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Solid anaerobic digestion of pig manure with dry and fresh food waste

A. Maragkaki, N. Papastefanakis, G. Daskalakis, N. Markakis,
E. Michalodimitraki, E. Stafilarakis, C. Tsompanidis, T. Manios

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Διαρθρωτικό και Επενδυτικό Ταμείο
Επιχειρησιακό Πρόγραμμα ΚΡΗΤΗ 2014 - 2020
ΕΣΠΑ 2014-2020
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

ENVIROPLAN S.A.
Consultants & Engineers

Chania, June 2023

The project

DRYGAS

Developing Solid State Anaerobic Bioreactors Aiming in Optimum Utilization of Mediterranean Agro-wastes for Energy Production

European Commission

RIS3 Στρατηγική Έξυπνης Εξειδίκευσης Περιφέρειας Κρήτης

National/Regional Research and Innovation Strategies for Smart Specialisation (RIS3), Region of Crete

ΕΣΠΑ 2014-2020
ανάπτυξη - εργασία - αλληλεγγύη
Partnership Agreement 2014 - 2020

ΠΕΡΙΦΕΡΕΙΑ ΚΡΗΤΗΣ
REGION OF CRETE

The project

The DRYGAS (KPHP1 – 0028938) project consortium consists of: two SME and one University department. ENVIROPLAN S.A. is the leader partner.

The project's duration is 35 months.

Start date 23/04/2020

End date 23/09/2023

Laboratory of Natural Resources Development & Agricultural Engineering

The project

DRYGAS aims to :

- ✓ the development / optimization of dry anaerobic digestion as a technology of energy utilization of the Mediterranean Agro-waste.
- ✓ the development of a dry anaerobic bioreactor (Solid State Anaerobic Bioreactor), able to produce the max possible volume & optimal biogas composition.
- ✓ the development of 2 basic types of dry anaerobic reactors (batch mode), with the maximum possible degree of automated operation

The project consists of the following Work Packages:

- •WP1 Determination of Optimal Operational Parameters of Dry Anaerobic Digestion
- •WP2 Development of Technical Structures for Dry Anaerobic Bio-reactors
- •WP3 Development of Operational Control Software (Dry Anaerobic Digestion Operating System -DABOPS)
- •WP4 Operation and Optimization of Pilot Bio-reactors
- •WP5 Environmental & Economic Assessment - Results of Exploitation Actions

The expected results from the DRYGAS implementation is an optimum management especially for the residues produced in the Mediterranean basin, and a technological step, which will allow the transfer of knowledge from the laboratory to the field, allowing the commercial development of dry anaerobic digestion.

DEVELOPMENT / OPTIMIZATION:

First step Aim is to determine:

- the **optimum inoculum** to substrate ratio
- **operational conditions** (temperature, moisture, Hydraulic Retention Time)

that will allow the **maximization of the efficiency of the system**, and therefore lead to the development / **optimization of dry anaerobic digestion** as a technology of energy utilization of the Mediterranean Agro-waste.

Second step Aim is to determine:

To **identify all the parameters** in order to develop a dry anaerobic bioreactor (Solid State Anaerobic Bioreactor), which will be able to **manage in an automated and optimal way**, all the Mediterranean Agro-waste and produce:

- Maximum possible volume
- Optimal biogas composition.

Development of Dry Anaerobic Bioreactors

Design, synthesis, testing and improvement of different electromechanical structures.
Key technical questions:

- How to safely remove biogas,
- How to heat bioreactors,
- The material and design of structures inside them, and
- The operation of sensors and data transfer.

