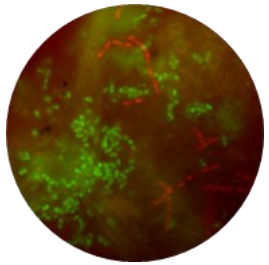
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
SUS-MIRRI.IT

Bioaugmentation strategies to improve the energy valorization of organic waste

Giulia Massini
Valentina Mazzurco Miritana

Rome, November 27th 2023

Laboratory of BIOtechnological Processes for Energy and Industry



The laboratory is engaged in activities concerning:

...research, technological development and demonstration activities in the field of biological processes for the conversion of different types of biomass into energy vectors such as:

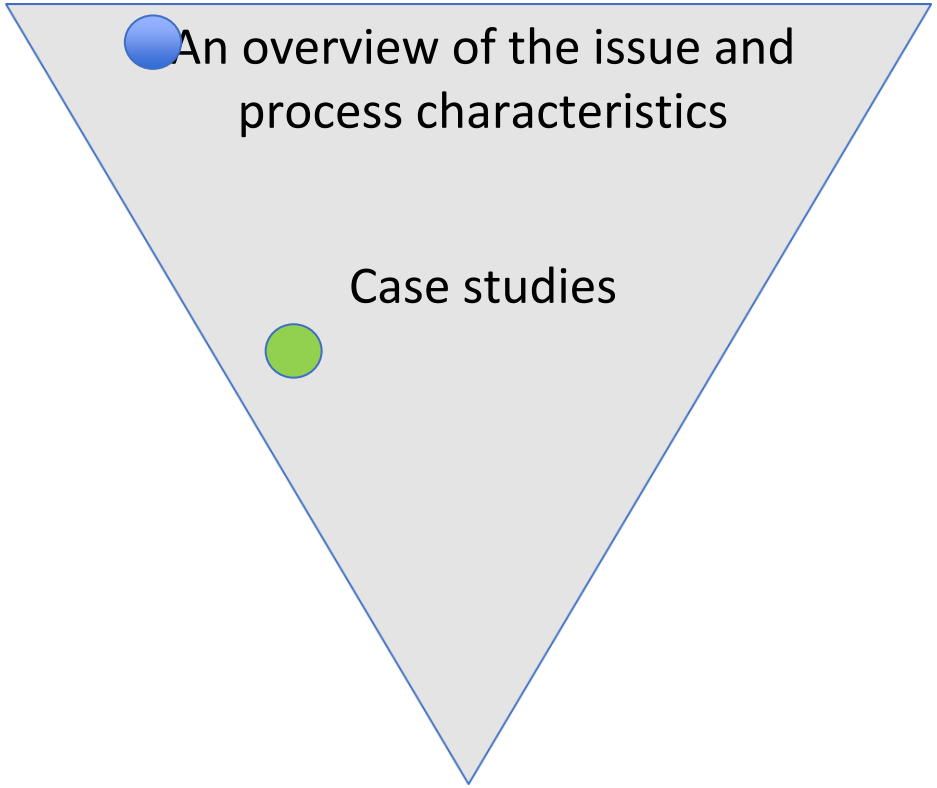
BIOGAS, BIOHYDROGEN, BIOMETHANE…

AND ADVANCED BIOFUELS

and their integration in a biorefinery perspective.....

Bioenergy productions

Producing energy exploiting organic waste and/or by products of low economic value

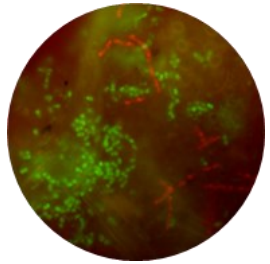


- Fermentations
- Anaerobic digestion process

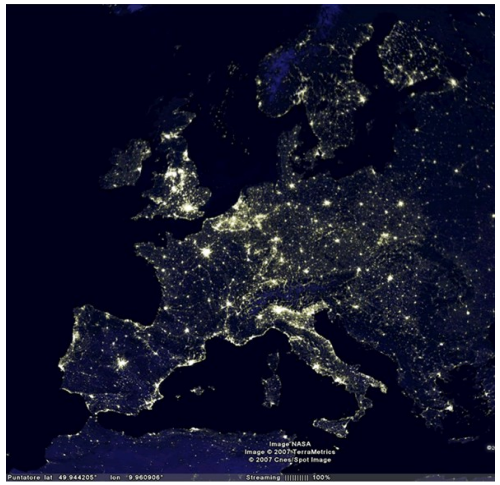
Strategies of:

- Bioaugmentation
- Biostimulation
- Bioremediation

It is mandatory a microbial ecology approach



Organic waste disposal and energy demand two issues associated with any human settlement



Anaerobic digestion (AD) is a sequence of metabolic steps by which microorganisms break down organic material in oxygen-free environments

AD is a spontaneous process occurring in marshes, wetlands, paddies, shallow freshwater, agroecosistems, digestive tract of herbivores

Pristine ecosystems

agroecosystems

to produce energy

heat

electricity

Gut of herbivorous

…and is applied in anaerobic reactors,

i.e. engineered ecosystems

fed with biomass/organic wastes (food, manure, cheese whey…)

BIOGAS

Upgrading

BIOMETHANE

(CH4 ≥ 97%)

Role of microorganisms

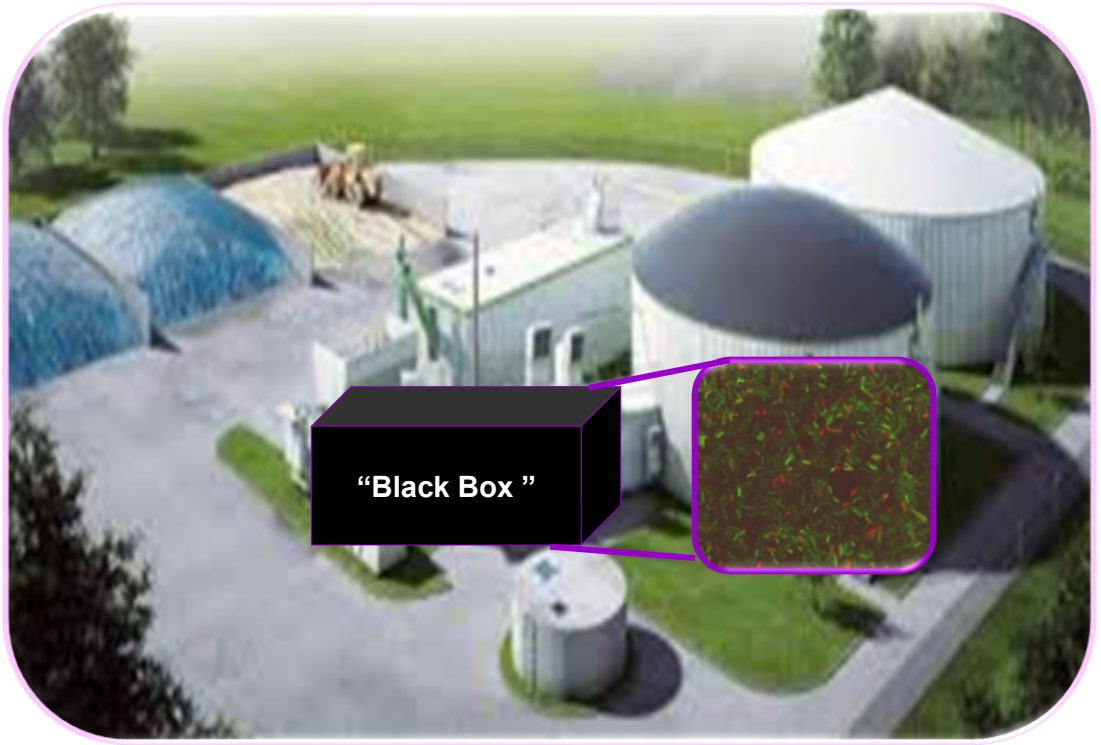
Most of the AD plants works below their carrying capacity and sub-optimals productions are obtained

This is in part due to the fact that composition and dynamics of the microbial community,
the **very engine** of the AD process,
are not well known

