ASSOCIATION POUR LE DÉVELOPPEMENT DE L'ENSEIGNEMENT
ET DE LA RECHERCHE EN SYSTÉMATIQUE APPLIQUÉE

MELISSA

Complete loop control : first study
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SOMMAIRE

1. INTRODUCTION

Melissa is composed of several compartments. The functioning of each compartment is studied by different Melissa partners. But, as the compartments will be linked together in the final functioning, it is necessary to study the global functioning of the loop, and to analyse the effect of the interactions between each compartment. This global analysis will be very useful for the design of the global and hierarchical control system.

A first analysis of the complete loop has yet been realized by LGCB Clermont-Ferrand, TN 14.1, TN 17.1, TN 17.2, TN 17.3, TN 23.1, TN 23.2, TN 23.3. But, this analysis was just realized in static functioning with analysis of the steady state. So it is interesting to study now the dynamical functioning of the complete loop.

2. FUNCTIONAL ANALYSIS OF THE GLOBAL LOOP

2.1. Goal of the loop

To design the control system of Melissa, it is necessary to elaborate first the functional analysis of the loop. That is to determine what are the actions, what are the variables to be controlled, what are the variables that can be measured... This functional analysis depends on the goal of the loop, that's why the main goal of the loop must be previously defined.

It has been decided that the main goal of the loop will be to maximally recycle the wastes of the crew, and not to feed the crew. So, in the global functioning of Melissa, an addition of food can be given to the crew. This addition of food, on the fifth compartment is supposed to be the sole external input of Melissa. In this first study, the Melissa loop will be supposed to be open before this crew compartment. So the crew compartment will be considered as the first compartment of the open loop Melissa.

2.2. Functional analysis of the loop Melissa

To elaborate the functional analysis, each compartment is considered successively. For each compartment, we define the lists of the measured variables, the variables to be controlled, the possible actions, and the disturbance variables. For the measured variables, we precise if it is easy, possible, difficult, or impossible to be measured. If it is impossible, it will be estimated by a model from other measurements :

- *** : easy to measure
- ** : possible to measure
- * : difficult to measure

(estim) : estimated by a model

COMPARTMENT V : Crew

- Measured variables

*** : flow of gas
** : gas composition
* : output flow (urea, faeces)

- Actions

- exogen water flow
- solid flow
- other flows

- Controlled variables

- dietetic

- Disturbance variables

- activity

COMPARTMENT I : Liquefying

• Measured variables

** : gas composition (chromatography) : H_2, VFA, CH_4
*** : flow of gas
*** : flow of liquid
* : urea
*** : temperature T
*** : pH
*** : total pressure P_T
** : redox potential pE
*** : dissolved O_2

(estim) : VFA (liquid)

• Actions

- exogen water flow
- output flow
- acid/base ($\rightarrow$ pH)
- valve ($\rightarrow P_T$)
- heater ($\rightarrow$ T)

• Controlled variables

- temperature T, total pressure P_T, pH
- dissolved O_2,
- volume, dilution rate
- NH_4^+, VFA/CO_2

COMPARTMENT II : Photosynthetic - Rhodobacter

- Measured variables

**	: gas composition
***	: flow of gas
***	: flow of liquid
***	: total pressure P_T
***	: temperature T
***	: pH
*	: urea
***	: biomass
**	: acetate, lactate
**	: NH_4^+
(estim)	: quality of biomass
**	: light

- Actions

- exogen water flow
- output flow
- incoming gas flow
- heater ($\rightarrow$ T)
- light power ($\rightarrow$ light)
- acid/base ($\rightarrow$ pH)
- valve ($\rightarrow P_T$)

- Controlled variables

- temperature T, total pressure P_T, pH
- urea
- VFA
- biomass

- Disturbance variables

- liquid output of liquefying compartment (flow, composition)

COMPARTMENT III : Nitrifying

• Measured variables

***	: gas composition (O_2, CO_2)
***	: gas flow
***	: liquid flow
**	: NH_4^+
**	: NO_3^-
(estim)	: NO_2^-
***	: temperature T
***	: pH
***	: total pressure P_T
***	: dissolved O_2
(estim)	: biomass

• Actions

- exogen water flow
- exogen O_2 flow
- output flow
- heater ($\rightarrow$ T)
- acid/base ($\rightarrow$ pH)
- valve ($\rightarrow P_T$)

• Controlled variables

- temperature T, pH, total pressure P_T
- volume, dilution rate
- dissolved O_2
- NH_4^+, NO_3^-, NO_2^-

• Disturbance variables

- liquid output of Rhodobacter compartment (VFA, NH_4^+, urea)

COMPARTMENT IV : Photosynthetic - Spirulina

• Measured variables

**	: gas composition (O_2, CO_2)
***	: flow of gas
***	: total pressure P_T
***	: temperature T
***	: pH
**	: light (Eb)
***	: dissolved O_2
***	: level
***	: output liquid flow
**	: biomass
(estim)	: biomass quality
**	: NO_3^-
(estim)	: dissolved CO_2

• Actions

- exogen water flow
- output flow
- light power
- heater ($\rightarrow$ T)
- incoming flow of CO_2

• Controlled variables

- temperature T, pH, total pressure P_T
- volume, dilution rate
- biomass
- dissolved CO_2

• Disturbance variables

- liquid output of nitrifying compartment (flow, NO_3^-)

The main actions and the main controlled variables are summarized in the following table (MV : manipulated variable, CV : controlled variable).

