Eco Process Assistance

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TECHNICAL NOTE 56.2

Biodegradation of non edible parts of plants and bacterial biomass

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ABBREVIATIONS

DW	Dry weight
OM	Organic material
VFA	Volatile fatty acids
EC	Conductivity

1. Introduction

A balanced diet for the crew will consist of mainly higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum*. The *Arthrospira platensis* and *Rhodospirillum rubrum,* produced in the MELiSSA loop, will not be totally consumed by the astronauts, because the high content of nucleic acid in micro-organisms limits the quantity that can be consumed.

With data of the production of faecal material per man a day and with the information of a diet made for astronauts, a ratio could be calculated in order to prepare the feed of the anaerobic reactor.

In this technical note the results of the biodegradation efficiencies of a mix of faecal material, non edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum* are represented and compared with previous conversion efficiencies.

2. Preparation of the waste materials

The waste fed to the liquefying compartment consists of faecal material, non-edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum*.

One person a day produces:

486 g DW non-edible parts of higher plants

30 g DW faecal material

Per person a day the following quantities of *Arthrospira* and *Rhodospirillum* are not consumed:

25 g *Arthrospira platensis*

100 g *Rhodospirillum rubrum*

These values were utilised to prepare the waste mixture.

The inedible parts of higher plants were partly obtained from the University of Guelph and partly from the open field. The lignin content of open field vegetables differs from the lignin content of greenhouse vegetables. Since the collection of greenhouse vegetables was difficult, open field vegetables were chosen. This has to be kept in mind.

The plants that were selected were lettuce, spinach, carrots, potatoes and beet. The inedible parts like leaves, roots and stems (depending on the vegetable) were dried in an oven at 105°C during two days and were ground in a commercial coffee grinder for 2 minutes. The percentages of the different higher plants are represented in Table 2-1.

Table 2-1 Percentage of the different plants in the higher plant mixture

Higher plant	Origin	Percentage
Lettuce	Field	21%
	Greenhouse	5%
Spinach	Field	21%
Carrots	Field	16%
Potatoes	Field	30%
Beet	Greenhouse	6%

The freeze-dried *Rhodospirillum* was obtained from the University 'Autonoma' of Barcelona and the *Arthrospira* was obtained from ESTEC.

To prepare the waste, the faecal material, non-edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum* were diluted with water and grounded with a grinder until a homogenous liquid was obtained.

3. Reactor set-up

The demonstration reactor (Figure 3-1) had a wet volume of 1 litre and a temperature of 55°C. 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 16 days. At first the reactor was fed with only faecal material, since no vegetables were available at that time. At day 203 the reactor was fed with 150 ml of a solution containing human faecal material, non-edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum* at a ratio mentioned in paragraph 2.

Figure 3-1 Demonstration reactor

Three times a week a concentration of 3.3g DW was fed into the reactor, by means of 150 ml waste mixture after removing 150 ml of the reactor content. Afterwards the reactor was flushed with 100 % N_2-gas, during 5 minutes, in order to obtain anaerobic conditions. The characteristics of the feed from day 203 are represented in Table 3-1.

Table 3-1 Characteristics of the waste materials

Parameter	Unit	Mean value
pH		7
Dry matter	g/l	40
Ash	g/l	9,7
Total nitrogen	mg/l	885
Ammonium nitrogen	mg/l	23
VFA	mg/l	240
Acetic acid		172
Propionic acid		24
Iso Butyric acid		9
Butyric acid		16
Iso valeric acid		8
Valeric acid		4
Isocaproic acid		1
Caproic acid		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 3-2. Every time before feeding the reactor, the produced biogas was read.

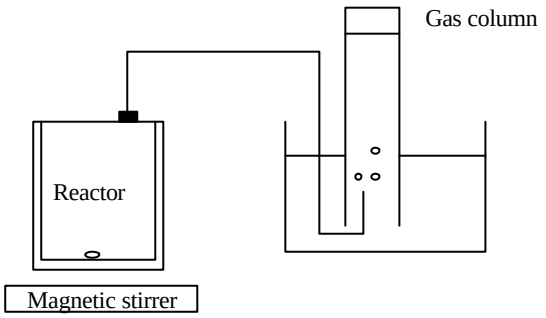

Figure 3-2 Reactor set-up

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

4. Results

4.1 pH and EC

In Figure 4-1 the pH and EC is represented. The pH of the reactor fluctuated around 8. This pH is optimal for the anaerobic bacteria and is obtained during the entire period, in order to evaluate the biodegradability of non-edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum* by anaerobic bacteria in

optimal conditions. The EC fluctuated between 4 and 6. During the Christmas period (day 233 until day 245), the reactor was fed with starch and gelatine. The gelatine caused an increase in EC. After two more weeks (day 245 until day 259), the gelatine and starch was removed from the reactor, since the residence time was 16 days, After this period the original value of 6 mS/cm was again found.

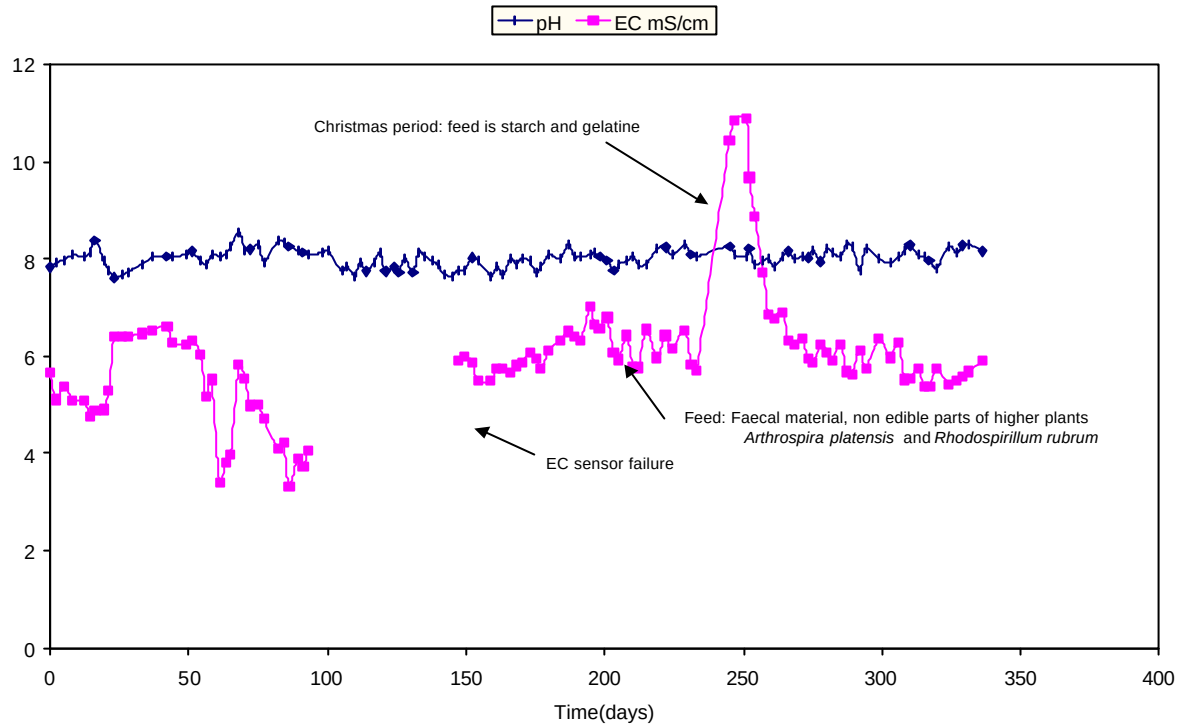

Figure 4-1 pH and EC in reactor

4.2 Dry matter and organic matter

In Figure 4-2 the organic matter is represented. The organic matter fluctuated around 13 g/l until day 203. From day 203 the reactor was fed with a solution containing, faecal material, non-edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum*. The organic matter decreased gradually until a value of around 7 g/l was reached. Since the same amount of organic material was fed into the reactor during the entire test period, the decrease in organic matter concentration is due to a better biodegradation. The conversion efficiency will be explained in paragraph 4.6.

4.3 NH_4-N and N-org

The fluctuations noticed in Figure 4-3 are due to a change in feed. At day 203 the reactor was fed with the new mixture. The ammonium concentration decreased at that time due to the small ammonium concentration in the waste mixture. During Christmas period (1,5 week), the reactor was fed with gelatine and starch. This caused an increase in ammonium content. From day 245 until day 259 (after the Christmas break) the concentration decreased until a stable value of around 450 mg/l was found. This period can be seen as a recovery period. During this period, the remaining gelatine was removed from the reactor, since the residence time was 16 days.

