ANAEROBIC BIODEGRADABILITY OF TYPICAL ORGANIC AGRO-WASTES IN WESTERN GREECE

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Outline

- Typical Western Greece agro-industrial wastes (i.e. manure, slaughterhouse, fruit and vegetable wastes etc.)
- Environmental problem of their disposal
- Experimental procedure: Biochemical methane potential assays
- Main results- conclusions

Regional agro-industrial wastes

Characteristics of regional agro-industrial wastes (i.e. manure, slaughterhouse, fruit and vegetable wastes etc.):

- High organic content (difficulty in biodegradation)
- Seasonal production
- Small amount of wastes from dispersed regional (local) units
- Lack of nutrients necessary for the bioprocess (anaerobic digestion)

Negative impacts from agro-wastes disposal

- **Environmental: Pollution of natural ecosystems i.e. rivers, sea**
- **Social (to public health, land degradation)**
- **Financial (i.e. tourism, limitations of agricultural and poultry units growth)**


Vouraikos


Aliakmonas

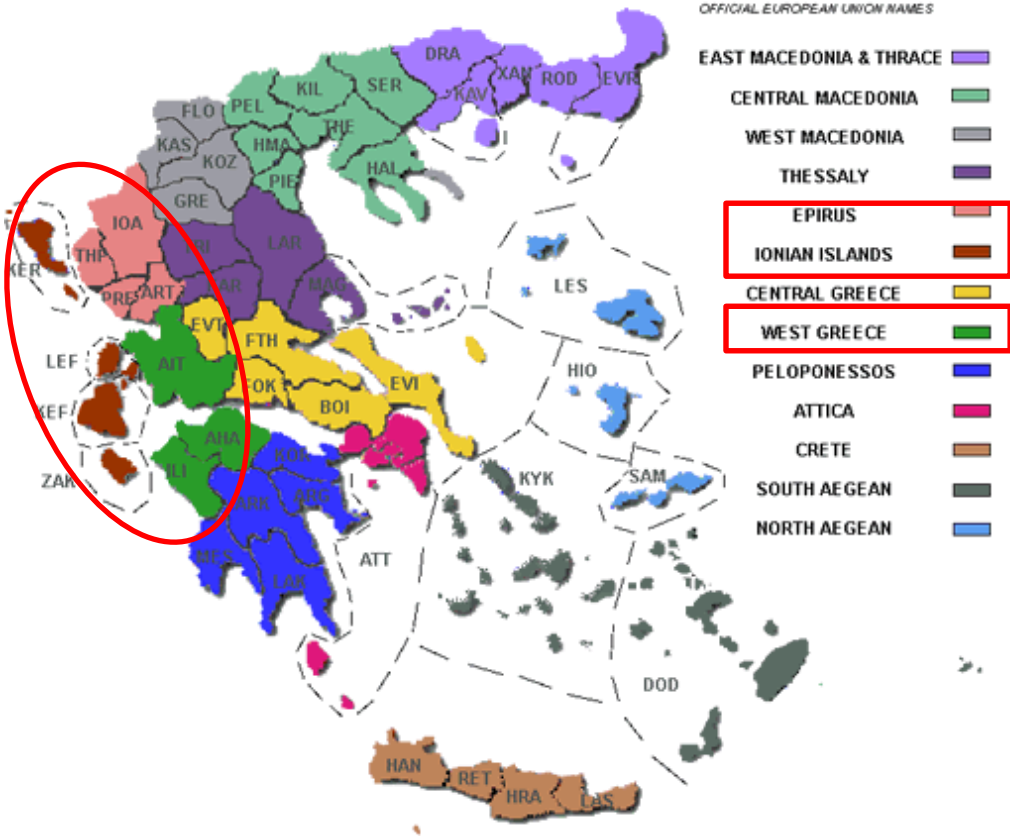

Kotichi, Ilias


Pinios

Western Greece agro-industrial wastes

Study area:
Regional entities of Western Greece Region

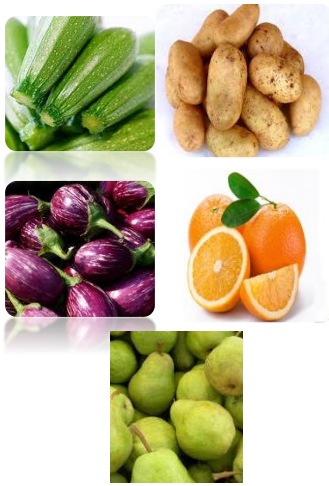
- **Cow, pig, sheep and poultry manure** from farms in Arta
- **Slaughterhouse wastes** (viz. contents of intestines of bovine , soft offal and bones) from a pig/ lamp slaughterhouse in Preveza
- **Oranges, eggplants, zucchinis, pears and potatoes** from Preveza
- **Seagrass (washed up)** of *Posidonia Oceanica* from Mitikas, Preveza
- **Grape marcs** from wineries and distilleries located in Achaia



General characteristics of agro-wastes

- High organic load & solids concentration
- High nitrogen & phosphorus content

- High organic load & solids concentration
- High concentration of nitrogen & phenols (toxicity)