It is managed as ***Black Box***

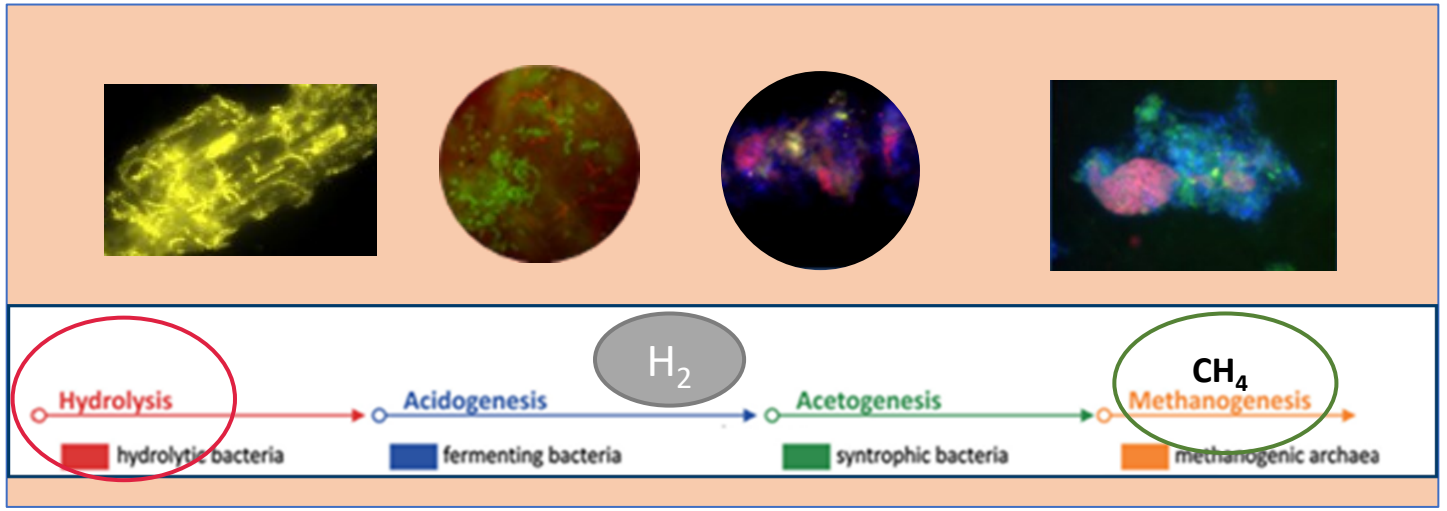
The necessity to increase AD efficiency,
- reducing retention times
- increasing methane yields and amount
- avoiding process failure

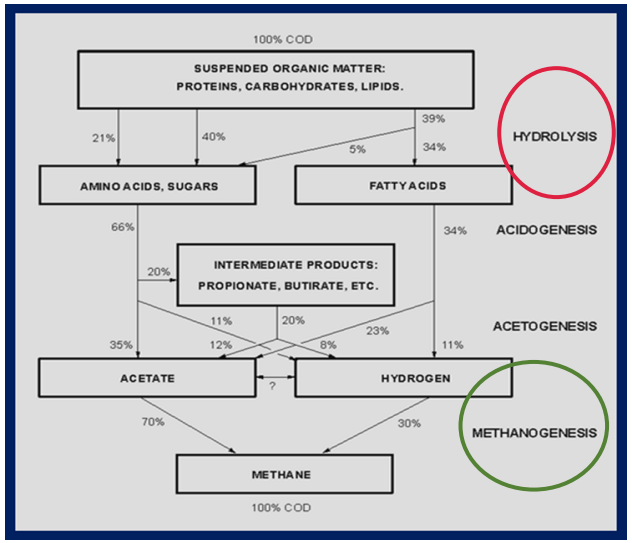
requires:
- to identify the critical steps of the process
- to understand the interactions occurring within the microbial community
- to find nature based solutions



Anaerobic Digestion Process: an ecological point of wiew

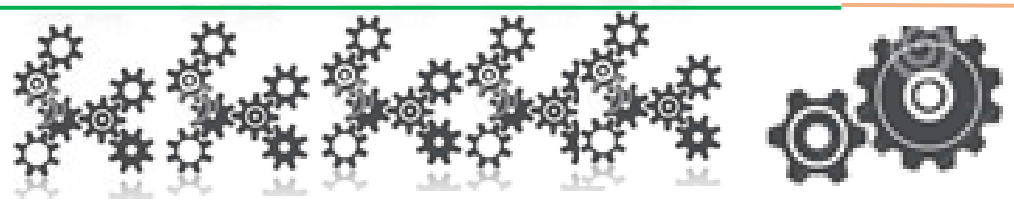
Four main functional microbial components





