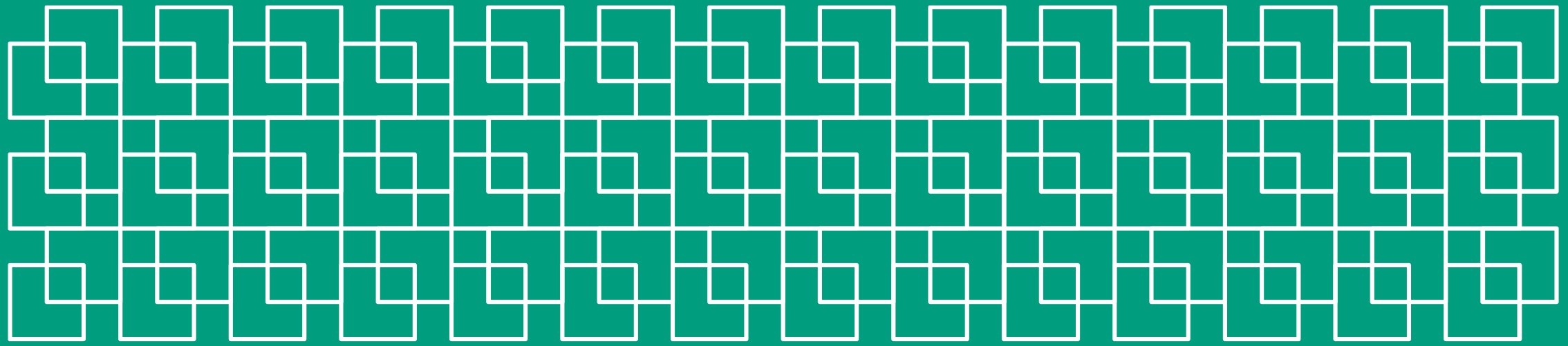
Process controle



Anaerobic Digestion Process

Methane Formers:

Slow Growers

Very Sensitive to Changes

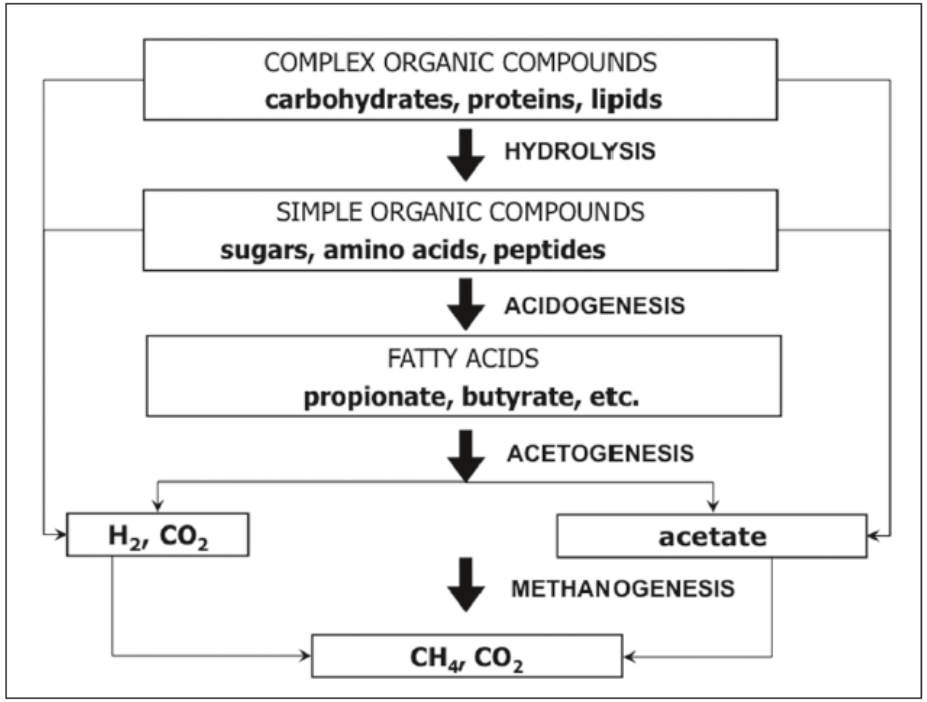
- **Loading**
- **pH**
- **Temperature**

Digester Operation Depends On Maintaining Proper Environment for METHANE FORMERS

BALANCE !

Process monitoring

- Instability
  - Change in feeding rate
  - Change in feedstock
    - Organic overload
    - Hydraulic overload
  - Inhibitation
    - Ammonia
    - Antibiotics and disinfectants



Results of imbalance

- Quantity and gas composition
- Change in degradation
- pH value
- Volatile fatty acids
- Hydrogen

Stability limits (1)

	Range of parameter	Interpretation
NH_4-N	<5,000 mg L^{-1}	In some cases NH_4-N concentrations of 3,000-5,000 mg L^{-1} can already pose stability problems. A stable process up to 5,000 mg L^{-1} is commonly achievable especially if nitrogen concentration is increased slowly in order to allow microorganisms to adapt or an inoculum already adapted to high nitrogen concentrations is used for inoculation.
	>5,000 mg L^{-1}	It is possible to operate stable degradation processes beyond 5,000 mg L^{-1}, however, it is often not an easy task. Microorganisms have to be adapted and in good condition (e.g. no lack in trace elements). The exact limit up to which a stable degradation process is possible depends on temperature, pH and the performance of the microorganisms. VFA will often be accumulated in the biogas plant, although the degradation process operates in a stable manner. High amounts of NH_4-N increase the buffering capacity which supports a stable process. Nevertheless, the process is less robust against additional process problems and if an imbalance emerges it can be more drastic than at low nitrogen concentrations.
pH	7 - 8	A stable biogas process is normally operated between pH 7 and 8. Yet, it is important to know that in practice temperature, sampling and storage can have an influence on pH measurement. The pH itself influences the dissociation of ammonia, hydrogen sulphide and volatile acids and by that their inhibitory effect.
	< 7	If volatile fatty acids accumulate (e.g. by organic overload) and exceed the buffering capacity, this will lead to a decline in pH. At pH values below 7 the activity of the microorganisms which degrade volatile fatty acids is reduced so that biogas production stops.
	> 8	Increased alkalinity will lead to process instabilities. One reason is the pH-influence on the dissociation equilibrium of NH_3 and NH_4^+. High pH values and increased temperature conditions favour the accumulation of $NH_{3(aq)}$, which is able to pass through microbial membranes, affecting the cellular osmoregulation and thus inhibits microbial performance.
TS	< 10	In CSTR reactors TS concentration normally needs to be below 10% in order to prevent stirring problems.
	> 10	TS values higher than 10% can lead to stirring problems in CSTR reactors. In other reactor types higher TS concentrations are possible.