- Rich in proteins & lipids



- High organic load & solids concentration
- High concentration of carbohydrates
- Low concentration of nitrogen & phosphorus

- High organic load concentration
- High concentration of phenols

- High organic load & solids concentration

Composition analysis of agro-wastes I

[a]Waste types / [b]Parameters	CM	PM	SM	PoM	SW	SG
pH	7.37 ± 0.05	8.24 ± 0.01	8.59 ± 0.06	8.79 ± 0.06	4.79 ± 0.27	6.55 ± 0.02
TS (g/L)	30.99 ± 0.24	73.43 ± 0.12	35.32 ± 2.88	61.59 ± 0.97	19.18 ± 0.67	62.48 ± 2.68
VS (g/L)	90.04 ± 0.01	76.53 ± 0.00	80.96 ± 0.02	73.25 ± 0.02	92.24 ± 0.00	61.71 ± 0.01
total COD (g/L)	59.92 ± 0.69	70.79 ± 0.77	96.74 ± 0.21	80.38 ± 0.46	110.34 ± 2.61	87.48 ± 0.88
soluble COD (g/L)	2.82 ± 0.10	4.81 ± 0.03	5.49 ± 0.01	9.05 ± 0.16	9.21 ± 0.22	2.45 ± 0.07
[c]total carbohydrates (g/L)	27.17 ± 1.22	22.05 ± 3.06	36.63 ± 0.72	22.48 ± 1.03	0.87 ± 1.08	24.02 ± 0.56
[c]soluble carbohydrates (g/L)	0.82 ± 0.37	1.06 ± 0.27	27.75 ± 0.25	0.95 ± 0.15	0.12 ± 0.18	0.30 ± 0.39
TKN (g/L)	1.23 ± 0.00	1.23 ± 0.25	1.05 ± 0.10	1.68 ± 0.20	3.69 ± 0.32	0.08 ± 0.00
Ammonium-N (g/L)	0.14 ± 0.02	0.21 ± 0.02	0.07 ± 0.00	0.64 ± 0.01	0.29 ± 0.10	[e]N.D.
total phosphorus (g/L)	0.55 ± 0.01	2.08 ± 0.00	0.32 ± 0.00	2.03 ± 0.03	0.63 ± 0.03	[e]N.D.
soluble phosphorus (g/L)	0.27 ± 0.01	0.36 ± 0.00	0.09 ± 0.00	0.53 ± 0.00	0.39 ± 0.00	[e]N.D.
[d]total phenols (g/L)	0.13 ± 0.02	0.39 ± 0.02	0.34 ± 0.02	0.63 ± 0.01	0.26 ± 0.00	0.17 ± 0.01
alkalinity (g $CaCO_3$/L)	0.11 ± 0.01	0.67 ± 0.01	0.34 ± 0.02	0.87 ± 0.01	0.03 ± 0.01	0.19 ± 0.01

[a]**abbreviations:** CM: Cow Manure; PM: Pig Manure; SM: Sheep Manure; PoM: Poultry Manure; SW: Slaughterhouse wastes; SG: Seagrass; [b] all values are given as mean values ± standard deviation (calculated by triplicate analysis); [c]in equivalent glucose; [d]in equivalent syringic acid; [e]not determined

