BIORECOVERY OF SCANDIUM FROM BAUXITE RESIDUE

K. Kiskira, I. Lourentzatos, Th. Lymperopoulou, L.A. Tsakanika, Ch. Pavlopoulos, K. Papadopoulou, K.M. Ochsenkühn, G. Lyberatos, M. Ochsenkühn-Petropoulou

Inorganic and Analytical Chemistry Laboratory
Organic Chemical Technology Laboratory
Horizontal Laboratory of Quality Control of Processes and Products

School of Chemical Engineering
National Technical University of Athens, Athens, Greece

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Introduction

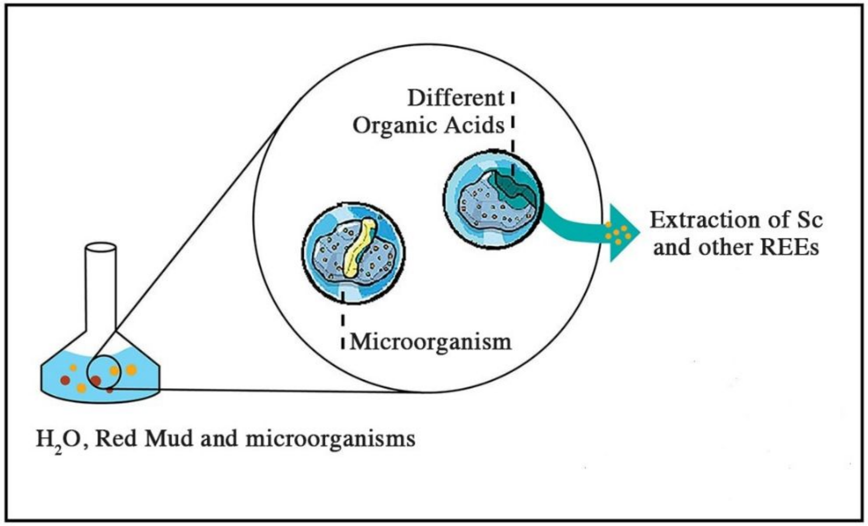
- The bauxite residue (BR), is a highly alkaline waste by-product.
- 3.5 billion tons of BR have been stockpiled globally in storage areas
- The disposal of BR □ universal environmental concern.
- BR contains valuable metals, such as rare earth elements (REEs), in particular, Scandium (Sc).
- Higher demand for critical raw materials (CRMs).
- The most senior supply risk of CRMs corresponds to REEs.

Filter-pressed (dry) bauxite residue being stockpiled in Greece, at Mytilneos S.A. (former Aluminum of Greece)

Scandium crystals

Bioleaching

- Biotechnologies Essential role in metal recovery
- Sustainable technology for waste
- Eco-friendly ''Green technology''
- Operational flexibility
- Low energy requirements



Bioleaching of Red Mud

Materials and methods

Batch experiments

Microbial sources:

1. Digestate (anaerobic digestion effluent) collected from a pilot-scale anaerobic digester
2. Chemoheterotrophic Bacterium, *Acetobacter tropicalis* (Pure Culture)
3. Chemoheterotrophic Fungus, *Aspergillus niger* (Pure Culture)

- Bauxite Residue (BR) provided by Mytilineos S.A. (ferroalumina 12/2016) – Sc content: 100±5 mg/kg
- The initial pH of the BR was 11.3.

Materials and methods

1. Digestate

- AMPTS' bottles (500 ml total volume; 400 ml working volume and 100 ml headspace)
- Bench-scale anaerobic bioreactor
- **Subculturing (8 months period)**

BIOMASS 10% v/v

pH adjustment to 7 with HCl

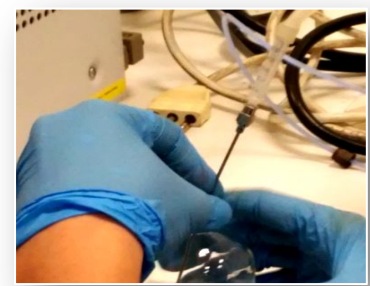
T=35°C

10%, 20% and 30% w/v BR pulp density

Incubation time 0-30 days

*Digester Effluent**

Automated Methane Potential Test System II (AMPTS)



Flushing with N_2

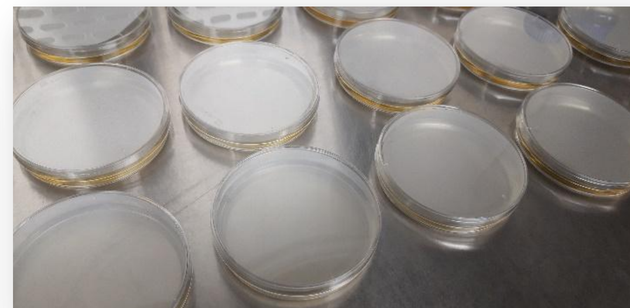
* Waste4Think Project (EU H2020) – Moving towards Life Cycle Thinking by integrating Advanced Waste Management Systems.

Materials and methods

2. *Acetobacter tropicalis* (1/2)

Bacterial growth

- Inoculation into leaching medium and incubated at 30°C and 80 rpm in an shaking incubator for 1 month for activation.



Materials and methods

2. *Acetobacter tropicalis* (2/2)

Bioleaching experiments

- 10% and 20% v/v of bacterium suspension was inoculated into 150 mL of leaching medium in 250 mL Erlenmeyer flask
- 120 RPM

Incubation time 0-30 days

pH adjustment to 7 with HCl

BIOMASS 10% and 20% v/v

1%, 2%, 10%, 20% and 30% w/v BR pulp density

T= 20 and 30 °C

Aerobic conical flasks

Materials and methods

3. *Aspergillus niger* (Pure culture)

Bioleaching experiments

- 2, 4 ή 6 % v/v of fungus suspension was inoculated into 120 mL of leaching medium in 250 mL Erlenmeyer flask
- 100 RPM