VFA and alkalanity

- Individual VFA (C2 – C6) (HPLC or GC)
  - Ratio acetic /propionic acid
- FOS/TAC
  - Titration with sulphuric acid in two steps (pH 5 bicarbonate alkalinity)
  - Down to pH 4.4 alkalinity caused by VFA)

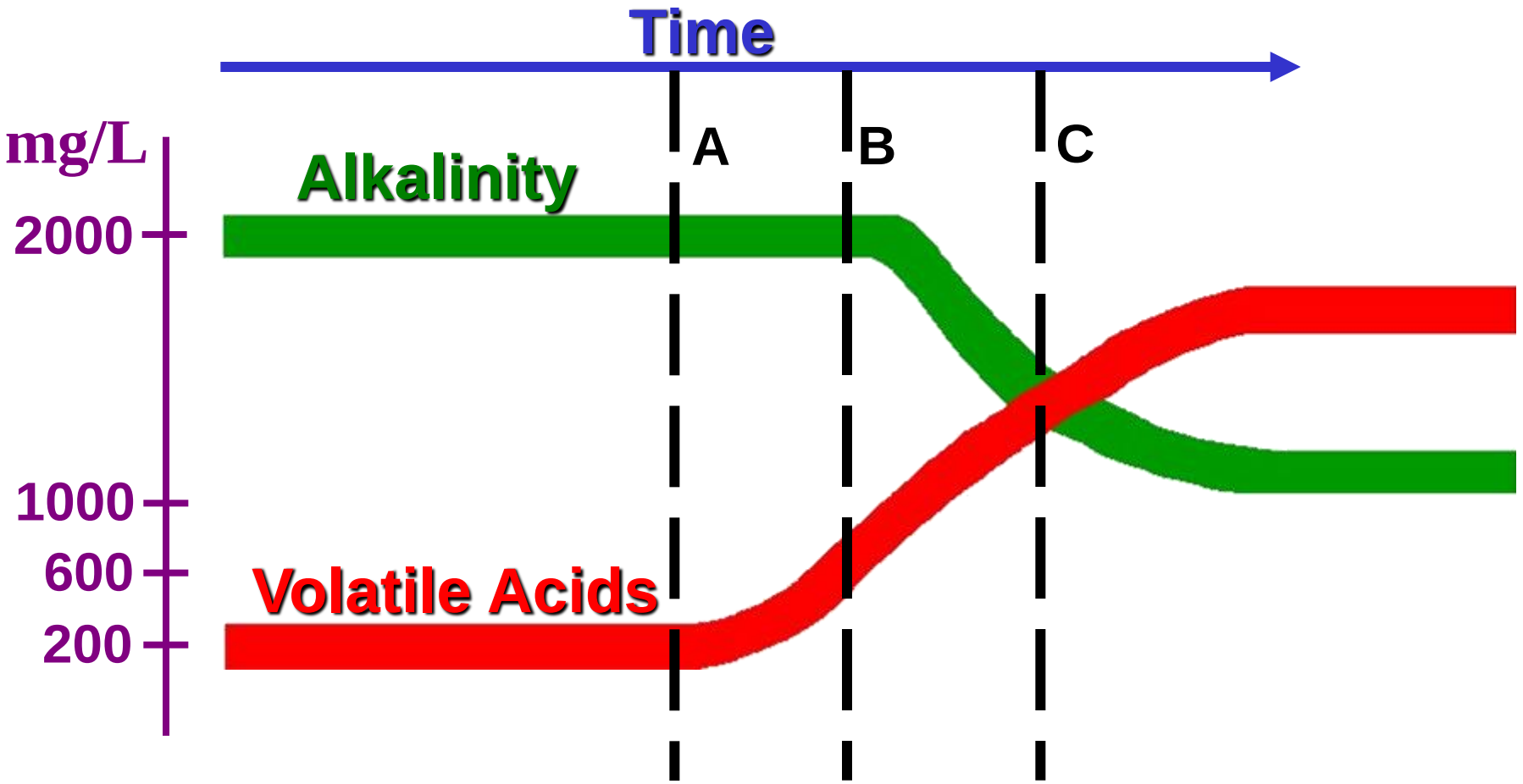
Figure 11 High pressure liquid chromatography (HPLC) measuring system for the determination of individual VFA

Figure 12 Automated laboratory titration device (reproduced with the kind permission of HACH LANGE).

Stability limits (2)

	Range of the parameter		Interpretation
Total VFA [mg L^{-1}]	<1,000 mg L^{-1}		Stable process
	1,000–4,000 mg L^{-1}		Range in which stable as well as unstable processes are possible. In biogas processes using feedstocks relatively hard to digest (e.g. energy crops with high TS content) where the rate limiting step is the hydrolysis step, the concentration of total VFA is normally lower than in waste digesters where the feedstock is readily degradable. Increased VFA concentrations can also be an indication of a lack of trace elements.
	>4,000 mg L^{-1}		High VFA concentrations are normally an indication of process problems, especially if VFA concentrations are increasing rapidly. Yet, also stable degradation processes are possible at higher VFA concentrations, e.g. at higher ammonia concentrations. The concentration of VFA which will lead to a decrease in pH and consequently to process problems depends on the buffer capacity and is plant specific.
Individual VFA	Acetic acid	<1,000 mg L^{-1}	Stable process
		1,000–4,000 mg L^{-1}	Stable as well as unstable processes are possible
		>4,000 mg L^{-1}	High probability of unstable process
	Propionic acid	<250 mg L^{-1}	Stable process
		250–1,000 mg L^{-1}	Stable as well as unstable processes are possible
		>1,000 mg L^{-1}	High probability of unstable process
	Longer chained VFA (butyric, valeric)	<50 mg L^{-1}	Stable process
		>50 mg L^{-1}	If longer chained VFA (and especially branched isomers) accumulate, severe process problems occur
	Ratio acetic/ propionic acid	>2	Stable process
		1-2	Stable as well as unstable processes are possible
		<1	High probability of unstable process
Alkalinity ratio (FOS/TAC)	<0.3		Alkalinity ratios below 0.3 are in general considered to indicate stable processes
	0.3–0.8		As alkalinity ratios are not comparable between different biogas plants it is very difficult to generalise. Stability limits have to be defined for every specific biogas plant. The maximum limits reported in literature for stable processes range from 0.3 to 0.8.
	>0.8		Unstable process
H_2	<100 ppm		Stable process
	100-500 ppm		In practice, it is quite difficult to guarantee accurate H_2 measurements. For this reason the range where stable as well as unstable processes are possible is assumed to be quite big. If at a biogas plant accurate H_2 measurements can be guaranteed, a smaller range of stability limits can be defined.
	>500 ppm		Unstable process