Composition analysis of agro-wastes II

[a]Waste types / [b]Parameters	OR	EG	ZU	PE	PO	GMW	GMD
pH	3.56 ± 0.04	4.06 ± 0.05	7.77 ± 0.06	5.93 ± 0.01	4.74 ± 0.06	3.73 ± 0.04	3.87 ± 0.02
TS (g/L)	16.54 ± 0.29	8.18 ± 0.04	6.41 ± 0.02	14.83 ± 0.11	19.65 ± 0.19	20.68 ± 0.24	11.22 ± 0.45
VS (g/L)	96.09 ± 0.00	93.28 ± 0.01	84.87 ± 0.00	96.31 ± 0.02	93.96 ± 0.00	93.69 ± 0.00	91.89 ± 0.00
total COD (g/L)	106.70 ± 0.15	110.76 ± 1.36	101.06 ± 0.64	113.82 ± 0.46	103.13 ± 0.40	129.39 ± 1.24	116.24 ± 2.03
soluble COD (g/L)	68.28 ± 0.06	43.91 ± 0.11	36.94 ± 0.10	67.14 ± 0.14	18.47 ± 0.12	24.47 ± 0.26	40.36 ± 0.81
[c]total carbohydrates (g/L)	73.48 ± 0.78	34.13 ± 1.36	59.64 ± 0.44	68.02 ± 4.64	66.44 ± 5.08	25.32 ± 1.67	26.76 ± 0.38
[c]soluble carbohydrates (g/L)	63.05 ± 4.64	27.68 ± 0.29	27.75 ± 0.25	63.52 ± 2.12	6.31 ± 2.56	4.46 ± 0.46	5.78 ± 1.11
TKN (g/L)	0.70 ± 0.00	1.54 ± 0.00	2.42 ± 0.02	0.59 ± 0.02	0.88 ± 0.17	1.26 ± 0.00	1.11 ± 0.10
Ammonium-N (g/L)	0.07 ± 0.00	0.16 ± 0.06	0.58 ± 0.01	0.08 ± 0.01	0.17 ± 0.10	0.14 ± 0.09	0.11 ± 0.04
total phosphorus (g/L)	0.17 ± 0.00	0.42 ± 0.00	0.11 ± 0.00	0.08 ± 0.01	0.23 ± 0.02	0.41 ± 0.00	0.27 ± 0.01
soluble phosphorus (g/L)	0.14 ± 0.01	0.37 ± 0.00	0.86 ± 0.01	0.07 ± 0.03	0.18 ± 0.01	0.28 ± 0.02	0.25 ± 0.02
[d]total phenols (g/L)	1.70 ± 0.00	1.0 ± 0.01	0.92 ± 0.02	[e]N.D.	0.58 ± 0.01	1.05 ± 0.00	3.77 ± 0.00
alkalinity (g $CaCO_3$/L)	[e]N.D.	[e]N.D.	0.19 ± 0.00	0.01 ± 0.00	0.17 ± 0.01	[e]N.D.	[e]N.D.

[a]**abbreviations:** OR: Oranges; EG: Eggplants; ZU: Zucchinis; PE: Pears; PO: Potatoes; GMW: Grape Marcs from Wineries GMD: Grape Marcs from Distilleries; [b] all values are given as mean values ± standard deviation (calculated by triplicate analysis); [c]in equivalent glucose; [d]in equivalent syringic acid; [e]not determined

Biochemical Methane Potential Assay (BMP)

- **Batch-mode test, generally 60 day duration**
- **Developed to determine anaerobic biodegradability of substrate**
- **Substrate is tested in a laboratory environment under stable conditions (i.e. temperature, initial organic load, nutrients)**

BMP is used:

- ✓ **To determine concentration of organics in a wastewater that can be anaerobically converted to CH_4**
- ✓ **To evaluate potential efficiency of anaerobic process for a specific waste**
- ✓ **To measure residual organic material amenable to further anaerobic treatment**

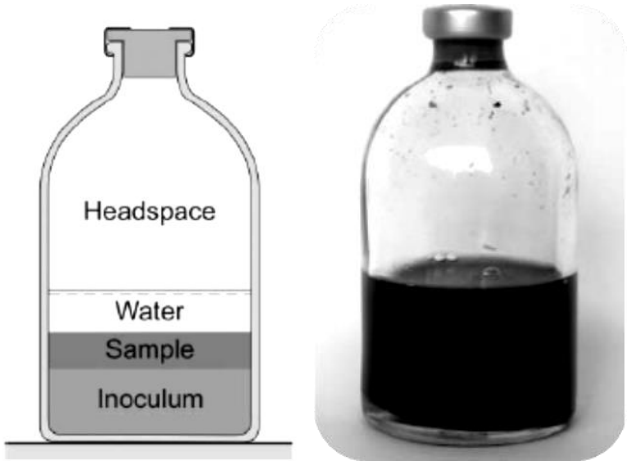
[Owen et al., 1979]

BMP General Principles I.