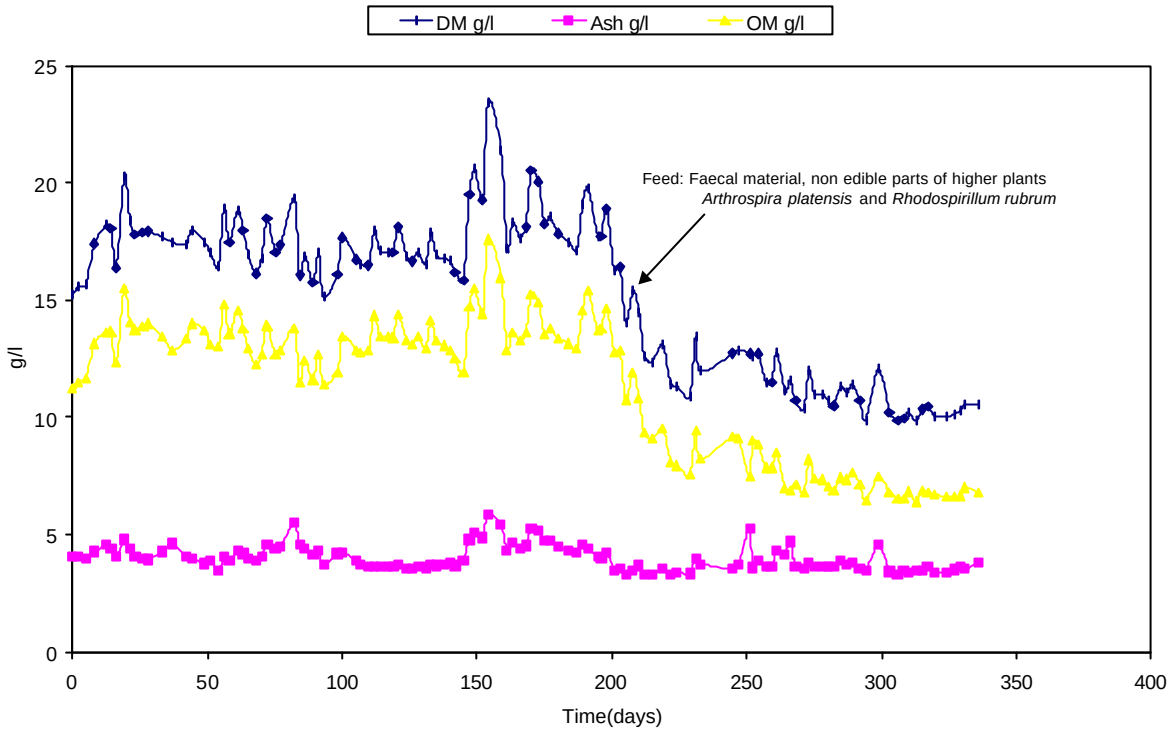

Figure 4-2 Dry matter and organic matter in the reactor

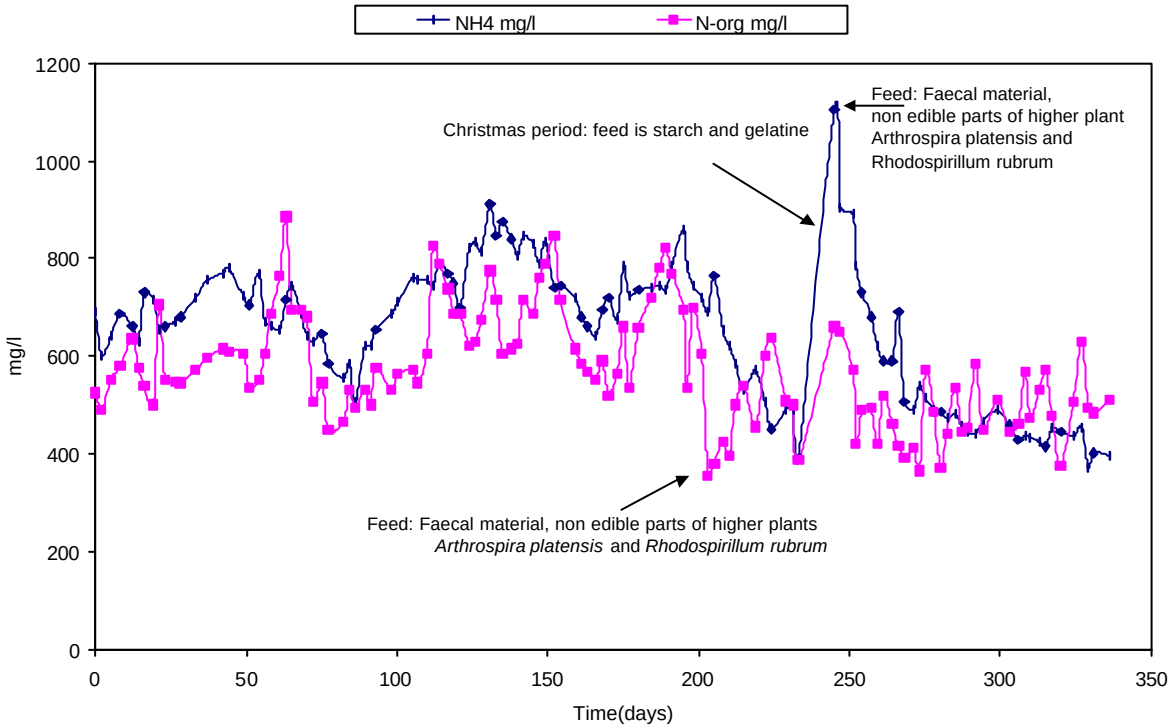

Figure 4-3 NH_4-N and N-org in reactor

4.4 Volatile fatty acids

Also in Figure 4-4 high fluctuations are noticed, due to different waste compositions fed to the reactor. From day 100 until day 200 high VFA concentrations were noticed, mainly consisting of acetic acid. In this period the methanogenesis is partly disturbed, resulting in a accumulation of acetic acid. During the Christmas period the reactor was fed with starch and gelatine. The increase of VFA at that time is due to the fact that starch is good biodegradable by the anaerobic bacteria. From day 245 until day 259 the remaining starch is converted and or washed out. After this recovery period, the VFA fluctuated around 290 mg/l. The recovery period corresponds with one residence time (16 days), therefore after this period the reactor content is renewed. In Figure 4-5 the composition of the VFA are represented. The majority of the produced VFA is acetic acid and propionic acid.

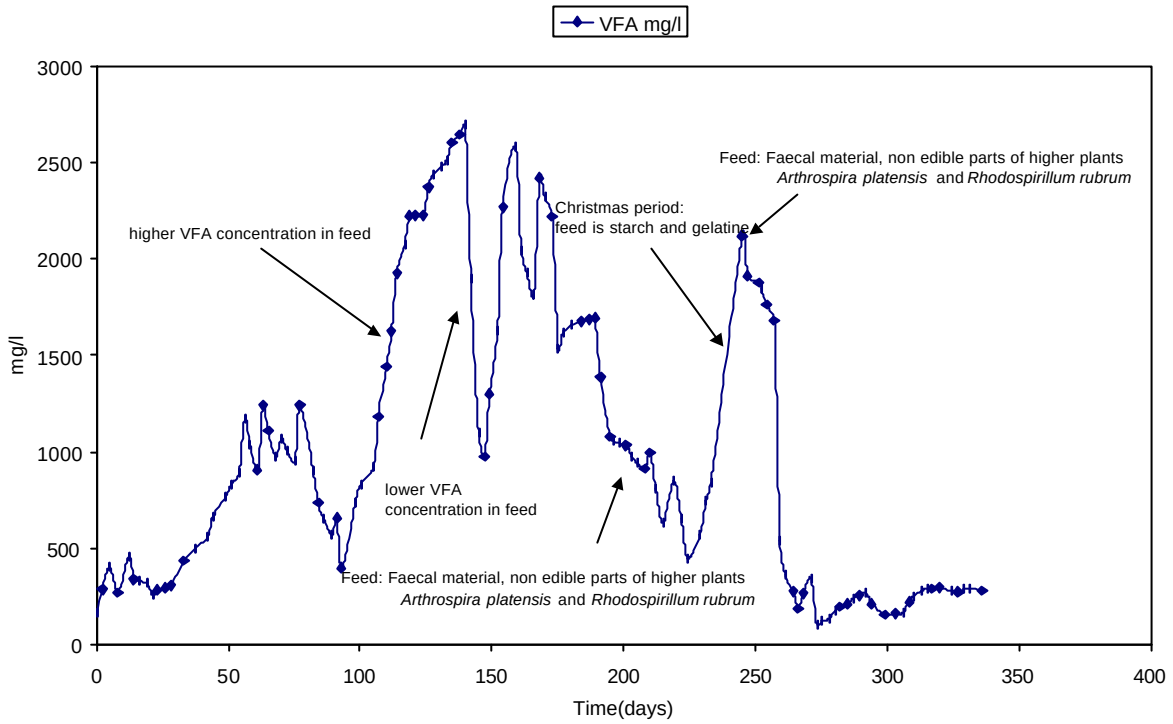

Figure 4-4 VFA in reactor

4.5 Biogas production

The biogas production is represented in Figure 4-6. The biogas production increased during the Christmas break (1 week). At that time the reactor was fed with starch and gelatine. Since starch is good biodegradable the biogas production was increased. Since the pH of the reactor was about 8, the biogas consisted of methane and carbon dioxide at an average concentration of 67% CH_4 and 33% CO_2. The methane concentration in the biogas is represented Figure 4-7.