Aspergillus niger culture from Institute Leibniz, DSMZ, Germany

NO pH adjustment to 7

Incubation time 20 days

1%, 5% and 10% w/v BR pulp density

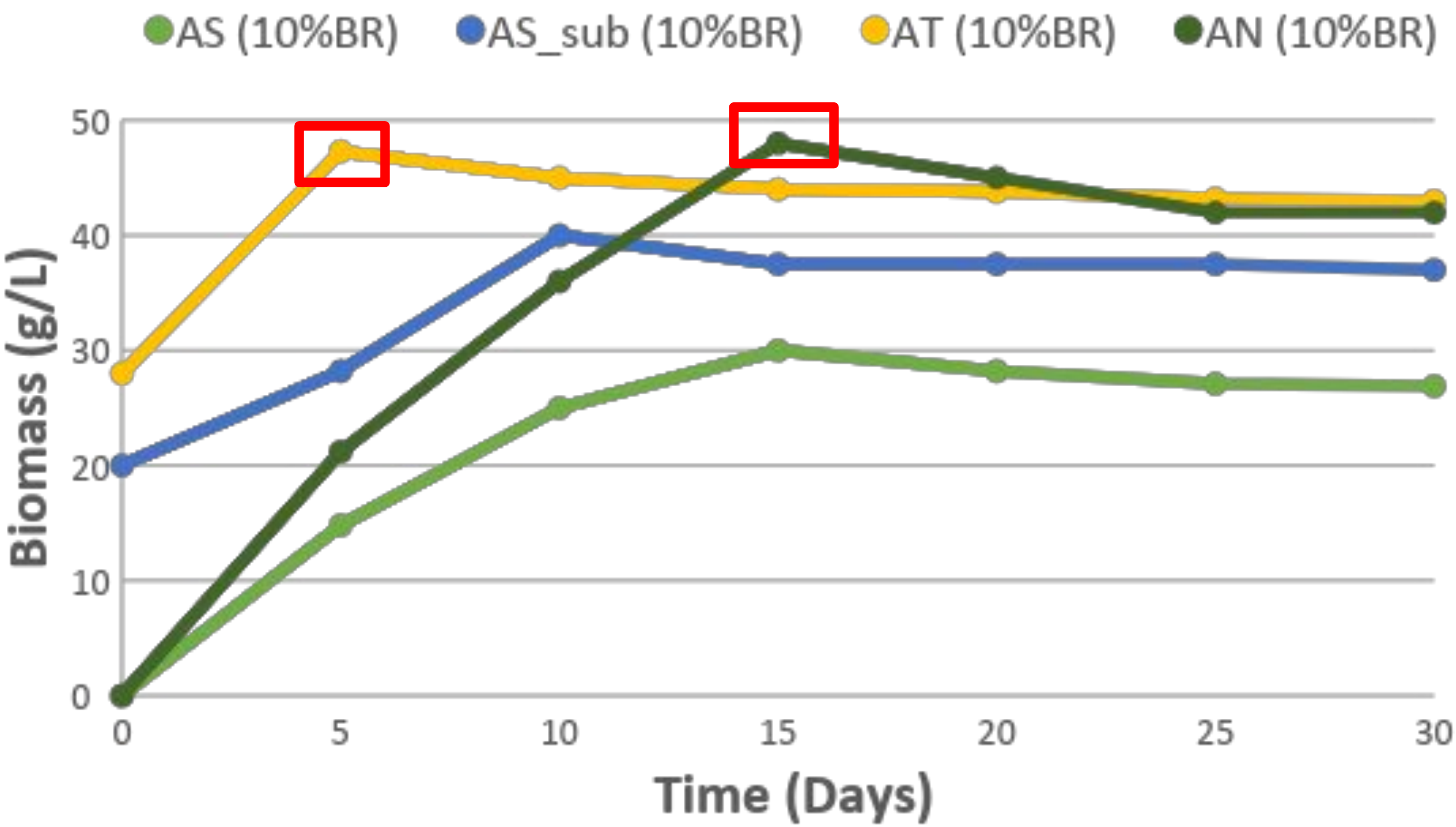
40, 90 and 140 g/L Sucrose

BIOMASS 2, 4, 6% v/v

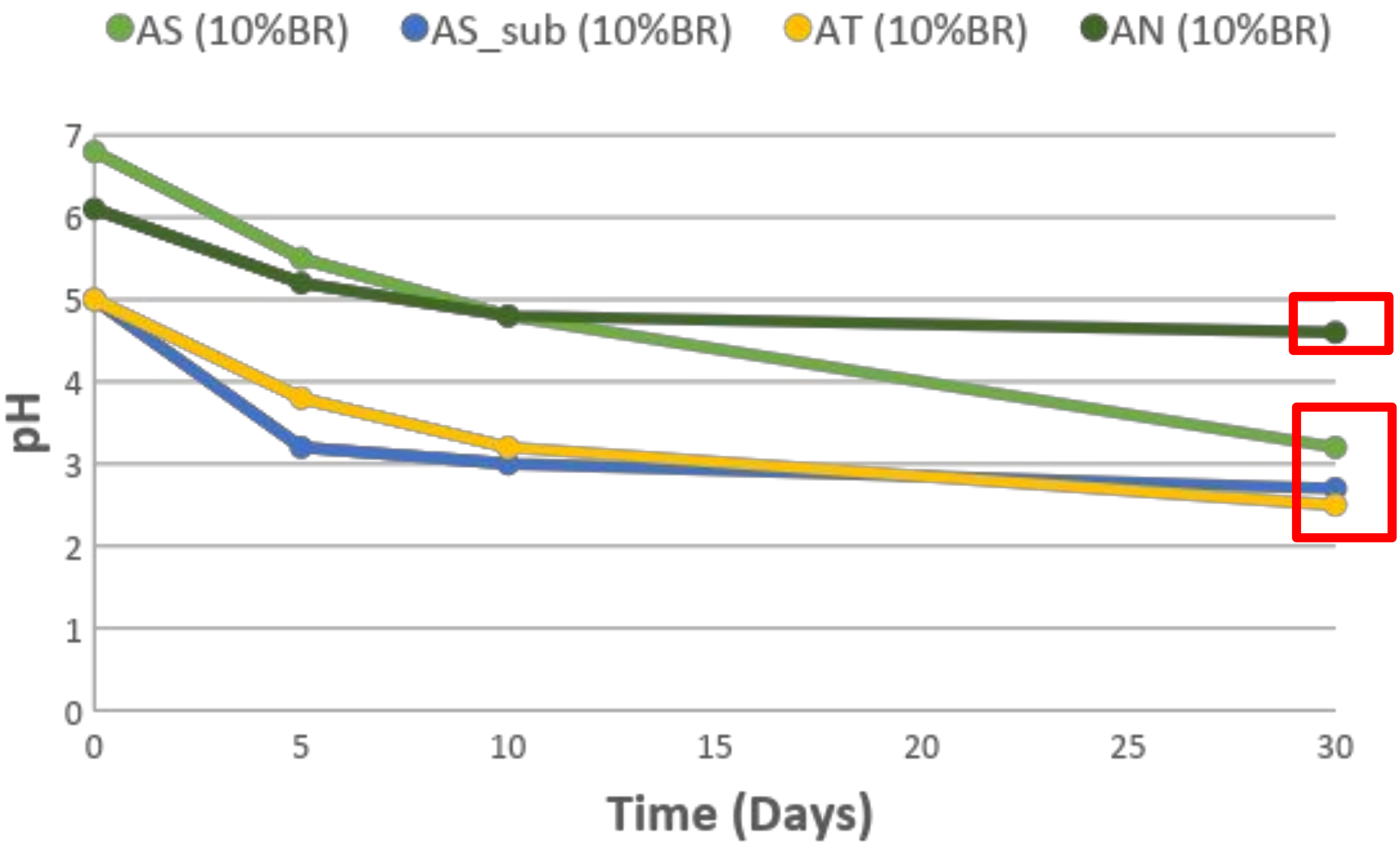
T=30°C

Incubation in an orbital shaking incubator

Biomass Production



pH monitoring

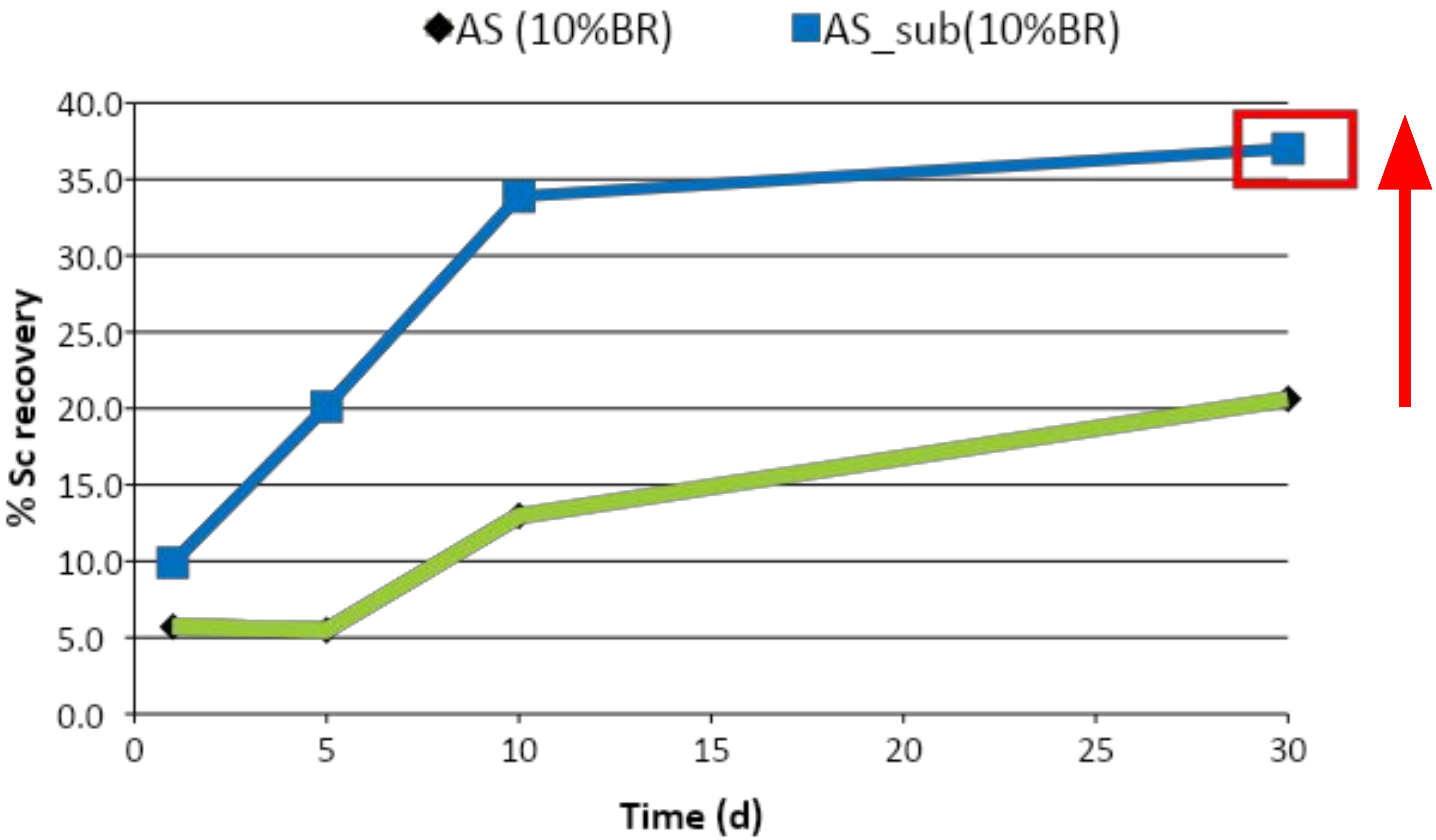


Sc % Recovery

Longer enrichment

***Stimulation** of Bioleaching!*

Digestate and subculturing



Sc % Recovery

Acetobacter Tropicalis

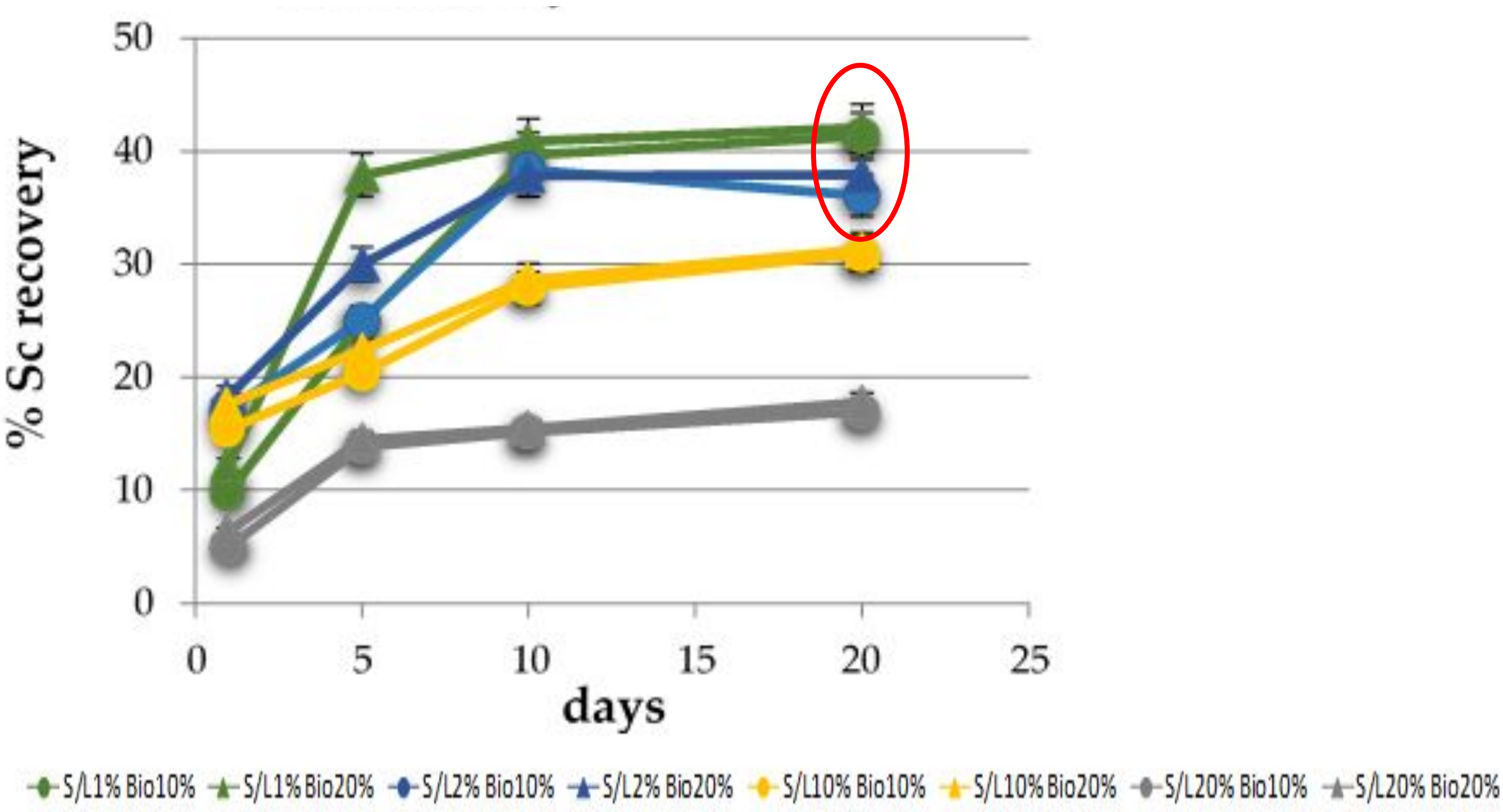
