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Valorization of medical plants residues through anaerobic digestion.

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Scope

- The European Biogas Association (EBA) has set a target at 35 bcm of biomethane up to 2030 to cover energy demands in the frame of decarbonisation and sustainable development.
- In this direction unconventional biomasses must be considered as feedstock for anerobic digestion.
- Medical plant residues constitute a part of the total biomass in West Macedonia and its valorization through anaerobic digestion could be promising.
- The region of West Macedonia is the immediate area of the energy transition.

Scope

- This study aims to highlight the use of medical plant residues as an alternative fuel in the frame of the post lignite era.
- The different streams of residues were characterized and their biomethane potentials were measured.
- Anaerobic digestion of the abovementioned streams proved to be an economic feasible way for their energetic valorization.

Study Areas

- Lavender Straw originated from a distillery plant, Xirolimni, Kozani, Greece

Production process : dry stream distillation

Stored in open sites

Amounts & utilization of residues/ by-products:

Type of residues	Amount (tn/ yr)	Utilization – end use
Lavender straw	300-400	Soil amendment, Pesticides and Animal feeding

Study Areas

- Hemp residues from hemp cultivation (industrial hemp), Goules, Kozani, Greece

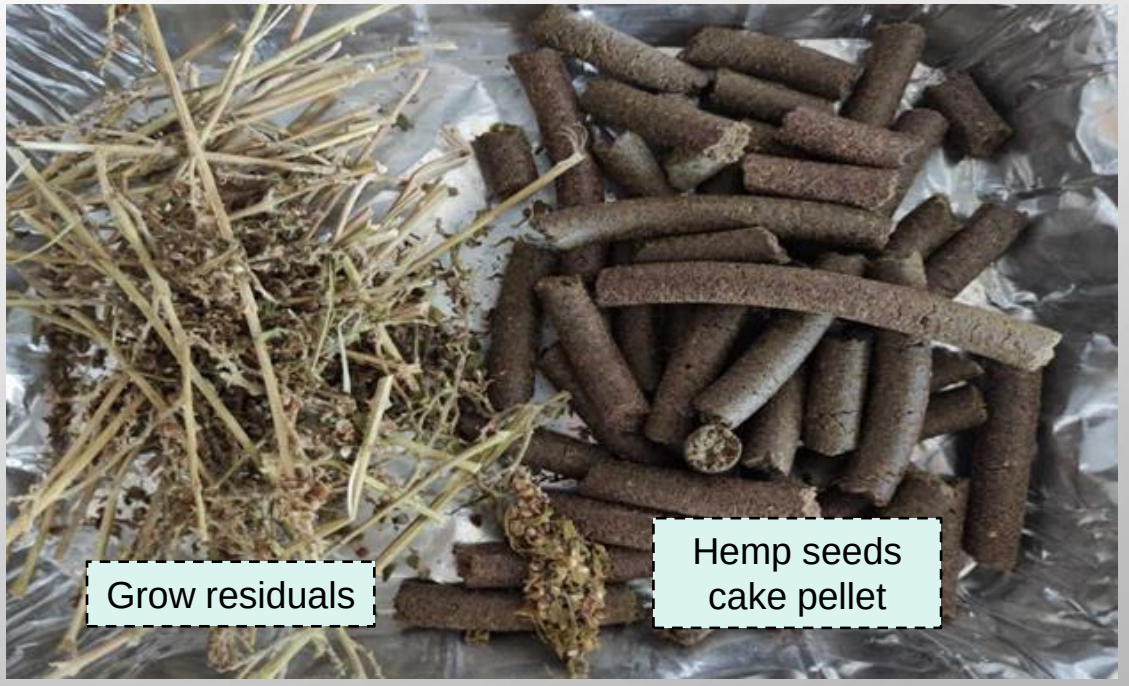
Two main types of residues/ by products:

1) grow residuals which remain at the field after the completion of harvesting (stems, stalks, leaves etc.) and
2) hempseeds cake pellet which are the by-products of CO_2 extraction process