I. Relationship of Volatile Acids to Alkalinity

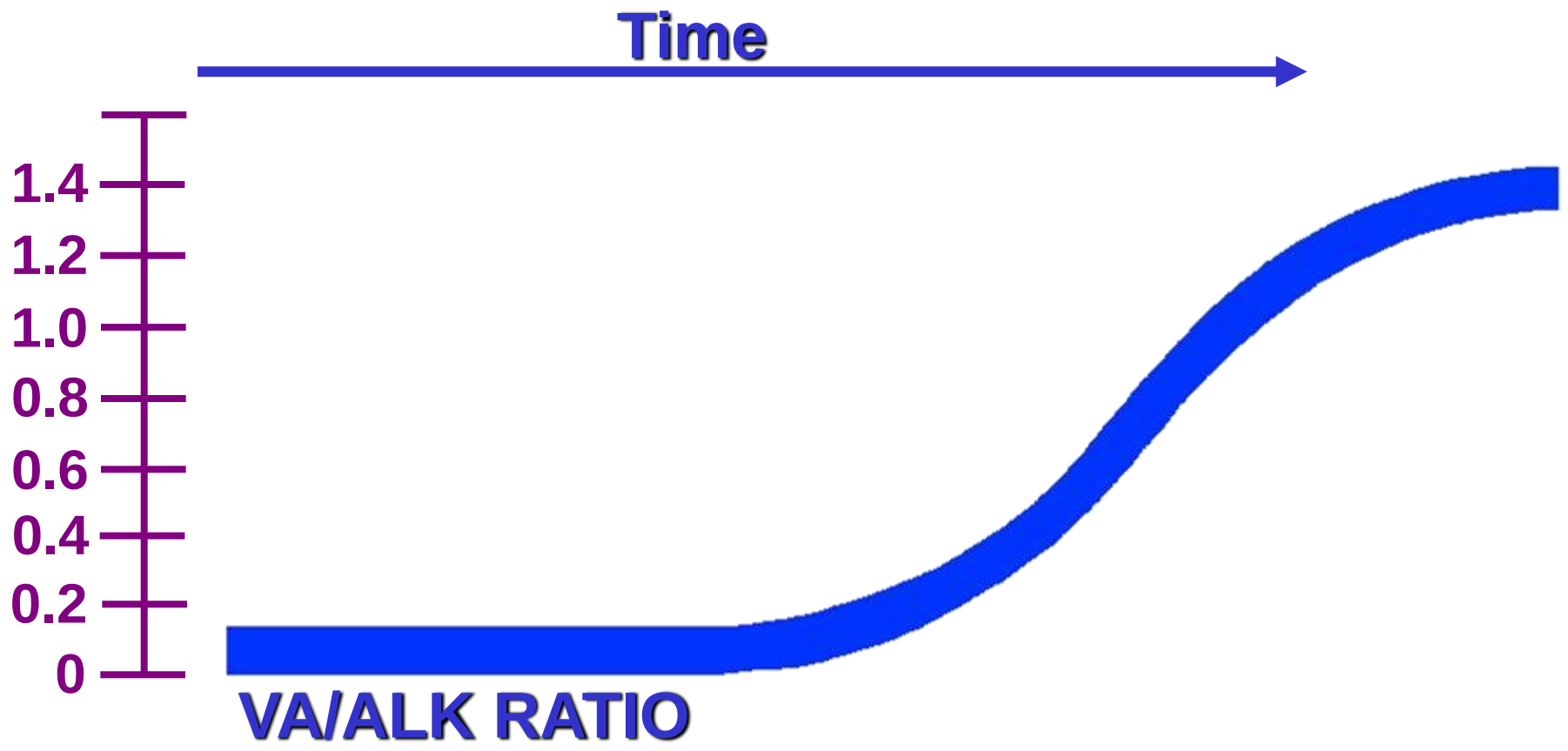


At Time A Something has Happened to Cause the Volatile Acids to Increase

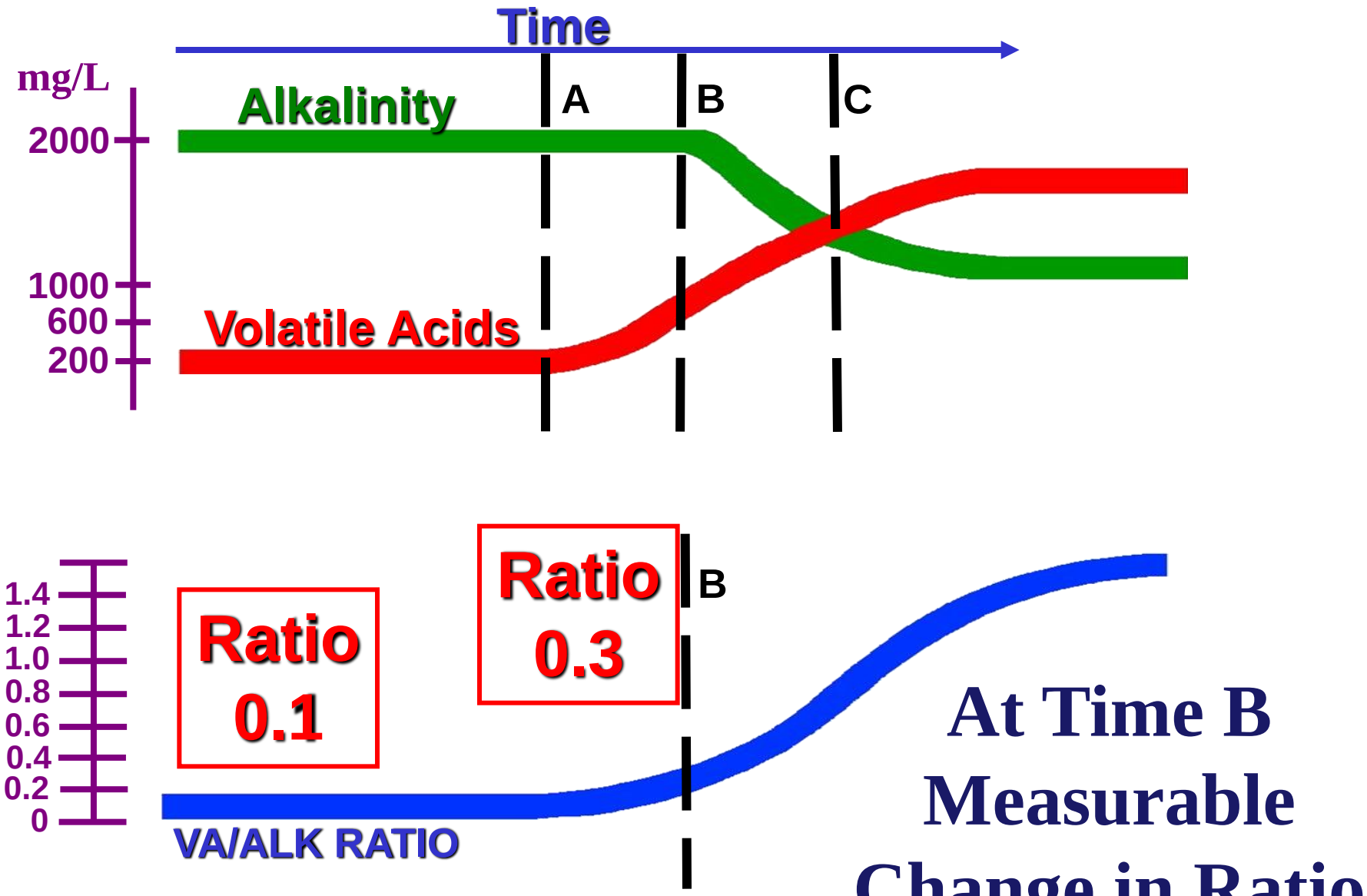
Followed by a Decrease in Alkalinity at Time B

