or other micro-organisms will be insufficient to meet the crew demands for a balanced diet. Therefore a higher plant compartment in the MELiSSA loop was introduced . The three main reasons for introducing a higher plant compartment are (Poughon, 1997) :

- The high content of nucleic acid in micro-organisms limit the quantity that can be consumed, even it is proven that *Spirulina* is not toxic for man.
- a well balanced diet is composed of more than two food sources.
- The proteins need of the crew was satisfied by the consumption of *Spirulina* and *Rhodospirillum*, but external food sources were necessary to supply the crew in carbohydrate and lipids.

Eight higher plants are considered in the approach of an higher plant compartment: lettuce, wheat, potato, tomato, soybean, rice, spinach and onion. The edible fraction of these plants will be consumed by the crew, but these plants also have inedible parts like leaves, roots and stems (depending on the vegetable). This inedible plant material has to be degraded. The inedible plant material together with faecal material was introduced in the liquefying compartment. With data of the production of faecal material and inedible parts of higher plants by one man per day a ratio could be calculated in order to prepare the feed of the anaerobic demonstration reactor. The data were obtained from the University ‘Blaise Pascal’.

In this technical note the results of the conversion efficiencies of a mix of faecal material together with non-edible parts of kale are represented and are compared with previous conversion efficiencies of faecal material.

2. Inedible parts of higher plants

The inedible parts of higher plants were obtained from the University of Guelph (Canada). The plant that was selected was kale. The samples were accumulated over a period of 8 weeks. Harvests were made periodically. Every 3 or 4 days 10 plants were selected at random from the population of 100 plants. The edible fractions of the plant (leaves and petioles) were separated from the inedible parts (roots and thick portions of the stem). These inedible parts were dried in a drying oven for a minimum of 48 hours and were ground in a commercially available coffee grinder for 2 minutes. Analysis were performed from the final harvest and are represented in Table 2-1. All the dried inedible parts were put together and mixed with the faecal material.

Table 2-1 Analysis results of the Kale samples

Sample ID	N %	P%	K%	Ca%	Mg%	Lignin%	Total C%	Inorganic C%	Organic C%
Edible part	6.46	0.880	4.86	2.43	0.95	6.82	37.89	0.41	37.47
Roots	3.15	1.880	2.86	7.69	0.50	10.40	25.89	<0.05	25.89
Stem	5.61	0.584	8.74	1.63	0.81	12.52	29.54	2.63	26.91

The diet composition for one man a day is represented in Table 2-2 (Poughon, 1997). It is assumed that 73% of the human diet will be produced by the MELiSSA loop. In this table can be seen that 53.8% of dry food are plants.

Table 2-2 Diet composition for one man a day (Poughon,1997)

Diet Composition (1 man.day)				
Total edible food g dry	Biomass in Diet % of dry food	Nucleic Acids % of dry food	Plants % of dry food	External % of dry food
680.63	20.00	0.85	53.80	26.20

Detailled Diet composition (1 man.day)					
	Waste g dry mass produced	Edible g Wet mass produced	Edible -plant g Dry mass produced	Edible % of total Edible	HPC Composition % mass
Fat (External source)	0.00	71.22	71.22	10.46	
Proteins (External source)	0.00	30.19	30.19	4.44	
Carbohyd. (External Source)	0.00	76.91	76.91	11.30	
Spirulines	0.00	442.29	132.69	19.49	
Rhobobacter	0.00	11.46	3.44	0.51	
Tomato	32.50	53.18	3.40	0.50	0.93
Rice	81.52	78.47	68.06	10.00	18.59
Lettuce	1.75	49.47	2.04	0.30	0.56
Potato	34.00	332.04	68.06	10.00	18.59
Soybean	3.80	7.60	6.81	1.00	1.86
Spinach	10.72	125.11	6.81	1.00	1.86
Onion	10.74	64.47	6.81	1.00	1.86
Wheat	311.38	235.90	204.19	30.00	55.76
Total	**486.42**	**1578.30**	**680.63**	**100.00**	**100.00**

Energetics-Metabolics				
	Total	Proteins	Lipids	Carbohyd+Exopoly
kcal	3000.04	537.00	851.04	1612.00
% of total	100.00	17.90	28.37	53.73

For one person a day:

Non-edible plant material (NEPM): 486.42 g DW

Faeces: 30 g DW

Therefore the ratio NEPM / faeces was used to prepare the feed for the MELiSSA liquefying reactor:

$$\frac{486.4gDW}{30gDW} = 16$$

3. Reactor set-up

The reactor had a wet volume of 0.9 litre and a temperature of 55 °C (thermophilic conditions). The reactor was continuously stirred with a magnetic stirrer and the pH fluctuated around 8. These conditions are optimal for anaerobic bacteria and are used to start up an anaerobic reactor. The hydraulic retention time was about 23 days. The reactor was fed with 100 ml of a solution containing a ratio of non-edible plant material (NEPM) to faeces of 16.

Last year a similar reactor was started up. This reactor was fed with faecal material at a concentration of 3.3 g DW three times a week. This same feeding regime was also obtained in the new demonstration reactor. Therefore the composition of the DW could be calculated taking into account the ratio NEPM/ faeces :

3.1 g DW NEPM and 0.2 g DW faeces was fed three times a week

Three times a week 100 ml of feed was fed into the reactor after sampling 100 ml from the reactor The characteristics of the feed are represented in Table 3-1. The reactor was closed and flushed with 100 % N_2 gas to obtain anaerobic conditions.