- I - Liquefying compartment		- II - Rhodobacter compartment		- III - Nitrifying compartment		- IV - Spirulina compartment	
MV	**CV**	**MV**	**CV**	**MV**	**CV**	**MV**	**CV**
- exogen water flow	- volume	- exogen water flow	- volume	- exogen water flow	- volume	- exogen water flow	- volume
- output flow	- dilution rate	- output flow	- dilution rate	- output flow	- dilution rate	- output flow	- dilution rate
	- Acetate/ CO_2	- light power	- VFA and/or urea	- exogen O_2 flow	- pO_2	- light power	- dissolved CO_2
	- NH_4^+		- biomass	- total gas flow	- NO_3^-	- incoming CO_2 flow	- biomass

This functional analysis has been elaborated during discussions between ESTEC, LGCB, and ADERSA. It will certainly evoluate with the study.

2.3. Gas, biomass and liquid flow

The interactions, and the different flows between the different compartments have to be specified. They are represented separatly.

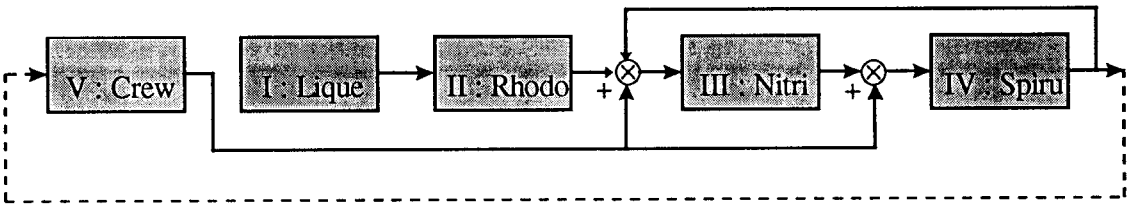

Figure 1 : Gas flow

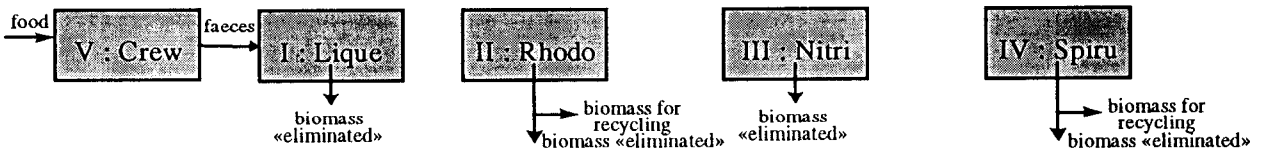

Figure 2 : Biomass flow

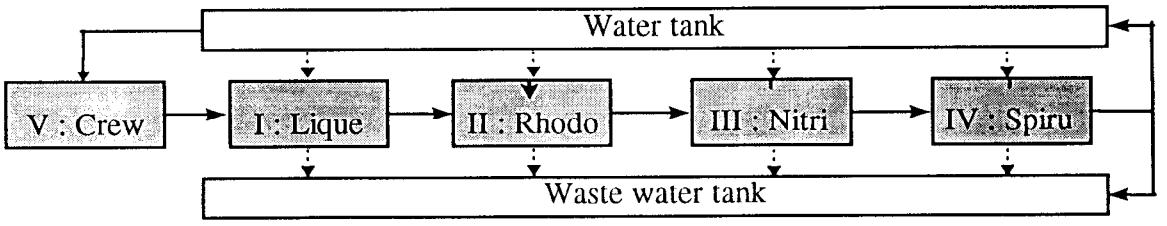

Figure 3 : Liquid flow

3. SIMULINK SIMULATOR

3.1. General presentation

The simulator of the complete loop is developed on Matlab-Simulink. This is a well dedicated tool for dynamical simulations. This simulator is composed of different blocks. The system is constituted of the 5 compartments, their local control blocks, and an upper control level, which allows to control the global loop, and to transfer some informations from one compartment to another (figure 4).

The physical transfers between the compartments are devided in two parts : the gas flows, and the liquid flows. All the solid components are supposed to be dilued in the liquid flow.

3.2. Global control Melissa

It corresponds to the level 2 of the control. Its goal is to determine the setpoints for each compartment, in function of a global objective and eventually in function of some constraints on other compartments.

If the local control block of a compartment needs some informations of another compartment, those informations will be transmitted through the global control level.

The alarm flow from the different compartments to their local control, and if necessary to the global control will be considered as other measured informations, and will be transmitted from one block to another through the hierarchical structure.

3.3. Local control of each compartment

Those blocks correspond to the level 1 of the control. There is one local control block for each compartment. Each local control receives the setpoints sended by the level 2, and the measures (and alarms) sended by the level 0 of the compartment. Then, it calculates the different manipulated variables (actions) to be applied to the compartment, and it sends to the level 2 the selected measures and informations, necessary for the global control of the loop.

In this version, only one local control is designed. It is the one corresponding to the Spirulina compartment. The non linear predictive control law developed and presented in TN 24 has been integrated in the simulator, in the local control block dedicated to the fourth compartment (figure 5).

The manipulated variables, calculated by the local control, are the light intensity (radiant flux Fr) and the liquid flow. They are sended by the control block (second output) to the Spirulina compartment (first input). The control law needs the measure of the Spirulina biomass concentration in the reactor. This is sended by the compartment (first output) to the control block (second output).