Introduction

Solid-state anaerobic digestion

Suitable technology for treating organic wastes with high total solids content (>15%) and compared with conventional wet AD will enhance digestion and reduce liquid digestate generation

Batch dry anaerobic digestion is a well-established technology

1. Inoculum to substrate ratio
2. Feedstock composition
3. Size of feedstock materials

Need further investigation - avoid process instability

Aim & Innovation

Examine the effect of different waste mixtures with >15 % solids (Mediterranean Agro-wastes) available in Crete for extracting energy with solid state anaerobic bioreactors

Key element: residue mixing will be achieving the desired moisture 70-85%, not the desired Volatile Solids (VS)

The approach and results could facilitate the development of biogas production in other Mediterranean regions with similar sources of organic residues

Raw Materials – Mediterranean

Food Waste (FW)

65% Cooked meal
15% Bread
20% Vegetable & salads

FW wet

dried FWD

Pig manure (PM)

FOOD WASTE

Food waste (FW) in their initial form (wet) used as a feedstock in our experiment, was collected from the students' restaurant at the Hellenic Mediterranean University, Heraklion.

- Homogenized using a mechanical mixer (approximately 4.0 mm).
- Solar drying process was used in order to dehydrate fresh food waste and produce dried material (FWD).

PIG MANURE

From a local pig farm in Crete.

INOCULUM

Inoculum was obtained from an anaerobic digester located at Wastewater Treatment Plant in Heraklion, Greece (population about 200,000).

FEED MIXTURE

Consisted of pig manure, food waste (wet or dry) and anaerobic sludge.

Raw Materials

Composition of Food Waste (FW), Pig Manure (PM) and Anaerobic sludge (AS)			
Parameters	AS	FW	PM
pH	7.7 ± 0.1	4.1 ± 0.1	7.3 ± 0.1
TS (g/kg)	46.1 ± 1.0	233.2 ± 4.8	199.5 ± 1.5
VS (g/kg)	20.5 ± 0.4	221.6 ± 3.1	159.1 ± 1.1
Moisture (%)	89 ± 0.4	79 ± 0.4	81.2 ± 3.2

Experimental procedure

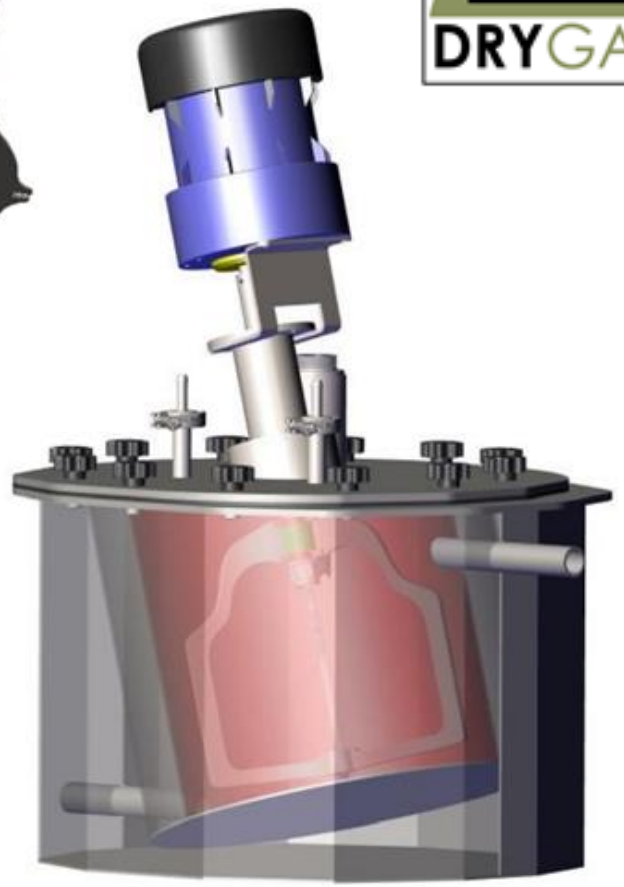
- ✓ **4 type of feedstock:**
- ❖ **D1: 100%** anaerobic sludge (**AS**) *(as blind)*
- ❖ **D2:** 60% AS, 40% PM
- ❖ **D3:** 40% AS, 50% PM, 10% FW
- ❖ **D4:** 40% AS, 50% PM, 10g FWD
- ❖ **Mesophilic AD,** 37° (±2°) C,
- ✓ Influent & effluent samples analyzed TS, VS, pH and methane content in biogas

Food Waste wet and dry (FW, FWD)
Pig Manure (PM)
Anaerobic sludge (AS)