Table 3-1 Characteristics of the feed

Parameter	**Unit**	**Mean value**
pH		6.6
Dry matter	g/l	20
Ash	g/l	4.9
Total nitrogen	mg/l	1038
Ammonium nitrogen	mg/l	102
VFA	mg/l	77
Acetic acid		68
Propionic acid		3.7
Iso Butyric acid		0.9
Butyric acid		2.3
Iso valeric acid		1.4
Valeric acid		0.5

The produced biogas was measured using a gas column that was connected to the demonstration reactor. The gas column contained a coloured solution at pH 3. This low pH was used to prevent the CO_2 being absorbed by the liquid in the gas column. The set-up is represented in Figure 3-1. Every time before feeding the reactor, the produced biogas was read. The volume of biogas produced was calculated using the following formula:

$$V_{biogas} = \pi * R^2 * height$$

With:

V_{biogas}: volume of biomass expressed in ml

R: radius of column in cm (=4 cm)

height: height of the column in cm

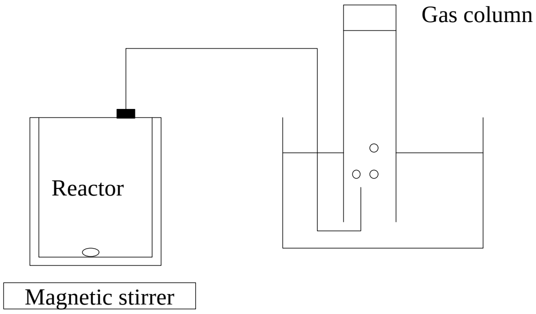

Figure 3-1 Reactor set-up

The parameters analysed on the feed and effluent are pH, conductivity (EC), dry matter, organic matter, ammonium-N, total-N and volatile fatty acids. Biogas was frequently measured with an Infrared gas analyser. With these results, the conversion efficiencies could be calculated.

4. Results

4.1 pH and EC

The pH fluctuated around 8. The methanogens were not inhibited, since the reactor was operated in its optimal conditions (pH 7-8 and thermophilic conditions). During the Christmas period, the reactor was fed with 0.5g starch and 1g gelatine. The conductivity increased from 7 mS/cm to 11.5 mS/cm, due to the NH_4^+ obtained from gelatine. The minor fluctuations noticed in Figure 4-1 were due to measurements errors.

4.2 Dry matter, organic matter and ashes

At day 49 the reactor was diluted with around 100 ml of water. This can be seen in a small decrease of dry matter. The fluctuations which can be seen in Figure 4-2 are due to measurement errors. Part of the plant material which is not biodegraded by the autochtonous bacteria in the thermophilic reactor are floating in the reactor, which made it difficult to take a homogenous, reliable sample for analysis. The ash concentration fluctuated around 5 g/l during the whole period.