At Time C the Digester has Become Sour

II. Volatile Acids / Alkalinity Ratio

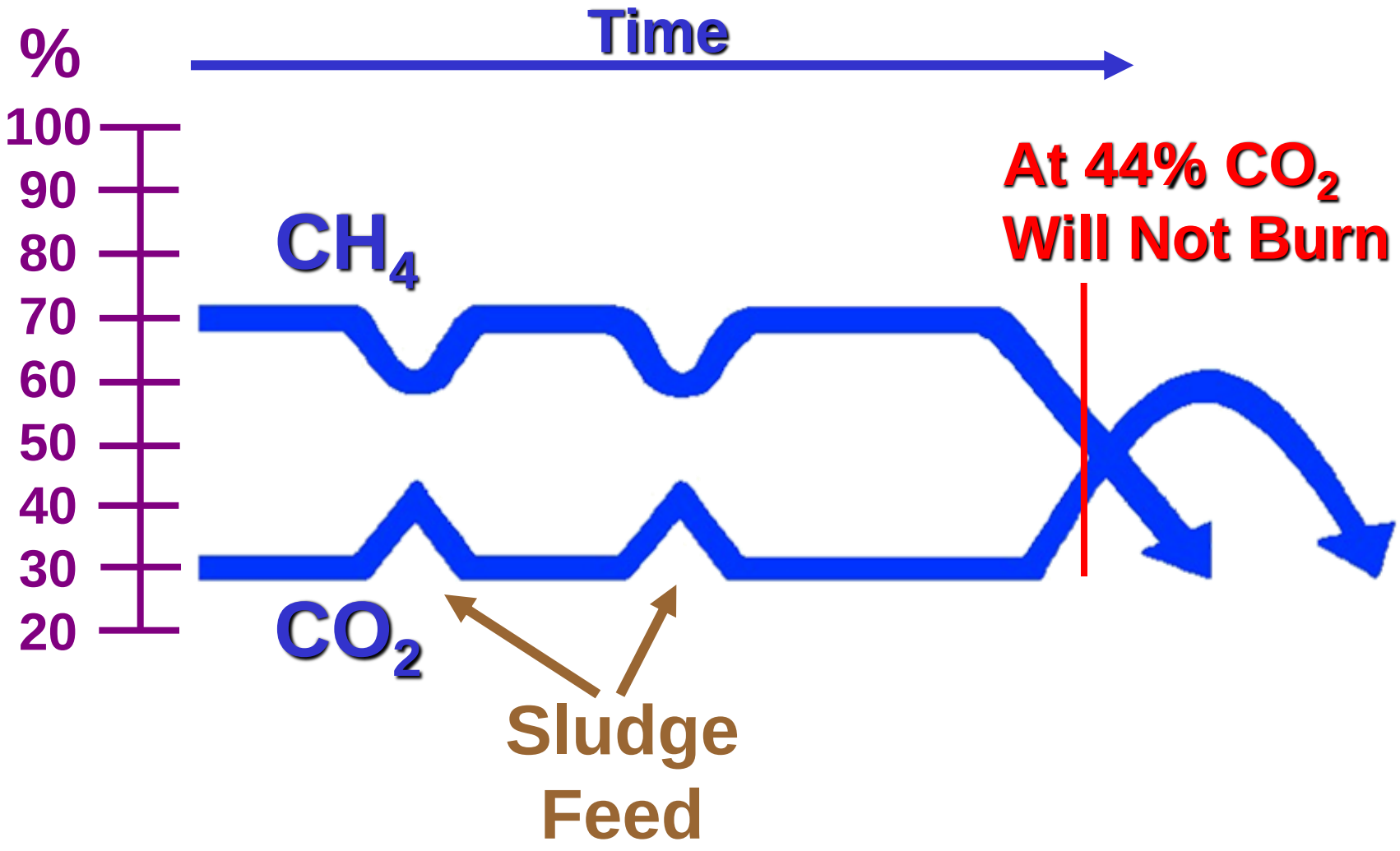


Comparing Graph I to Graph II

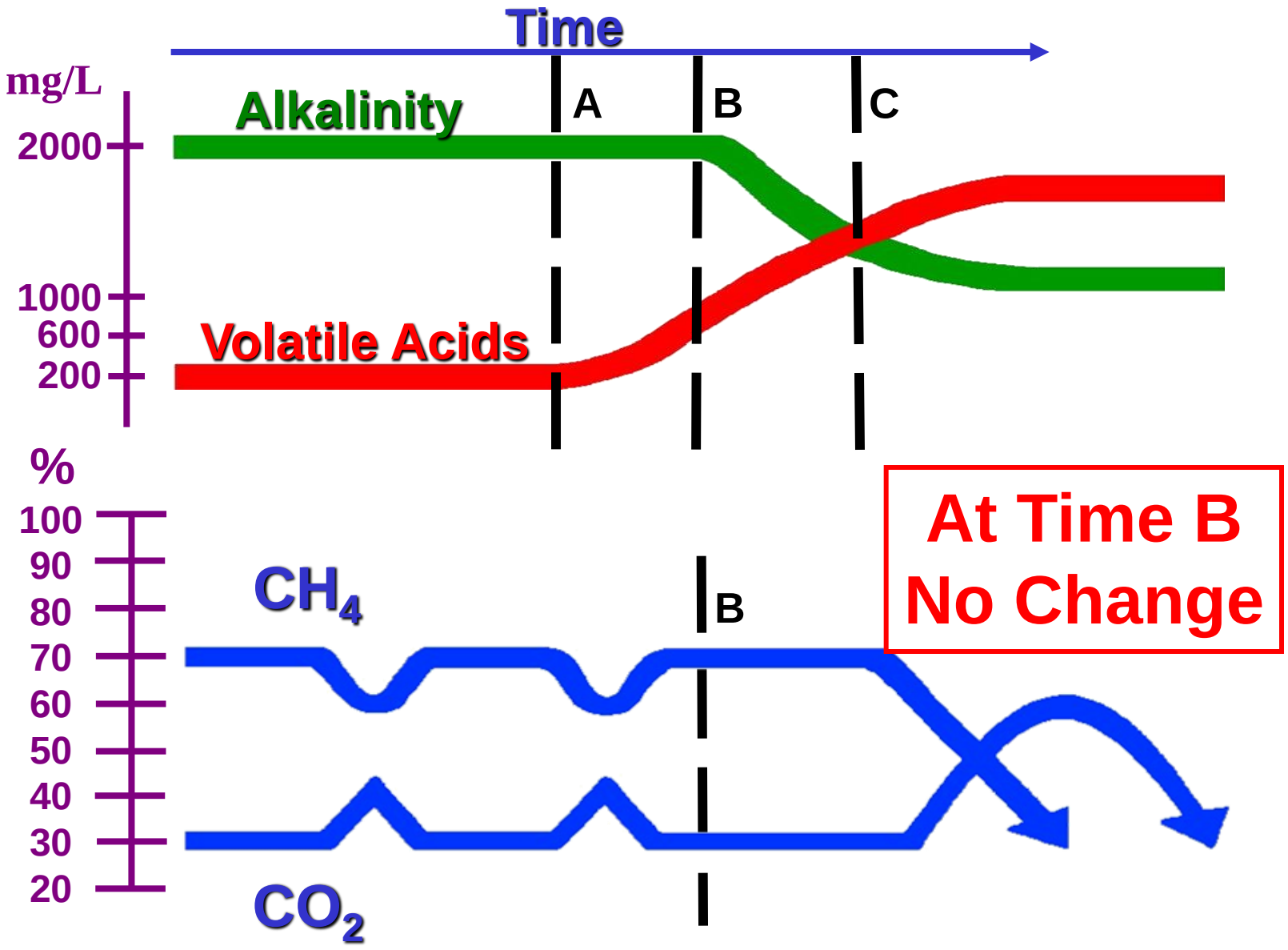


At Time B Measurable Change in Ratio

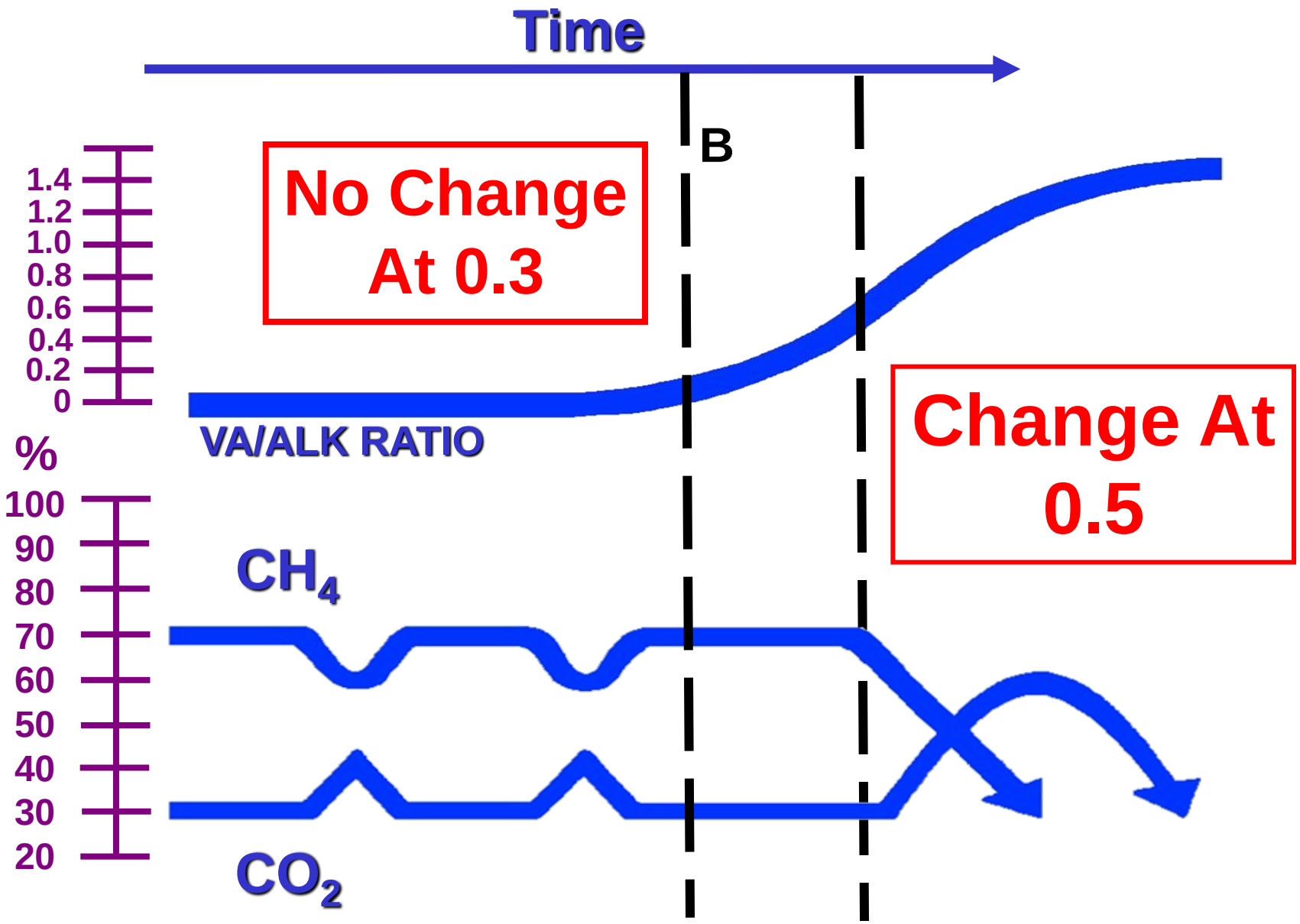
III. Relationship of Methane and Carbon Dioxide