Operational parameters - Digester characteristics			
Digester no	**Digester working volume (L)**	**Time (days)**	**Feedstock**
1	4	65	AS (100%)
2	4	65	60% AS, 40% PM
3	4	65	40% AS, 50% PM, 10% FW
4	4	45	40% AS, 50% PM, 10g FWD

Lab scale solid anaerobic digester

Designed with:
-Inter-changeable three-leg mixer
- bed bottom for better agitation

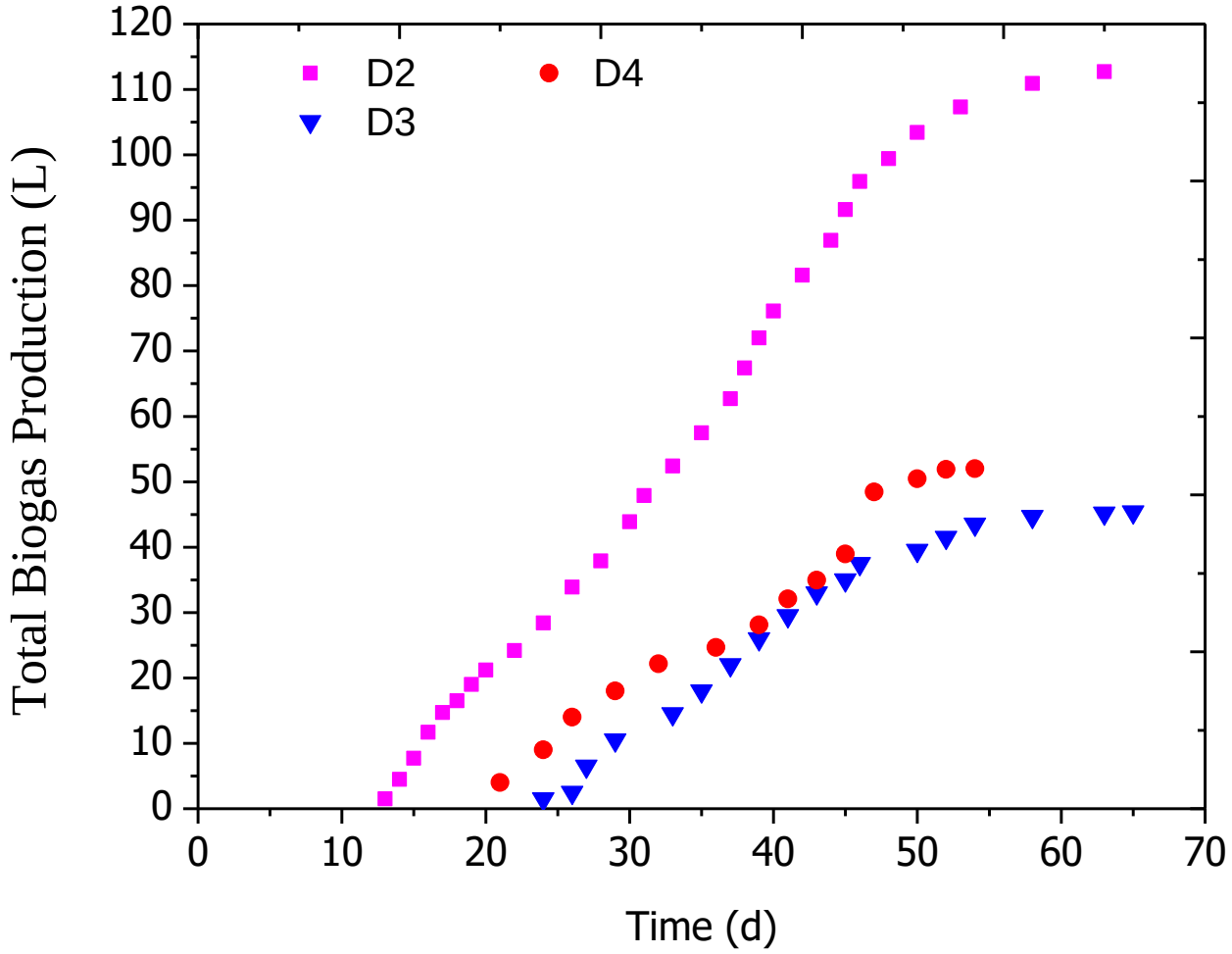


Feedstock Results

Characteristics of experimental materials as feedstock			
Parameters	D2	D3	D4
pH	7.1 ± 0.1	7.3 ± 0.1	7.3 ± 0.1
VS (g/kg)	78.5±6.9	107.9±2.6	144.2±1.3
Moisture (%)	82.3 ± 0.5	83.9 ± 1.2	83.3 ± 1.1