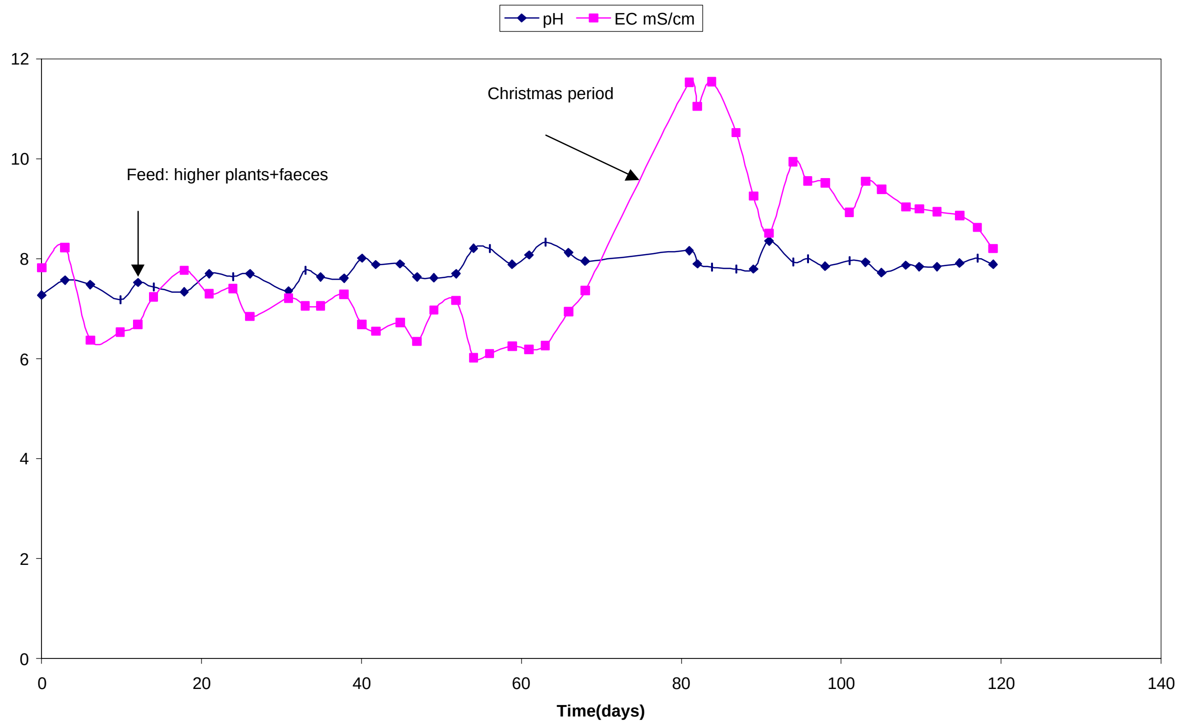

Figure 4-1 pH and EC in reactor

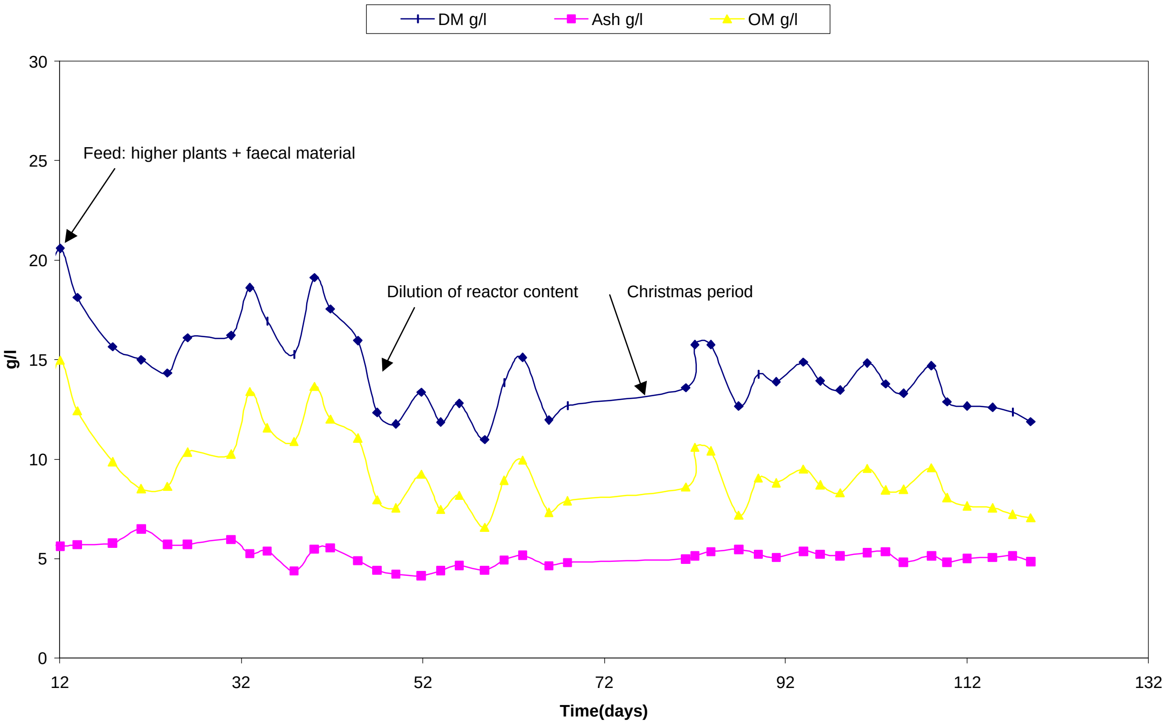

Figure 4-2 Dry matter, ash and organic material in reactor

4.3 NH_4-N and N-org

The dilution of the reactor content is also visible in Figure 4-3. During the Christmas period a large increase of NH_4-N was noticed, due to the fact that during this period the reactor was fed with starch and gelatine . The NH_4-N concentration increased from 565 mg/l to 1275 mg/l. The period after the Christmas period was to small to notice a stable value of NH_4-N.

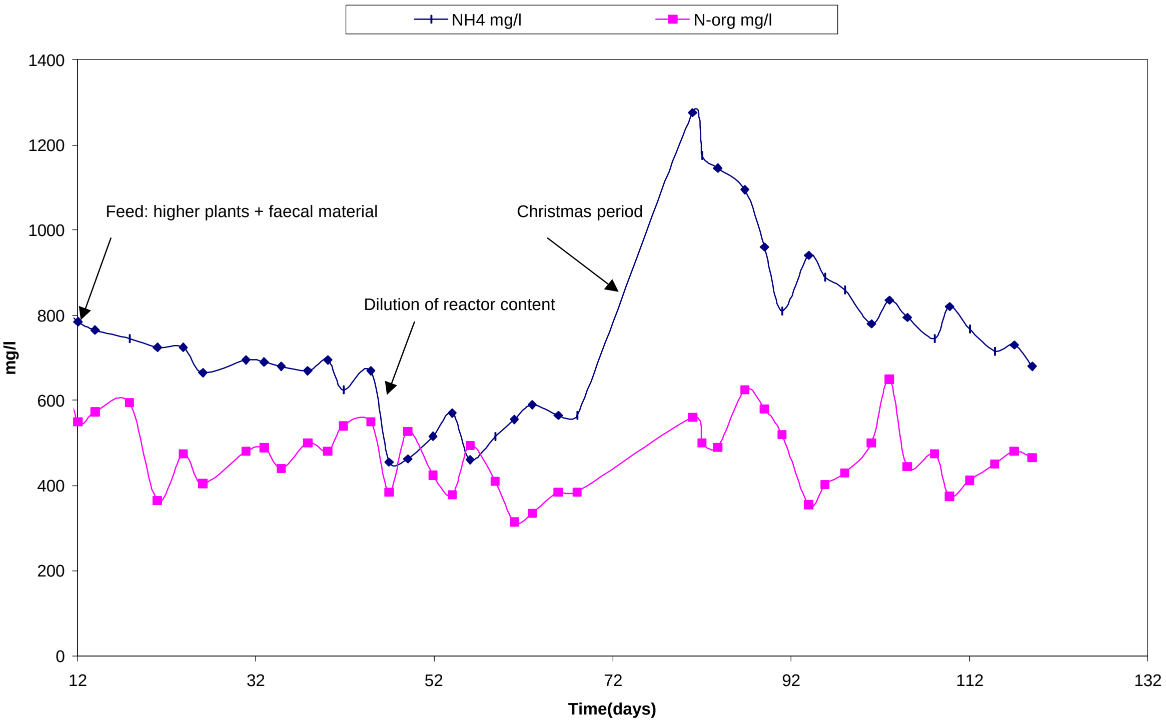

Figure 4-3 NH_4-N and N-org in reactor

4.4 Volatile fatty acids

The VFA increased in the first weeks of the addition of plant material and faecal material. The dilution can also be seen in Figure 4-4. During the Christmas period, an increase of VFA is noticed, due to the fact that the reactor was fed with starch, a good biodegradable substance. From this graph can be concluded that the operation of this reactor is not long enough to find a stable value for the VFA. In Figure 4-5 the composition of VFA is represented. The majority of the produced VFA is acetic acid and propionic acid.