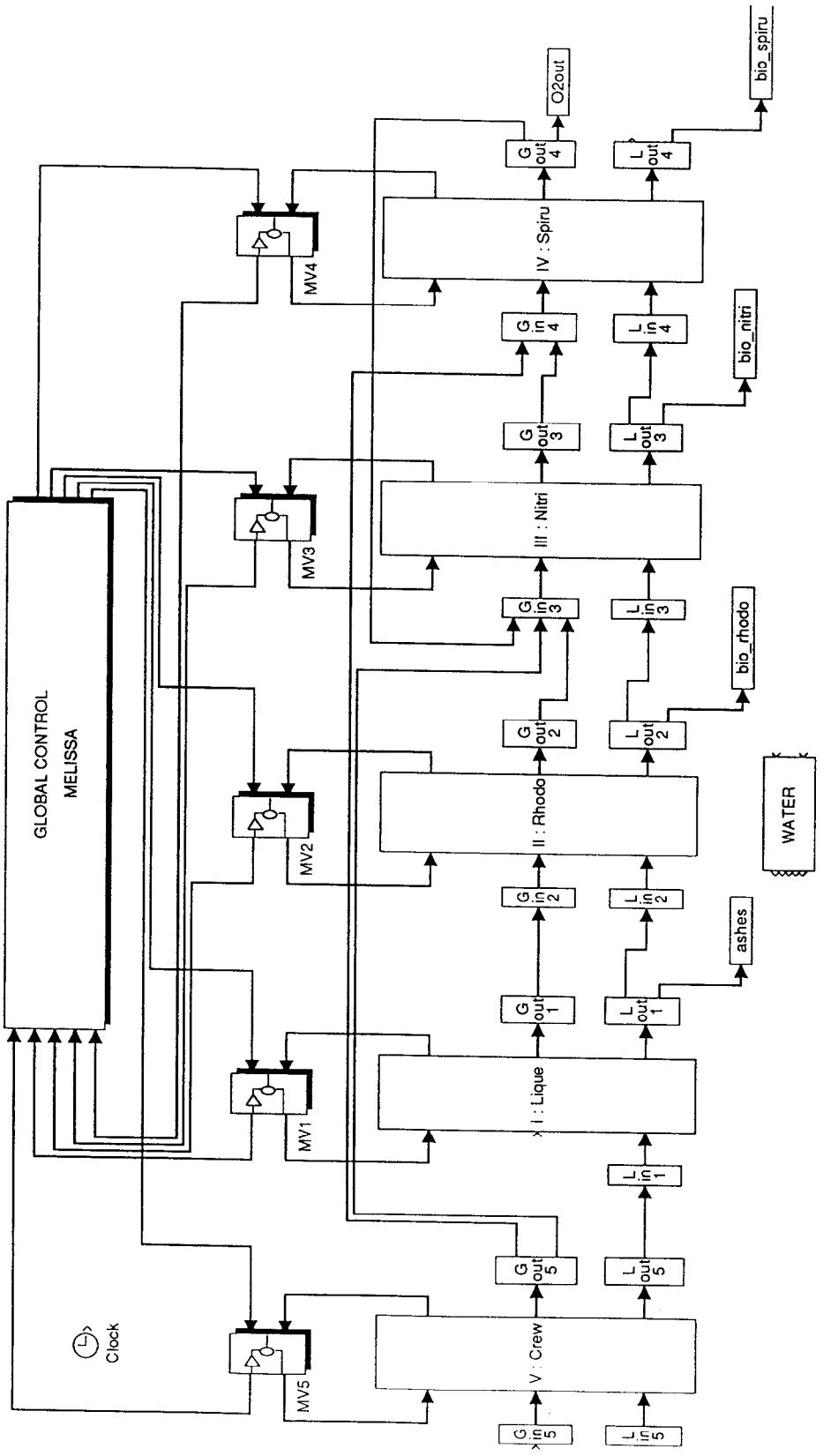

Figure 4 : Global simulator

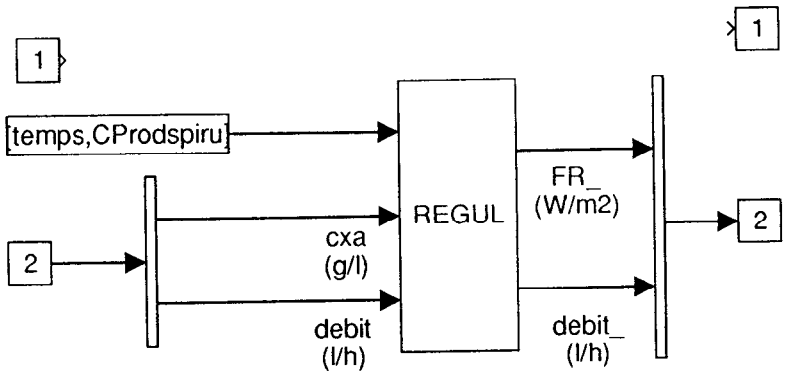

Figure 5 : Spirulina control

3.4. Compartments

Each compartment is represented in the same way, with 3 inputs and 3 outputs, each input and output is vectorial. The first input corresponds to the vector of manipulated variables calculated by the local control. Its constitution, and its dimension is specific to each compartment. The second input represents the incoming gas flow. It is expressed in mol/h for all the components. The third input represents the incoming liquid flow. It is also expressed in mol/h, for all the solid and liquid components.

The first output represents all the measures that have to be transmitted to the local control. As for the first input vector, the constitution and the dimension of this output depends on the compartment. The second output represents the output flow of gas. The third output represents the output flow of liquid. Both flows are constituted of the value of "partial flow" for each component, in mol/h.

All the flows (gas and liquid) between the compartments are represented by a vector with the same length, that is the number of different components considered in the global system Melissa. Many values will be equal to zero, in the ideal case, but this option has been chosen in order to be more general and let this simulator have an easier evolution.

The internal state of the compartments is calculated in function of the global input and output flows, and in function of the stoichiometries and their associated kinetics.

The internal equations of each compartment are :

$$\frac{dM_i}{dt} = q_{in} \cdot C_{i,e} - q_{out} \frac{M_i}{Vol} + \langle r_i \rangle \cdot Vol$$

and :

$$\frac{dVol}{dt} = q_{in} - q_{out}$$

where :

M_i	: mass of each species in the compartment	(g)
q_{in}	: input flow	(l/h)
q_{out}	: output flow	(l/h)
Vol	: total volume	(l)
$C_{i,e}$	: input flow concentration	(g/l)
$\langle r_i \rangle$	: growth rate	(g/l/h)

In a first time, the kinetics are very simple except for the Spirulina compartment. They are based on the hypothesis that the key component of each stoichiometric equation is completely transformed.