Stored in piles enclosed facilities

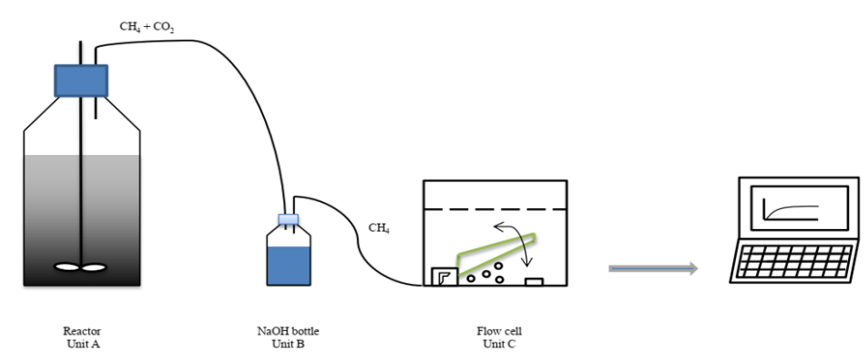
Amounts & utilization of residues/ by-products:

Type of residues	Amount (tn/ yr)	Utilization – end use
Grow residuals	0,5	Flour or solid biofuel depending on the quality parameters
Hemp seeds cake pellet	0,15 – 0,25	Solid biofuel



➢ Methods of Analysis

Test	Standard Method
pH	4500 H^+,APHA 23th Ed
Alkalinity	2320 B, APHA 23th Ed
Ammonium	EPA 350.1
Chemical Oxygen Demand	EPA 410.1
Total Solids	2540 B, APHA 23th Ed
Volatile Solids	2540 F, APHA 23th Ed
Total Organic Carbon	5310 B, APHA 23th Ed
Metals (Major and Trace)	APHA Standard Methods/ISO 15586 EN 15410/EN 15411



Flow chart of the experimental process

➢ Apparatus

BMP (AMPTS II)
According to VDI 4630

Characterization of inoculum and medical plant residues substrates

Parameter (unit)	Inoculum	Lavender residues	Cannabis S. residues	Hempseeds cake pellets
pH	8,25	-	-	-
VS (g/L)	24,0	171,0	172,0	470,0
TOC (g/L)	6,6	-	-	-
COD (g/L)	23,0	-	-	-
COD (g/g)*	-	0,85	0,90	0,86
NH_4^+ (g/L)	1,2	-	-	-
Alkalinity (g/L $CaCO_3$)	15,0	-	-	-

*COD (g/g) is theoretically estimated based on elemental analysis

Ultimate analysis of medical plant residues in dry basis

Parameter (unit)	Lavender residues	Cannabis S. residues	Hempseeds cake pellets
C (%)	47,2	46,5	47,3
H (%)	5,4	5,9	6,37
N (%)	1,2	1,3	1,41
S (%)	0,4	0,16	0,16
C/N	39,3	35,8	32,8

Major and trace metals of medical plant residues in dry basis

Parameter (unit)	Lavender residues	Cannabis S. residues	Hempseeds cake pellets
Al (ppm)	584,0	330,0	376,0
Ca (%)	0,93	1,52	1,45
Fe (ppm)	141,0	108,0	324,0
K (%)	2,12	1,09	0,93
Mg (%)	0,49	0,62	0,57
Na (ppm)	0,02	0,04	0,03
Si (%)	0,13	0,37	0,46
Cr (ppm)	0,77	0,40	1,80
Cu (ppm)	6,90	14,5	18,0
Pb (ppm)	0,14	0,20	0,10
Zn (ppm)	10,2	32,3	98,0
Cd (ppm)	0,16	0,14	0,14

- ✓ Anaerobic sludge obtained from a commercial mesophilic anaerobic digester plant in the region of Eordea (West Macedonia) was used as inoculum
- ✓ The SIR ratio was determined according to the VS of the substrate and the inoculum. SIR 0,8 g VSsub/g VSinoc
- ✓ Temperature 35 ◦C
- ✓ All tests performed in triplicate