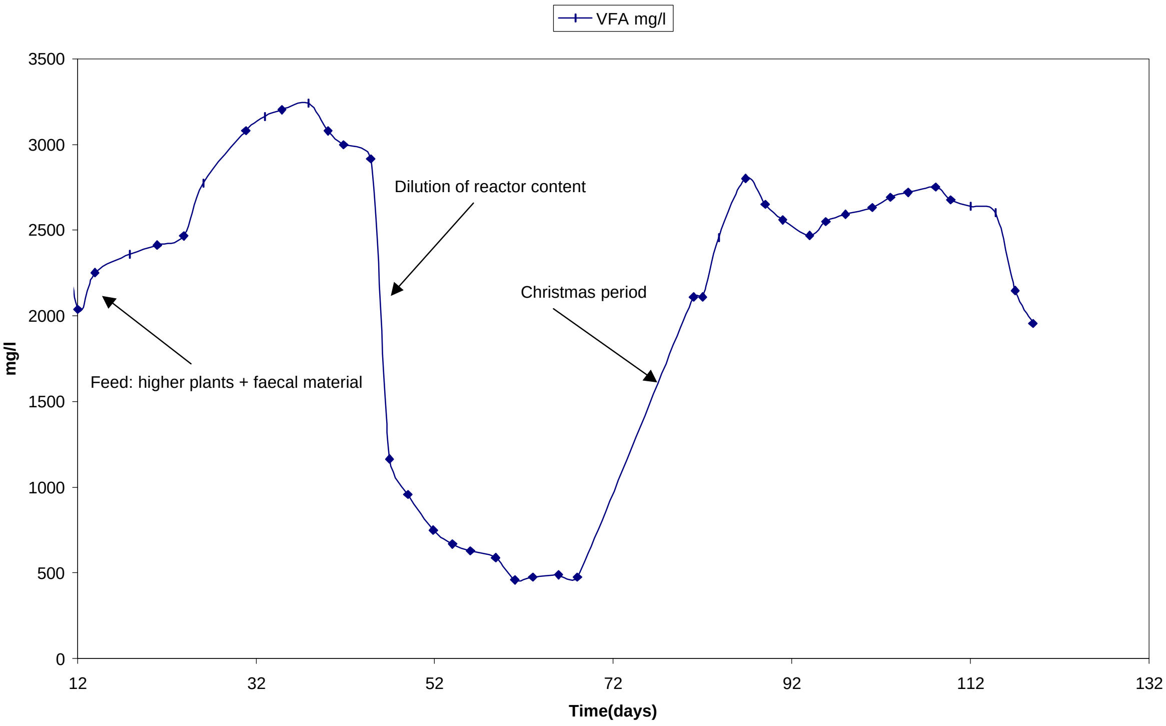

Figure 4-4 Volatile fatty acids in reactor

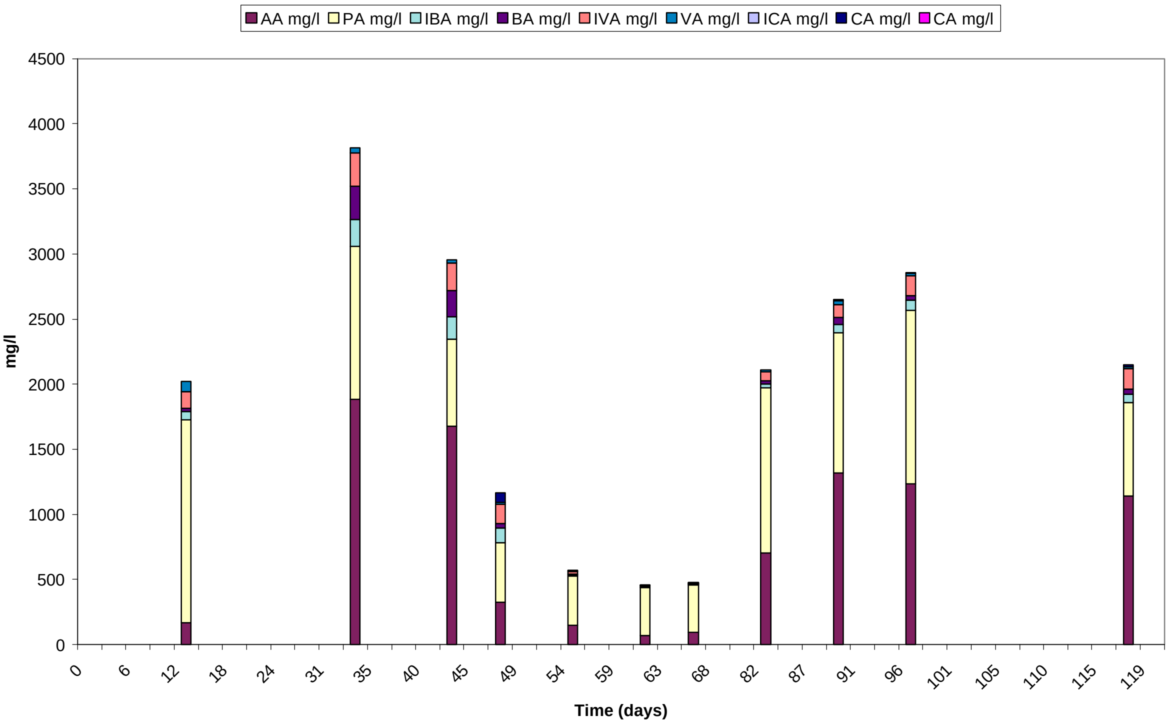

Figure 4-5 Volatile fatty acids composition in reactor

4.5 Biogas production

The cumulative biogas production is represented in Figure 4-6. During the Christmas period the biogas was not measured. The biogas produced during the operation of the reactor consisted of 54% methane and 46% carbondioxide. These values are the averages found along the whole period.