metals

MDPI

Article

Study of Microbial Cultures for the Bioleaching of Scandium from Alumina Industry By-Products †

Kyriaki Kiskira [1,*], Theopisti Lymperopoulou [2], Lamprini-Areti Tsakanika [1], Charalampos Pavlopoulos [3], Konstantina Papadopoulou [3], Klaus-Michael Ochsenkühn [1], Gerasimos Lyberatos [3] and Maria Ochsenkühn-Petropoulou [1]



Bioleaching Experiments

Aspergillus Niger

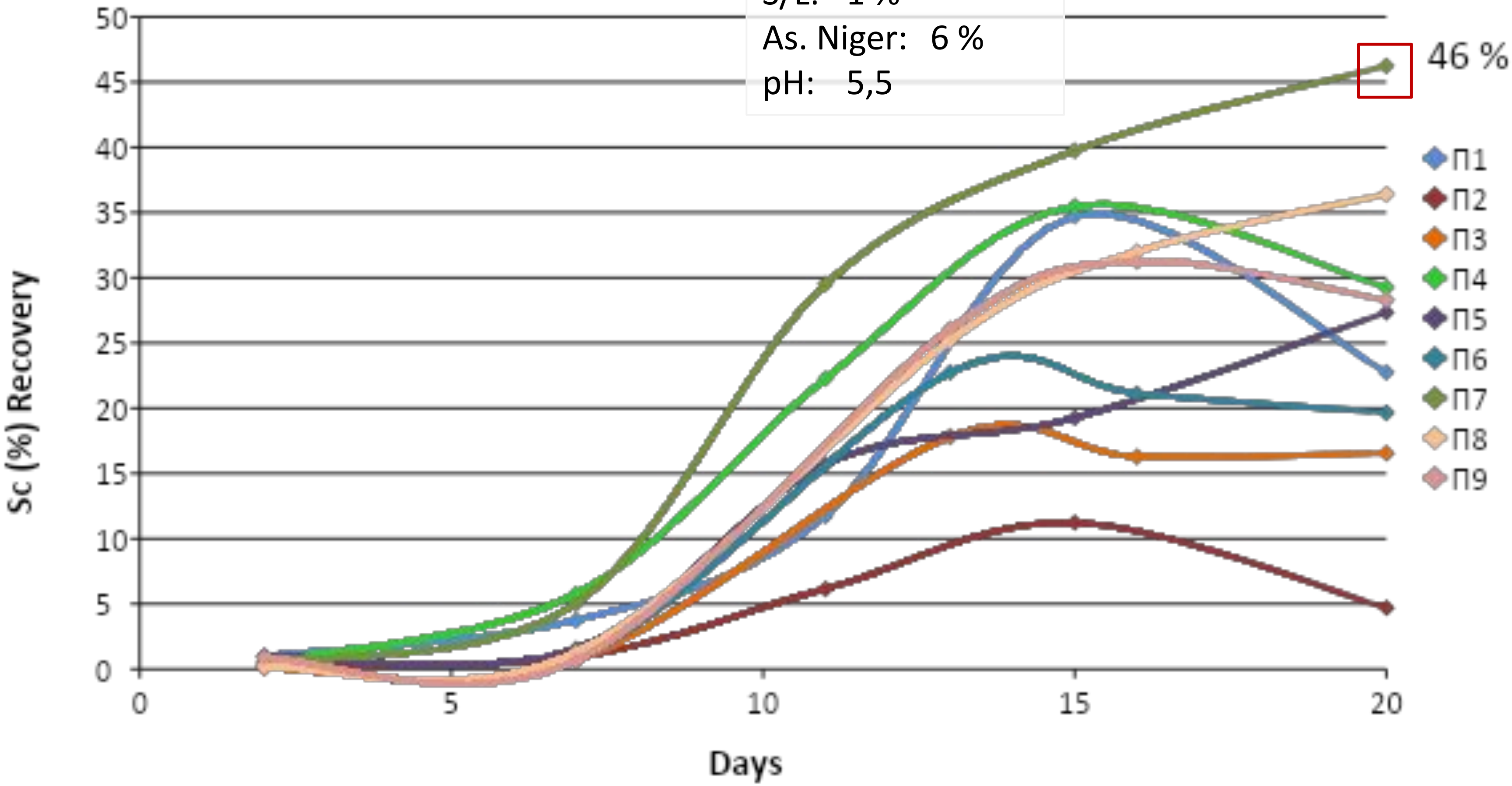
- **Bioleaching Conditions:** 30 °C, 120 rpm
- **Time:** 20 days
- **Optimization of scandium extraction using Taguchi methodology**