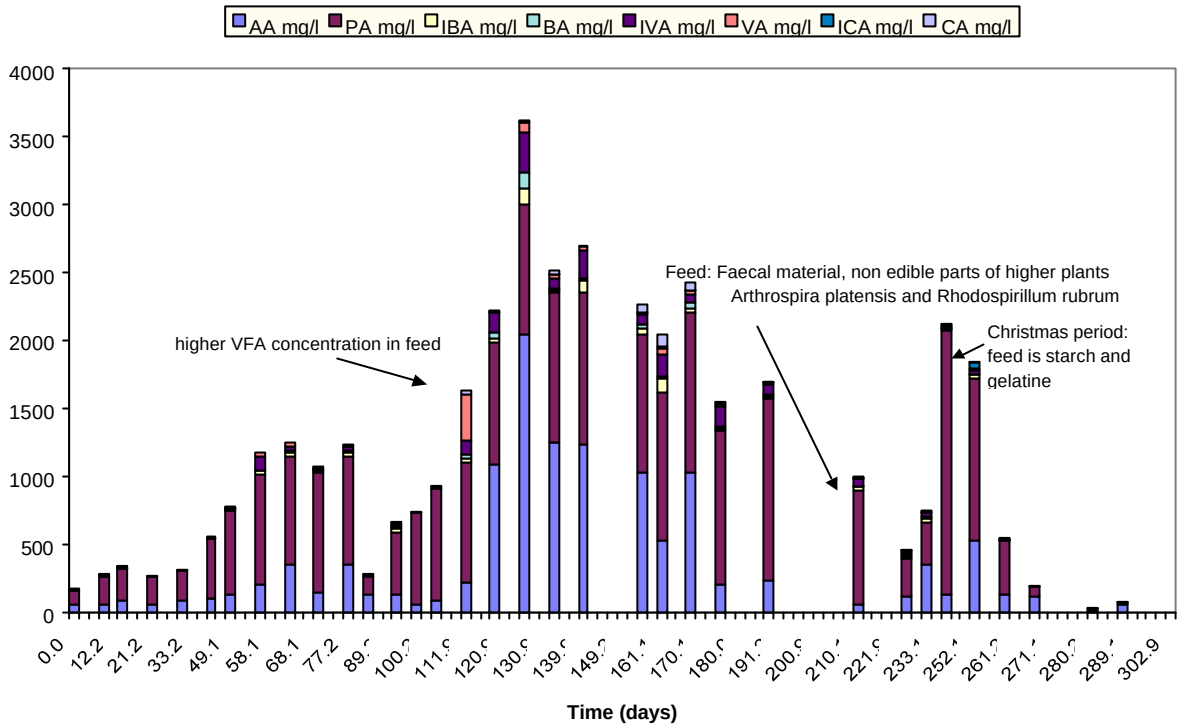

Figure 4-5 Volatile fatty acids composition in reactor

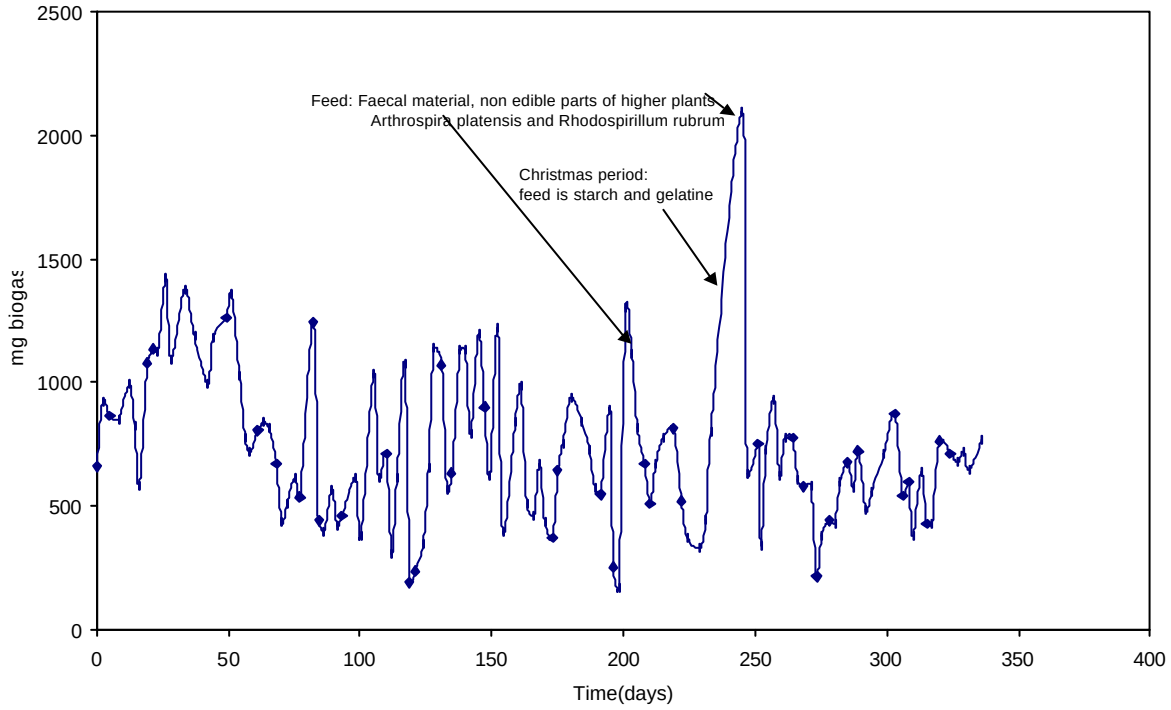

Figure 4-6 Biogasproduction

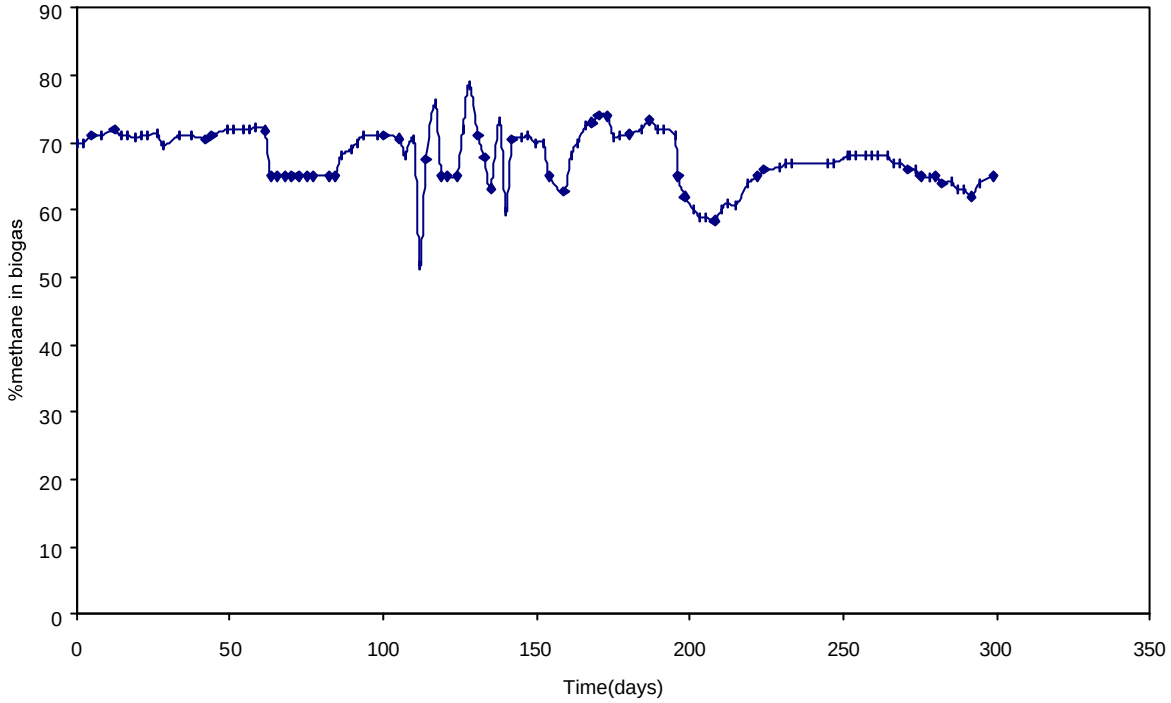

Figure 4-7 Percentage of methane in biogas

4.6 Conversion efficiencies

The test period is divided in two parts. In the first period the demonstration reactor was fed with faecal material. The total and MEliSSA conversion efficiency was calculated using the model of Anglidaki, From this model can be concluded that 1 gram of organic material will be converted in 1 gram of VFA, what results in 1 gram of biogas. This model was designed for the anaerobic conversion of cattle manure, thus can not be used during the second period when the reactor was fed with a mixture of faecal material, non edible parts of higher plants, *Arthrospira platensis* and *Rhodospirillum rubrum*. The conversion efficiency of this period was calculated using information about the organic matter fed to the reactor and the organic matter removed from the reactor. In Table 4-1 an overview of the two test periods is shown.