The output flow is supposed to be calculated in order to have no accumulation.

A list of the components considered in the global loop Melissa is given hereafter. We only consider the presence of C, H, O and N elements. The S and P elements will be introduced later if necessary.

The considered components are deduced from the stoichiometric equations given by Poughon, LGCB [TN 17.3], without the S and P elements, as following :

$$C\ H_a\ O_b\ N_c\ S_d\ P_e = C\ H_{a+6d-e}\ O_{b-3e}\ N_c + e\ .\ H_3\ PO_4 + d\ H_2\ SO_4 - (e + 4d)\ .\ H_2O$$

For food, faeces and biomass, a global formula is considered.

The twenty components considered in the five compartments are :

1 : food	$C\ H_{1.89516}O_{0.52775}N_{0.06974}$
2 : faeces	$C\ H_{1.649}O_{0.15}N_{0.1055}$
3 : urea	CH_4ON_2
4 : acetic acid	$C_2H_4O_2$
5 : butyric acid	$C_4H_8O_2$
6 : biomass Rhodo	$CH_{1.6003}O_{0.3243}N_{0.2094}$
7 : biomass nitri	$CH_{1.6268}O_{0.3639}N_{0.1994}$
8 : carbohydrate	$CH_{1.670}O_{0.711}$
9 : fat	$CH_{1.714}O_{0.204}$
10 : proteins	$CH_{1.526}O_{0.327}N_{0.2496}$
11 : nucleic acid	$CH_{1.273}O_{0.710}N_{0.393}$
12 : exopolysaccharide	$CH_{1.650}O_{0.950}$
13 :water	H_2O
14 : oxygen	O_2
15 : carbon dioxid	CO_2
16 : ammonia	NH_3
17 : hydrogen	H_2
18 : nitrous acid	HNO_2
19 : nitric acid	HNO_3
20 : nitrogen	N_2 (inert)

The stoichiometric equations considered are the following :

3.4.1. Compartment V : Crew

Degradation of food : stoichio 1 :

$$3.1142\ [food] + 3.48555\ O_2 \downarrow$$
$$2.9157\ CO_2 + 0.10358\ CH_4ON_2 + 0.0950\ [faeces] + 2.6654\ H_2O$$

The coefficients are given in mol/h for 3 persons. So, if the input flow is supposed to be equal to 3.1142 mol/h of food and 3.48555 mol/h of O_2, they are completely transformed. The key element of this stoichiometric equation is [food].

An input of water is added, equal to 10.4167 mol/h. This liquid water is transformed into gas water, by perspiration. But, in this version of simulator when the gas/liquid equilibrium is not considered, this water can be considered as directly recycled.

Those coefficients are given for an energetic need of 3000 Kcal/day/person.

3.4.2. Compartment I : Liquefying

Degradation of faeces : stoichio 2 :

$$1\ [faeces] + 0.975\ H_2O \downarrow$$
$$0.25\ CO_2 + 0.89125\ H_2 + 0.25\ C_2H_4O_2 + 0.0625\ C_4H_8O_2 + 0.1055\ NH_3$$

Degradation of urea : stoichio 3 :

$$CH_4ON_2 + H_2O \rightarrow CO_2 + 2\ NH_3$$

The key element for the degradation of faeces is faeces ; the key element for the degradation of urea is urea. In both equations, water is supposed in excess and as an unlimiting factor. The key elements are supposed to be completely degradated.

3.4.3. Compartment II : Rhodobacter

Degradation of acetic acid and butyric acid :

- *Stoichio 4 :*

$$C_2H_4O_2 + 0.9281\ NH_3 + 2.4314\ CO_2 + 5.5790\ H_2 \downarrow 4.4314\ [\text{biomass Rhodo}] + 5.4254\ H_2O$$

- *Stoichio 5 :*

$$C_2H_4O_2 + 0.3873\ NH_3 \downarrow 1.8505\ [\text{biomass Rhodo}] + 0.1495\ CO_2 + 1.1007\ H_2O$$

- *Stoichio 6 :*

$$C_4H_8O_2 + 0.9689\ NH_3 + 0.6261\ CO_2 \downarrow 4.6261\ [\text{biomass Rhodo}] + 1.7518\ H_2O$$

The key element of stoichiometric equations n°4 is H_2, for the n°5, it is acetic acid, and for the n°6, it is butyric acid. They are supposed to be completely degradated, if there is no limiting factors.

3.4.4. Compartment III : Nitrifying

The degradation of NH_3 is realized in 2 steps :

- *Stoichio 7 : Nitrosomonas*

$$CO_2 + 26.0166\ O_2 + 18.2606\ NH_3 \downarrow [\text{biomass nitri}] + 18.0612\ HNO_2 + 17.5469\ H_2O$$

- *Stoichio 8 : Nitrobacter*

$$CO_2 + 38.8496\ O_2 + 79.8494\ HNO_2 + 0.1994\ NH_3 + 0.5143\ H_2O \downarrow [\text{biomass nitri}] + 79.8494\ HNO_3$$

The key elements are supposed to be NH_3 for the equation n°7 and HNO_2 for the equation n°8.

We suppose that HNO_2 is completely transformed. We must verify that O_2 is not a limiting factor. If there is no limiting factor, the key elements are supposed to be completely transformed.

3.4.5. Compartment IV : Spirulina

We suppose that biomass is composed of 5 different components (carbohydrate, fat, proteins, nucleic acid and exopolysaccharide). A stoichiometric equation is dedicated to each component.