	Parameters Taguchi		
	Sucrose (g/L)	S/L BR (%)	*A. Niger* (%)
П1	40	1	2
П2	40	5	4
П3	40	10	6
П4	90	1	4
П5	90	5	6
П6	90	10	2
П7	140	1	6
П8	140	5	2
П9	140	10	4

Sc % Recovery

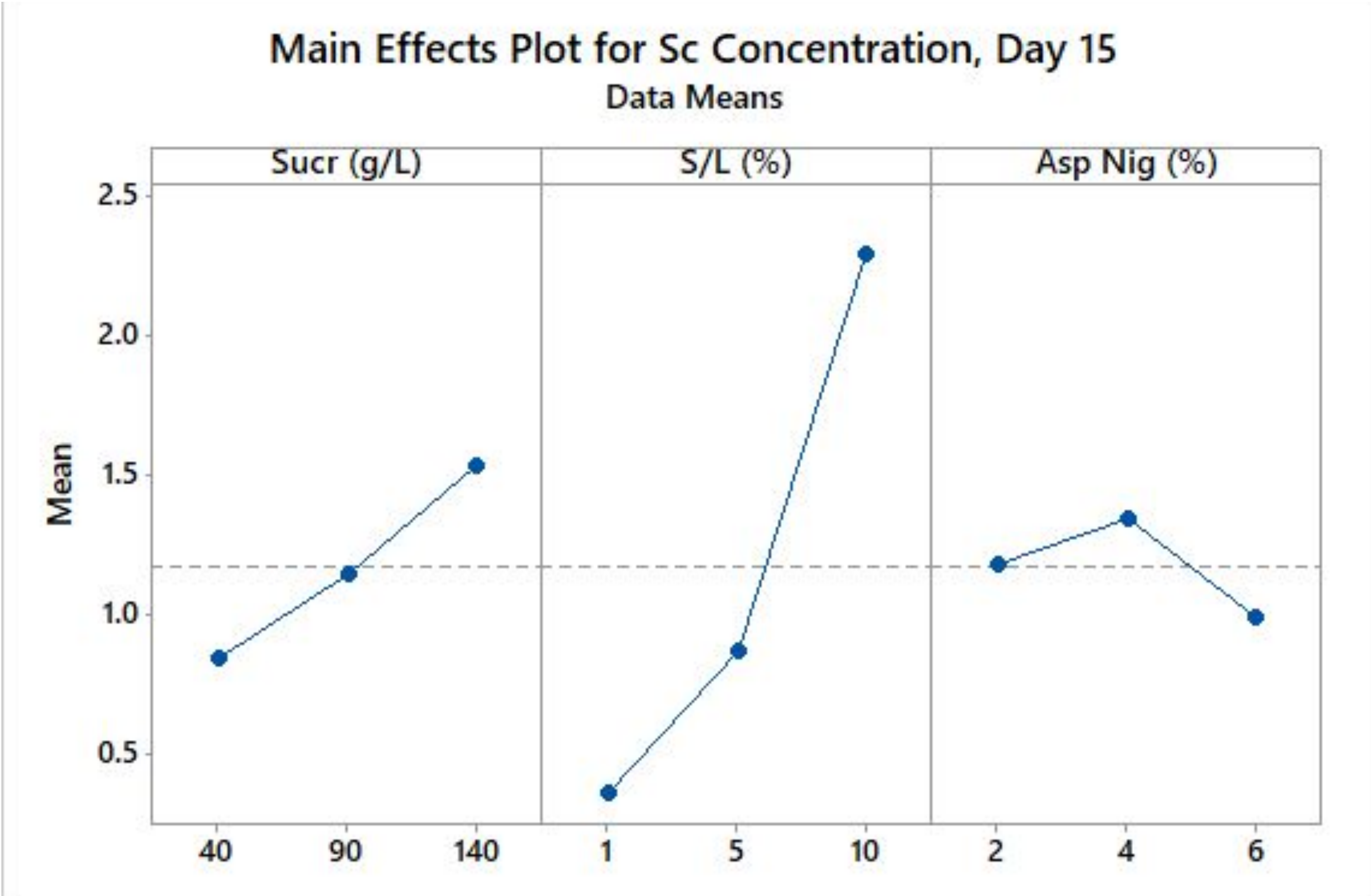
Aspergillus Niger

Sucrose: 140 g/L
S/L: 1 %
As. Niger: 6 %
pH: 5,5

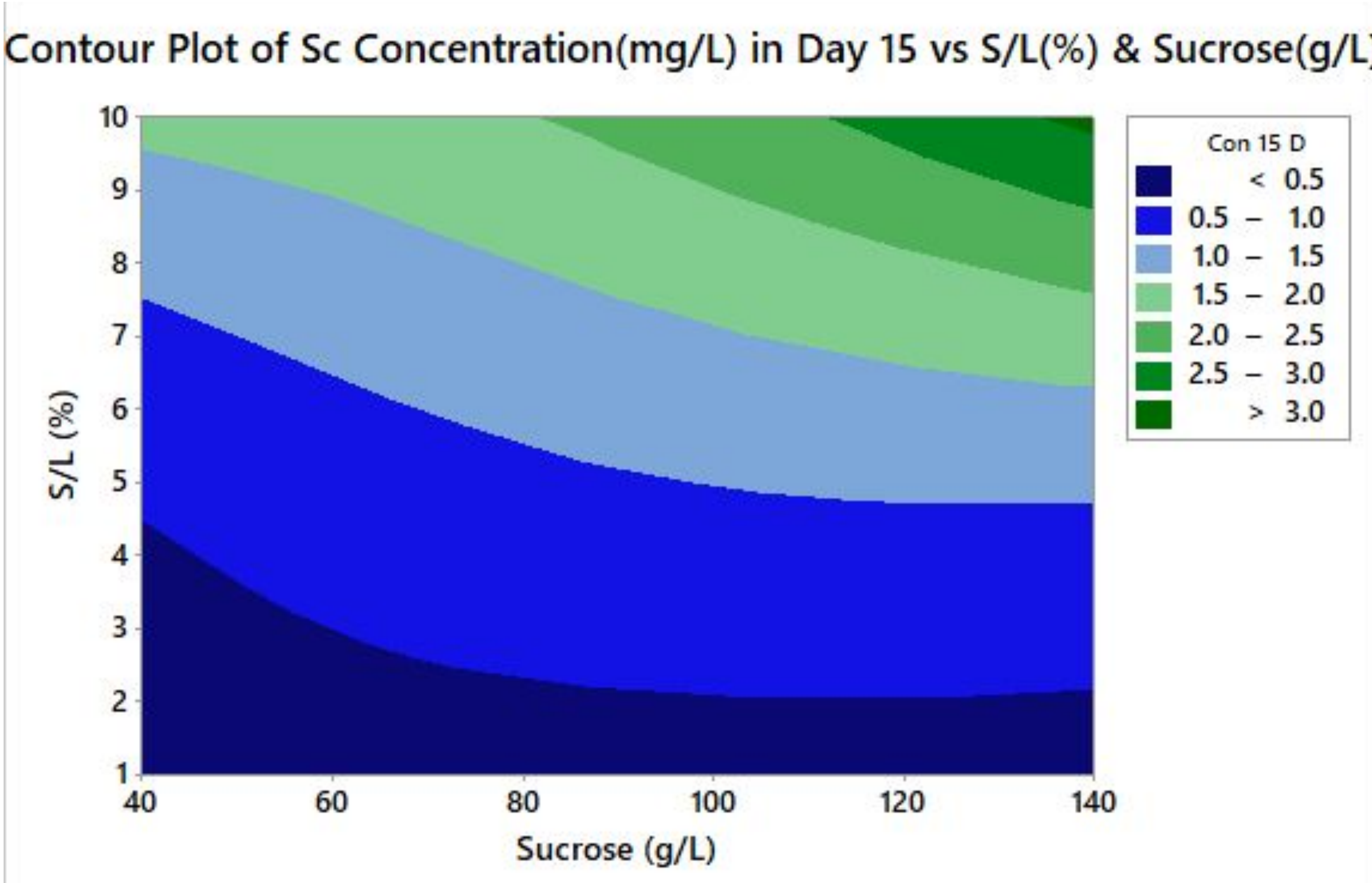


pH **7** **5**

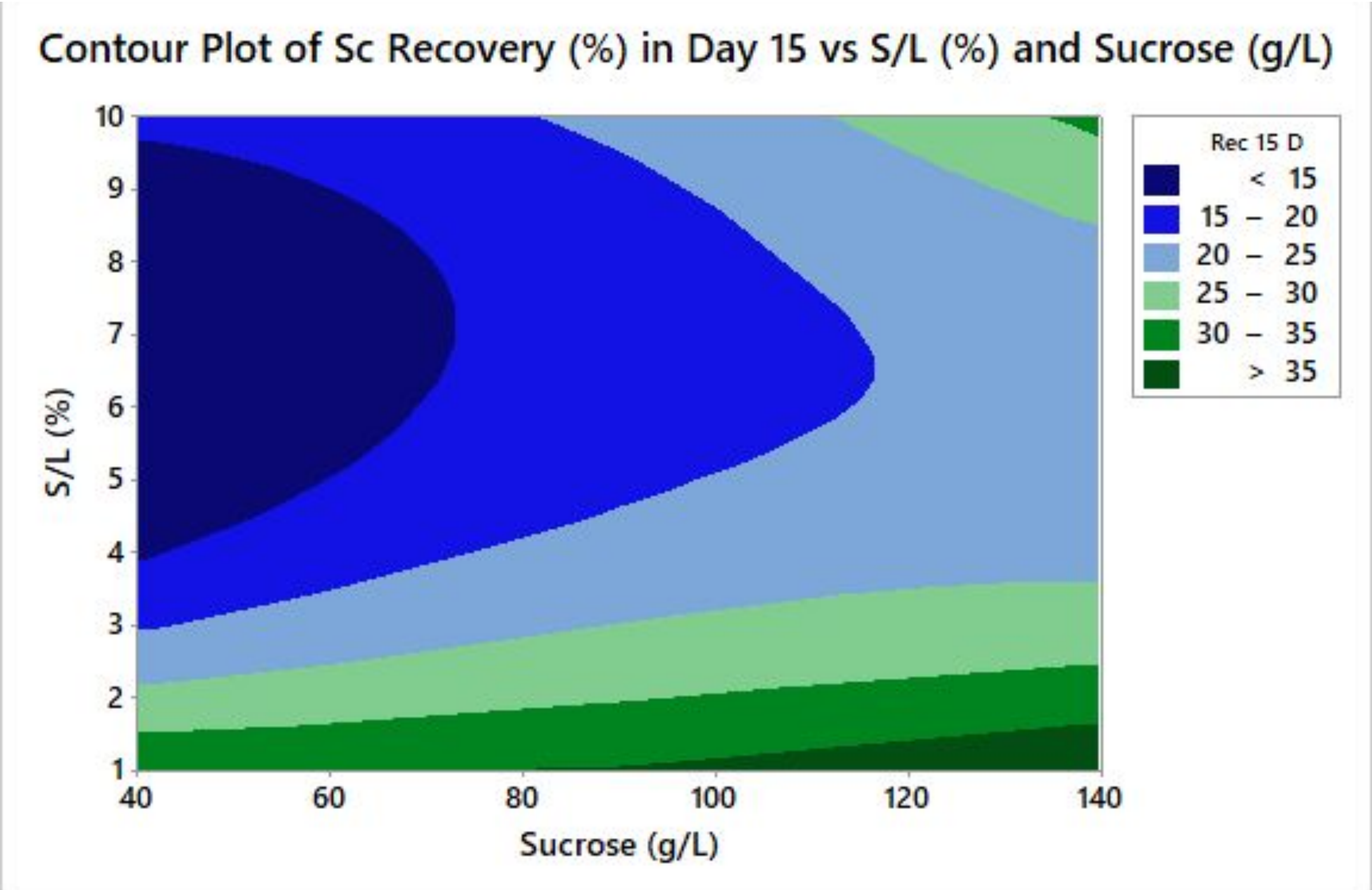
Effect of Taguchi Parameters



Estimated Sc Concentrations

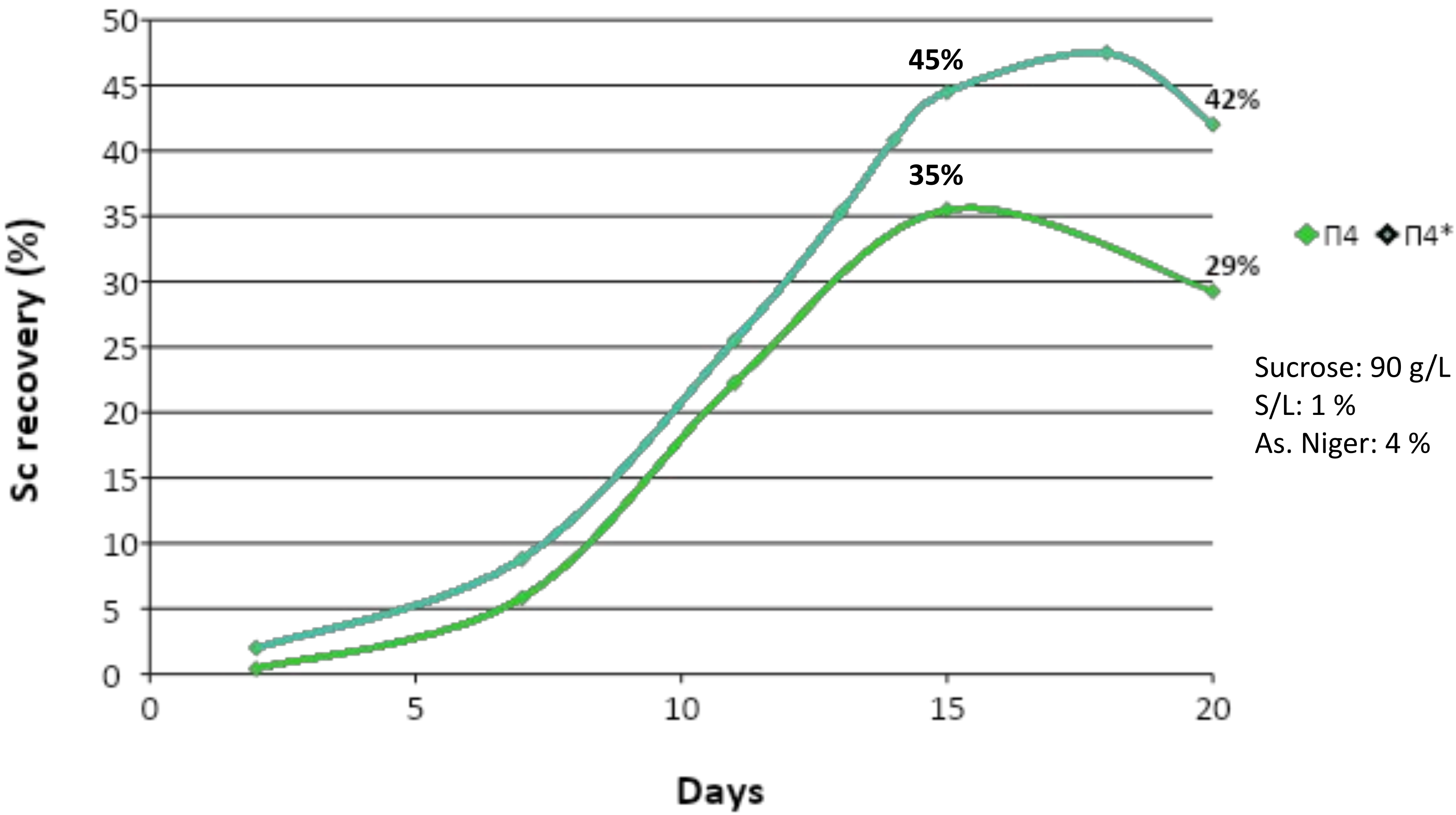


Estimated Sc Recoveries



Effect of Subculturing

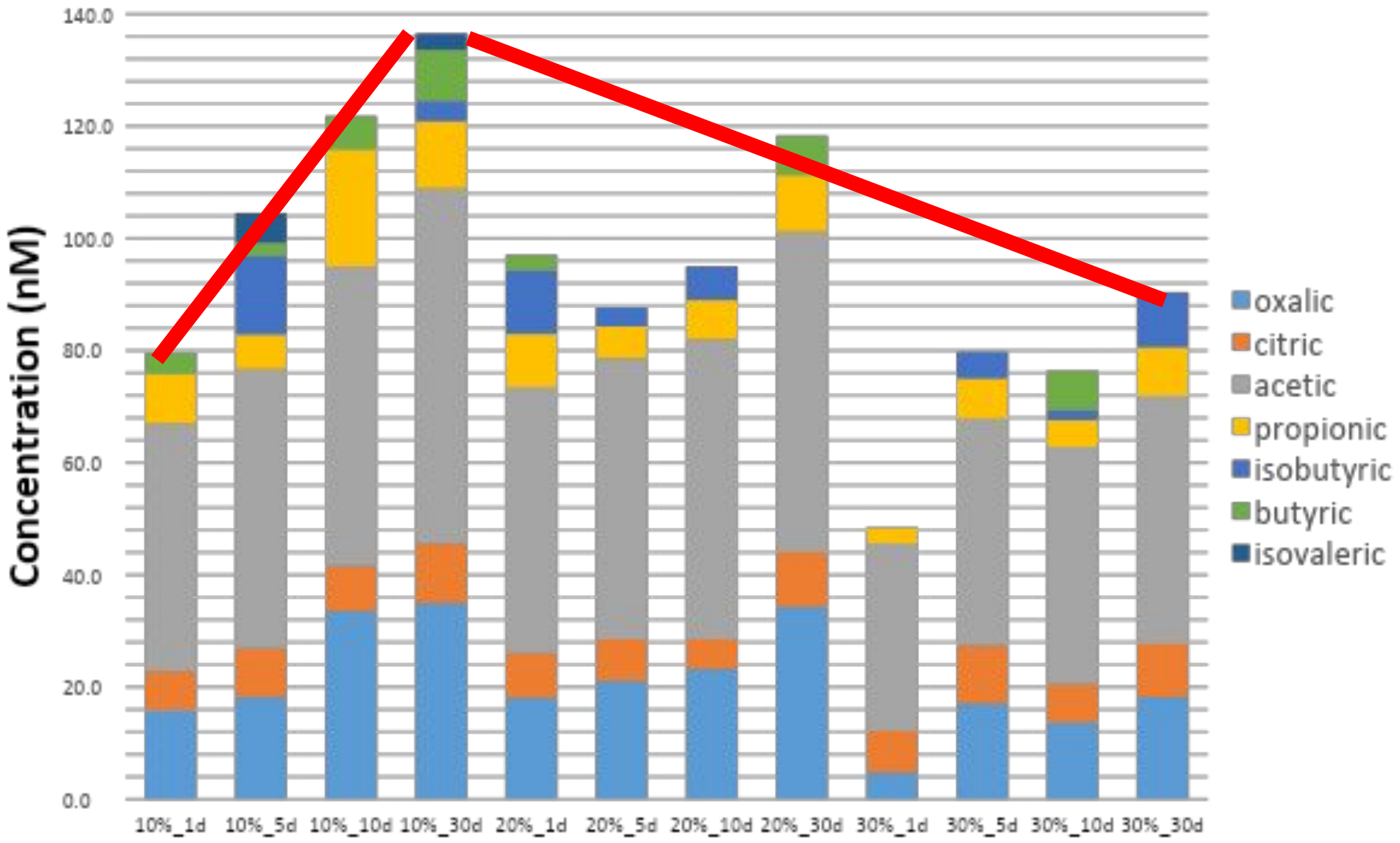
Aspergillus Niger



Sucrose: 90 g/L
S/L: 1 %
As. Niger: 4 %