Table 4-1 Overview of the two different test periods

First Period	
Feed:	Faecal material
Calculations:	• Based on model of Anglidaki: Total conversion efficiency (based on production of VFA and biogas (CH_4, CO_2) MELiSSA conversion efficiency (based on production of VFA and CO_2) • Based on OM converted
Second period	
Feed:	Mixture of faecal material, higher plant material, *Arthrospira plantensis* and *Rhodospirillum rubrum*
Calculations:	• Based on OMconverted

In Figure 4-8 the conversion efficiencies of the first period, when the reactor was fed with only faecal material, are represented. The total and MELiSSA efficiencies, based on the model of Anglidaki, are respectively 32% and 17%. The OM conversion efficiency is about 35%. This value correspond to the total

conversion efficiency (32%), and confirms that the model of Anglidaki can be used for faecal material. Fibres were converted for 17% and proteins for 61%.

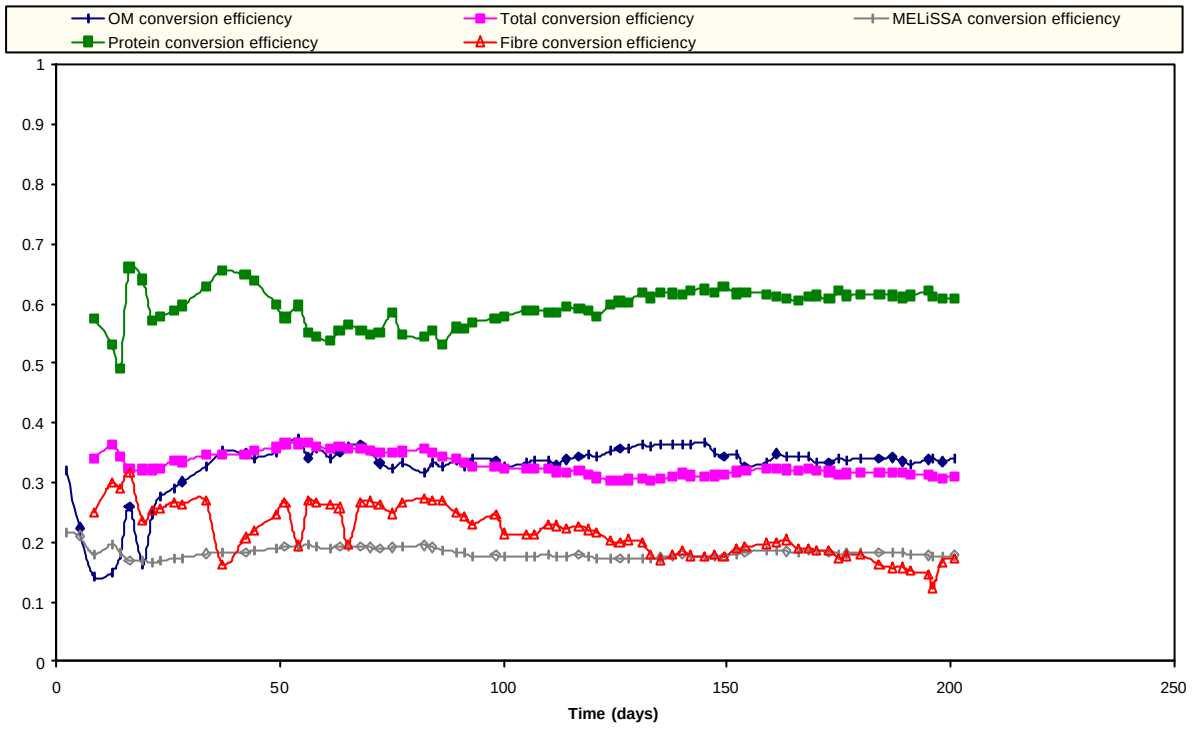

Figure 4-8 Conversion efficiencies first period

In Figure 4-9 the conversion efficiencies during the second period are presented. From day 233 until day 245 the reactor was fed with a mixture of gelatine and starch and the period from day 245 until day 259 is considered as a recovery period were the remainder of starch and gelatine are washed out and/or converted. The test period, from day 233 until day 259, is not taken into account when calculating the efficiencies. In the second period, the model of Anglidaki could not be used to calculate the total conversion efficiency, since a different type of feed was used, namely a mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum*. The conversion efficiency was calculated based on organic material fed to the reactor and organic material converted. The OM efficiency reached a value of 54%. Proteins were converted for 47% and fibres for 58%. In the first period when the reactor was fed with faecal material only, lower OM and fibre conversion efficiencies were reached. The proteins present in the faecal material were more easily converted than the proteins of the mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum*.

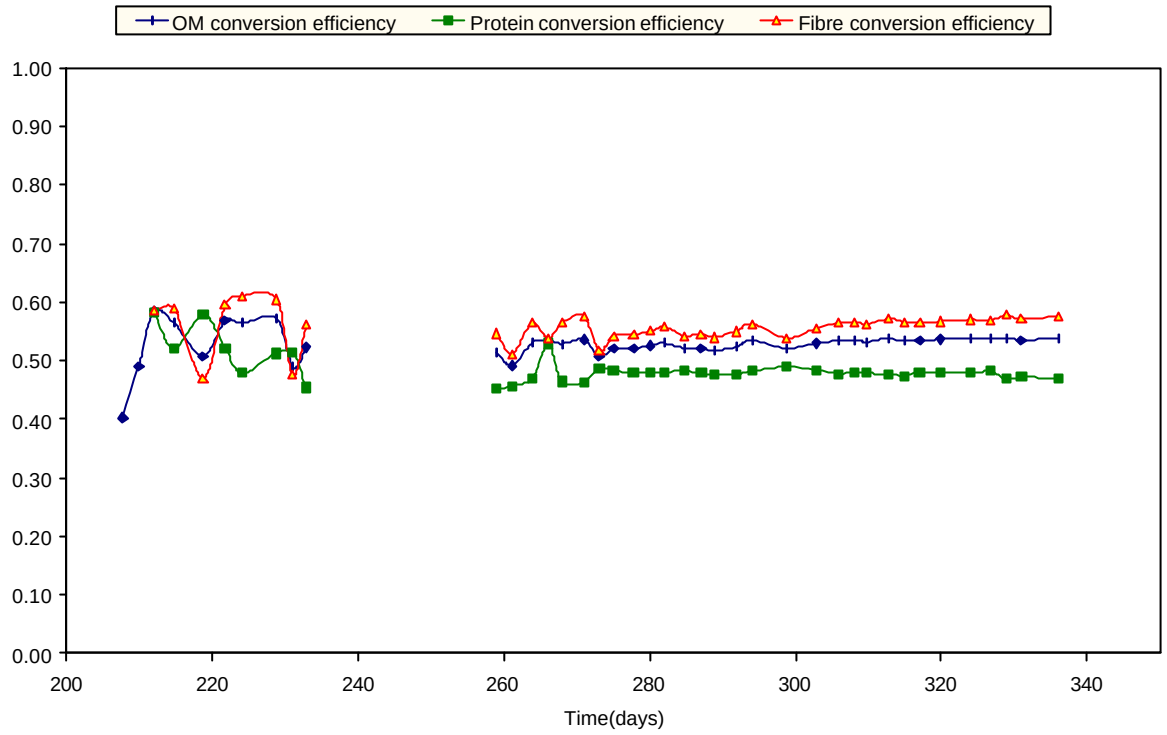

Figure 4-9 Conversion efficiencies second period

5. Conclusion

The conversion efficiency of a mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum* 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 amount of waste (faecal material and non-edible parts of higher plants) produced by a man a day and the amount of *Arthrospira* and *Rhodospirillum*, produced in the MELiSSA loop, and not consumed by a man a day were taken into account when calculating and preparing the waste mixture. The conversion efficiency was not calculated based on the model of Anglidaki, since this model can only be used for the anaerobic conversion of manure, but the calculations were based on the organic material fed to the reactor and the organic material removed from the reactor. The test period can be divided into two periods. In the first period the reactor was fed with faecal material. During this period some temporary disturbances of the methanogenesis occurred, resulting in an increase of acetic acid concentration in the reactor. In the second period the reactor was fed with a mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum*. The results of both periods were compared. In Table 5-1 the conversion efficiencies of both periods are represented. From the results could be concluded that the OM conversion efficiency was higher in case of the mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum*, since the fibres, present in the higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum* are more easily converted. The proteins on the other hand were less biodegradable when the mixture of faecal material, higher plant material, *Arthrospira platensis* and *Rhodospirillum rubrum* was fed into the demonstration reactor.