- Stoichio 9 : Carbohydrate

$$CO_2 + 0.8355\ H_2O \rightarrow [\text{carbohydrate}] + 1.06225\ O_2$$

- Stoichio 10 : Fat

$$CO_2 + 0.8570\ H_2O \rightarrow [\text{fat}] + 1.3265\ O_2$$

- Stoichio 11 : Proteins

$$CO_2 + 0.6383\ H_2O + 0.2496\ HNO_3 \downarrow [\text{proteins}] + 1.5302\ O_2$$

- Stoichio 12 : Nucleic acid

$$CO_2 + 0.440\ H_2O + 0.396\ HNO_3 \downarrow [\text{nucleic acid}] + 1.4545\ O_2$$

- Stoichio 13 : Exopolysaccharide

$$CO_2 + 0.825\ H_2O \rightarrow [\text{EPS}] + 0.9375\ O_2$$

For this compartment, the analysis of kinetics is more developped, so we consider a growth rate for active biomass $\langle r_{XA} \rangle = f(C_{XA}\ F_r)$ function of concentration in biomass, and of radiant flux. This relation was given in TN 19.1, TN 19.2, TN 19.3 by J.F. Cornet, LGCB.

We consider all the more that the mass repartition between the different macroelement is function of the radiant flux F_r, as given in the following tables (from TN 17.3).

macro element M	% m_M (mass percentage function of F_r (W/m^2))
proteins	% m_P = -0.106705 Fr + 66.088123
fat	% m_F = 10
carbohydrate	% m_C = 100 - (% m_P + % m_F + %m_E)
exopolysaccharide	% m_E = 0.109770 F_r + 9.028736

If we add the nucleic acid, supposing that it represents 4 % of the active biomass, it gives the following results for the corrected percentage.

	macro element M	% m_{M_C} : corrected percentage
active biomass	proteins	% m_{P_C} = % m_P * 0.96
	fat	% m_{F_C} = % m_F * 0.96
	carbohydrate	% m_{C_C} = % m_C * 0.96
	nucleic acid	% m_{AN_C} = 0.04 (100 - % m_E)
	exopolysaccharide	% m_{E_C} = % m_E

The 5 compartments are represented on figures 6 to 10. We can note that Spirulina compartment is more detailed because of the knowledge model of growth rate function of light and concentration. All other compartments are considered in steady state functioning.