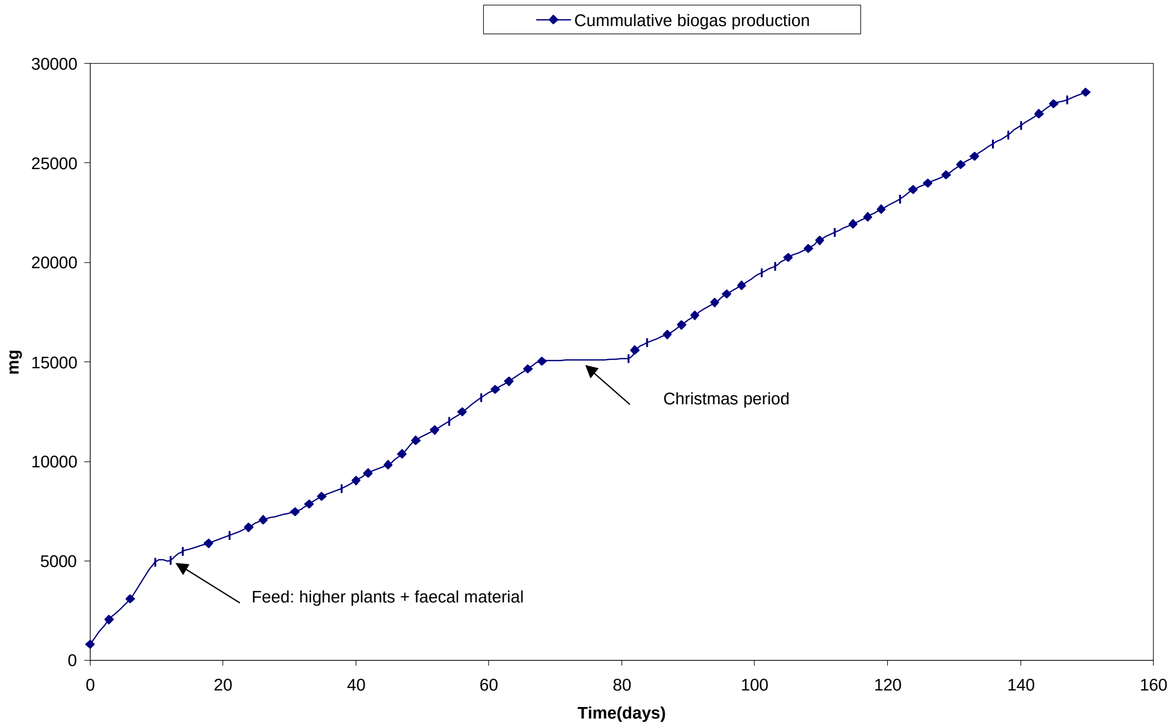

Figure 4-6 Cumulative biogas production

4.6 Conversion efficiency

In Figure 4-7 the conversion efficiencies are represented. For the calculation of the MELiSSA conversion efficiency, the methane production is not taken into account, since methane is of no use in the MELiSSA cycle. The total conversion efficiency is higher than the MELiSSA efficiency due to the additional methane production. The total and MELiSSA conversion efficiency reached a stable value of respectively 45% and 34%. The protein conversion efficiency increased during the Christmas period due to the addition of gelatine. After this period the efficiency decreased to its equilibrium of around 70%. Fibres were converted for 27%. These values are similar to the values obtained in earlier investigations were the conversion of faecal material under thermophilic conditions and with autochtonous bacteria at pH around 8 was tested (TN43.1).