D2: 60% AS, 40% PM
D3: 40% AS, 50% PM, 10% FW
D4: 40% AS, 50% PM, 10g FWD

Results – Total Biogas production



FW & FWD addition – VS increase but decrease biogas production in solid state reactors

2 times

D2: 60% AS, 40% PM
D3: 40% AS, 50% PM, 10% FW
D4: 40% AS, 50% PM, 10g FWD

RESULTS

- After co-digestion of **D2**: 60% AS, 40% PM , the **total biogas production was 111.2 L** while when FW wet (**D3**) and FW dry (**D4**) were added to the feed, the total biogas production was **45.4 L** and **52 L** respectively.

I.e. the **total biogas production was decreased approximately 2 times**, **although VS is higher**.

Probably depends of VS concentration of the mixture, i.e. whet VS are very hight, the increase after a specific threshold is acting suspendigly.

- The **Inoculum - Anaerobic Sludge is very important for the begging** of Solid state anaerobic process.

The Inoculum - Anaerobic Sludge, that was used, was liquid anaerobic sludge.

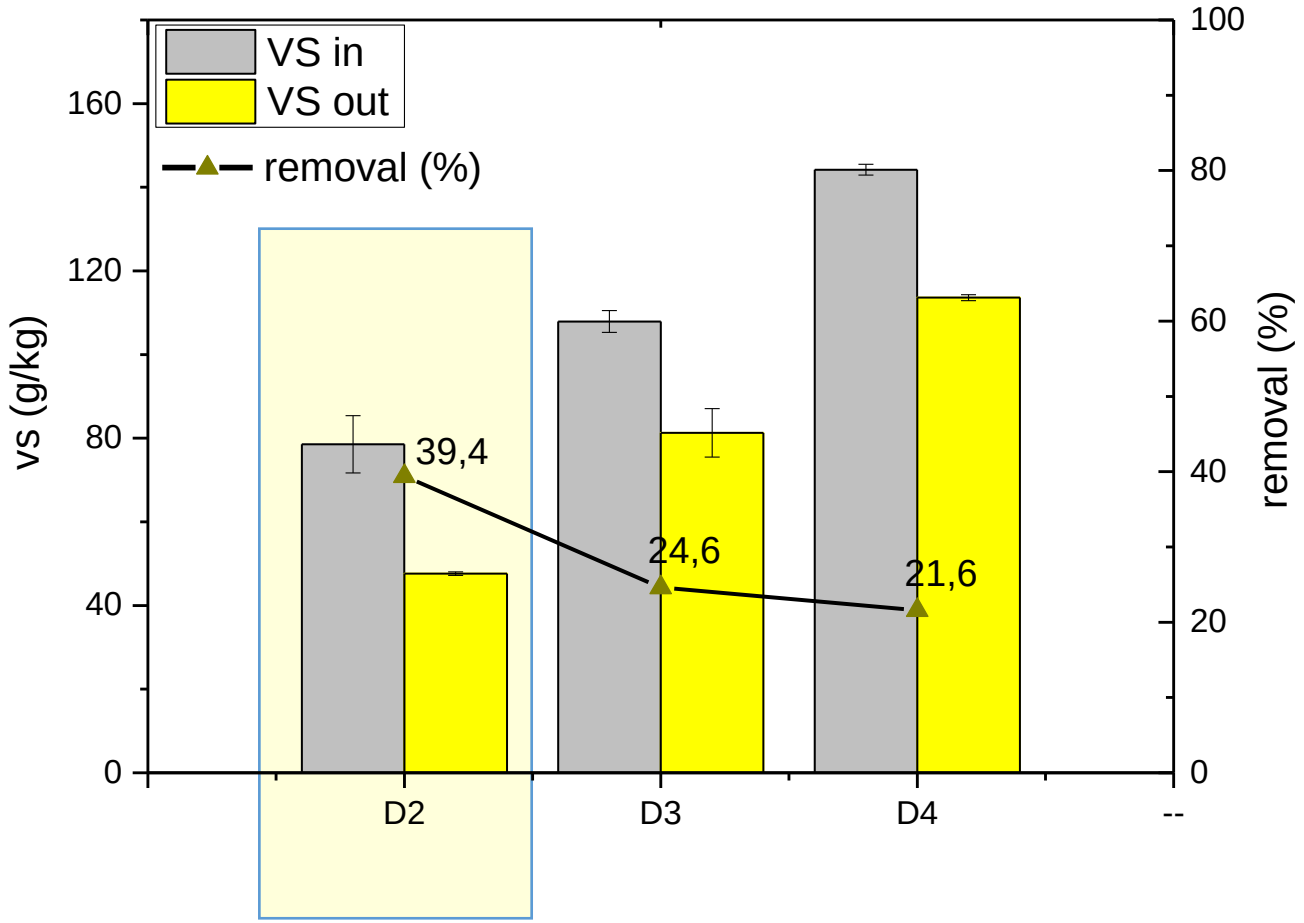
The anaerobic process begun after 10 days for D2 and 20 days for D3 and D4.