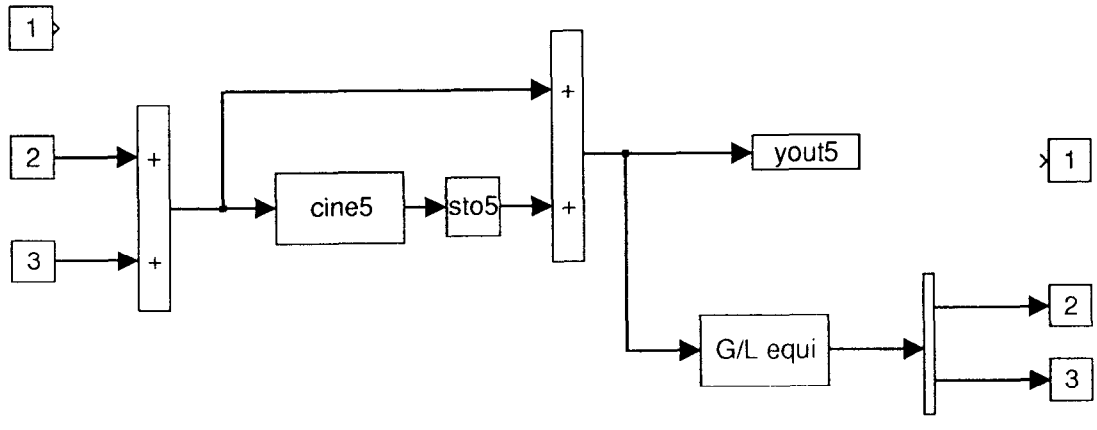

Figure 6 : Crew compartment

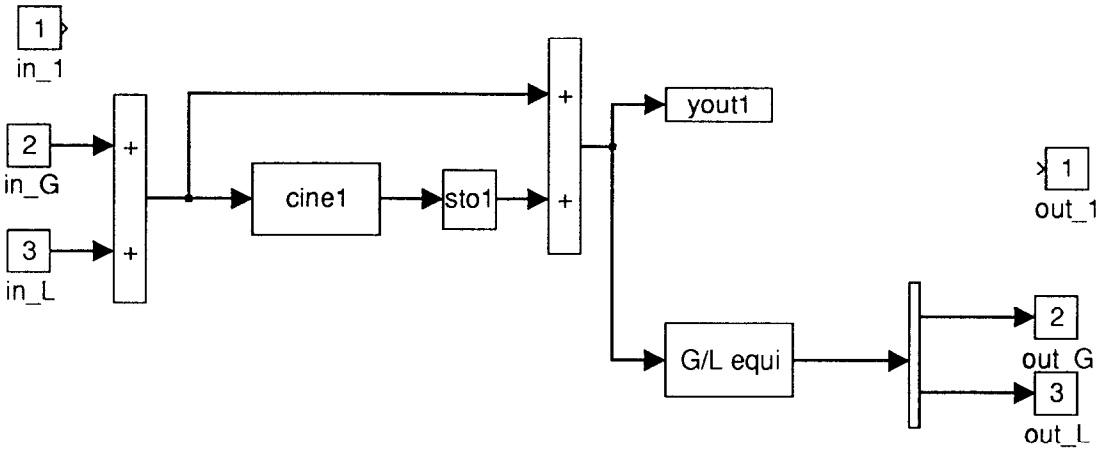

Figure 7 : Liquefying compartment

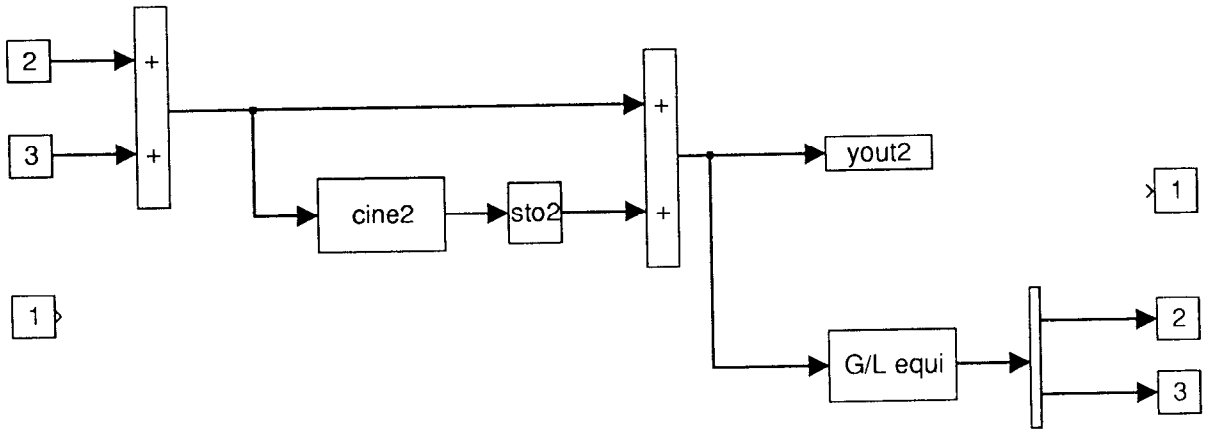

Figure 8 : Rhodobacter compartment

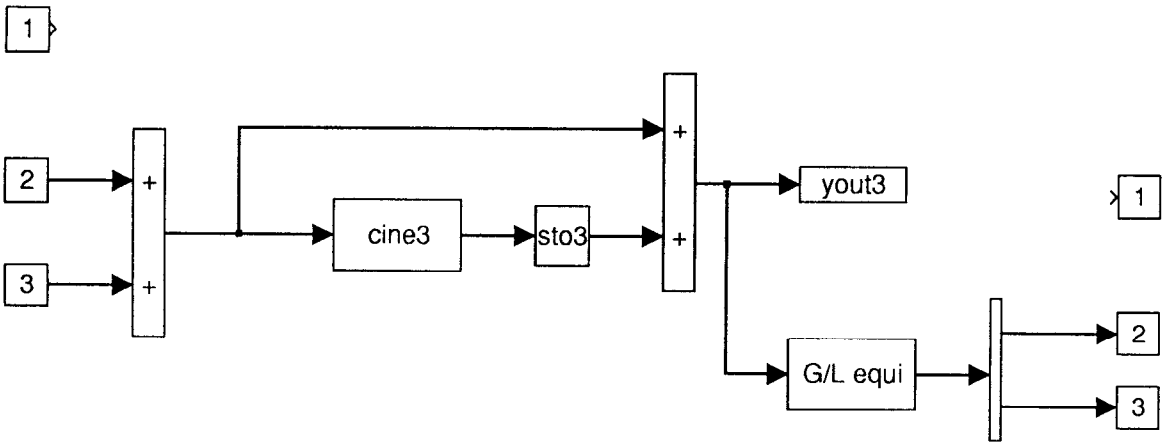

Figure 9 : Nitrifying compartment

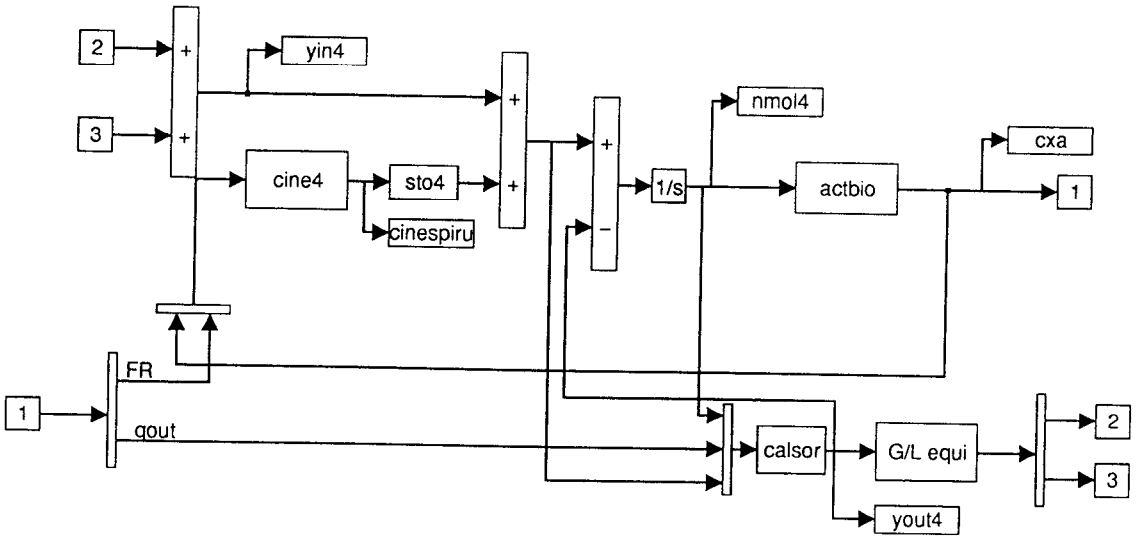

Figure 10 : Spirulina compartment

3.5. Simulation results

At that time, the simulations have been done in open loop. The crew compartment is at the beginning of the loop and is continuously fed for a crew of 3 persons. The input flows are given in table 0. The energetic need of the crew is supposed to be equal to 3000 kcal/day/person, their need of water is equal to 10.41 mol/h. The input flow of food is equal to 3.1142 mol/h, and the flow of O_2 is equal to 3.48555 mol/h. They are supposed to be completely transformed, they give an output flow composed of CO_2, urea, faeces and water, calculated with the first stoichiometric equation (degradation of food). The output flows of the first compartment are given in the table n° 1, in 3 different units (mol/h, g/h, g/day).