Bacteria

Archaea

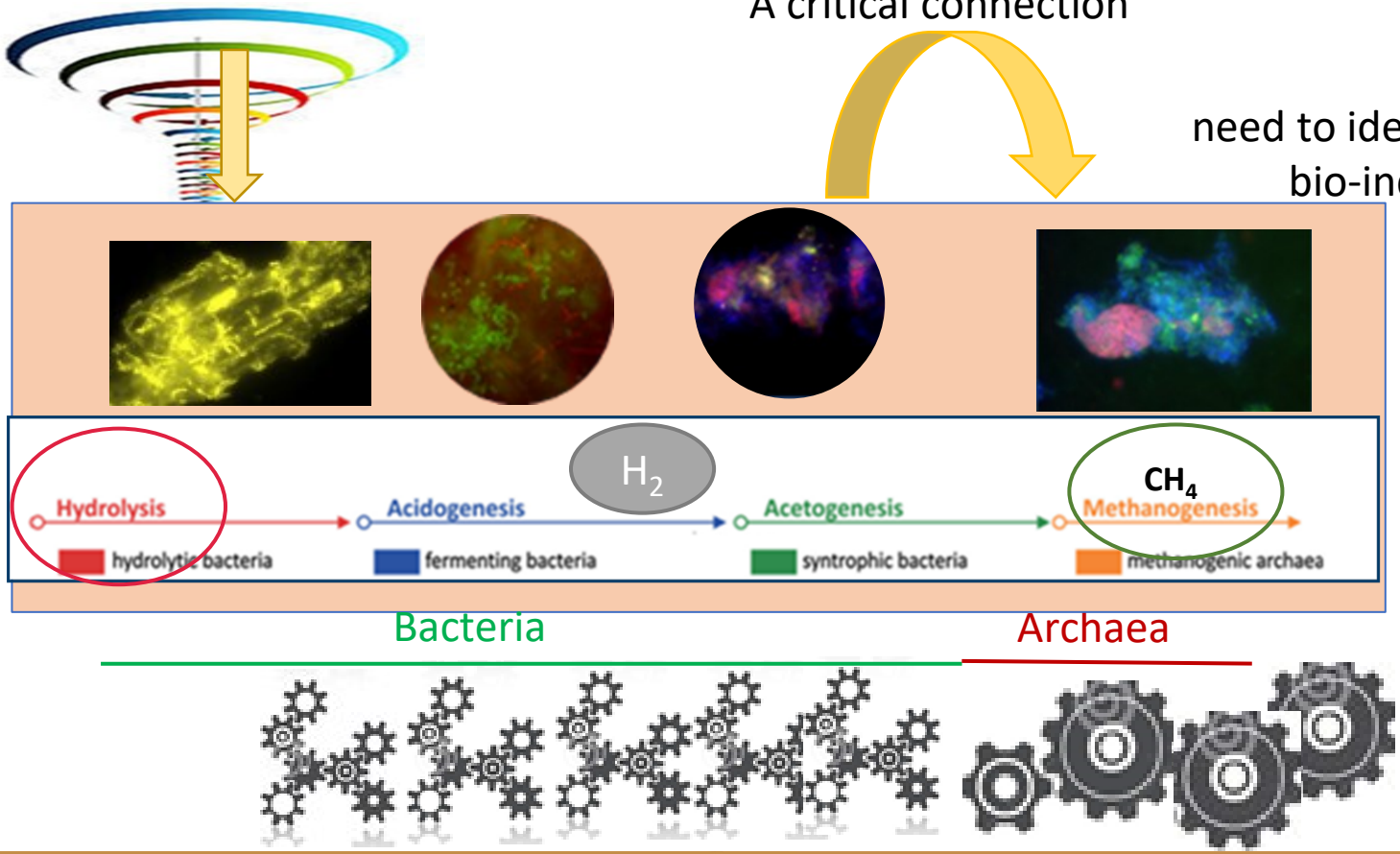


Anaerobic Digestion Trophic Chain: critical steps

Hydrolysis:on its efficiency depends the amount of the final CH4 production

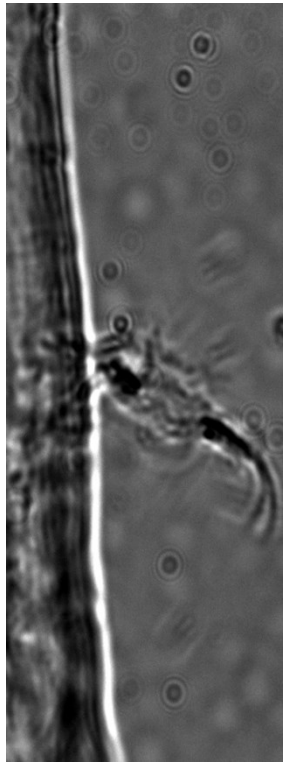
A critical connection

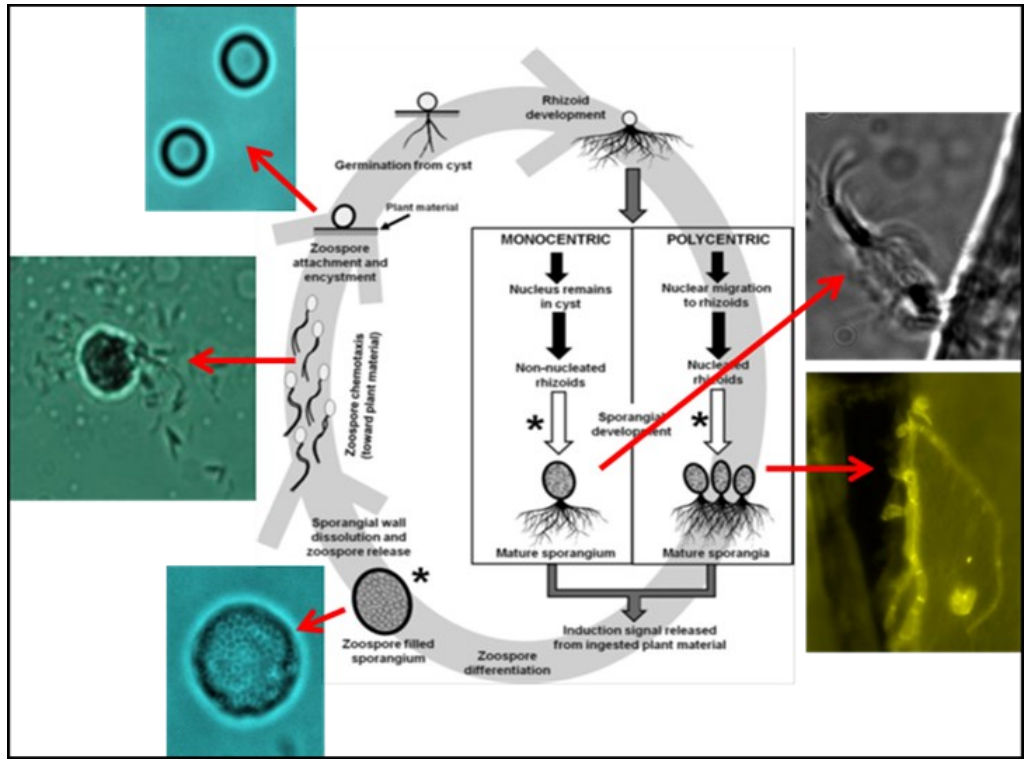
need to identify process bio-indicators

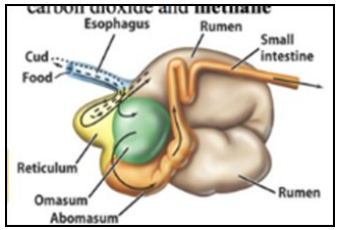


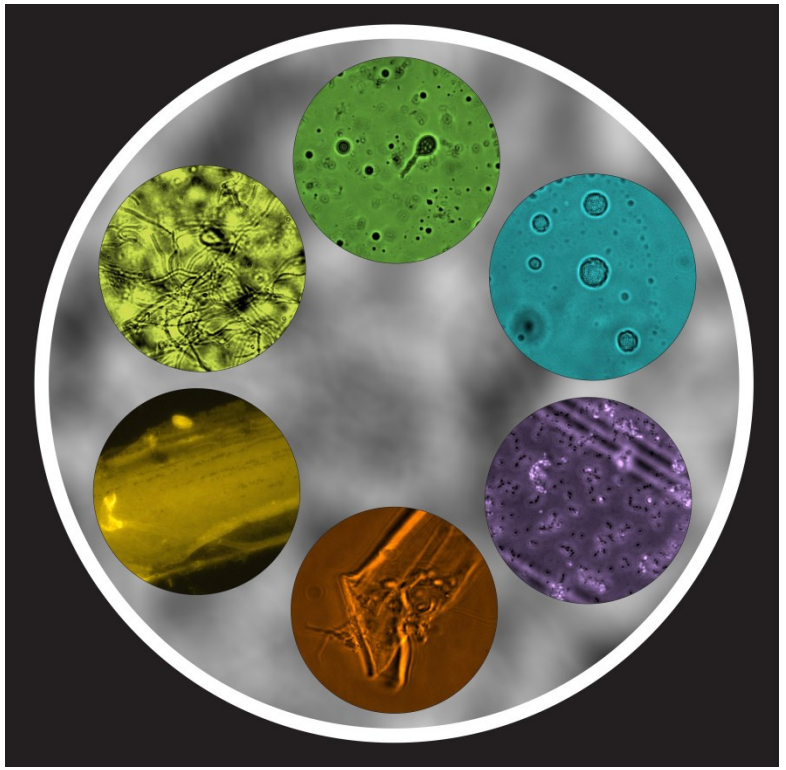
Anaerobic Fungi: a promising microbial source for biotechnological applications

Life cycle





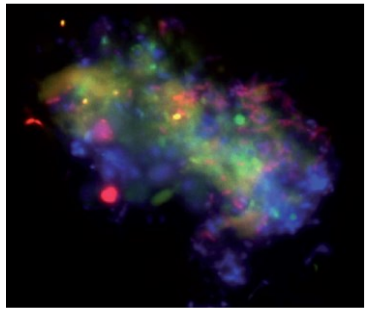


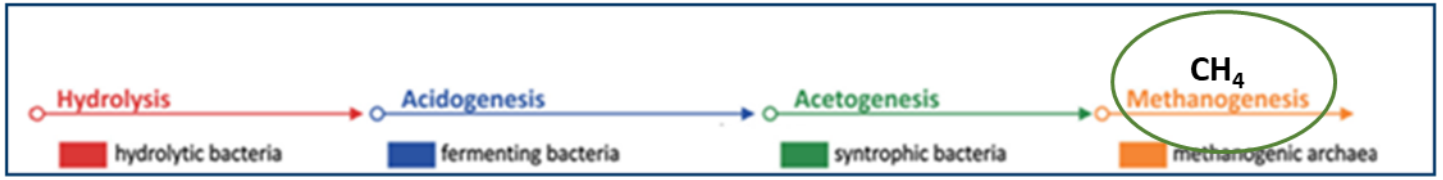


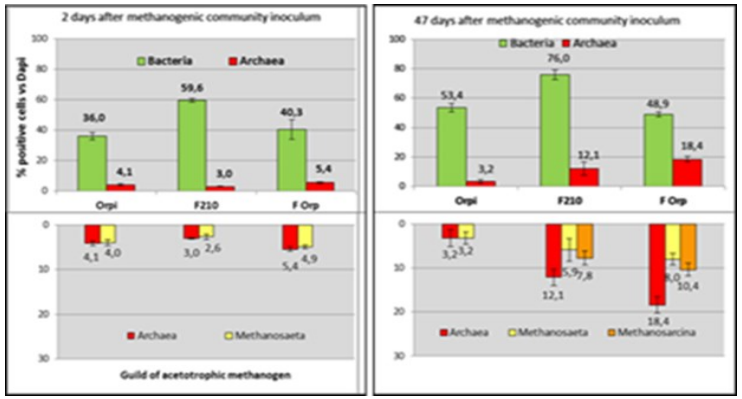
Anaerobic Digestion Process: the methanogenic phase and and identification of process bio-indicators

a phase performed by Archaea, micro-organisms that have slower duplication times than Bacteria and thus control the speed of CH_4 production and sometimes hinder it.