Comparing Graph I to Graph III

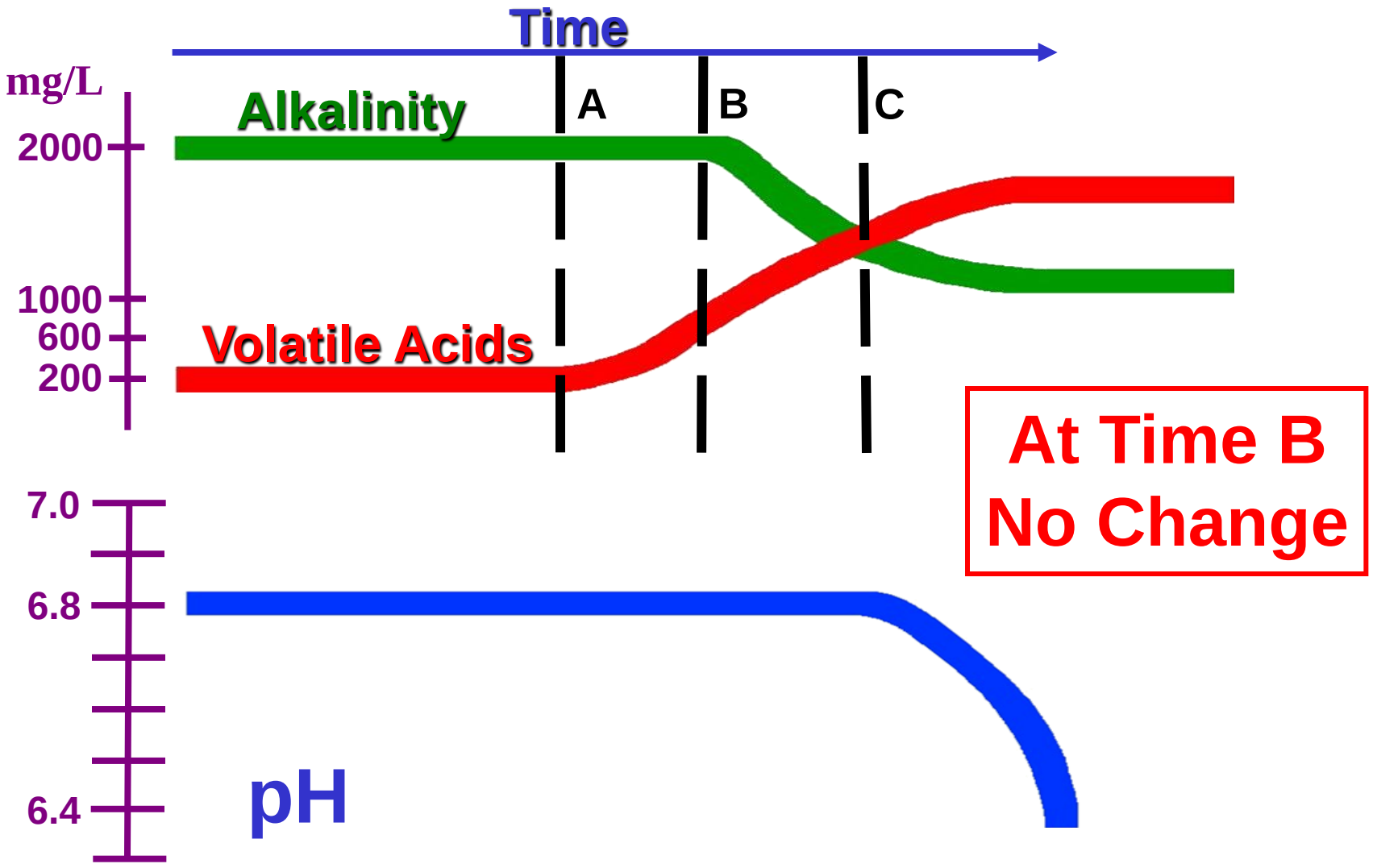


Comparing Graph II to Graph III

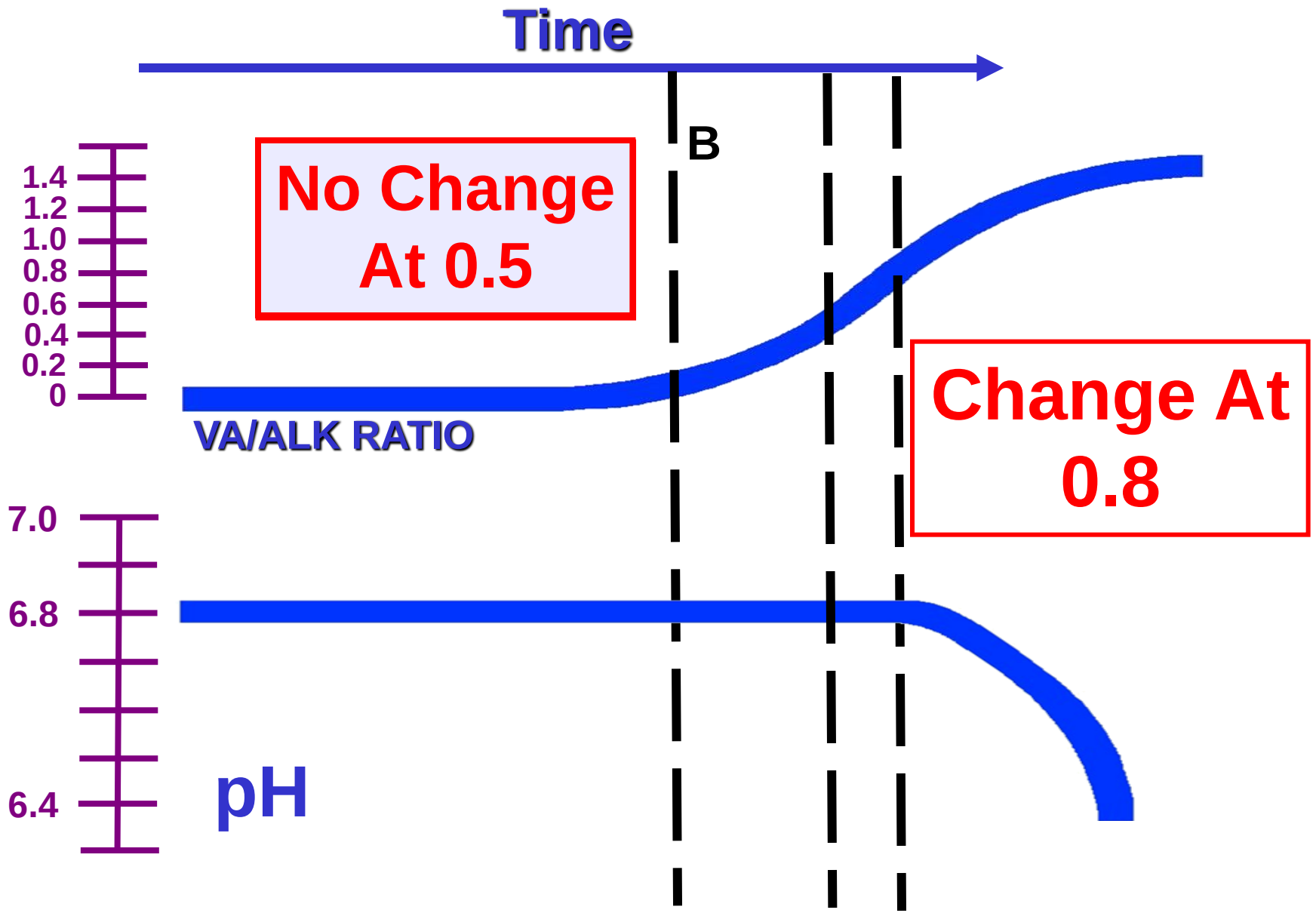


IV. Relationship of pH Change

Comparing Graph I to Graph IV

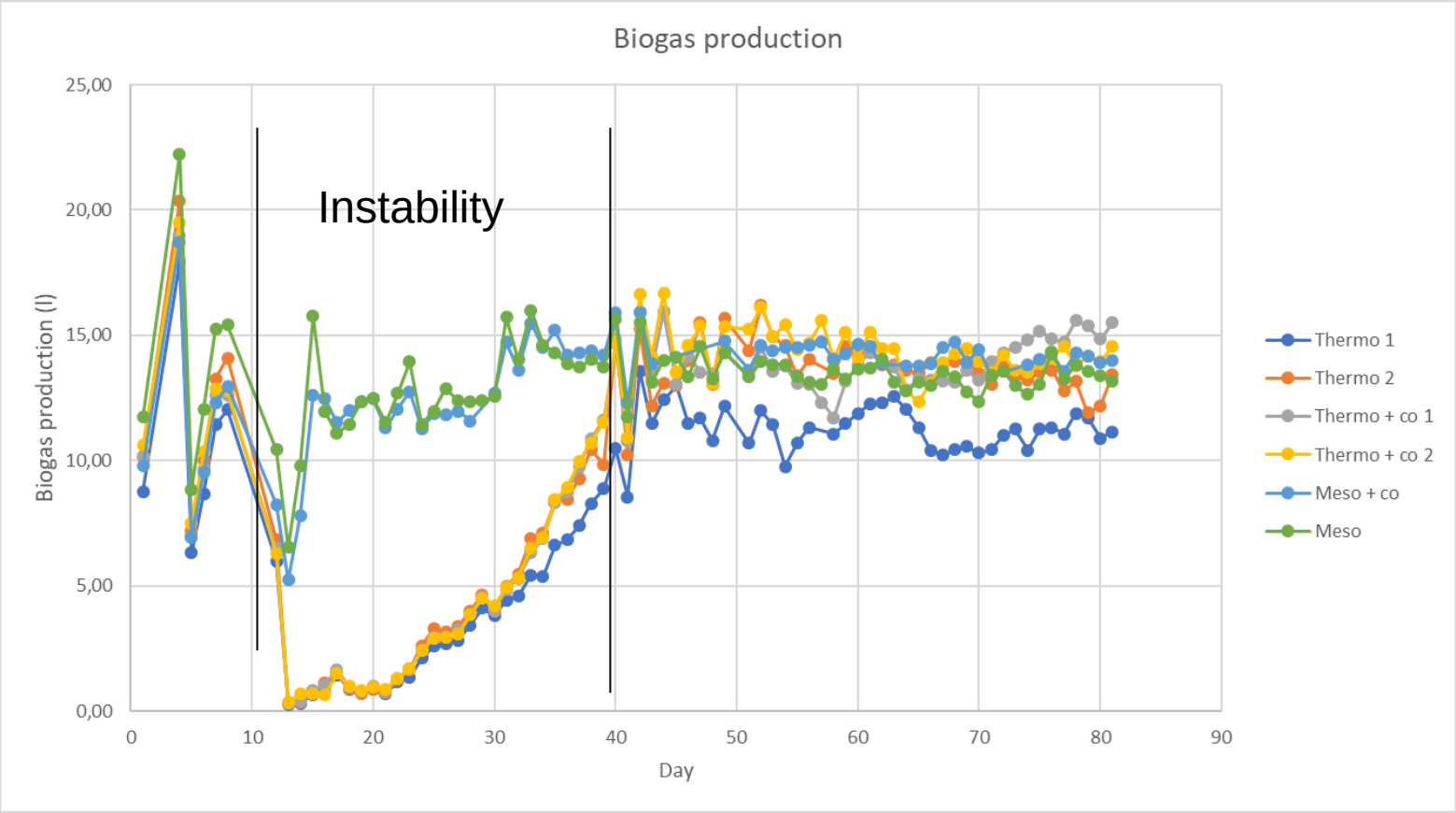


Comparing Graph II to Graph IV