Input flow of crew compartment			
	mol/h	g/h	g/day
[food]	3.1142	72.61	1742
O_2	3.48555	111.54	2677
H_2O	10.4167	187.50	4500

Table 0

Output flow of crew compartment			
	mol/h	g/h	g/day
CO_2	2.9157	128.29	3080
CH_4ON_2	0.1036	6.21	150
[faeces]	0.0950	1.66	40
H_2O	13.0821	235.48	5650

Table 1

In the compartment I, liquefying compartment, the two stoichiometric equations (degradation of faeces and degradation of urea) are supposed to be used for the complete degradation of faeces and urea : water is in excess. The obtained output flows are composed of CO_2, H_2, $C_2H_4O_2$, $C_4H_8O_2$, NH_3 and water. Their values are given in the table 2.

Output flow of liquefying compartment			
	mol/h	g/h	g/day
CO_2	0.12733	5.60	134
H_2	0.0846687	0.17	4
$C_2H_4O_2$	0.02375	1.42	34
$C_4H_8O_2$	0.0059375	0.52	12
NH_3	0.2171825	3.69	89
H_2O	12.885895	231.94	5567

Table 2

The liquid and solid output of crew compartment is supposed to be completely sended to the liquefying compartment, but the gaseous flow (CO_2) is sended to the nitrifying compartment. In this version, the gaseous/liquid equilibrium is considered in its basic form : CO_2, O_2 and H_2 (and N_2) are supposed totally gaseous, the other components are supposed solid or liquid.

In the second compartment, the 3 stoichiometric equations are used to consume hydrogen, acetic acid and butyric acid. NH_3 is in excess, the 3 key elements (H_2, $C_2H_4O_2$ and $C_4H_8O_2$) are completely transformed. The output flow of Rhodobacter compartment is given in table 3. It is composed of Rhodobacter biomass, NH_3, CO_2 and H_2O. The biomass is expressed in dry mass.

Output flow of Rhodobacter compartment			
	mol/h	g/h	g/day
[biomass Rhodo]	0.1106	2.40	58
NH_3	0.1940	3.30	79
CO_2	0.0879	3.87	93
H_2O	12.9881	233.78	5611

Table 3

In the third compartment, the two stoichiometric equations (nitrosomonas and nitrobacter) are supposed to be equilibrated in HNO_2 (all HNO_2 produced by nitrosomonas is consumed by nitrobacter).

The input flow of gas is supposed to come from crew compartment (CO_2), from Rhodobacter compartment (CO_2) and from Spirulina compartment (O_2). The flow of O_2 coming from Spirulina compartment is just calculated to have enough O_2 in nitrifying compartment to consume all NH_3.

The liquid flow composed of NH_3 and H_2O is coming from Rhodobacter compartment. Rhodobacter biomass is supposed to be extracted from the loop. The output flow of nitrifying compartment is composed of biomass, CO_2, HNO_3 and H_2O. The value of flow of each component is given in table 4. The biomass is expressed in dry mass.

Output flow of nitrifying compartment			
	mol/h	g/h	g/day
[biomass nitri]	0.0130	0.29	7
CO_2	2.9907	131.59	3158
HNO_3	0.1914	12.06	289
H_20	12.4166	223.49	5364

Table 4

The four represented compartments are maintained in steady state functioning. They are only characterized by the input and output flows.

The Spirulina compartment is simulated in a more detailed way. The kinetics corresponding to the stoichiometric equations are calculated in function of light and biomass concentration. So, a dimensioning of this compartment is absolutely necessary.

This dimensioning is realized in the more simple way for the first simulations. The geometry of the reactor is supposed cylindrical with the same diameter as actually. So, taking into account those considerations, the only way to increase the volume is to increase the length of the reactor (a more realistic geometry will be proposed later).

For this dimensioning, the light power is supposed to be limited to a value of 400 W/m^2, which is the actual limitation. The volume must be determined in order to consume sufficient load, and in order to furnish sufficient O_2 and Spirulina biomass.

An initialization of each component concentration is necessary. The output flow is fixed by the control block, through the dilution rate. It concerns all the liquid and solid components. For the gaseous components, the output flow is calculated in order to maintain the initial composition of gaseous phase.

The reactor is initialized with an active biomass concentration equal to 0.725 g/l.

The simulation is done with a radiant flux maintained at 400 W/m^2, and with a dilution rate equal to 0.03 h^{-1}. The illuminated volume is equal to 70 % of the total volume. To consume nearly all the HNO_3 load, the total volume must be equal to 1350 l, the illuminated volume is then equal to 945 l.

The output flows with those functioning conditions are given in figure 11, they are reported in the table 5 :

Output flow of Spirulina compartment			
	mol/h	g/h	g/day
carbohydrate fat proteins nucleic acid	. 35 . 38 . 68 . 042 } active biomass	32	768
EPS	. 1	36	864
O_2	3.1	101.5	2 435
CO_2	0.3	12	288
HNO_3	0.003	0.2	5

Table 5

The performance in O_2 recycling can be evaluated with those results. An input flow of O_2 equal to 3.485 mol/h is necessary for a crew of 3 persons.

A part of the output flow of O_2 in Spirulina compartment is sended to nitrifying compartment. So, the real output flow of O_2 is equal to 2.9 mol/h, which cover 83 % of the need of the crew in O_2.

In the Spirulina compartment, the production of exopolysaccharide is very high (53 %). This is due to the high value of radiant flux (400 W/m^2).

Concerning the food, the input dry mass of food is equal to 1742 g/day. The dry mass of Rhodobacter and Spirulina biomass is equal to 1690 g/day (58 + 768 + 864). So, the recycling performance of food is equal to 97 %.