Table 5-1 Conversion efficiencies obtained during test period

Period 1 (faecal material)	
Total conversion efficiency	32 %
MELiSSA conversion efficiency	17 %
OM conversion efficiency	35%
Protein conversion efficiency	61%
Fibre conversion efficiency	17%
Period 2 (faecal material, non edible parts of higher plants, *A. platensis* and *R. rubrum)*	
OM conversion efficiency	54%
Protein conversion efficiency	47%
Fibre conversion efficiency	58%

6. References

Anglidaki I., Ellegaard L. and Ahring B.K. (1993). A mathematical Model for Dynamic Simulation of Anaerobic Digestion of Complex substrates: Focusing on Ammonia Inhibition. Biotechnology and bioengineering, Vol. 42, pp.159-166.

ADDENDUM

Feed of reactor

Date	Day	pH	DM g/l	ASH g/l	NH4-N mg/l	N-tot mg/l	VFA mg/l	Amount l
03-05-00	0.00	6.6	25.76	3.54	70	1040	648	0.1
05-05-00	2.18	6.6	25.76	3.54	70	1040	648	0.1
08-05-00	5.03	6.6	25.76	3.54	70	1040	648	0.1
11-05-00	8.20	6.6	25.76	3.54	70	1040	648	0.1
15-05-00	12.24	6.6	25.76	3.54	70	1040	648	0.1
17-05-00	14.24	6.6	25.76	3.54	70	1040	648	0.1
19-05-00	16.18	6.8	32.42	4.11	93	1060	700	0.1
22-05-00	19.24	6.8	32.42	4.11	93	1060	700	0.1
24-05-00	21.24	6.8	32.42	4.11	93	1060	700	0.1
26-05-00	23.16	6.8	32.42	4.11	93	1060	700	0.1
29-05-00	26.20	6.8	32.42	4.11	93	1060	700	0.1
31-05-00	28.18	6.8	32.42	4.11	93	1060	700	0.1
05-06-00	33.22	6.8	32.42	4.11	93	1060	700	0.1
09-06-00	37.12	6.6	29.53	3.51	130	1455	922	0.1
14-06-00	42.18	6.6	29.53	3.51	130	1455	922	0.1
16-06-00	44.16	6.6	29.53	3.51	130	1455	922	0.1
21-06-00	49.10	6.6	29.53	3.51	130	1455	922	0.1
23-06-00	51.09	6.6	29.53	3.51	130	1455	922	0.1
26-06-00	54.15	6.8	26.00	4.45	105	1290	917	0.1
28-06-00	56.22	6.8	26.00	4.45	105	1290	917	0.1
30-06-00	58.15	6.8	26.00	4.45	105	1290	917	0.1
03-07-00	61.20	6.8	26.00	4.45	105	1290	917	0.1
05-07-00	63.24	6.8	26.00	4.45	105	1290	917	0.1
07-07-00	65.16	7.4	18.79	3.73	55	795	832	0.1
10-07-00	68.09	7.4	18.79	3.73	55	795	832	0.1
12-07-00	70.18	7.4	18.79	3.73	55	795	832	0.1
14-07-00	72.18	7.4	18.79	3.73	55	795	832	0.1
17-07-00	75.22	7.4	18.79	3.73	55	795	832	0.1
19-07-00	77.23	7.4	18.79	3.73	55	795	832	0.1
24-07-00	82.20	7.4	18.79	3.73	55	795	832	0.1
26-07-00	84.16	7.0	25.79	3.59	68	1090	832	0.1
28-07-00	86.17	7.0	25.79	3.59	68	1090	832	0.1
31-07-00	89.24	7.0	25.79	3.59	68	1090	832	0.1
02-08-00	91.22	7.0	25.79	3.59	68	1090	832	0.1
04-08-00	93.12	7.0	25.79	3.59	68	1090	832	0.1
09-08-00	98.16	6.7	28.67	4.02	108	1275	934	0.1
11-08-00	100.24	6.7	28.67	4.02	108	1275	934	0.1
16-08-00	105.12	6.7	28.67	4.02	108	1275	934	0.1
18-08-00	106.94	6.7	28.67	4.02	108	1275	934	0.1
21-08-00	109.93	7.0	32.40	3.89	66	1225	1370	0.1
23-08-00	111.94	7.0	32.40	3.89	66	1225	1370	0.1
25-08-00	113.93	7.0	32.40	3.89	66	1225	1370	0.1
28-08-00	116.94	7.0	32.40	3.89	66	1225	1370	0.1
30-08-00	118.90	7.0	32.40	3.89	66	1225	1370	0.1
01-09-00	120.91	7.0	32.40	3.89	66	1225	1370	0.1
4-09-00	123.91	7.0	32.40	3.89	66	1225	1370	0.1
6-09-00	125.91	7.0	32.40	3.89	66	1225	1370	0.1
8-09-00	127.91	7.0	32.40	3.89	66	1225	1370	0.1
11-09-00	130.91	7.0	32.40	3.89	66	1225	1370	0.1
13-09-00	132.91	7.0	23.62	3.79	84	1040	652	0.1
15-09-00	134.91	7.0	23.62	3.79	84	1040	652	0.1
18-09-00	137.91	7.0	23.62	3.79	84	1040	652	0.1
20-09-00	139.91	7.0	23.62	3.79	84	1040	652	0.1
22-09-00	141.92	7.0	23.62	3.79	84	1040	652	0.1
25-09-00	144.95	7.0	23.62	3.79	84	1040	652	0.1
27-09-00	147.14	7.0	23.62	3.79	84	1040	652	0.1
29-09-00	149.21	7.0	23.62	3.79	84	1040	652	0.1
2-10-00	152.15	7.0	23.62	3.79	84	1040	652	0.1
4-10-00	154.13	7.0	23.62	3.79	84	1040	652	0.1
9-10-00	158.92	7.0	23.62	3.79	84	1040	652	0.1
11-10-00	161.10	7.0	23.62	3.79	84	1040	652	0.1
13-10-00	163.22	7.4	26.22	4.47	63	1160	674	0.1
16-10-00	165.92	7.4	26.22	4.47	63	1160	674	0.1
18-10-00	168.10	7.4	26.22	4.47	63	1160	674	0.1
20-10-00	170.10	7.4	26.22	4.47	63	1160	674	0.1
23-10-00	172.91	7.4	26.22	4.47	63	1160	674	0.1
25-10-00	175.10	7.4	26.22	4.47	63	1160	674	0.1
27-10-00	176.91	7.4	26.22	4.47	63	1160	674	0.1
30-10-00	179.97	7.4	26.22	4.47	63	1160	674	0.1
3-11-00	184.12	7.1	27.26	3.47	103	1435	887	0.1

Date	Day	pH	DM g/l	ASH g/l	NH4-N mg/l	N-tot mg/l	VFA mg/l	Amount l
6-11-00	186.92	7.1	27.26	3.47	103	1435	887	0.1
8-11-00	189.12	7.1	27.26	3.47	103	1435	887	0.1
10-11-00	191.17	7.1	27.26	3.47	103	1435	887	0.1
14-11-00	194.92	7.1	27.26	3.47	103	1435	887	0.1
15-11-00	196.12	6.7	17.84	1.22	47	890	871	0.1
17-11-00	198.12	6.7	17.84	1.22	47	890	871	0.1
20-11-00	200.92	6.7	17.84	1.22	47	890	871	0.1
22-11-00	203.14	7.1	19.28	4.13	23	885	240	0.15
24-11-00	205.16	7.1	19.28	4.13	23	885	240	0.15
27-11-00	207.93	7.1	19.28	4.13	23	885	240	0.15
29-11-00	210.12	7.1	19.28	4.13	23	885	240	0.15
1-12-00	212.14	7.1	19.28	4.13	23	885	240	0.15
4-12-00	214.93	7.1	19.28	4.13	23	885	240	0.15
8-12-00	218.91	7.1	19.28	4.13	23	885	240	0.15
11-12-00	221.92	7.1	19.28	4.13	23	885	240	0.15
13-12-00	224.18	7.1	19.28	4.13	23	885	240	0.15
18-12-00	228.93	7.1	19.28	4.13	23	885	240	0.15
20-12-00	231.20	7.1	19.28	4.13	23	885	240	0.15
22-12-00	233.05	7.1	19.28	4.13	23	885	240	0.15
3-01-01	244.97	7.1	19.28	4.13	23	885	240	0.15
5-01-01	246.88	7.1	19.28	4.13	23	885	240	0.15
9-01-01	251.14	7.1	19.28	4.13	23	885	240	0.15
10-01-01	252.14	7.1	19.28	4.13	23	885	240	0.15
12-01-01	254.16	7.1	19.28	4.13	23	885	240	0.15
15-01-01	257.12	7.1	19.28	4.13	23	885	240	0.15
17-01-01	259.20	7.1	19.28	4.13	23	885	240	0.15
19-01-01	261.21	7.1	19.28	4.13	23	885	240	0.15
22-01-01	264.15	7.1	19.28	4.13	23	885	240	0.15
24-01-01	266.19	7.1	19.28	4.13	23	885	240	0.15
26-01-01	268.13	7.1	19.28	4.13	23	885	240	0.15
29-01-01	271.12	7.1	19.28	4.13	23	885	240	0.15
31-01-01	273.21	7.1	19.28	4.13	23	885	240	0.15
2-02-01	275.15	7.1	19.28	4.13	23	885	240	0.15
5-02-01	277.91	7.1	19.28	4.13	23	885	240	0.15
7-02-01	280.16	7.1	19.28	4.13	23	885	240	0.15
9-02-01	282.19	7.1	19.28	4.13	23	885	240	0.15
12-02-01	284.93	7.1	19.28	4.13	23	885	240	0.15
14-02-01	287.20	7.1	19.28	4.13	23	885	240	0.15
16-02-01	289.10	7.1	19.28	4.13	23	885	240	0.15
19-02-01	291.92	7.1	19.28	4.13	23	885	240	0.15
21-02-01	294.20	7.1	19.28	4.13	23	885	240	0.15
26-02-01	298.93	7.1	19.28	4.13	23	885	240	0.15
2-03-01	302.91	7.1	19.28	4.13	23	885	240	0.15