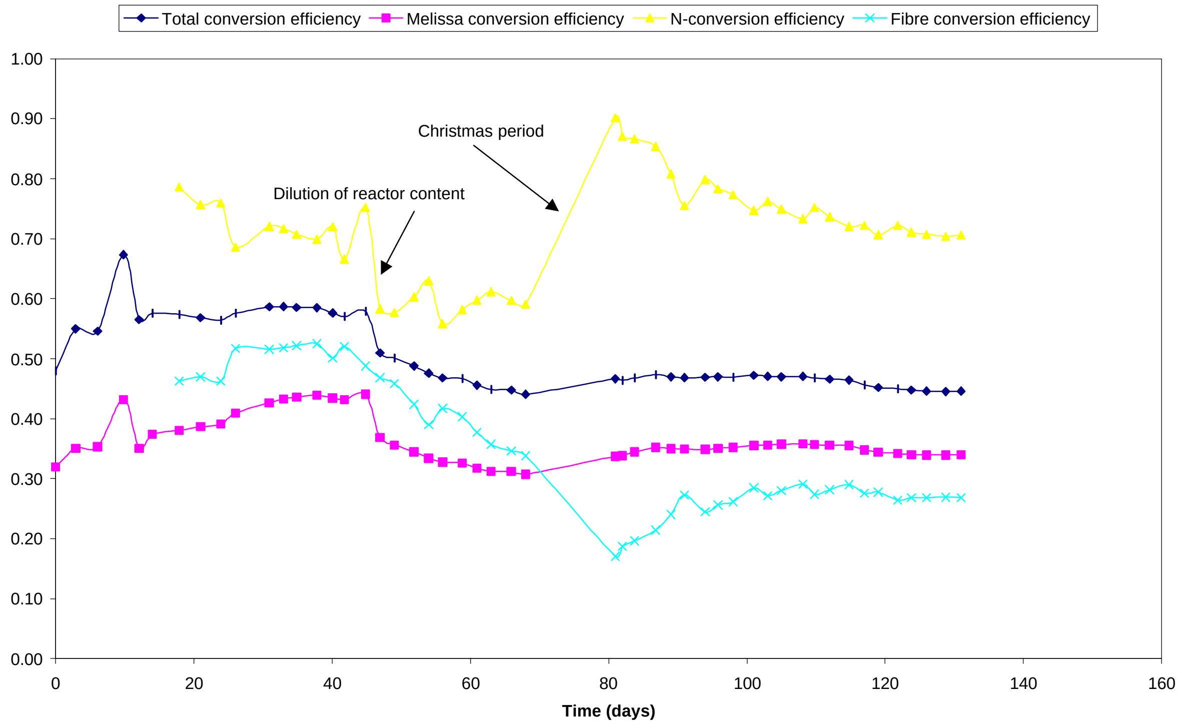

Figure 4-7 Conversion efficiencies

5. Conclusion

The conversion efficiency of non edible parts of higher plants was investigated using a thermophilic demonstration reactor with autochtonous bacteria of faecal material. The reactor was operated at pH 8 (optimal conditions for anaerobic bacteria). The feed consisted of a solution of faecal material and non edible parts of kale taken into account the amount of faecal material and waste of plants produced by a man per day. A total conversion efficiency of 45% was found. Proteins were biodegraded for 70% and fibres for 27 %. From these results can be concluded that the addition of non edible parts of higher plants together with faecal material didn’t result in lower conversion efficiencies in comparison with the conversion efficiencies obtained if only faecal material was introduced in the anaerobic, thermophilic reactor.

In future other plants need to be introduced in the anaerobic reactor, since eight higher plants are considered in the approach of an higher plant compartment: lettuce, wheat, potato, tomato, soybean, rice, spinach and onion. Also the excess of microbial biomass produced in compartment 1(*Rhodospirillum rubrum*) and 4 (*Spirulina platensis)* needs to be added to the anaerobic demonstration reactor in order to investigate the biodegradation efficiency. Since methane is of no use in the other compartments the methanogens need to be inhibited and therefore the pH needs to be decreased to 6-6.5.

6. References

Poughon, L. Including of a higher plant chamber in the MELiSSA loop, description of a higher plant compartment for MELiSSA loop steady state simulations. June 1997, PO 161081.

ADDENDUM

Feed of reactor

Date	Day	pH	DM g/l	Ash g/l	NH4 mg/l	Ntot mg/l	VFA mg/l	Amount L
15-10-99	0.0	7.0	19.19	2.38	320	1405	682	0.10
18-10-99	2.9	7.0	18.43	2.59	78	655	716	0.15
21-10-99	6.1	7.0	19.19	2.38	320	1405	682	0.15
25-10-99	9.8	7.4	24.14	4.60	58	1230	219	0.10
27-10-99	12.0	6.3	17.86	4.90	171	885	64	0.10
29-10-99	14.0	6.3	17.86	4.90	171	885	64	0.10
02-11-99	17.8	6.3	17.86	4.90	171	885	64	0.10
05-11-99	21.0	6.3	17.86	4.90	171	885	64	0.10
08-11-99	23.9	6.3	17.86	4.90	171	885	64	0.10
10-11-99	26.1	6.3	17.86	4.90	171	885	64	0.10
15-11-99	30.9	6.3	17.86	4.90	171	885	64	0.10
17-11-99	32.9	6.3	17.86	4.90	171	885	64	0.10
19-11-99	34.9	6.3	17.86	4.90	171	885	64	0.10
22-11-99	37.8	6.3	17.86	4.90	171	885	64	0.10
24-11-99	40.0	6.3	17.86	4.90	171	885	64	0.10
26-11-99	41.8	6.3	17.86	4.90	171	885	64	0.10
29-11-99	44.9	6.3	17.86	4.90	171	885	64	0.10
01-12-99	47.0	6.7	21.22	5.03	78	1005	60	0.10
03-12-99	49.0	6.7	21.22	5.03	78	1005	60	0.10
06-12-99	51.8	6.7	21.22	5.03	78	1005	60	0.10
08-12-99	54.0	6.7	21.22	5.03	78	1005	60	0.10
10-12-99	56.0	6.7	21.22	5.03	78	1005	60	0.10
13-12-99	58.8	6.7	21.22	5.03	78	1005	60	0.10
15-12-99	61.0	6.7	21.22	5.03	78	1005	60	0.10
17-12-99	63.0	6.7	21.22	5.03	78	1005	60	0.10
20-12-99	65.9	6.6	20.61	4.78	84	1110	98	0.10
22-12-99	68.0	6.6	20.61	4.78	84	1110	98	0.10
04-01-00	81.0	6.6	20.61	4.78	84	1110	98	0.10
05-01-00	82.0	6.6	20.61	4.78	84	1110	98	0.10
07-01-00	83.8	6.6	20.61	4.78	84	1110	98	0.10
10-01-00	86.8	6.6	20.61	4.78	84	1110	98	0.10
12-01-00	89.0	6.6	20.61	4.78	84	1110	98	0.10
14-01-00	91.0	6.6	20.61	4.78	84	1110	98	0.10
17-01-00	94.0	6.6	20.61	4.78	84	1110	98	0.10
19-01-00	95.8	6.6	20.61	4.78	84	1110	98	0.10
21-01-00	98.0	6.6	20.61	4.78	84	1110	98	0.10
24-01-00	101.0	6.6	20.61	4.78	84	1110	98	0.10
26-01-00	103.0	6.6	20.61	4.78	84	1110	98	0.10
28-01-00	105.0	6.6	20.61	4.78	84	1110	98	0.10
31-01-00	108.1	6.6	20.61	4.78	84	1110	98	0.10
02-02-00	109.8	6.6	20.61	4.78	84	1110	98	0.10
04-02-00	112.0	6.6	20.61	4.78	84	1110	98	0.10
07-02-00	114.8	6.6	20.61	4.78	84	1110	98	0.10
09-02-00	117.0	6.6	20.61	4.78	84	1110	98	0.10
11-02-00	119.0	6.6	20.61	4.78	84	1110	98	0.10
14-02-00	121.8	6.6	20.61	4.78	84	1110	98	0.10
16-02-00	123.8	6.6	20.61	4.78	84	1110	98	0.10
18-02-00	126.0	6.6	20.61	4.78	84	1110	98	0.10
21-02-00	128.8	6.6	20.61	4.78	84	1110	98	0.10
23-02-00	131.0	6.6	20.61	4.78	84	1110	98	0.10