The value of nearly 1700 g/day of biomass must be considered as dry mass. If we supposed that the wet biomass will be composed of 70 % water and 30 % dry biomass, this represents in fact a mass of 5.6 kg/day, which is very important.

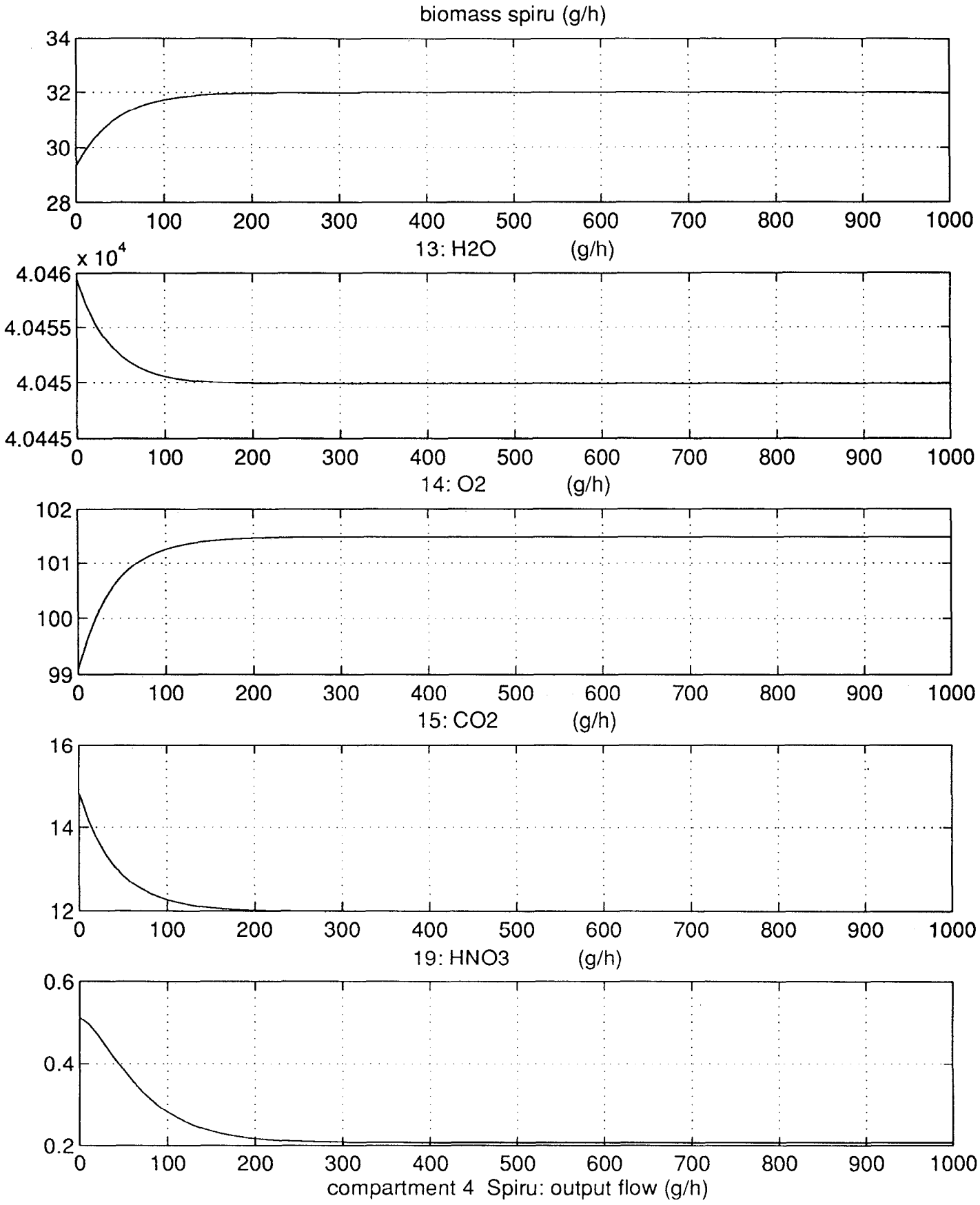
biomass spiru (g/h)
34
32
30
28
0 100 200 300 400 500 600 700 800 900 1000
13: H2O (g/h)
x 10^4
4.046
4.0455
4.045
4.0445
0 100 200 300 400 500 600 700 800 900 1000
14: O2 (g/h)
102
101
100
99
0 100 200 300 400 500 600 700 800 900 1000
15: CO2 (g/h)
16
14
12
0 100 200 300 400 500 600 700 800 900 1000
19: HNO3 (g/h)
0.6
0.4
0.2
0 100 200 300 400 500 600 700 800 900 1000
compartment 4 Spiru: output flow (g/h)

Figure 11

4. CONCLUSION

The global simulator presented in this T.N. is a first stage in the elaboration of the final global simulator. It will be improved and completed.

In this version, the compartments (except Spirulina compartment) are modelized with stoichiometric equations and a cinetic corresponding to an optimal conversion of the key elements for each stoichiometric equation.

Further developments will consist in improving the cinetic lows for each stoichiometric equations. It will be firstly done for Rhodobacter and nitrifying compartment.

A cinetic low with light as a limiting factor is already available for Rhodobacter compartment.

The gas-liquid equilibrium will also be improved, taking into account the results of LGCB (TN23).

In this version, the stoichiometric equations for nitrifying compartment correspond to biomass growth. It will be more realistic to use stoichiometric equations corresponding to maintenance functioning.

In the liquefying compartment for the faeces degradation, the considered stoichiometric equation produces lot of H_2. The last experimental results (TN 26.3) seem to show less production of H_2. A new stoichiometric equation will be proposed in the new simulator version.

This simulator will be used to dimension the different reactors. This has already be done for the Spirulina compartment.

It will also be used to test different strategies for the global control of the whole Melissa loop.

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