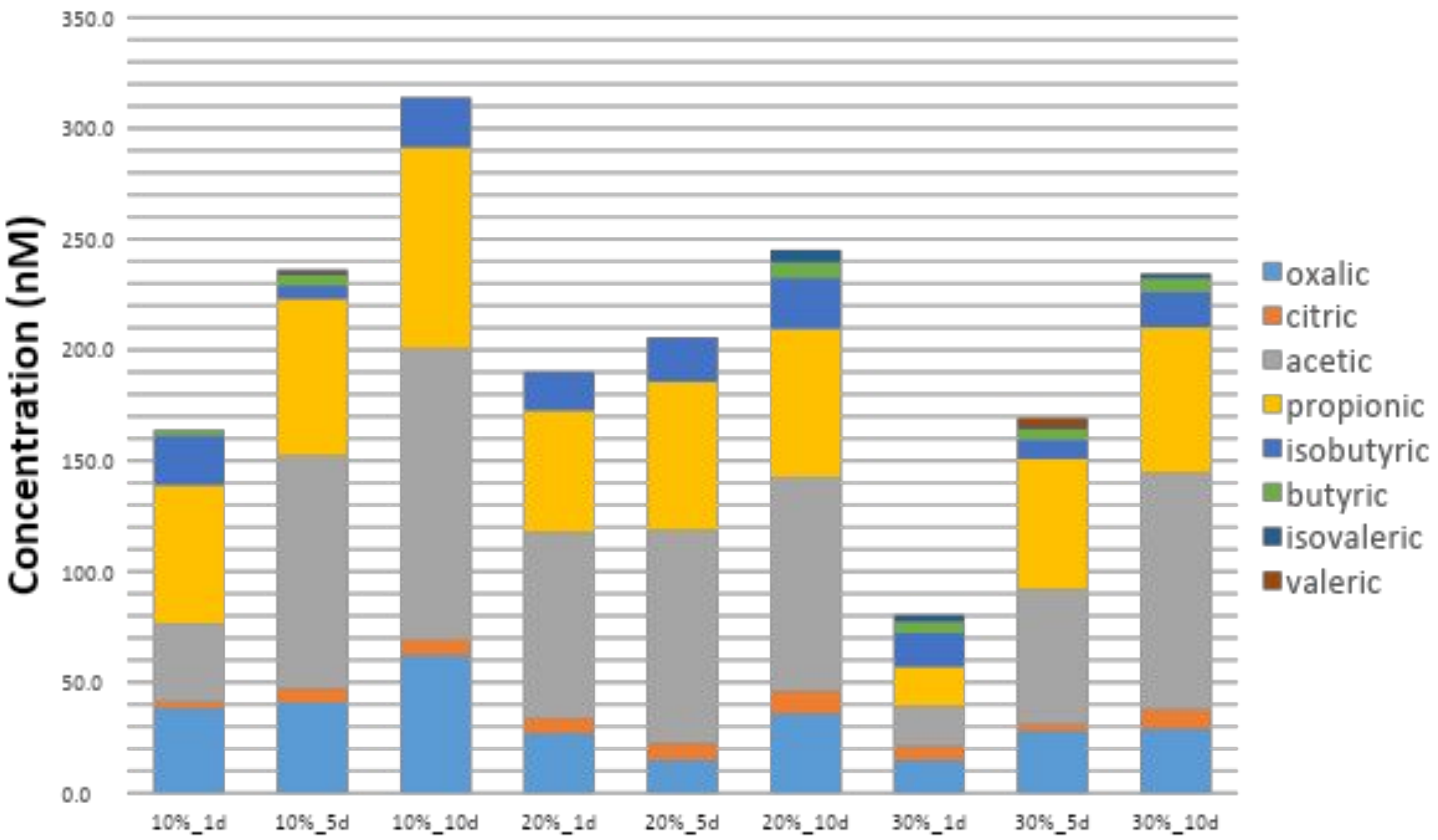
Organic Acids Production

Digestate



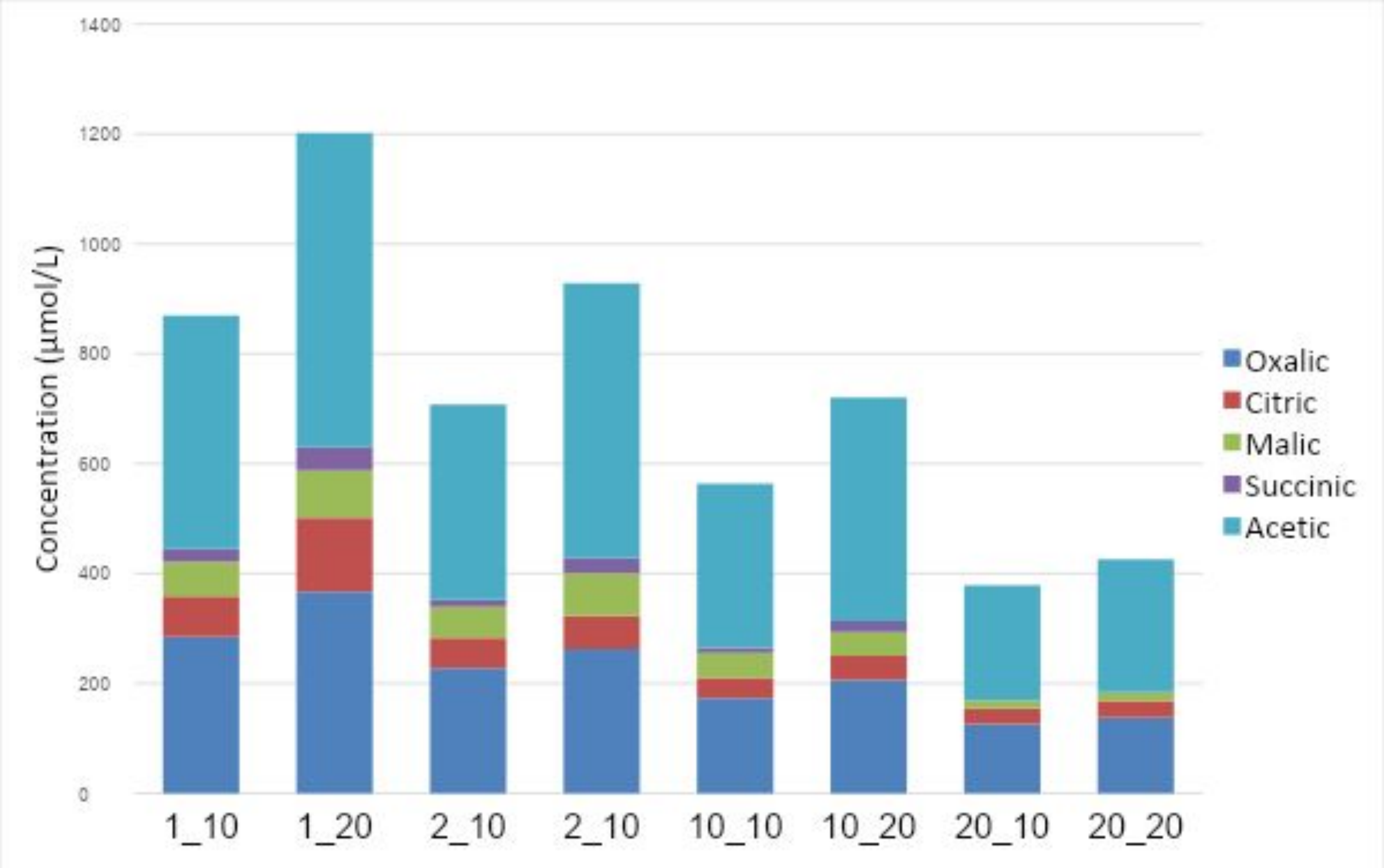
Organic Acids Production

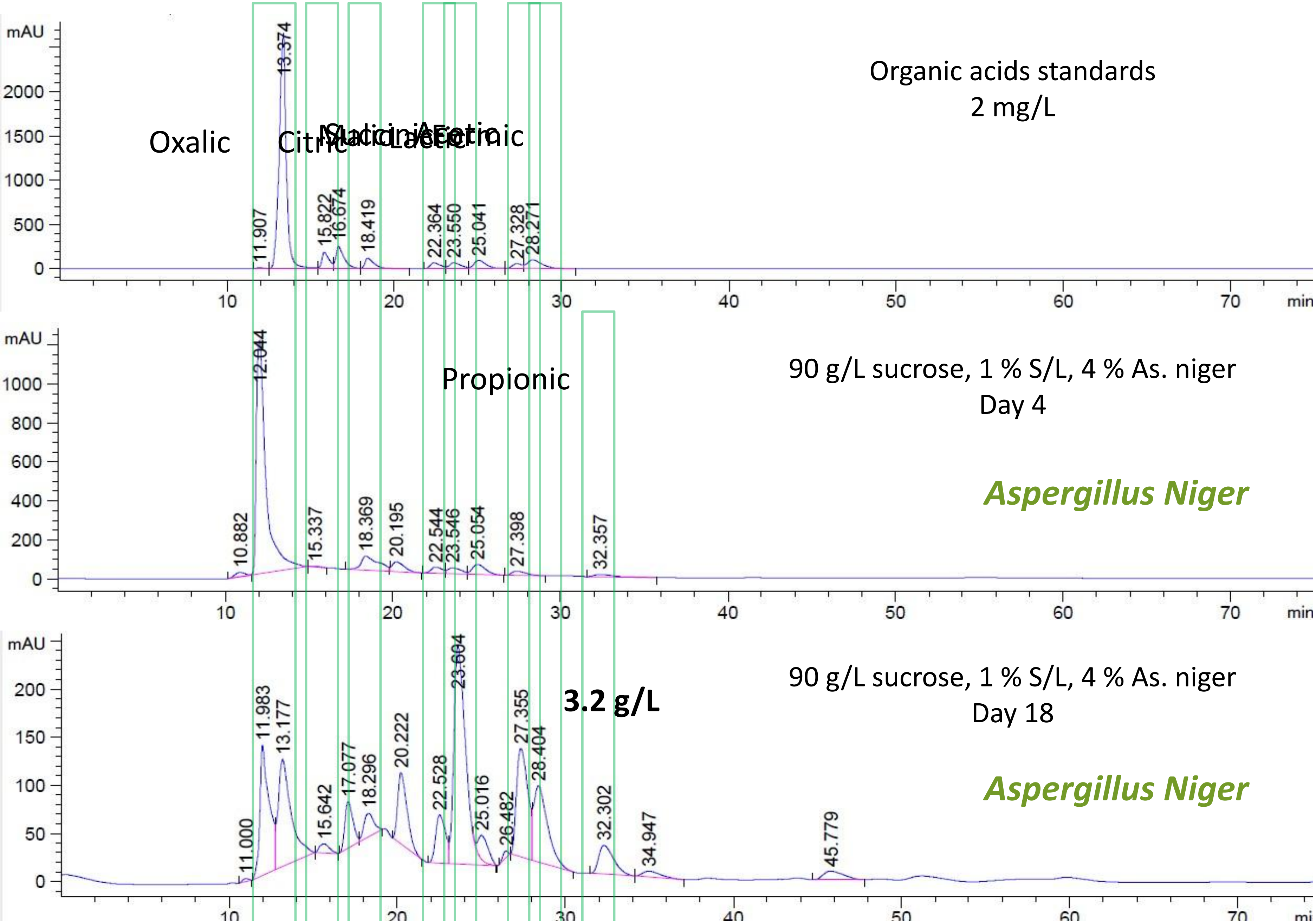
Digestate- Subculturing



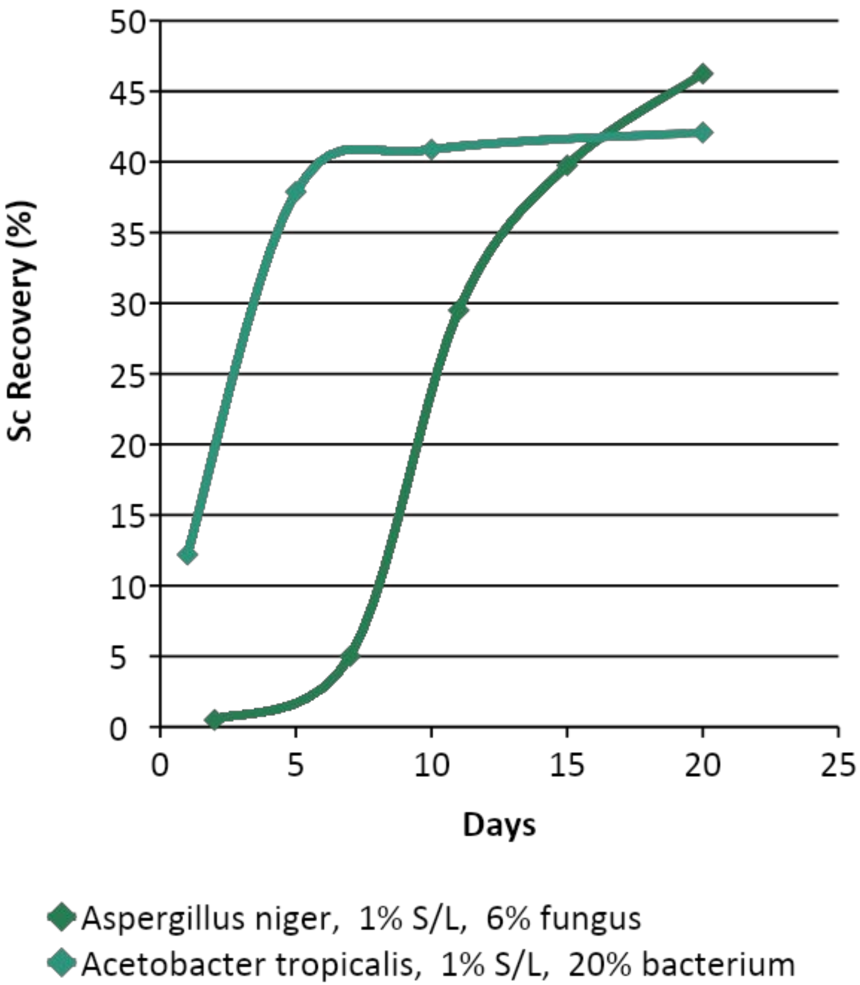
Organic Acids Production

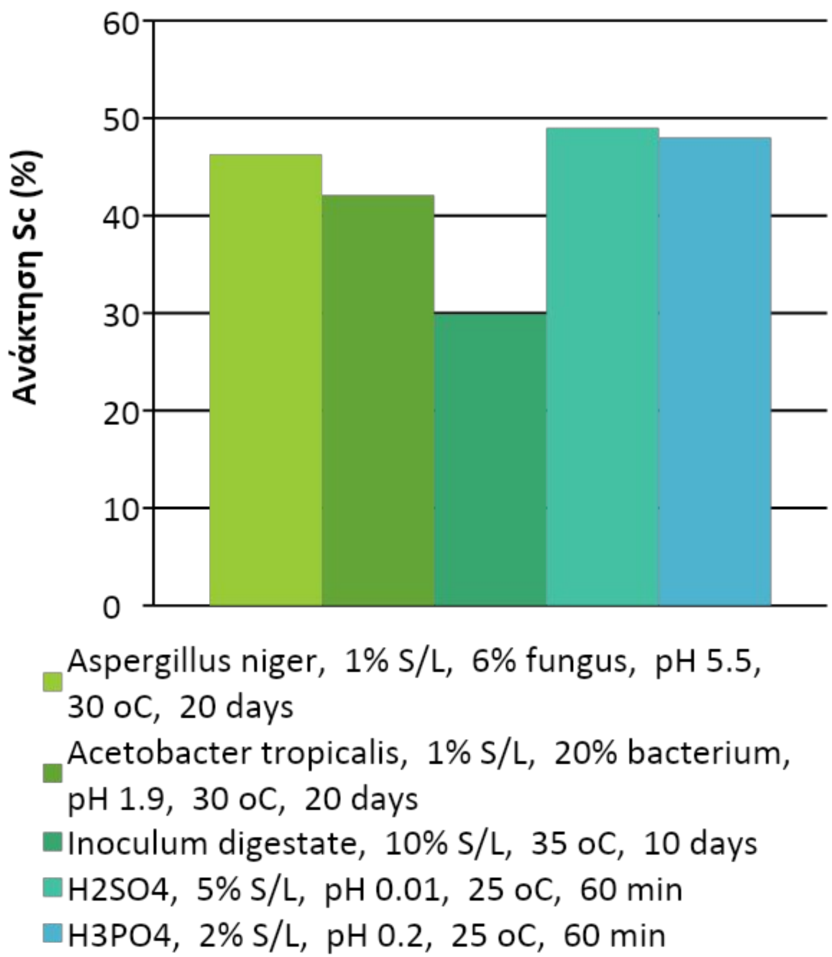
Acetobacter tropicalis



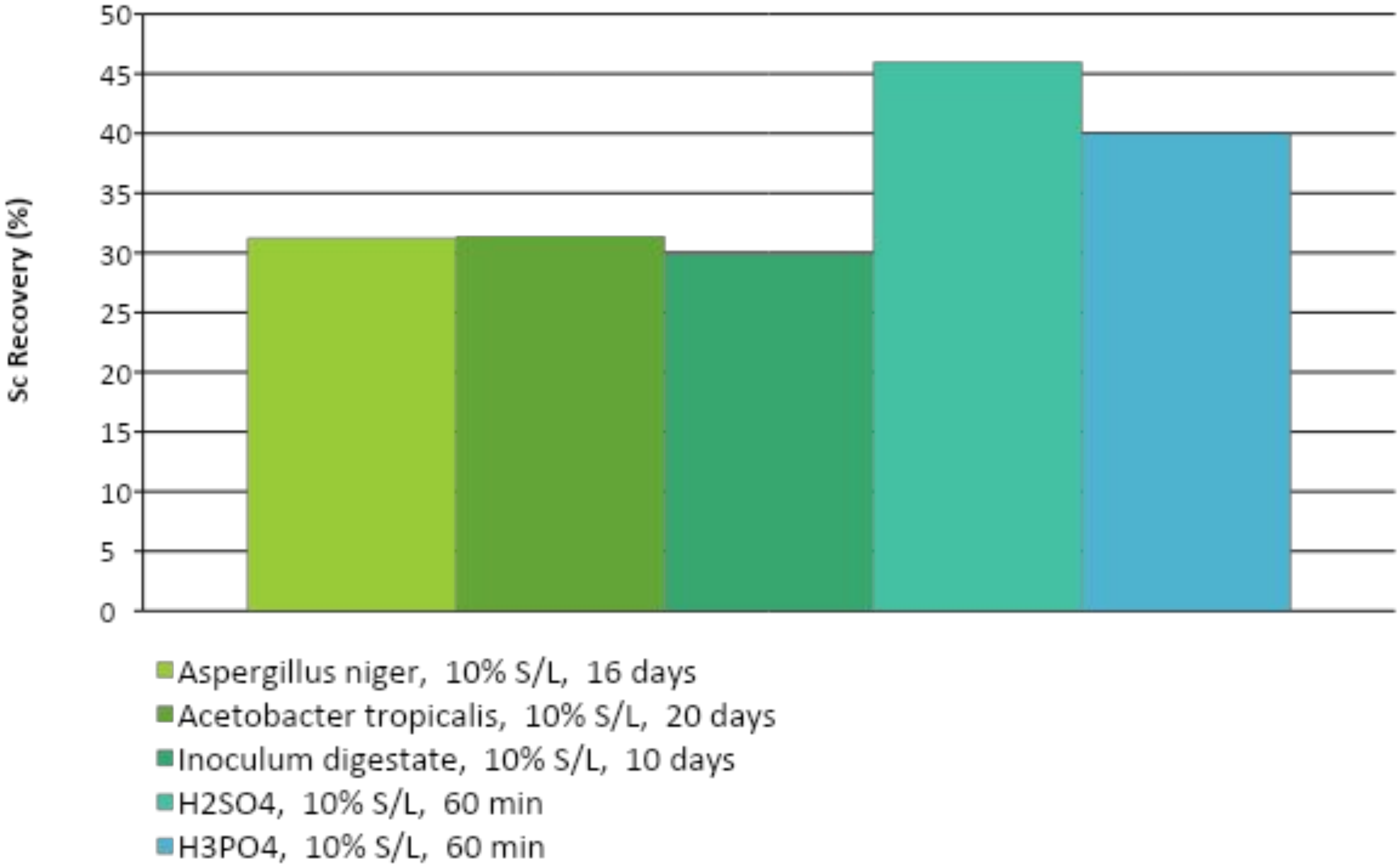

Organic acids standards
2 mg/L
Oxalic
Citric
Propionic
90 g/L sucrose, 1 % S/L, 4 % As. niger
Day 4
Aspergillus Niger
90 g/L sucrose, 1 % S/L, 4 % As. niger
Day 18
3.2 g/L
Aspergillus Niger
mAU
min

Maximum Sc recoveries





Sc Recovery – S/L 10%



Conclusions (1/2)