They can act as a stopper







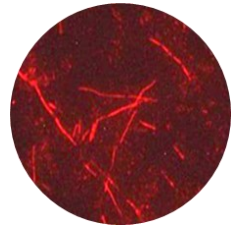
Ecology

Taxonomy

Methanosaeta sp

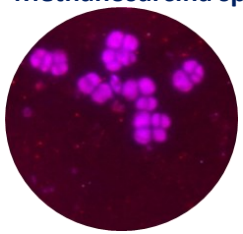
specialist acetoclast

($CH_3COOH \rightarrow CH_4 + CO_2$)



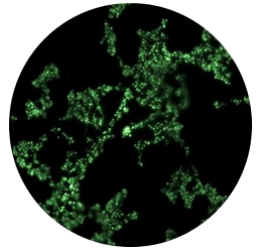
Methanosarcina sp

generalist



specialist hydrogenotrphic

($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$)



Methanobrevibacter smithii

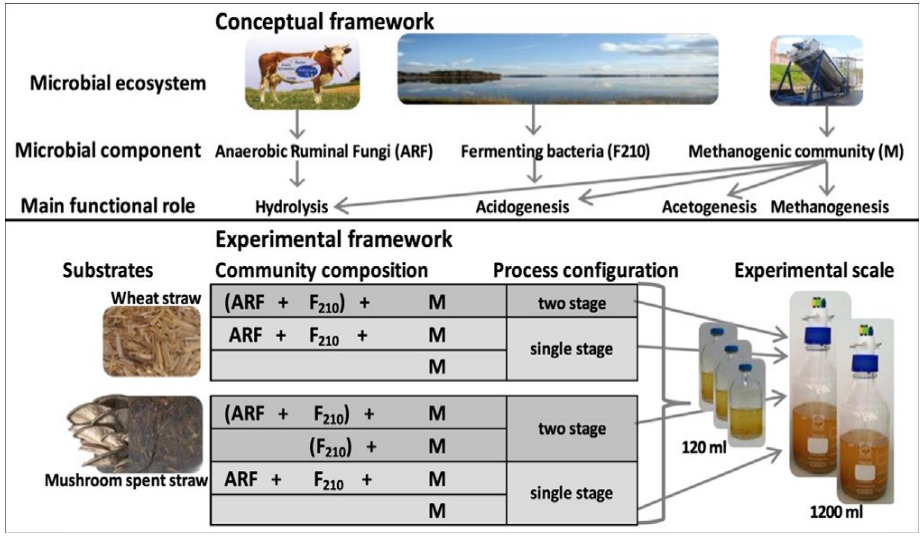
Case Studies

Case study 1: Combined bioaugmentation with different microbial functional components to produce CH_4 from straws

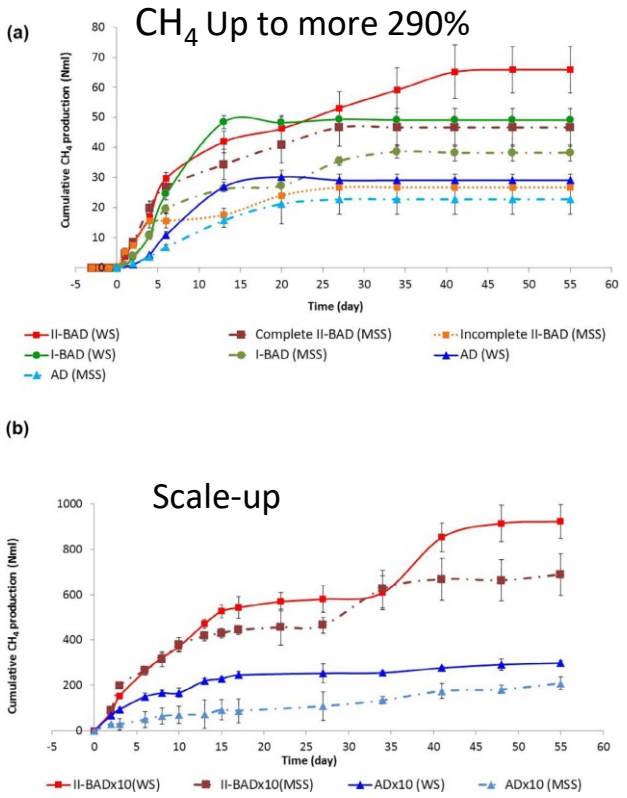
ELSEVIER
Bioresource Technology
Volume 260, July 2018, Pages 364-373

Combined bioaugmentation with anaerobic ruminal fungi and fermentative bacteria to enhance biogas production from wheat straw and mushroom spent straw

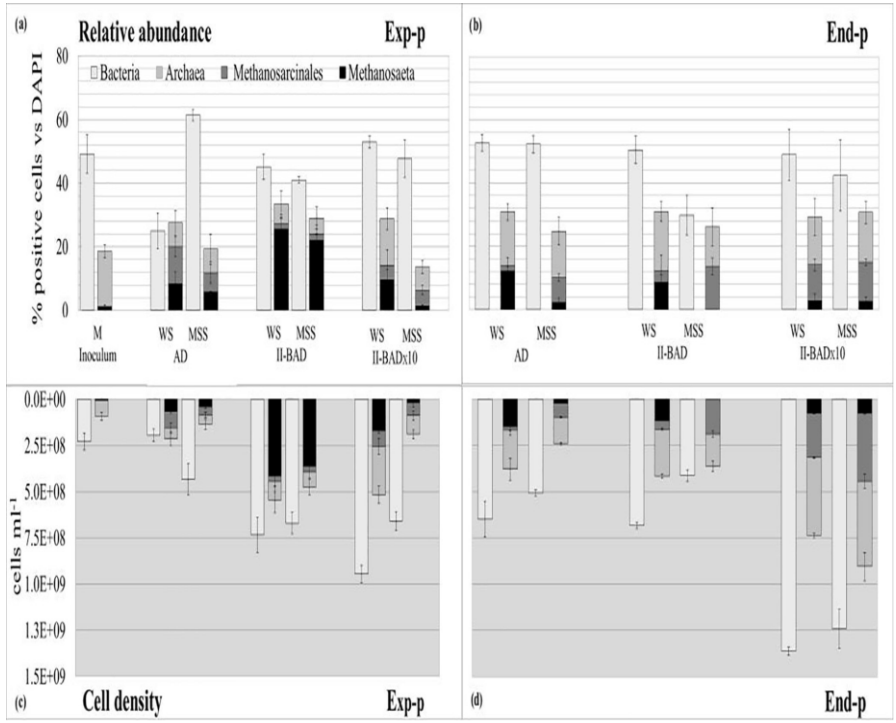
Alberto Ferraro [a], Giulia Dottorini [b c], Giulia Massini [b], Valentina Mazzurco Miritana [b d], Antonella Signorini [b], Giuseppe Lembo [b d], Massimiliano Fabbricino [e]



CH_4 Up to more 290%



Microbial investigation



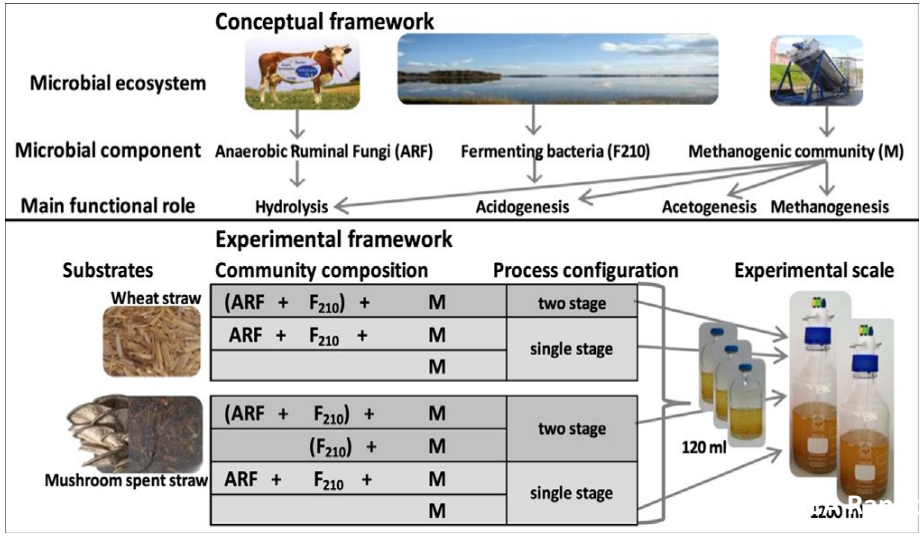
Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
SUS-MIRRI.IT

Case study 1: Combined bioaugmentation with different microbial functional components to produce CH_4 from straws

ELSEVIER
Bioresource Technology
Volume 260, July 2018, Pages 364-373

Combined bioaugmentation with anaerobic ruminal fungi and fermentative bacteria to enhance biogas production from wheat straw and mushroom spent straw