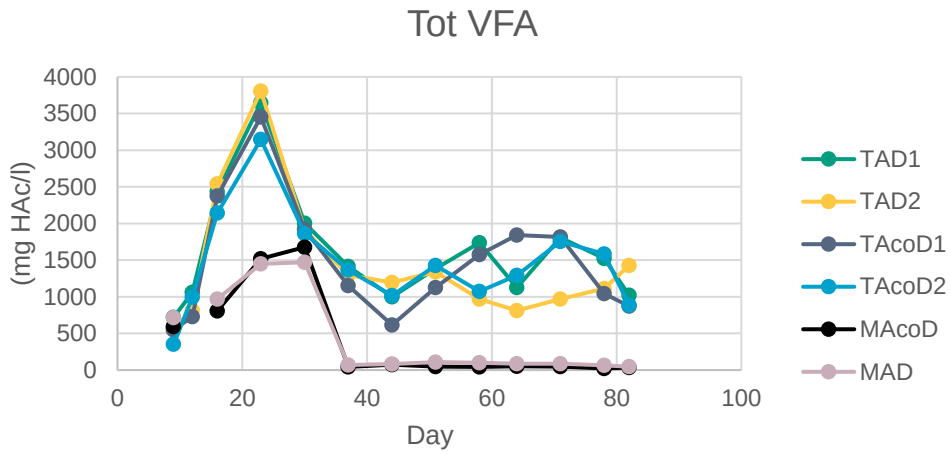


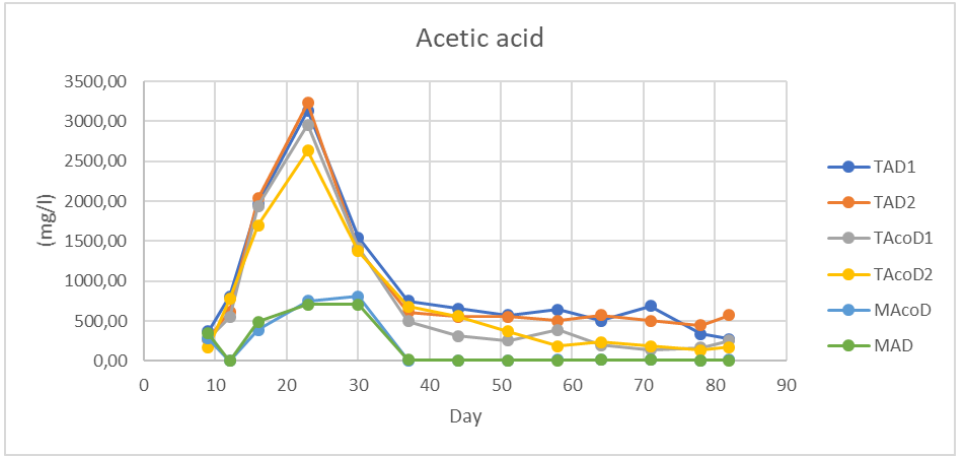
Analyse the following results from an experiment where with mesophilic and thermophilic temperatures, without and with co-substrate (two parallels of thermophilic)

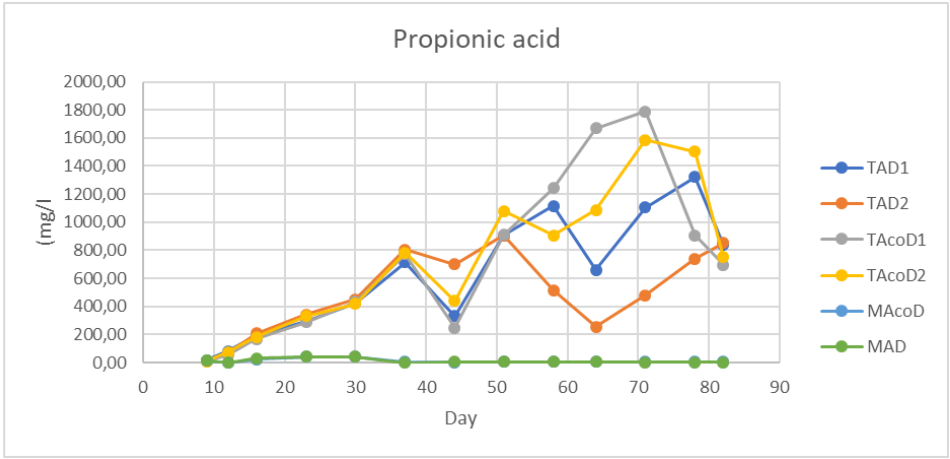