- **Characterize substrate/test material: pH, TS, VS, COD, carbohydrates prior to BMP tests**

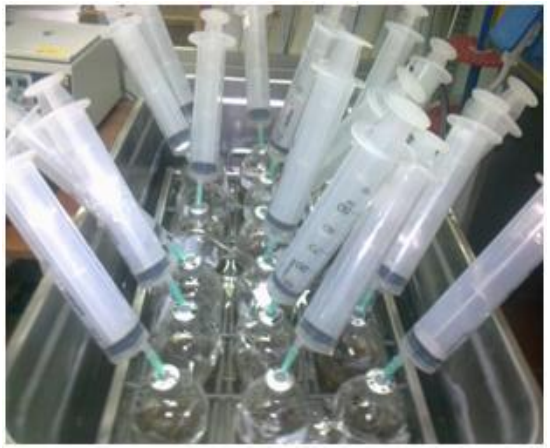
- **Place aliquot of test material in a serum bottle with inoculum & nutrient medium**
- **Inoculum: 20% acclimated methanogenic anaerobic sludge fed daily with a mixture of olive mill wastewaters: cheese whey: liquid cow manure (with a ratio of 55: 40: 5%, respectively) at HRT=25 days & OLR=1.66 kg VS m^{-3} day^{-1} (37 °C)**
- **Nutrient medium and vitamins for mixed anaerobic cultures were also added**

[Owen *et al.*, 1979]



BMP General Principles II.

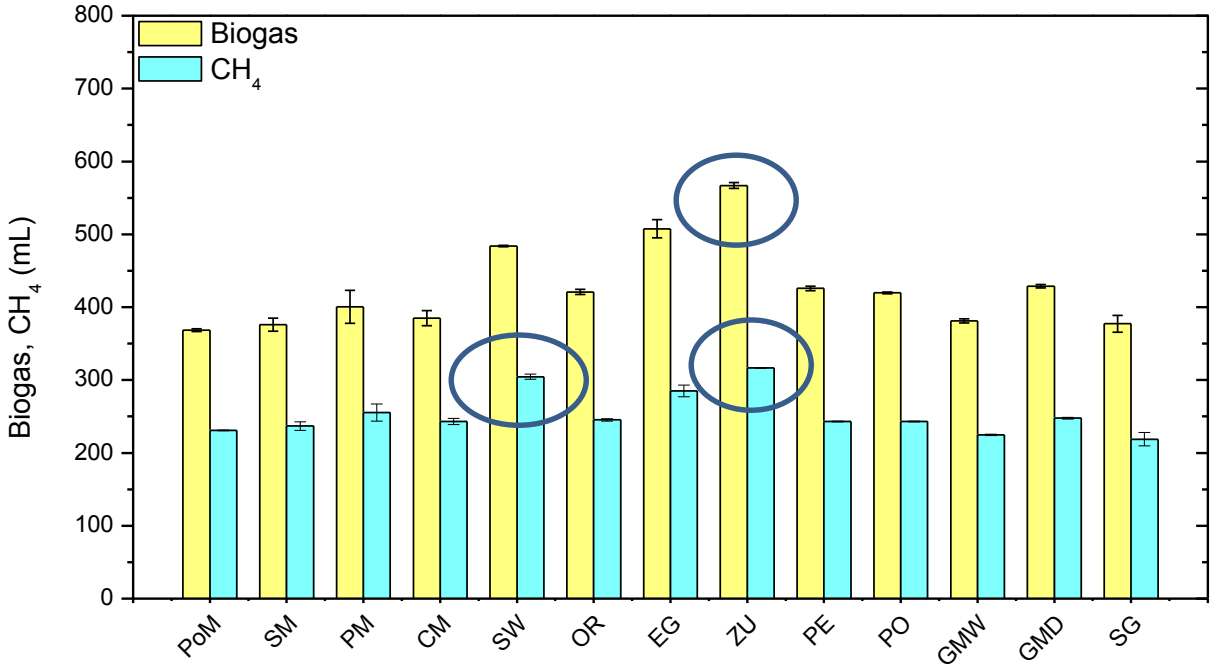
- **Prepare blank & samples with inoculum & nutrient medium (in duplicates)**
- **Serum bottles were flushed for 5min with N_2 gas →sealed immediately using butyl rubber septum and aluminum crimp → placed on a shaking water bath at 37^{o}C for 100 days**