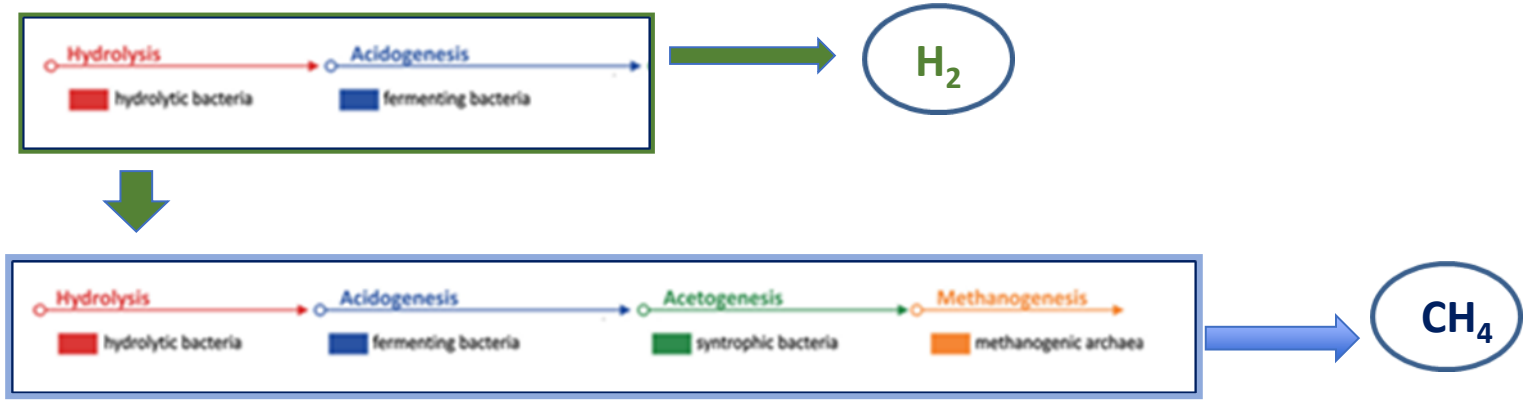
Alberto Ferraro [a], Giulia Dottorini [b c], Giulia Massini [b], Valentina Mazzurco Miritana [b d], Antonella Signorini [b], Giuseppe Lembo [b d], Massimiliano Fabbricino [e]



Anaerobic fungi

F210 inoculum

- Enrichmed in a Continuous Stirred Tank Reactor (CSTR)
- Microbial community characterization using molecular techniques
- F210 was previously successfully tested for H_2 production on different kinds of organic wastes.



Case study 1.1: A simplified model of combined bioaugmentation with different microbial functional components to produce CH_4 from straws

Science of the Total Environment 691 (2019) 885–895
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

A simplified model to simulate bioaugmented anaerobic digestion of lignocellulosic biomass: Biogas production efficiency related to microbiological data

Alberto Ferraro [a,*], Giulia Massini [b], Valentina Mazzurco Miritana [b], Antonella Signorini [b], Marco Race [c], Massimiliano Fabbricino [a]

MATHEMATICAL MODEL CALIBRATION

BIOAUGMENTATION TESTS (120 ml)

EXPERIMENTAL FRAMEWORK

Batch mode	1st stage	2nd stage
II-BAD	ARF+F210	+M
I-BAD		ARF+F210+M
AD		M

MEASURED PARAMETERS
- CH_4 production
- Process intermediates (VFAs)

MODEL PARAMETERS OPTIMIZATION

RESPONSE SURFACE METHODOLOGY:
- Normalized root mean square error (NRMSE)
- Modelling Efficiency (ME)
- Index of Agreement (IoA)

MATHEMATICAL MODEL VALIDATION

MODEL VALIDITY ASSESSMENT

USE OF CALIBRATED PARAMETERS:
- K_d (d^{-1}) – substrate degradation constant
- α – hydrolysis/ methanogenesis partition coefficient

SCALED BIOAUGMENTATION TESTS (12000 ml)

EXPERIMENTAL FRAMEWORK
- 100xII-BAD
- 100xI-BAD
- 100xAD

MEASURED PARAMETERS
- CH_4 production
- Process intermediates (VFAs)
- Microbial community composition

STATISTICAL ANALYSIS

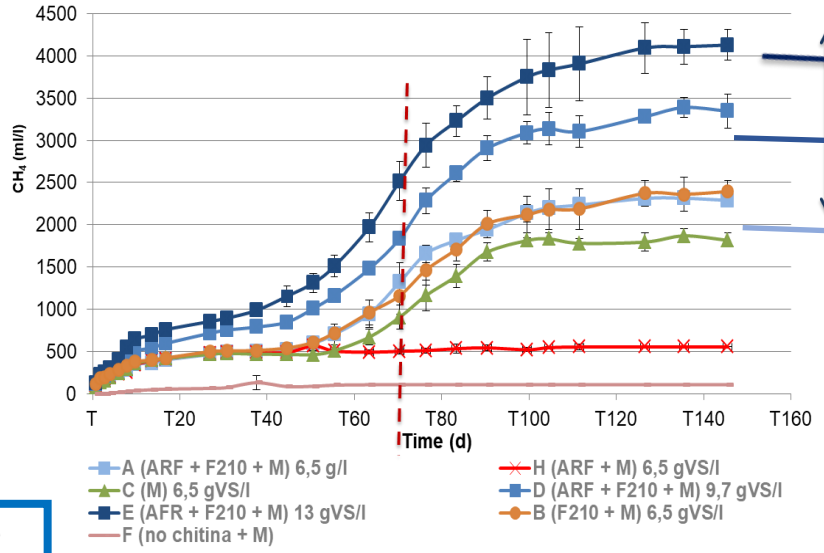
Case study 2: Bioaugmented AD community to enhance CH_4 production from shrimp shells

fermentation MDPI

Article

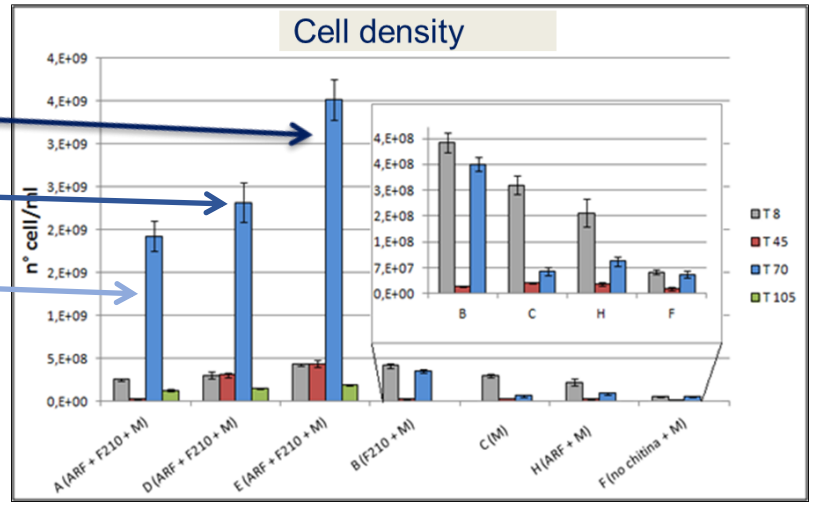
Bioaugmentation Strategies for Enhancing Methane Production from Shrimp Processing Waste through Anaerobic Digestion

Valentina Mazzurco Miritana [1,*], Alessia Gaetani [1,2], Antonella Signorini [1], Antonella Marone [1] and Giulia Massini [1,*]



+ 82%

+ 47%



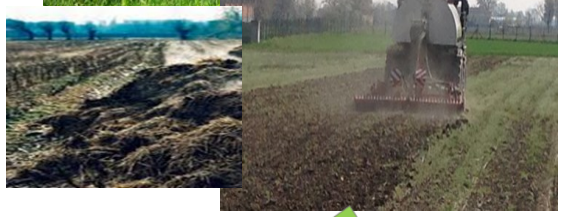
Bioaugmentation of chitinous substrate improve CH_4 production

Case study 3: AZeRO project

Antibiotics as Emerging Contaminants : What's the fate of veterinary antibiotics used in farms?

ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development

IRSA CNR



Effects of antibiotics on the efficiency of the anaerobic digestion process

Sulfamethoxazole
Enrofloxacin
Ciprofloxacin

Effects of anaerobic digestion on the degradation of antibiotics

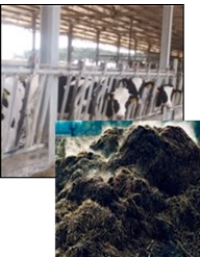
Agrozootechnical waste used to feed biogas plants

Digestate used as a fertilizer or amendment for agricultural soils

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
SUS-MIRRI.IT

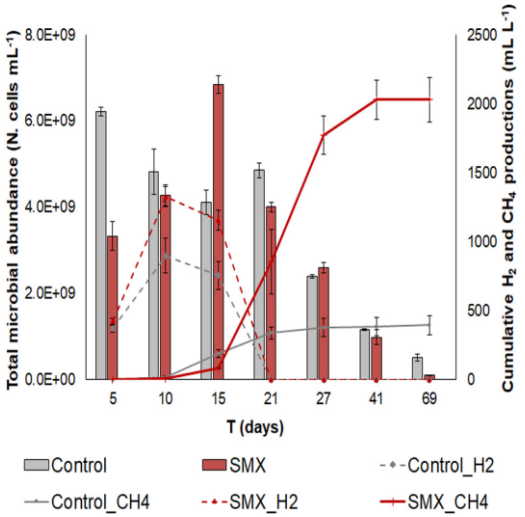
AZeRO project: some experimetations

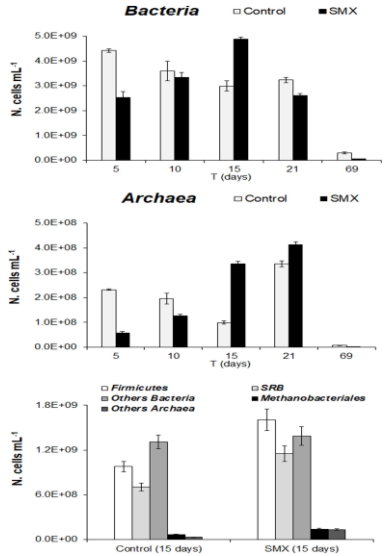
frontiers in Microbiology
ORIGINAL RESEARCH
published: 16 September 2020
doi: 10.3389/fmicb.2020.537783



Effects of Sulfamethoxazole on the Microbial Community Dynamics During the Anaerobic Digestion Process

Valentina Mazzurco Miritana[1], Giulia Massini[1,2*], Andrea Visca[1], Paola Grenni[1], Luisa Patrolecco[2], Francesca Spataro[3], Jasmin Rauseo[3], Gian Luigi Garbini[1], Antonella Signorini[2], Silvia Rosa[2] and Anna Barra Caracciolo[1]

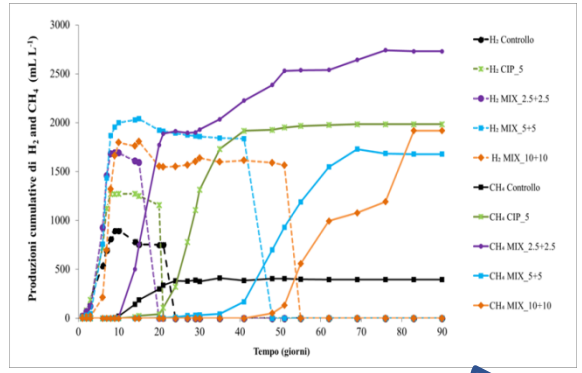


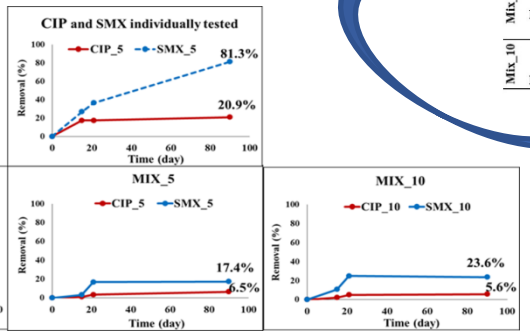


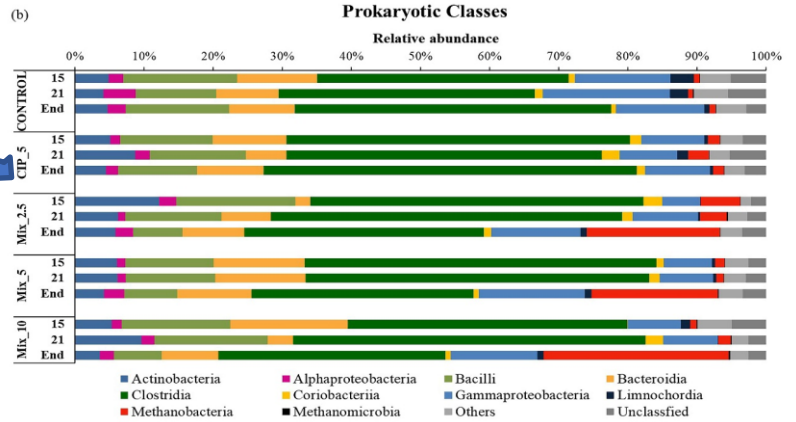
antibiotics
MDPI
Article

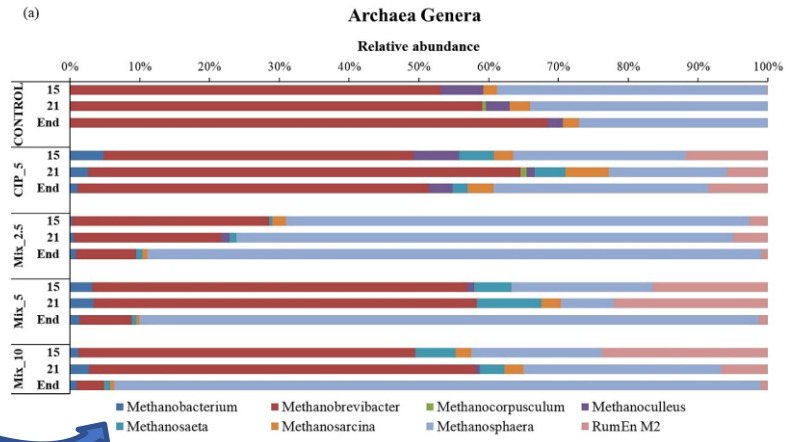
Effects of Ciprofloxacin Alone or in Mixture with Sulfamethoxazole on the Efficiency of Anaerobic Digestion and Its Microbial Community

Valentina Mazzurco Miritana [1,2], Luisa Patrolecco [3,*], Anna Barra Caracciolo [2,*], Andrea Visca [2], Flavia Piccinini [1], Antonella Signorini [1], Silvia Rosa [1], Paola Grenni [2], Gian Luigi Garbini [2], Francesca Spataro [3], Jasmin Rauseo [3] and Giulia Massini [1,2]









Case study 4: A novel enrichment approach to obtain specific microbial functional components

Bioresource Technology 313 (2020) 123703

Contents lists available at ScienceDirect

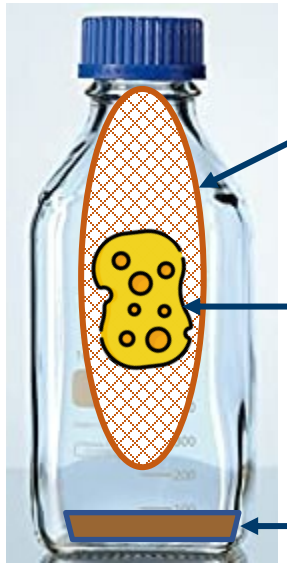
Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

A novel enrichment approach for anaerobic digestion of lignocellulosic biomass: Process performance enhancement through an inoculum habitat selection

Alberto Ferraro[a,*], Giulia Massini[b], Valentina Mazzurco Miritana[b], Silvia Rosa[b], Antonella Signorini[b], Massimiliano Fabbricino[a]