Note: In other experiments with solid state sludge the process starts from the first day and the biogas production is almost twice.

Results – Biogas production

Biogas and Biomethane production, biogas composition				
Parameter		D2	D3	D4
Total Biogas Production (L)		111.2	45.4	52
Total Biogas Production (ml/gr VS)		350	100	90
Biogas comp. (%)	CH_4	52.4±8.6 **max 63.9**	65.2±7.1 **max 72.8**	63.6±8.9 **max 72.6**
Total Biomethane production (L)		58.3	29.6	33.1

Results – VS



D2: 60% AS, 40% PM
D3: 40% AS, 50% PM, 10% FW
D4: 40% AS, 50% PM, 10g FWD

D2 → 39.4%
D3 → 24.6%
D4 → 21.6%

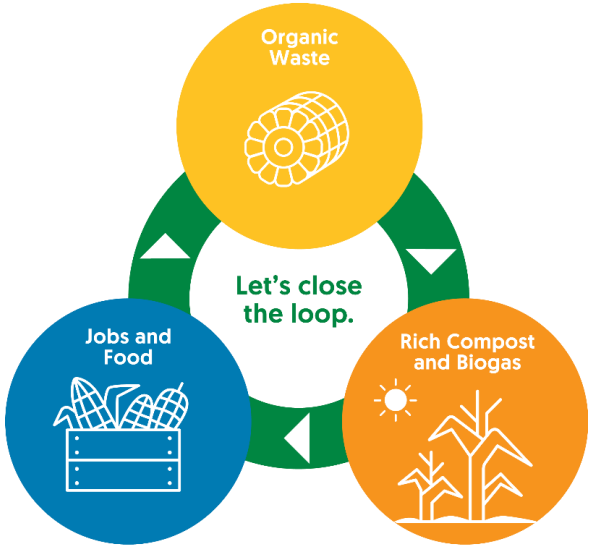
VS removal of PM in the feed was higher in comparison with wet and dry FW addition

The extra VS concentration in solid state anaerobic digestion decrease VS removal

Conclusions

- Solid state anaerobic digestion is a suitable technology for treating organic wastes with high total solids but it is important the VS concentration
- This new direction would generate insights into the upper limits to which volumetric feed rates can be supported
- The highest Methane composition was obtained by co-digestion of FW and PM

- Inoculum - Anaerobic Sludge is very important for the begging of SS-AD
- Inoculum with Digestate of the bioreactors is much more efficient
- Co-digestion and pretreatment are promising for improved methane yields and stability during SS-AD



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https://www.drygas.gr/

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