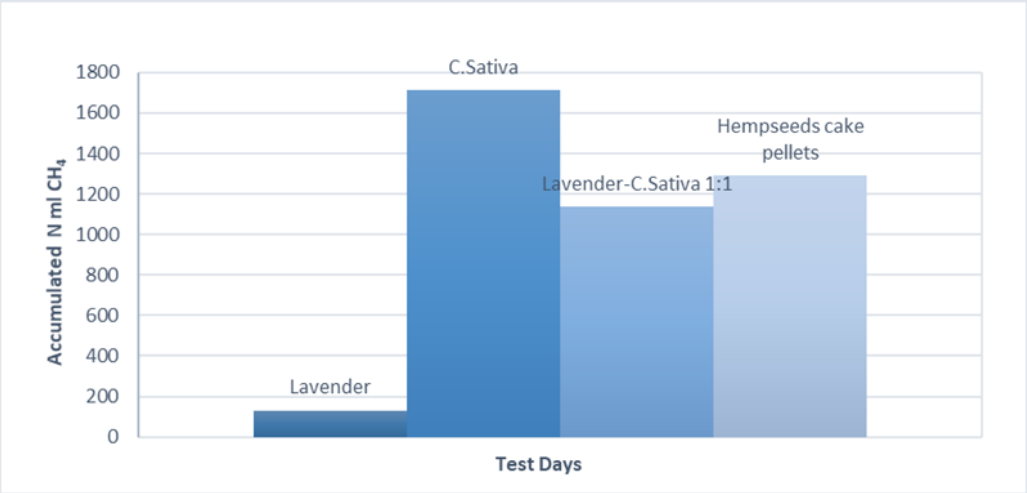
➢ BMP Test

Main Characteristics of the lab scale bioreactors (BMP), during the start-up and after the end of the experiment.

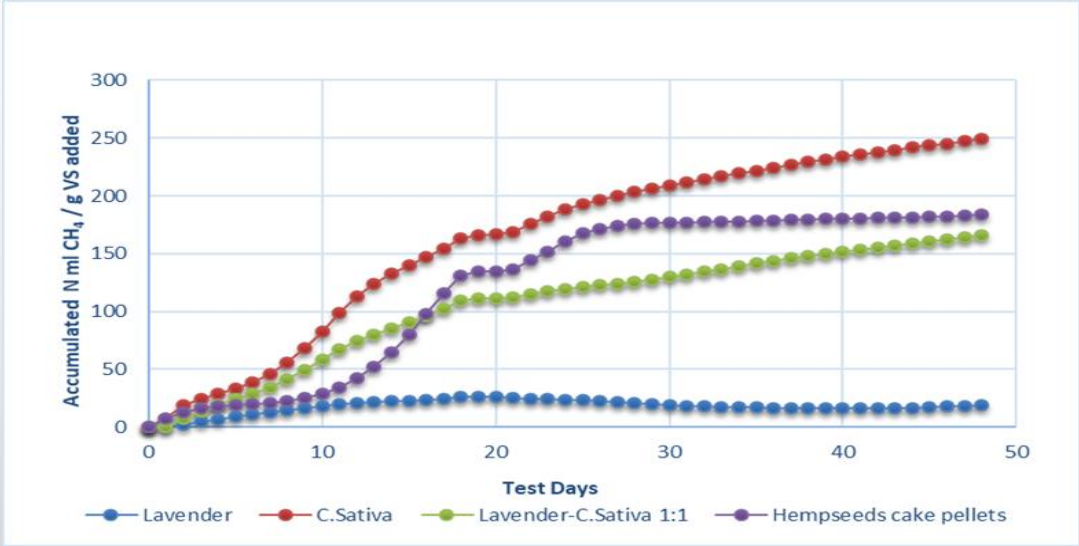
Parameter (unit)	Lavender residues		Cannabis S. residues		Blend of Lavender-Cannabis S. residues (1:1)		Hempseeds cake pellets	
	Start	End	Start	End	Start	End	Start	End
pH	7,90	7,91	7,79	8,02	7,96	7,74	7,78	8,06
VS (g/L)	39,0	14,0	39,0	18,0	39,0	19,0	41,0	7,0
COD (g/L)	-	4,15	-	2,29	-	3,22	-	2,96
TOC (g/L)	-	1,45	-	0,74	-	1,09	-	0,88
NH_4^+ (mg/L)	-	104,7	-	1713,0	-	1330,0	-	1011,0
Alkalinity (g/L $CaCO_3$)	-	2,5	-	5,0	-	5,0	-	1,7
mL CH_4/g VS	19,2		250,5		166,3		183,5	
Test Days	48		48		48		48	
VS_{deg} (%)	64,10		53,84		51,28		82,92	