Volatile fatty acid composition in feed

Date	Time days	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
03-05-00	0.00	648	297	149	16	106	26	37	0	17
05-05-00	2.18	648	297	149	16	106	26	37	0	17
08-05-00	5.03	648	297	149	16	106	26	37	0	17
11-05-00	8.20	648	297	149	16	106	26	37	0	17
15-05-00	12.24	648	297	149	16	106	26	37	0	17
17-05-00	14.24	648	297	149	16	106	26	37	0	17
19-05-00	16.18	701	299	143	19	151	30	37	0	22
22-05-00	19.24	701	299	143	19	151	30	37	0	22
24-05-00	21.24	701	299	143	19	151	30	37	0	22
26-05-00	23.16	701	299	143	19	151	30	37	0	22
29-05-00	26.20	701	299	143	19	151	30	37	0	22
31-05-00	28.18	701	299	143	19	151	30	37	0	22
05-06-00	33.22	701	299	143	19	151	30	37	0	22
09-06-00	37.12	922	555	142	14	124	23	41	0	23
14-06-00	42.18	922	555	142	14	124	23	41	0	23
16-06-00	44.16	922	555	142	14	124	23	41	0	23
21-06-00	49.10	922	555	142	14	124	23	41	0	23
23-06-00	51.09	922	555	142	14	124	23	41	0	23
26-06-00	54.15	918	463	151	25	142	44	47	0	46
28-06-00	56.22	918	463	151	25	142	44	47	0	46
30-06-00	58.15	918	463	151	25	142	44	47	0	46
03-07-00	61.20	918	463	151	25	142	44	47	0	46
05-07-00	63.24	918	463	151	25	142	44	47	0	46
07-07-00	65.16	831	409	199	17	134	24	35	0	13
10-07-00	68.09	831	409	199	17	134	24	35	0	13
12-07-00	70.18	831	409	199	17	134	24	35	0	13
14-07-00	72.18	831	409	199	17	134	24	35	0	13
17-07-00	75.22	831	409	199	17	134	24	35	0	13
19-07-00	77.23	831	409	199	17	134	24	35	0	13
24-07-00	82.20	831	409	199	17	134	24	35	0	13
26-07-00	84.16	831	409	199	17	134	24	35	0	13
28-07-00	86.17	831	409	199	17	134	24	35	0	13
31-07-00	89.24	831	409	199	17	134	24	35	0	13
02-08-00	91.22	831	409	199	17	134	24	35	0	13
04-08-00	93.12	831	409	199	17	134	24	35	0	13
09-08-00	98.16	934	613	127	12	95	20	41	1	25
11-08-00	100.24	934	613	127	12	95	20	41	1	25
16-08-00	105.12	934	613	127	12	95	20	41	1	25
18-08-00	106.94	934	613	127	12	95	20	41	1	25
21-08-00	109.93	1369	1273	67	0	18	3	3	0	5
23-08-00	111.94	1369	1273	67	0	18	3	3	0	5
25-08-00	113.93	1369	1273	67	0	18	3	3	0	5
28-08-00	116.94	1369	1273	67	0	18	3	3	0	5
30-08-00	118.90	1369	1273	67	0	18	3	3	0	5
01-09-00	120.91	1369	1273	67	0	18	3	3	0	5
4-09-00	123.91	1369	1273	67	0	18	3	3	0	5
6-09-00	125.91	1369	1273	67	0	18	3	3	0	5
8-09-00	127.91	1369	1273	67	0	18	3	3	0	5
11-09-00	130.91	1369	1273	67	0	18	3	3	0	5
13-09-00	132.91	652	369	121	15	100	25	20	0	2
15-09-00	134.91	652	369	121	15	100	25	20	0	2
18-09-00	137.91	652	369	121	15	100	25	20	0	2
20-09-00	139.91	652	369	121	15	100	25	20	0	2
22-09-00	141.92	652	369	121	15	100	25	20	0	2
25-09-00	144.95	652	369	121	15	100	25	20	0	2
27-09-00	147.14	652	369	121	15	100	25	20	0	2
29-09-00	149.21	652	369	121	15	100	25	20	0	2
2-10-00	152.15	652	369	121	15	100	25	20	0	2
4-10-00	154.13	652	369	121	15	100	25	20	0	2
9-10-00	158.92	652	369	121	15	100	25	20	0	2
11-10-00	161.10	652	369	121	15	100	25	20	0	2
13-10-00	163.22	674	380	98	18	99	34	27	0	18
16-10-00	165.92	674	380	98	18	99	34	27	0	18
18-10-00	168.10	674	380	98	18	99	34	27	0	18
20-10-00	170.10	674	380	98	18	99	34	27	0	18
23-10-00	172.91	674	380	98	18	99	34	27	0	18
25-10-00	175.10	674	380	98	18	99	34	27	0	18
27-10-00	176.91	674	380	98	18	99	34	27	0	18
30-10-00	179.97	674	380	98	18	99	34	27	0	18
3-11-00	184.12	887	493	150	27	119	44	37	0	16
6-11-00	186.92	887	493	150	27	119	44	37	0	16

Date	Time days	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
8-11-00	189.12	887	493	150	27	119	44	37	0	16
10-11-00	191.17	887	493	150	27	119	44	37	0	16
14-11-00	194.92	887	493	150	27	119	44	37	0	16
15-11-00	196.12	871	458	192	8	140	11	36	1	25
17-11-00	198.12	871	458	192	8	140	11	36	1	25
20-11-00	200.92	871	458	192	8	140	11	36	1	25
22-11-00	203.14	240	172	24	9	16	8	4	1	5
24-11-00	205.16	240	172	24	9	16	8	4	1	5
27-11-00	207.93	240	172	24	9	16	8	4	1	5
29-11-00	210.12	240	172	24	9	16	8	4	1	5
1-12-00	212.14	240	172	24	9	16	8	4	1	5
4-12-00	214.93	240	172	24	9	16	8	4	1	5
8-12-00	218.91	240	172	24	9	16	8	4	1	5
11-12-00	221.92	240	172	24	9	16	8	4	1	5
13-12-00	224.18	240	172	24	9	16	8	4	1	5
18-12-00	228.93	240	172	24	9	16	8	4	1	5
20-12-00	231.20	240	172	24	9	16	8	4	1	5
22-12-00	233.05	240	172	24	9	16	8	4	1	5
3-01-01	244.97	240	172	24	9	16	8	4	1	5
5-01-01	246.88	240	172	24	9	16	8	4	1	5
9-01-01	251.14	240	172	24	9	16	8	4	1	5
10-01-01	252.14	240	172	24	9	16	8	4	1	5
12-01-01	254.16	240	172	24	9	16	8	4	1	5
15-01-01	257.12	240	172	24	9	16	8	4	1	5
17-01-01	259.20	240	172	24	9	16	8	4	1	5
19-01-01	261.21	240	172	24	9	16	8	4	1	5
22-01-01	264.15	240	172	24	9	16	8	4	1	5
24-01-01	266.19	240	172	24	9	16	8	4	1	5
26-01-01	268.13	240	172	24	9	16	8	4	1	5
29-01-01	271.12	240	172	24	9	16	8	4	1	5
31-01-01	273.21	240	172	24	9	16	8	4	1	5
2-02-01	275.15	240	172	24	9	16	8	4	1	5
5-02-01	277.91	240	172	24	9	16	8	4	1	5
7-02-01	280.16	240	172	24	9	16	8	4	1	5
9-02-01	282.19	240	172	24	9	16	8	4	1	5
12-02-01	284.93	240	172	24	9	16	8	4	1	5
14-02-01	287.20	240	172	24	9	16	8	4	1	5
16-02-01	289.10	240	172	24	9	16	8	4	1	5
19-02-01	291.92	240	172	24	9	16	8	4	1	5
21-02-01	294.20	240	172	24	9	16	8	4	1	5
26-02-01	298.93	240	172	24	9	16	8	4	1	5
2-03-01	302.91	240	172	24	9	16	8	4	1	5