- **Measure biogas production & CH_4 content (daily or as needed depending on production)**
- **Determine normalized biogas & CH_4 production and CH_4 yield (STP L CH_4/ g VS added)**

STP: standard temperature and pressure (0°C, 1 atm)

BMP Results I. Biogas production

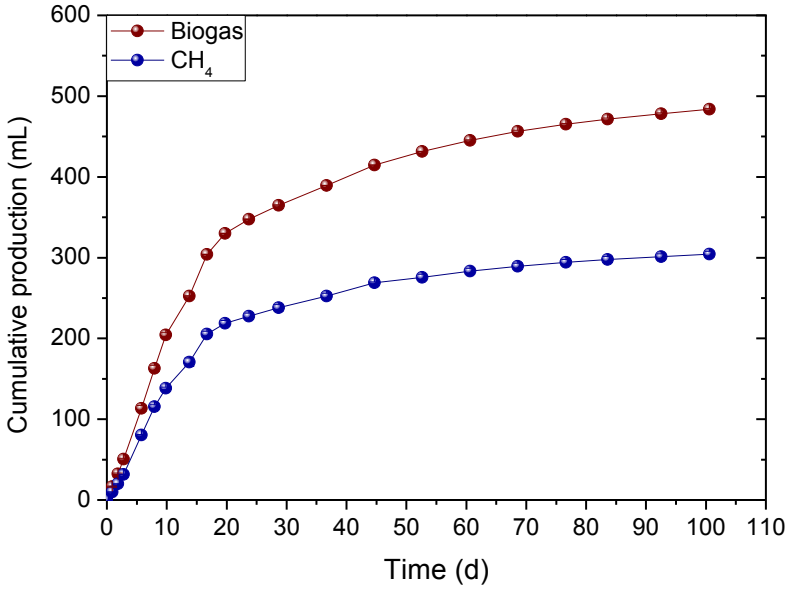


PoM, SM, PM, CM: Poultry, Sheep, Pig and Cow Manures respectively;
SW: Slaughterhouse Wastes;
OR: Oranges;
EG: Eggplants;
ZU: Zucchinis;
PE: Pears;
PO: Potatoes;
GMW, GMD: : Grape Marcs from Wineries and Distilleries, respectively;
SG: Seagrass

- **The biogas production for all tested substrates ranged : 376.16 and 566.89 mL**
- **The methane production for all tested substrates ranged: 218.84 and 316.39 mL CH_4.**