Questions: 1. What happened during the instability period? 2. What is the difference between mesophilic and thermophilic conditions?



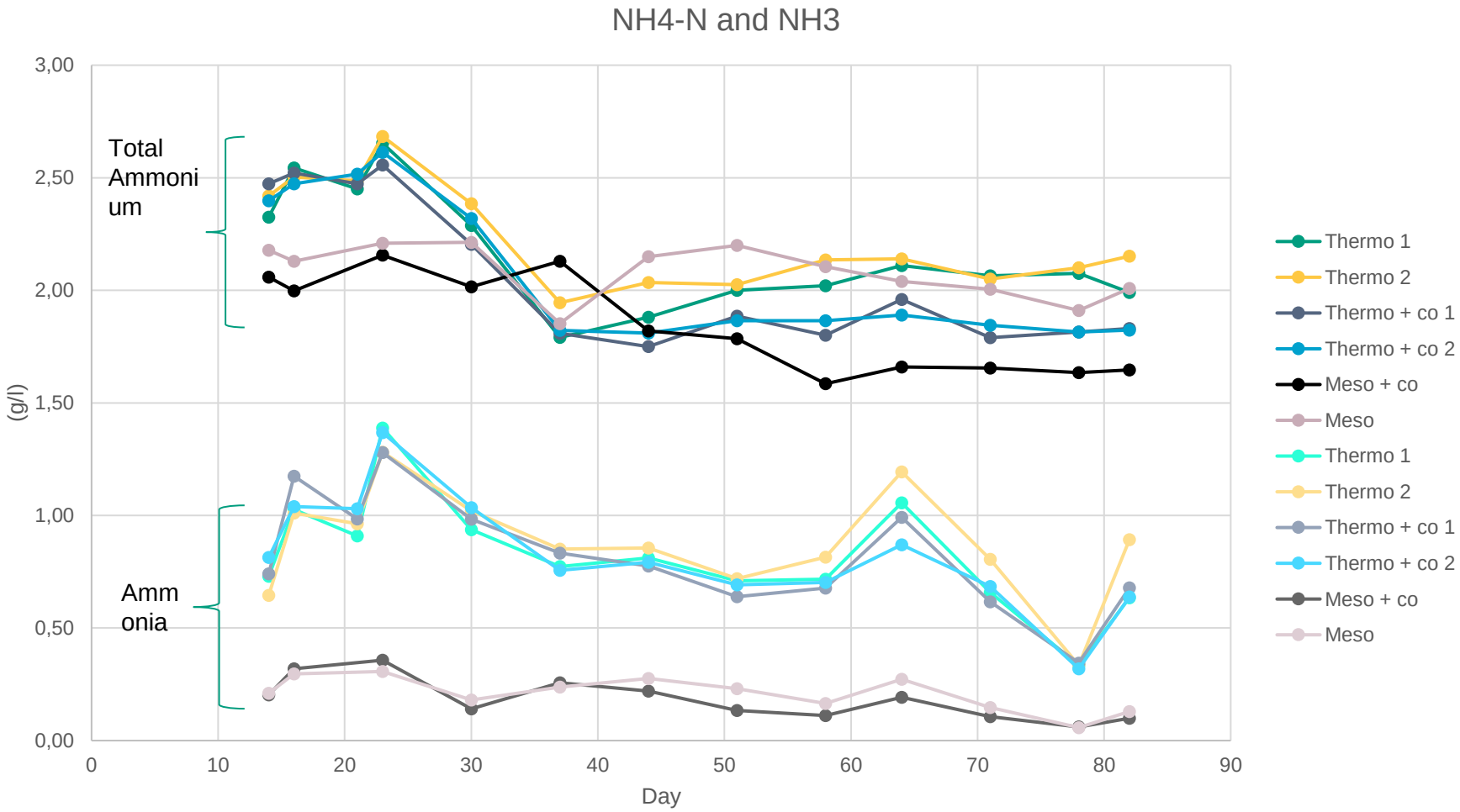
VFA


Tot VFA
(mg HAc/l)
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Day
TAD1
TAD2
TAcoD1
TAcoD2
MAcoD
MAD