Parameters of reactor

Date	Dav	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 %
03-05-00	0.00	0.9	7.83	5.67	15.25	4.05	11.20	690	1215	525	165	653	70
05-05-00	2.18	0.9	7.93	5.11	15.59	4.08	11.51	600	1090	490	286	915	70
08-05-00	5.03	0.9	7.98	5.39	15.68	3.99	11.69	640	1190	550	406	865	71
11-05-00	8.20	0.9	8.08	5.09	17.42	4.27	13.15	685	1265	580	272	854	71
15-05-00	12.24	0.9	8.06	5.09	18.21	4.56	13.65	660	1295	635	457	1005	72
17-05-00	14.24	0.9	8.13	4.75	18.09	4.42	13.67	630	1205	575	338	829	71
19-05-00	16.18	0.9	8.40	4.88	16.39	4.06	12.33	730	1210	538	329	583	71
22-05-00	19.24	0.9	7.97	4.91	20.31	4.78	15.53	715	1215	500	319	1081	71
24-05-00	21.24	0.9	7.76	5.29	18.41	4.37	14.04	655	1360	705	262	1141	71
26-05-00	23.16	0.9	7.62	6.41	17.79	4.05	13.74	660	1210	550	285	1131	71
29-05-00	26.20	0.9	7.68	6.41	17.87	3.99	13.88	670	1218	548	296	1433	71
31-05-00	28.18	0.9	7.74	6.40	17.94	3.93	14.01	680	1225	545	307	1081	70
05-06-00	33.22	0.9	7.90	6.47	17.70	4.27	13.43	718	1288	570	434	1382	71
09-06-00	37.12	0.9	8.05	6.53	17.47	4.62	12.85	755	1350	595	497	1191	71
14-06-00	42.18	0.9	8.05	6.61	17.39	4.03	13.36	770	1385	615	560	990	71
16-06-00	44.16	0.9	8.05	6.28	18.00	4.00	14.01	780	1358	610	665	1186	71
21-06-00	49.10	0.9	8.10	6.24	17.47	3.76	13.71	725	1330	605	769	1282	72
23-06-00	51.09	0.9	8.16	6.31	17.00	3.92	13.08	705	1240	535	831	1377	72
26-06-00	54.15	0.9	7.96	6.04	16.47	3.47	13.00	770	1320	550	892	1045	72
28-06-00	56.22	0.9	7.89	5.18	18.91	4.07	14.85	670	1275	605	1169	789	72
30-06-00	58.15	0.9	8.08	5.52	17.50	3.92	13.58	663	1348	685	1039	729	72
03-07-00	61.20	0.9	8.05	3.40	18.84	4.29	14.55	655	1420	765	908	814	72
05-07-00	63.24	0.9	8.10	3.81	17.95	4.19	13.76	715	1600	885	1241	789	65
07-07-00	65.16	0.9	8.26	3.98	16.96	4.00	12.97	745	1440	695	1109	764	65
10-07-00	68.09	0.9	8.56	5.84	16.14	3.87	12.27	685	1380	695	977	628	65
12-07-00	70.18	0.9	8.19	5.54	16.80	4.10	12.70	640	1320	680	1066	407	65
14-07-00	72.18	0.9	8.20	4.99	18.50	4.59	13.91	630	1135	505	1009	478	65
17-07-00	75.22	1	8.30	5.00	17.05	4.39	12.66	645	1190	545	951	578	65
19-07-00	77.23	0.9	7.94	4.72	17.33	4.48	12.85	585	1035	450	1241	503	65
24-07-00	82.20	0.9	8.37	4.10	19.34	5.52	13.82	555	1020	465	905	1166	65
26-07-00	84.16	0.9	8.36	4.24	16.06	4.56	11.51	585	1115	530	737	412	65
28-07-00	86.17	0.9	8.27	3.33	16.86	4.43	12.43	505	1000	495	653	382	68
31-07-00	89.24	0.9	8.17	3.91	15.73	4.13	11.61	620	1150	530	569	553	69
02-08-00	91.22	0.9	8.14	3.74	17.01	4.30	12.72	620	1120	500	659	417	70
04-08-00	93.12	0.9	8.09	4.07	15.13	3.71	11.43	655	1230	575	399	462	71
09-08-00	98.16	0.9	8.13		16.12	4.19	11.94	685	1215	530	738	613	71
11-08-00	100.24	0.9	8.18		17.67	4.23	13.44	710	1273	563	832	377	71
16-08-00	105.12	0.9	7.76		16.73	3.86	12.87	760	1330	570	926	1035	71
18-08-00	106.94	0.9	7.86		16.53	3.73	12.80	755	1300	545	1185	598	68
21-08-00	109.93	0.9	7.66		16.48	3.60	12.88	755	1360	605	1443	709	71
23-08-00	111.94	0.9	7.94		17.99	3.64	14.35	745	1570	825	1624	251	52
25-08-00	113.93	0.9	7.75		17.09	3.61	13.48	790	1580	790	1925	593	68
28-08-00	116.94	0.9	7.94		17.06	3.62	13.45	770	1508	738	2075	1141	76
30-08-00	118.90	0.9	8.13		17.04	3.63	13.41	750	1435	685	2225	176	65
01-09-00	120.91	0.9	7.75		18.11	3.75	14.37	700	1385	685	2226	221	65
4-09-00	123.91	0.9	7.83		16.87	3.56	13.31	820	1440	620	2226	327	65
6-09-00	125.91	0.9	7.74		16.66	3.57	13.09	835	1465	630	2370	663	72
8-09-00	127.91	0.9	8.01		17.03	3.60	13.43	815	1490	675	2442	1252	79
11-09-00	130.91	0.9	7.74		16.55	3.58	12.97	910	1685	775	2478	1076	71
13-09-00	132.91	0.9	8.15		17.86	3.74	14.12	845	1560	715	2514	543	68
15-09-00	134.91	0.9	8.06		16.92	3.67	13.25	875	1480	605	2604	583	63
18-09-00	137.91	0.9	7.97		16.79	3.73	13.07	840	1455	615	2649	1166	73
20-09-00	139.91	0.9	7.88		16.67	3.78	12.89	805	1430	625	2693	1005	60
22-09-00	141.92	0.9	7.69		16.21	3.68	12.53	845	1560	715	1897	789	70
25-09-00	144.95	0.9	7.66		15.83	3.91	11.92	830	1515	685	1100	1196	71
27-09-00	147.14	0.9	7.78	5.93	19.49	4.79	14.70	790	1550	760	973	905	71
29-09-00	149.21	0.9	7.77	6.00	20.62	5.10	15.52	835	1625	790	1301	613	70
2-10-00	152.15	0.9	8.03	5.89	19.29	4.87	14.43	740	1585	845	1629	1211	70
4-10-00	154.13	0.9	7.98	5.51	23.47	5.87	17.60	745	1460	715	2267	372	65
9-10-00	158.92	0.9	7.66	5.50	21.38	5.42	15.96	720	1335	615	2582	769	63
11-10-00	161.10	0.9	7.85	5.76	17.17	4.31	12.87	680	1263	583	2041	955	68
13-10-00	163.22	0.9	7.68	5.76	18.30	4.67	13.63	660	1227	567	1928	503	70
16-10-00	165.92	0.9	8.01	5.66	17.66	4.41	13.25	640	1190	550	1814	467	73
18-10-00	168.10	0.9	7.90	5.81	18.11	4.53	13.59	695	1285	590	2422	689	73
20-10-00	170.10	0.9	8.01	5.86	20.54	5.27	15.27	720	1240	520	2320	452	74
23-10-00	172.91	0.9	7.96	6.08	20.07	5.20	14.87	675	1240	565	2217	382	74
25-10-00	175.10	0.9	7.72	5.96	18.27	4.73	13.55	785	1445	660	1538	643	71
27-10-00	176.91	0.9	7.85	5.74	18.56	4.75	13.81	725	1260	535	1617	754	71
30-10-00	179.97	0.9	8.08	6.13	17.84	4.48	13.37	735	1393	658	1656	945	71
3-11-00	184.12	0.9	8.02	6.32	17.48	4.34	13.15	740	1459	719	1676	854	72
6-11-00	186.92	0.9	8.31	6.51	17.13	4.21	12.92	745	1525	780	1686	749	73
8-11-00	189.12	0.9	8.04	6.41	19.10	4.58	14.53	735	1555	820	1695	578	72
10-11-00	191.17	0.9	8.07	6.33	19.79	4.40	15.39	785	1555	770	1385	553	72
14-11-00	194.92	0.9	8.08	7.03	17.74	4.07	13.68	860	1555	695	1075	895	71
15-11-00	196.12	0.9	8.13	6.66	17.73	3.96	13.77	785	1320	535	1054	236	65
17-11-00	198.12	0.9	8.04	6.57	18.87	4.24	14.64	745	1445	700	1044	151	62
20-11-00	200.92	0.9	7.97	6.80	16.26	3.49	12.77	720	1325	605	1033	1161	60
22-11-00	203.14	0.9	7.78	6.09	16.40	3.55	12.86	690	1045	355	972	980	59
24-11-00	205.16	0.9	7.89	5.94	14.06	3.30	10.76	765	1145	380	942	719	59
27-11-00	207.93	0.9	7.96	6.43	15.42	3.48	11.94	655	1080	425	911	588	58
Date	Dav	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 %