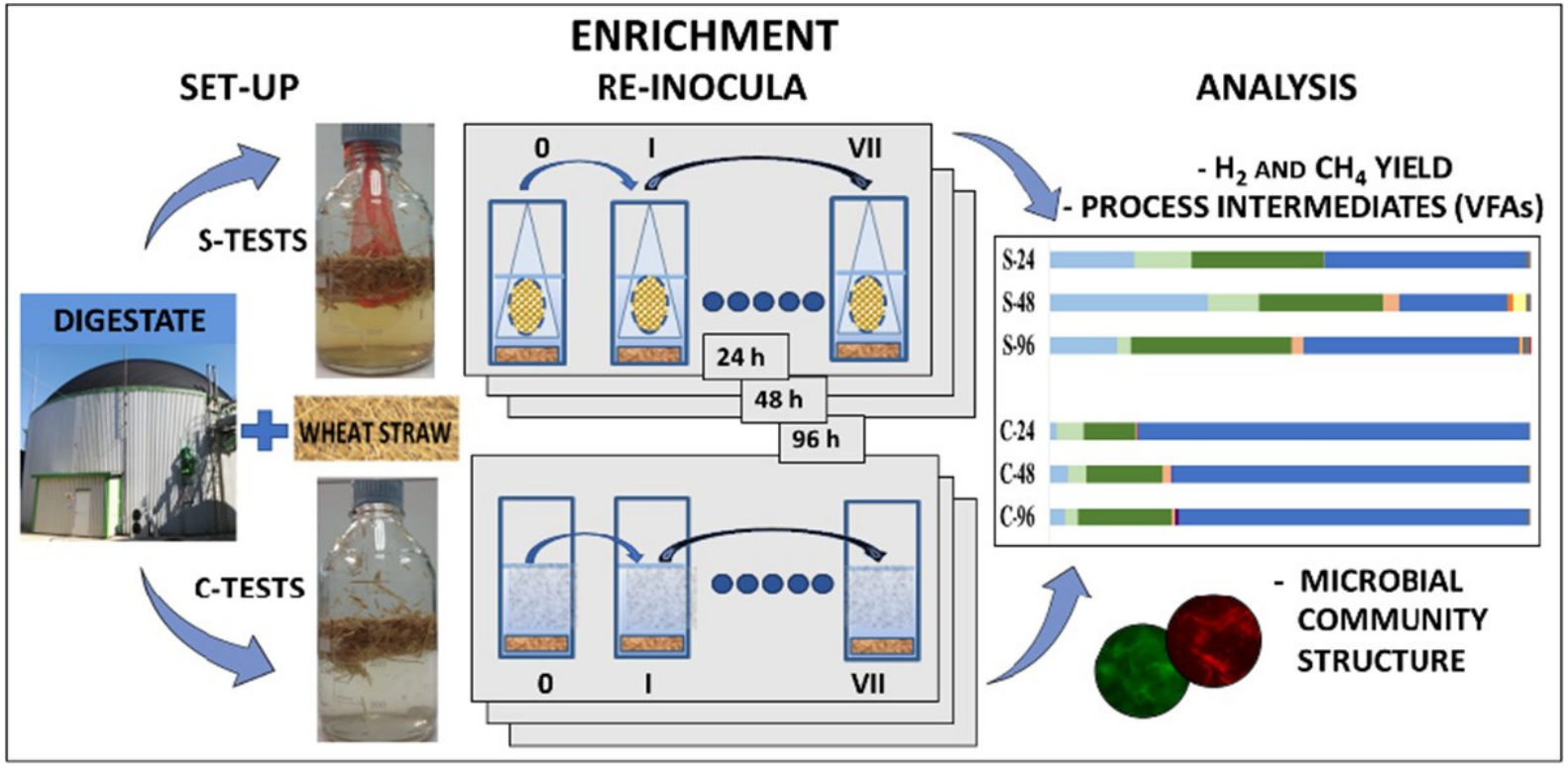
[a] Department of Civil, Architectural and Environmental Engineering, University of Naples "Federico II", Via Claudio 21, 80125 Naples, Italy
[b] Department of Energy Technologies, Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Via Anguillarese 301, 00123 Rome, Italy



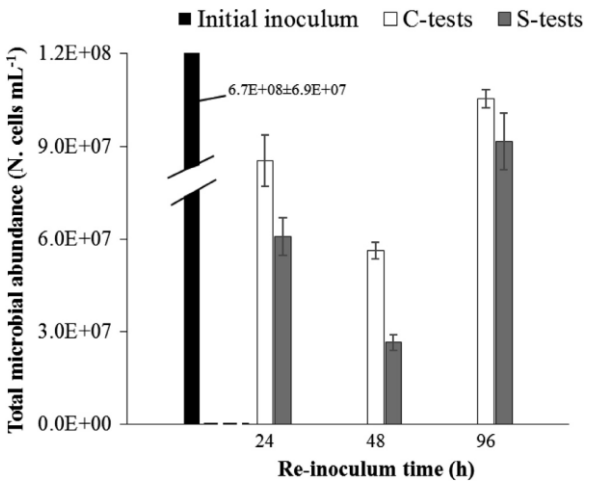
MESH (3x3 mm)

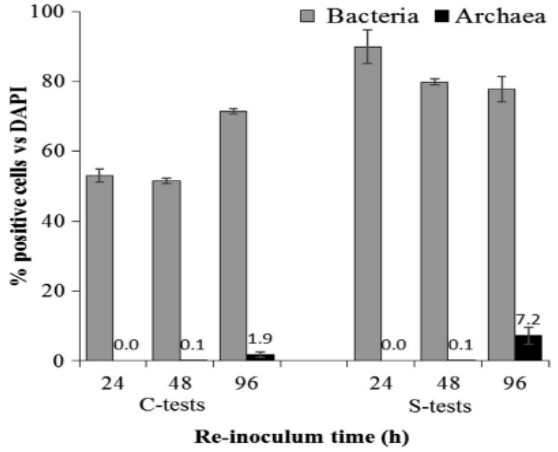
STERILIZED NATURAL SPONGE (120°; 15')
(holding 10 mL of medium)

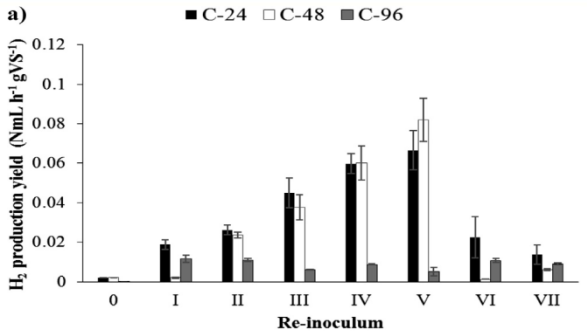
WHEAT WTRAW and DIGESTATE

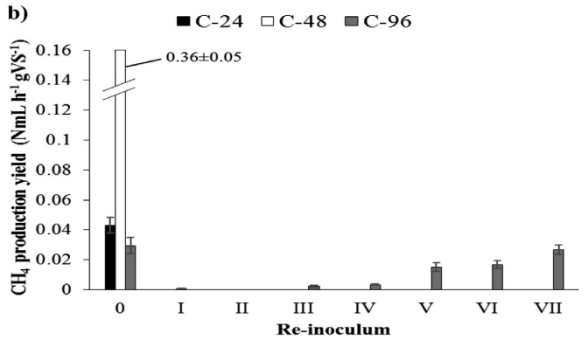


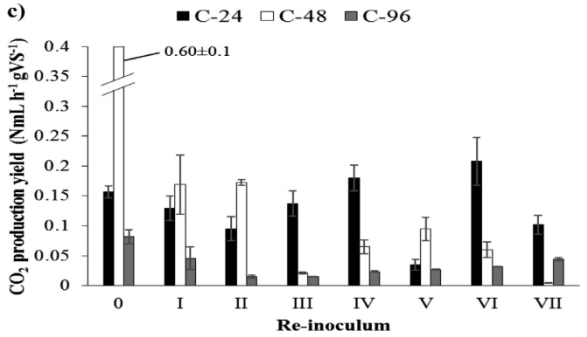
Case study 4: some results

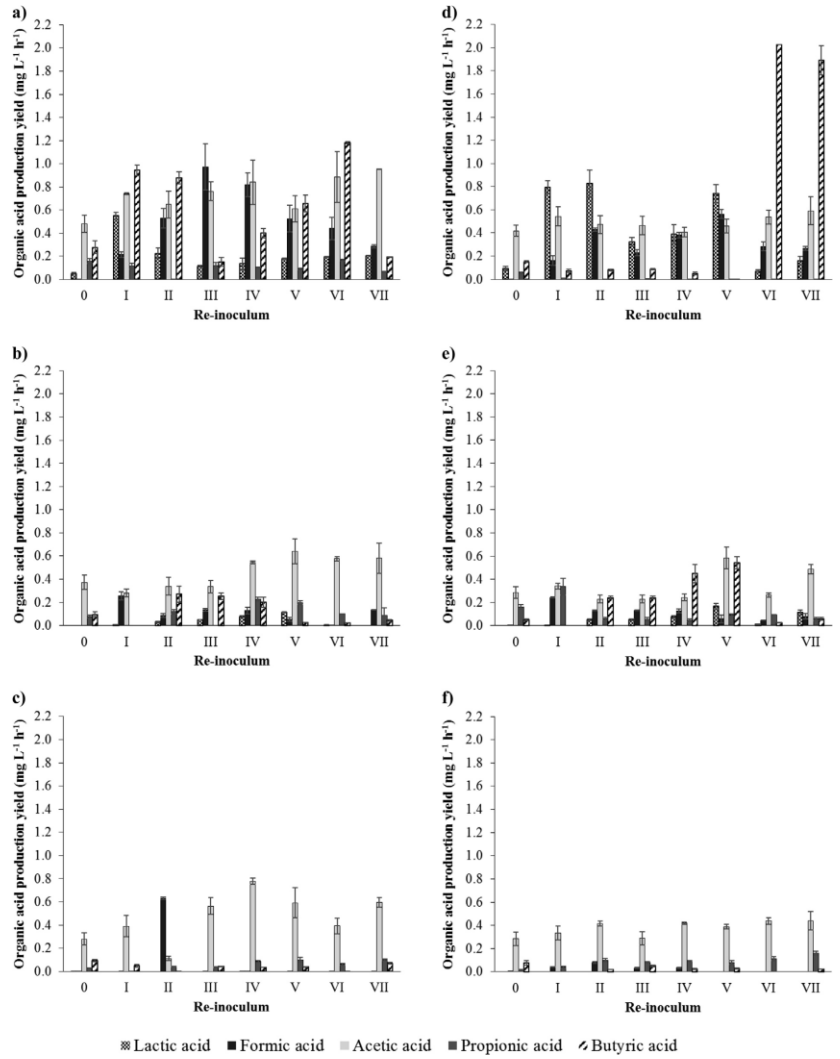












Case studies 5: Bioaugmentation strategy to enhance PAHs degradation using the selected inoculum