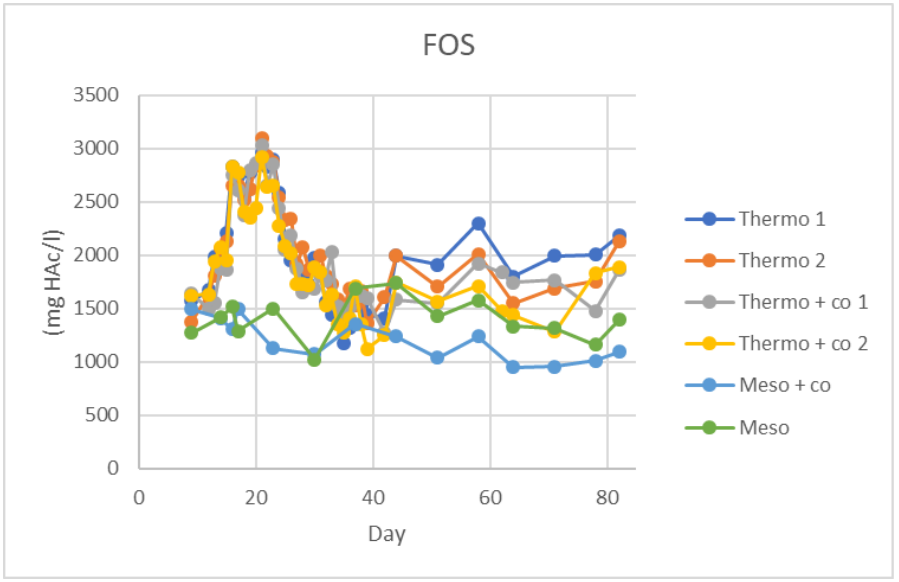

Acetic acid
(mg/l)
3500,00
3000,00
2500,00
2000,00
1500,00
1000,00
500,00
0,00
0
10
20
30
40
50
60
70
80
90
Day
TAD1
TAD2
TAcoD1
TAcoD2
MAcoD
MAD

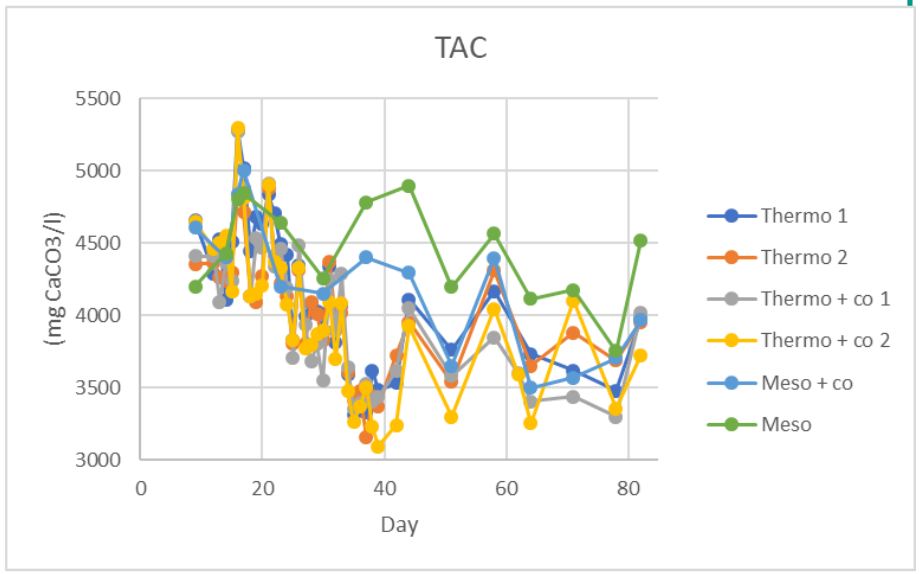

Propionic acid
(mg/l
2000,00
1800,00
1600,00
1400,00
1200,00
1000,00
800,00
600,00
400,00
200,00
0,00
0
10
20
30
40
50
60
70
80
90
Day
TAD1
TAD2
TAcoD1
TAcoD2
MAcoD
MAD

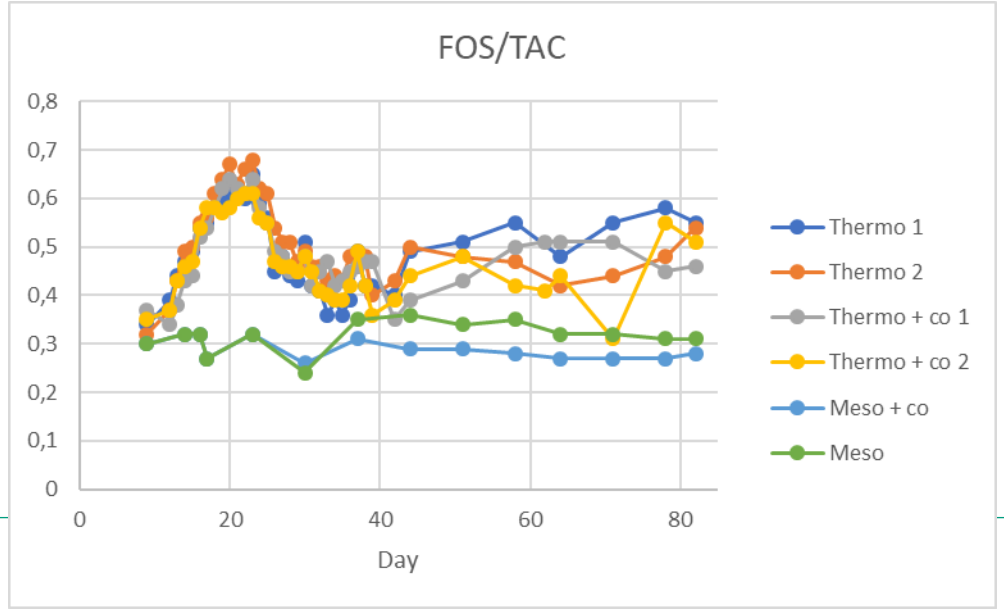
Ammonium and ammonia



FOS/TAC


FOS
3500
3000
2500
2000
1500
1000
500
0
(mg HAc/l)
0
20
40
60
80
Day
Thermo 1
Thermo 2
Thermo + co 1
Thermo + co 2
Meso + co
Meso


TAC
5500
5000
4500
4000
3500
3000
(mg CaCO3/l)
0
20
40
60
80
Day
Thermo 1
Thermo 2
Thermo + co 1
Thermo + co 2
Meso + co
Meso


FOS/TAC
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
20
40
60
80
Day
Thermo 1
Thermo 2
Thermo + co 1
Thermo + co 2
Meso + co
Meso