29-11-00	210.12	0.9	8.06	5.79	14.46	3.67	10.80	620	1015	395	993	452	60
1-12-00	212.14	0.9	7.88	5.77	12.62	3.28	9.34	585	1085	500	812	603	61
4-12-00	214.93	0.9	7.90	6.55	12.37	3.29	9.08	530	1070	540	631	694	61
8-12-00	218.91	0.9	8.22	5.98	13.09	3.57	9.53	570	1025	455	849	754	64
11-12-00	221.92	0.9	8.24	6.43	11.41	3.31	8.10	505	1105	600	650	488	65
13-12-00	224.18	0.9	8.09	6.16	11.34	3.41	7.94	451	1090	639	451	352	66
18-12-00	228.93	0.9	8.29	6.53	10.87	3.33	7.54	491.5	1000	508.5	569	312	66
20-12-00	231.20	0.9	8.09	5.83	13.46	4.00	9.46	489.5	990	500.5	743	422	67
22-12-00	233.05	0.9	8.05	5.72	11.98	3.74	8.24	390.5	778	387.5	840	764	67
3-01-01	244.97	0.9	8.26	10.45	12.73	3.54	9.19	1105	1765	660	2121	2011	67
5-01-01	246.88	0.9	8.08	10.87	12.87	3.74	9.13	905	1555	650	1914	603	67
9-01-01	251.14	0.9	8.06	10.90	12.72	5.26	7.46	890	1460	570	1879	729	68
10-01-01	252.14	0.9	8.23	9.68	12.57	3.58	8.99	785	1205	420	1844	327	68
12-01-01	254.16	0.9	7.88	8.88	12.72	3.87	8.86	730	1220	490	1763	704	68
15-01-01	257.12	0.9	7.97	7.73	11.49	3.63	7.86	680	1175	495	1682	905	68
17-01-01	259.20	0.9	8.00	6.85	11.51	3.65	7.86	620	1040	420	540	603	68
19-01-01	261.21	0.9	7.85	6.79	12.76	4.29	8.48	590	1110	520	364	754	68
22-01-01	264.15	0.9	8.05	6.91	11.12	4.15	6.97	590	1050	460	276	754	68
24-01-01	266.19	0.9	8.16	6.33	11.57	4.70	6.87	690	1105	415	188	578	67
26-01-01	268.13	0.9	8.02	6.23	10.73	3.61	7.12	505	895	390	266	553	67
29-01-01	271.12	0.9	8.06	6.37	10.35	3.55	6.81	489.5	900	410.5	343	553	66
31-01-01	273.21	0.9	8.03	5.95	12.01	3.81	8.21	540	905	365	108	201	66
2-02-01	275.15	0.9	8.17	5.87	11.00	3.64	7.37	515	1085	570	121	352	65
5-02-01	277.91	0.9	7.95	6.24	10.99	3.64	7.35	488	975	487	134	412	65
7-02-01	280.16	0.9	8.21	6.09	10.72	3.64	7.08	485	855	370	174	402	65
9-02-01	282.19	0.9	8.14	5.91	10.50	3.62	6.89	472.5	915	442.5	194	553	64
12-02-01	284.93	0.9	8.07	6.25	11.32	3.89	7.43	480.5	1015	534.5	213	628	64
14-02-01	287.20	0.9	8.32	5.69	11.05	3.69	7.36	456.5	900	443.5	241	528	63
16-02-01	289.10	0.9	8.27	5.63	11.43	3.79	7.64	443.5	895	451.5	255	663	63
19-02-01	291.92	0.9	7.78	6.13	10.70	3.54	7.16	442.5	1025	582.5	269	437	62
21-02-01	294.20	0.9	8.23	5.75	9.89	3.43	6.46	465.5	915	449.5	213	518	64
26-02-01	298.93	0.9	8.01	6.37	12.05	4.59	7.47	489	1000	511	157	669	65
2-03-01	302.91	0.9	7.92	5.98	10.24	3.42	6.83	459	905	446	162	804	63
5-03-01	305.93	0.9	8.04	6.28	9.84	3.27	6.57	428	890	462	166	488	61
7-03-01	308.17	0.9	8.18	5.52	9.97	3.43	6.54	438	1005	567	223	553	64
9-03-01	309.89	0.9	8.28	5.53	10.22	3.39	6.83	432.5	905	472.5	252	352	65
12-03-01	312.93	0.9	8.08	5.75	9.87	3.46	6.41	424	955	531	280	608	66
14-03-01	314.99	0.9	8.05	5.37	10.34	3.44	6.90	414	985	571	289	402	66
16-03-01	317.12	0.9	7.97	5.38	10.45	3.66	6.79	451.5	930	478.5	293	402	66
19-03-01	319.93	0.9	7.82	5.76	10.07	3.35	6.72	445	820	375	297	719	65
23-03-01	324.10	0.9	8.27	5.41	10.03	3.41	6.62	435	940	505	280	653	63
26-03-01	326.92	0.9	8.12	5.51	10.15	3.51	6.64	454.5	1085	630.5	275	603	60
28-03-01	329.12	0.9	8.28	5.58	10.28	3.62	6.67	372.5	865	492.5	287	653	62
30-03-01	331.10	0.9	8.31	5.69	10.55	3.53	7.02	401.5	885	483.5	290	593	63
4-04-01	336.12	0.9	8.16	5.91	10.58	3.79	6.79	395.5	905	509.5	280	714	64

Volatile Fatty acids composition in reactor

Date	Time days	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
03-05-00	0.00	165	56	105	1	2	1	0	0	0
11-05-00	8.20	272	57	208	2	2	2	0	0	0
17-05-00	14.24	338	86	234	2	2	4	0	10	0
24-05-00	21.24	261	49	209	1	0	1	0	0	0
31-05-00	28.18	307	77	222	2	2	4	0	0	0
14-06-00	42.18	560	91	449	3	2	15	0	0	0
21-06-00	49.10	769	120	624	7	4	10	2	1	1
28-06-00	56.22	1169	199	813	32	2	105	18	0	0
05-07-00	63.24	1241	343	802	31	13	28	24	0	0
12-07-00	70.18	1066	145	875	16	3	15	13	0	0
19-07-00	77.23	1240	342	802	31	13	28	24	0	0
26-07-00	84.16	276	123	140	0	11	0	0	2	0
02-08-00	91.22	658	122	469	20	15	21	8	3	0
09-08-00	98.16	739	48	688	0	0	1	1	0	0
16-08-00	105.12	925	78	828	0	0	15	1	3	0
23-08-00	111.94	1625	223	874	32	32	94	344	0	26
30-08-00	118.90	2225	1087	897	37	30	157	4	0	13
6-09-00	125.91	3627	2037	961	124	118	298	69	4	16
13-09-00	132.91	2513	1247	1105	13	19	78	25	5	21
20-09-00	139.91	2694	1226	1125	97	12	197	32	5	0
4-10-00	154.13	2266	1027	1016	38	40	74	15	2	54
11-10-00	161.10	2040	531	1090	97	16	165	48	3	89
18-10-00	168.10	2423	1027	1172	34	42	69	21	2	56
25-10-00	175.10	1537	209	1129	18	5	159	14	2	1
8-11-00	189.12	1694	236	1338	15	10	75	18	1	1
29-11-00	210.12	993	54	845	20	8	50	11	2	4
13-12-00	224.18	451	115	283	14	4	24	5	1	5
20-12-00	231.20	744	342	321	22	13	34	6	1	5
3-01-01	244.97	2121	126	1947	8	7	8	14	10	1
10-01-01	252.14	1844	531	1195	16	10	27	15	45	5
17-01-01	259.20	539	130	388	3	4	6	6	2	0
24-01-01	266.19	188	115	66	0	2	1	0	4	0
7-02-01	280.16	27	11	14	0	2	1	0	0	0
14-02-01	287.20	70	52	12	1	3	2	0	0	0