Volatile fatty acid composition in feed

Date	Day	VFA mg/l	AA mg/l	PA mg/l	IBA mg/l	BA mg/l	IVA mg/l	VA mg/l	ICA mg/l	CA mg/l
15-10-99	0.0	682	304	189	20	113	28	28	0	0
18-10-99	2.9	716	357	176	18	117	27	21	0	0
21-10-99	6.1	682	304	189	20	113	28	28	0	0
25-10-99	9.8	219	128	35	11	15	21	8	0	0
27-10-99	12.0	64	64	0	0	0	0	0	0	0
29-10-99	14.0	64	64	0	0	0	0	0	0	0
02-11-99	17.8	64	64	0	0	0	0	0	0	0
05-11-99	21.0	64	64	0	0	0	0	0	0	0
08-11-99	23.9	64	64	0	0	0	0	0	0	0
10-11-99	26.1	64	64	0	0	0	0	0	0	0
15-11-99	30.9	64	64	0	0	0	0	0	0	0
17-11-99	32.9	64	64	0	0	0	0	0	0	0
19-11-99	34.9	64	64	0	0	0	0	0	0	0
22-11-99	37.8	64	64	0	0	0	0	0	0	0
24-11-99	40.0	64	64	0	0	0	0	0	0	0
26-11-99	41.8	64	64	0	0	0	0	0	0	0
29-11-99	44.9	64	64	0	0	0	0	0	0	0
01-12-99	47.0	60	60	0	0	0	0	0	0	0
03-12-99	49.0	60	60	0	0	0	0	0	0	0
06-12-99	51.8	60	60	0	0	0	0	0	0	0
08-12-99	54.0	60	60	0	0	0	0	0	0	0
10-12-99	56.0	60	60	0	0	0	0	0	0	0
13-12-99	58.8	60	60	0	0	0	0	0	0	0
15-12-99	61.0	60	60	0	0	0	0	0	0	0
17-12-99	63.0	60	60	0	0	0	0	0	0	0
20-12-99	65.9	98	79	8	2	5	3	1	0	0
22-12-99	68.0	98	79	8	2	5	3	1	0	0
04-01-00	81.0	98	79	8	2	5	3	1	0	0
05-01-00	82.0	98	79	8	2	5	3	1	0	0
07-01-00	83.8	98	79	8	2	5	3	1	0	0
10-01-00	86.8	98	79	8	2	5	3	1	0	0
12-01-00	89.0	98	79	8	2	5	3	1	0	0
14-01-00	91.0	98	79	8	2	5	3	1	0	0
17-01-00	94.0	98	79	8	2	5	3	1	0	0
19-01-00	95.8	98	79	8	2	5	3	1	0	0
21-01-00	98.0	98	79	8	2	5	3	1	0	0
24-01-00	101.0	98	79	8	2	5	3	1	0	0
26-01-00	103.0	98	79	8	2	5	3	1	0	0
28-01-00	105.0	98	79	8	2	5	3	1	0	0
31-01-00	108.1	98	79	8	2	5	3	1	0	0
02-02-00	109.8	98	79	8	2	5	3	1	0	0
04-02-00	112.0	98	79	8	2	5	3	1	0	0
07-02-00	114.8	98	79	8	2	5	3	1	0	0
09-02-00	117.0	98	79	8	2	5	3	1	0	0
11-02-00	119.0	98	79	8	2	5	3	1	0	0
14-02-00	121.8	98	79	8	2	5	3	1	0	0
16-02-00	123.8	98	79	8	2	5	3	1	0	0
18-02-00	126.0	98	79	8	2	5	3	1	0	0
21-02-00	128.8	98	79	8	2	5	3	1	0	0
23-02-00	131.0	98	79	8	2	5	3	1	0	0