- ✓ The batch test lasted 48 days until little or no biogas production was obtained
- ✓ Lavender residues produced 19,2 Nml CH_4/ g VS added
- ✓ Cannabis S. 250,5 Nml CH_4/g VS added
- ✓ Co-digestion produced 166,5 Nml CH_4/ g VS added
- ✓ Hempseed cake pellets from Cannabis S. produced 183,5 Nml CH_4/ g VS added

➢ BMP Test



Accumulated biomethane (Nml) produced by medical plant residues



Accumulated Nml CH_4/g VS added of herb residues

➢ BMP Test

- ✓ Final COD & TOC exhibit a high amount of the organic matter decomposed.
- ✓ Final NH_4^+ concentration for Cannabis S, blend and hempseeds cake pellets is 1g/L.
- ✓ The degradation of VS for Lavender residues and hempseeds cake pellets were at 64 % and 82,92 %, respectively. Whilst Cannabis S. residues and blend, the degradation of VS reached at 54 %.

➢ Conclusions

- ✓ The lower biomethane produced yield was 19,23 Nml CH_4/g VS added from Lavender residues and the higher biomethane value was 250,5 Nml CH_4/g VS added from Cannabis S. residues.

- ✓ The produced biomethane derived from the anaerobic digestion of the Cannabis S. residues (including hempseeds cake pellets and blend) consider as promising and interesting possibility for renewable fuel originated from agricultural sector.

- ✓ As the demanding for renewable energy is growth as the biogas plants are increased, it is required to established a database with the biomethane produced yield by each waste, or co-digestion.

- ✓ BMP provide technical and financial analysis to the biogas unit.

- ✓ Except of the chemical composition of a plant that affect the biomethane yield, there are also other critical factors:
  - the maturity of the plant
  - the harvest time (flowering stage or vegetative stage)
  - the frequency of harvesting

➢ Future steps

- ✓ Co-digestion of medical plants substrates in a pilot 30L CSTR bioreactor
- ✓ Upgrade the produced biogas to biomethane through the pilot capture CO_2 unit, using a K_2CO_3 solution and novel Carbonic Anhydrase enzymes

➢ Funding

- ✓ This research has been co-financed by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code:T1EDK01656)
- ✓ $\underline{CO_2}$ Capture and Utilization using enzyme boosted K_2CO_3 Solvents- CoCCUS

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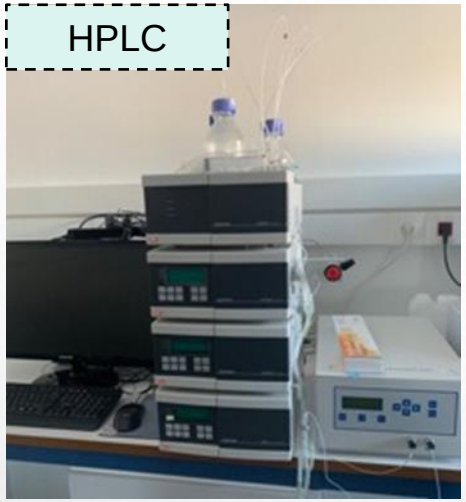
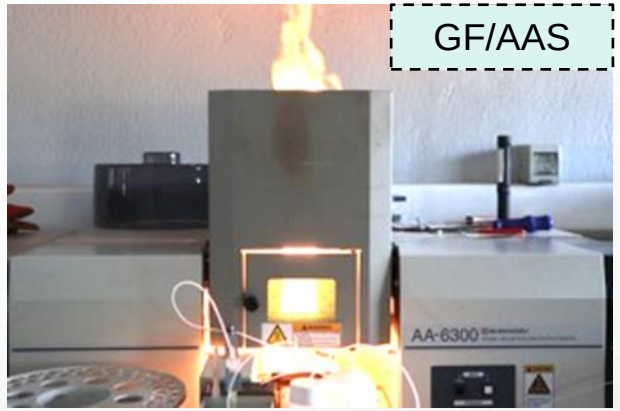
TOC/TN Analyser



HPLC



GF/AAS

XRF

30L CSTR Bioreactor

BioMethane Potential (BMP)

MicroGC-Biogas Analyser

GC/MS-GC FID

CO_2 capture pilot unit

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Thank you for your attention!!

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