- After a longer acclimation the activated sludge inoculum (mixed culture) resulted in higher Sc recovery, equal to 33% (previous 20%) at 10% pulp density and shorter time.

- *Acetobacter tropicalis* resulted Sc recovery of 42% that was observed with 1% S/L- BR pulp density with 20% w/w of bacterium suspension, recorded after 20 days.

- *Aspergillus Niger* resulted in maximum Sc recovery: **46 %**

S/L	Sucrose	As. niger	pH	Days
1 %	140 g/L	6 %	5,5	20

Conclusions (2/2)

- *Acetobacter Tropicalis* resulted in mainly acetic and oxalic acids with lower concentrations of citric acid, malic and succinic acid.
- *Aspergillus Niger* resulted also in mainly acetic and oxalic acids with lower concentrations of citric, malic, succinic, lactic, propionic and formic acid.
- Synergistic effect of the different organic acids produced by microorganisms.
- Factors affecting Sc recovery
  - BR Solid to liquid ratios (S/L)
  - Sucrose concentrations
  - Subculturing

Future work

Optimization of the bioleaching process

- Different microorganisms A fungus, *Penicillium oxalicum*
- Investigation of **biosorption**
- Incubation time minimization
- Maximize Sc recovery

References

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THANK YOU FOR YOUR ATTENTION

Analytical Methods

- Chemical analysis of the leachate solutions after filtration for the identification of Sc was conducted by ICP-OES.
- The pH was measured using a digital pH-meter.
- The identification of organic acids was performed by HPLC and gas chromatograph.
- Volatile solids (VS) were carried out according to Standard Methods. VS determined as a measure of biomass production. By measuring VS, the organic portion of the total dry weight could be measured.
- The numbers of bacterial cell during bacterial growth was counted performed by standard plate count (SPC) method.
- Optical Density: Absorbance of the samples during time with a spectrophotometer at 600 nm.