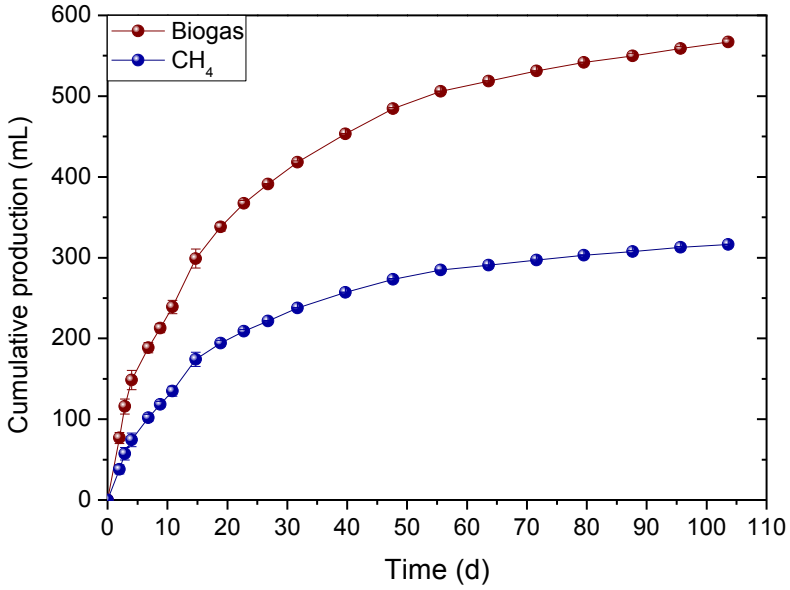
BMP Results II. Example

SW: Slaughterhouse Wastes



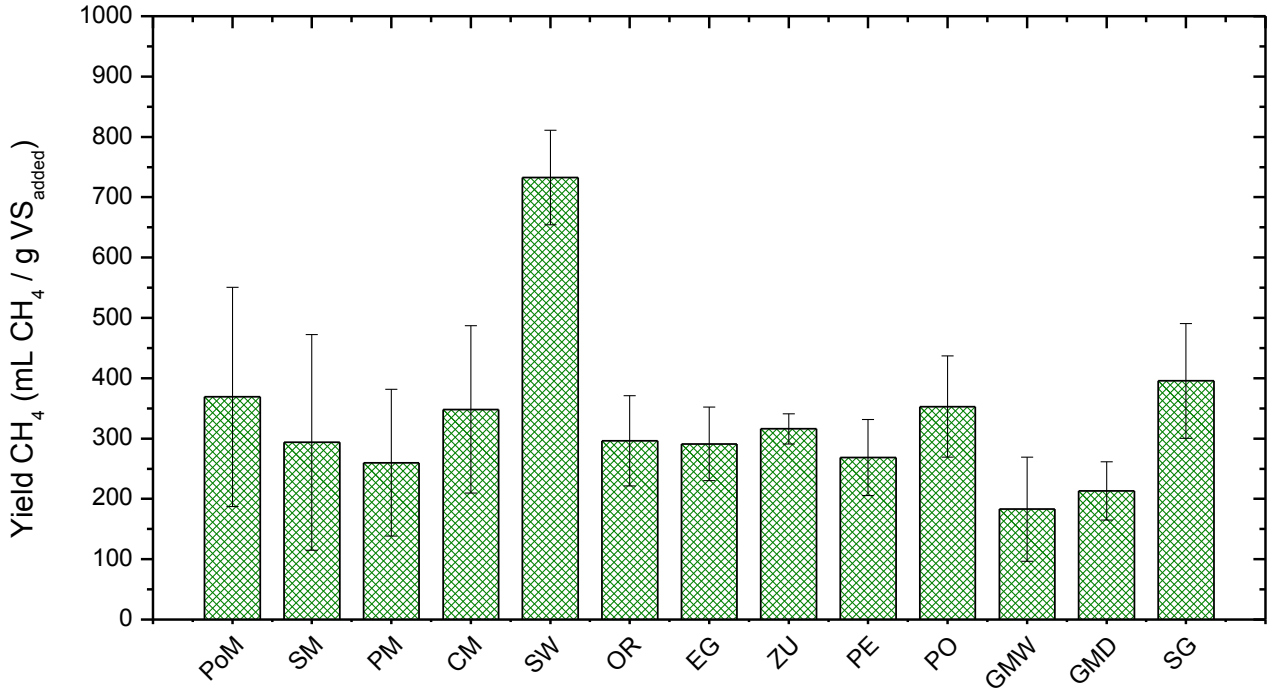
Standard Error : 1.11%

ZU: Zucchinis



Standard Error : 0.06%

BMP Results III. Methane yields



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- **The methane yields for all tested substrates ranged: 162.92 and 732.58 mL CH_4/ g VS added.**
- **The highest methane yield for the Slaughterhouse wastes (SW) (732.58 mL CH_4/ g VS added) after 100 days of incubation**

Conclusions

- ✓ **The potential for methane production from thirteen wastes was evaluated in laboratory batch assays →Obtained methane yields ranged from 162.92 - 732.58 mL CH_4/ g VS added.**
- ✓ **The highest methane yield was obtained for Slaughterhouse wastes (SW) (732.58 mL CH_4/ g VS added) after 100 days of incubation**

- ✓ **The estimation of high methane potentials from BMP assays of regional waste streams suggest that anaerobic digestion may be considered as a sustainable solution for the valorization of agro-industrial wastes generated in the Region of Western Greece**

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Thank you for your attention..