Chemosphere 275 (2021) 130091

Contents lists available at ScienceDirect

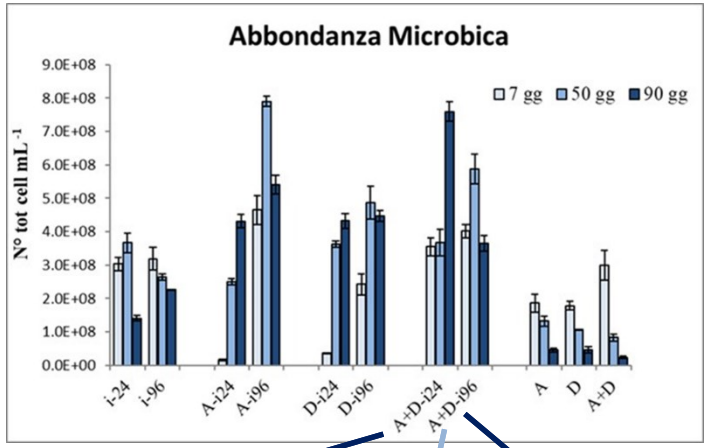
Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Bioaugmentation strategy to enhance polycyclic aromatic hydrocarbons anaerobic biodegradation in contaminated soils

Alberto Ferraro [a, b], Giulia Massini [c], Valentina Mazzurco Miritana [c], Antonio Panico [d, e, *], Ludovico Pontoni [a], Marco Race [f], Silvia Rosa [c], Antonella Signorini [c], Massimiliano Fabbricino [a], Francesco Pirozzi [a]

[a] Department of Civil, Architectural and Environmental Engineering, University of Naples "Federico II", Via Claudio 21, 80125, Naples, Italy
[b] Department of Civil, Environmental, Land, Building Engineering and Chemistry, Polytechnic University of Bari, Via E. Orabona 4, 70125, Bari, Italy
[c] Department of Energy Technologies, Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Via Anguillarese 301, 00123, Rome, Italy
[d] Department of Engineering, University of Campania "L. Vanvitelli", Via Roma, 29, 81031, Aversa, Italy
[e] Telematic University Pegaso, Piazza Trieste e Trento 48, Naples, Italy
[f] Department of Civil and Mechanical Engineering, University of Cassino and Southern Lazio, Via di Biasio 43, 03043, Cassino, Italy

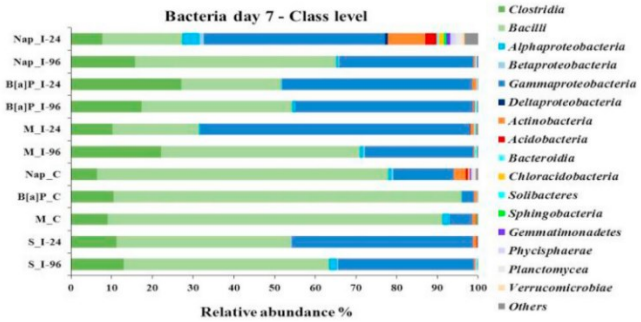


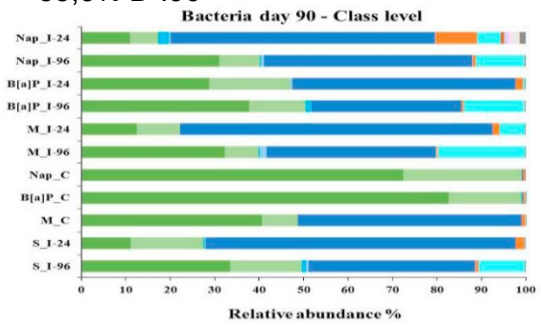
76,5% A-I24
70,6% D-I24

76,5% A-I96
35,3% D-I96

94,1% A-I96
88,2% D-I96

Bioaugmentation with allochtonous microorganisms promote PHA degradation

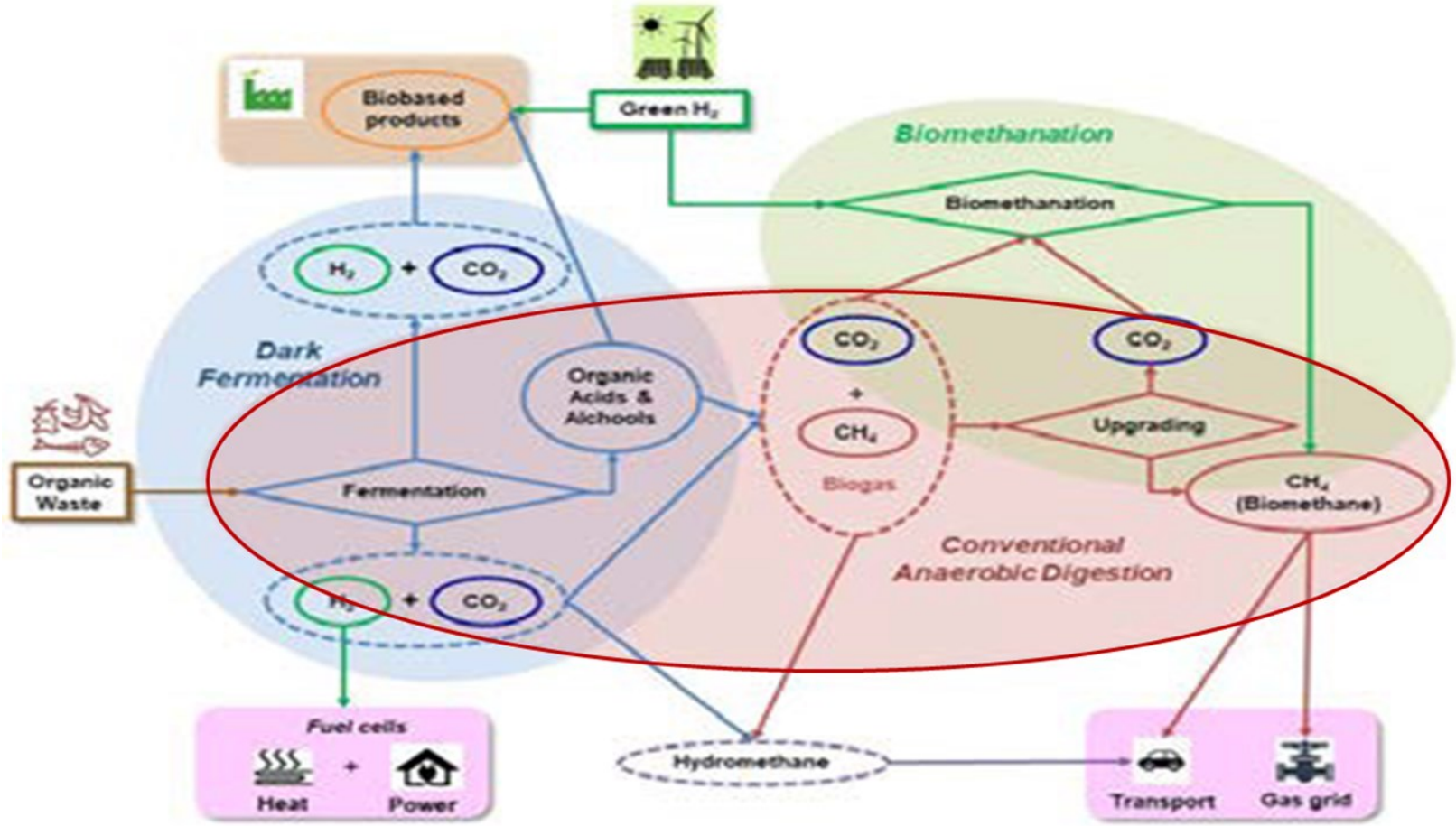




Thank you for your attention

email: giulia.massini@enea.it

email: valentina.mazzurco@enea.it



SIST, 2021 Marone A., Massini G., Pignatelli V., Rosa S., Signorini A. "Biological processes in the Green Hydrogen value chain."