Parameters of reactor

Date	Day	Volume L	pH	EC mS/cm	DM g/l	Ash g/l	OM g/l	NH4 mg/l	Ntot mg/l	N-org mg/l	VFA mg/l	Gas ml	CH4 %
15-10-99	0.0	0.9	7.3	7.8	25.96	6.73	19.23	800	1825	1025	2543	703.70	58
18-10-99	2.9	0.9	7.6	8.2	26.06	6.47	19.59	835	1740	905	2543	1201.31	68
21-10-99	6.1	0.9	7.5	6.4	26.17	6.22	19.95	920	1735	815	2587	1015.33	68
25-10-99	9.8	0.9	7.2	6.5	19.16	5.90	13.26	830	1540	710	2631	1779.35	68
27-10-99	12.0	0.9	7.5	6.7	20.59	5.62	14.97	785	1335	550	2037	100.53	70
29-10-99	14.0	0.9	7.4	7.2	18.12	5.70	12.42	765	1338	573	2252	376.98	53
02-11-99	17.8	0.9	7.3	7.8	15.65	5.78	9.88	745	1340	595	2359	376.98	63
05-11-99	21.0	0.9	7.7	7.3	14.99	6.49	8.50	725	1090	365	2413	316.66	49
08-11-99	23.9	0.9	7.6	7.4	14.34	5.71	8.63	725	1200	475	2466	316.66	50
10-11-99	26.1	0.9	7.7	6.8	16.09	5.73	10.36	665	1070	405	2774	316.66	50
15-11-99	30.9	0.9	7.4	7.2	16.21	5.95	10.26	695	1175	480	3082	316.66	50
17-11-99	32.9	0.9	7.8	7.1	18.63	5.24	13.39	690	1179	489	3162	316.66	50
19-11-99	34.9	0.9	7.6	7.1	16.94	5.37	11.57	680	1120	440	3202	316.66	50
22-11-99	37.8	0.9	7.6	7.3	15.26	4.37	10.89	670	1170	500	3241	316.66	50
24-11-99	40.0	0.9	8.0	6.7	19.13	5.47	13.66	695	1175	480	3079	316.66	50
26-11-99	41.8	0.9	7.9	6.6	17.54	5.53	12.01	625	1165	540	2998	316.66	53
29-11-99	44.9	0.9	7.9	6.7	15.96	4.90	11.06	670	1220	550	2916	402.11	64
01-12-99	47.0	0.9	7.6	6.4	12.35	4.41	7.94	455	840	385	1165	583.06	77
03-12-99	49.0	0.9	7.6	7.0	11.75	4.21	7.55	463	990	528	957	693.64	73
06-12-99	51.8	0.9	7.7	7.2	13.36	4.13	9.23	516	940	424	749	477.51	61
08-12-99	54.0	0.9	8.2	6.0	11.86	4.40	7.47	570	948	378	668	412.16	69
10-12-99	56.0	0.9	8.2	6.1	12.81	4.65	8.16	461	955	494	628	437.30	62
13-12-99	58.8	0.9	7.9	6.3	10.98	4.42	6.56	515	925	410	588	628.30	58
15-12-99	61.0	0.9	8.1	6.2	13.84	4.92	8.92	555	870	315	459	366.93	57
17-12-99	63.0	0.9	8.3	6.3	15.12	5.17	9.95	590	925	335	474	351.85	60
20-12-99	65.9	0.9	8.1	6.9	11.97	4.64	7.33	565	950	385	490	527.77	55
22-12-99	68.0	0.9	8.0	7.4	12.69	4.79	7.90	565	950	385	475	321.69	55
04-01-00	81.0	0.9	8.2	11.5	13.58	4.99	8.60	1275	1835	560	2109	125.66	55
05-01-00	82.0	0.9	7.9	11.1	15.75	5.15	10.60	1175	1675	500	2109	276.45	27
07-01-00	83.8	0.9	7.8	11.5	15.76	5.34	10.42	1145	1635	490	2456	266.40	36
10-01-00	86.8	0.9	7.8	10.5	12.66	5.47	7.19	1095	1720	625	2802	316.66	45
12-01-00	89.0	0.9	7.8	9.3	14.27	5.22	9.05	960	1540	580	2651	402.11	54
14-01-00	91.0	0.9	8.4	8.5	13.88	5.07	8.82	810	1330	520	2560	402.11	54
17-01-00	94.0	0.9	7.9	9.9	14.87	5.37	9.50	940	1295	355	2468	603.17	65
19-01-00	95.8	0.9	8.0	9.6	13.93	5.23	8.70	890	1293	403	2550	336.77	44
21-01-00	98.0	0.9	7.9	9.5	13.46	5.14	8.32	860	1290	430	2591	326.72	44
24-01-00	101.0	0.9	8.0	8.9	14.83	5.30	9.54	780	1280	500	2632	502.64	48
26-01-00	103.0	0.9	7.9	9.6	13.78	5.34	8.45	835	1485	650	2691	231.21	36
28-01-00	105.0	0.9	7.7	9.4	13.31	4.81	8.50	795	1240	445	2721	326.72	40
31-01-00	108.1	0.9	7.9	9.0	14.69	5.14	9.55	745	1220	475	2750	382.01	53
02-02-00	109.8	0.9	7.8	9.0	12.89	4.83	8.06	820	1195	375	2675	331.74	53
04-02-00	112.0	0.9	7.8	8.9	12.66	5.00	7.66	768	1180	412	2638	336.77	53
07-02-00	114.8	0.9	7.9	8.9	12.61	5.07	7.55	715	1165	450	2600	361.90	54
09-02-00	117.0	0.9	8.0	8.6	12.36	5.14	7.22	730	1210	480	2148	301.58	53
11-02-00	119.0	0.9	7.9	8.2	11.87	4.84	7.04	680	1145	465	1955	311.64	52
14-02-00	121.8	0.9	7.9	8.9	12.73	5.11	7.62	755	1330	575	1859	447.35	60
16-02-00	123.8	0.9	8.1	8.6	12.73	4.90	7.83	715	1190	475	1762	402.11	55
18-02-00	126.0	0.9	8.1	8.7	12.46	4.99	7.47	710	1133	423	1847	276.45	54
21-02-00	128.8	0.9	8.1	8.9	12.20	5.09	7.11	705	1075	370	1890	351.85	56
23-02-00	131.0	0.9	8.0	8.4	13.14	4.96	8.18	725	985	260	1933	427.24	49

Volatile fatty acid composition in reactor

Date	Day	VFA mg/l	AA mg/l	PA mg/l	IBA mg/l	BA mg/l	IVA mg/l	VA mg/l	ICA mg/l	CA mg/l
27-10-99	12.0	2019	169	1556	63	27	129	76	0	0
17-11-99	32.9	3817	1881	1176	206	256	254	44	0	0
26-11-99	41.8	2954	1675	672	167	205	213	22	0	0
01-12-99	47.0	1165	324	457	113	38	143	20	0	70
08-12-99	54.0	568	149	379	8	6	20	2	0	4
15-12-99	61.0	457	70	368	5	0	7	2	0	5
20-12-99	65.9	475	91	368	4	2	7	3	0	0
05-01-00	82.0	2109	701	1271	31	26	63	16	0	1
12-01-00	89.0	2651	1316	1076	64	57	98	25	0	15
19-01-00	95.8	2854	1233	1335	76	37	148	24	1	0
09-02-00	117.0	2148	1142	717	66	35	157	20	0	12
16-02-00	123.8	1762	812	690	59	28	155	18	0	0
23-02-00	131.0	1933	965	726	58	22	155	7	0	0