Integrated biological treatment and agricultural reuse of olive mill effluents with the concurrent recovery of energy sources (BIOTROLL)

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Total budget: 1,700,000 €
Project duration: 36 months

BIOTROLL research partners

- EMB group, Biocentrum-DTU, Denmark
  - Leading scientist and project coordinator: Prof. B.K. Ahring
- LBEET, Department of Chemical Engineering, University of Patras, Greece
  - Leading scientist: Prof. G. Lyberatos
- Department of Agro-Environmental Sciences and Technology, University of Bologna, Italy
  - Leading scientist: Prof. C. Ciavatta
- Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College, London
  - Leading scientist: Prof. E.N. Pistikopoulos

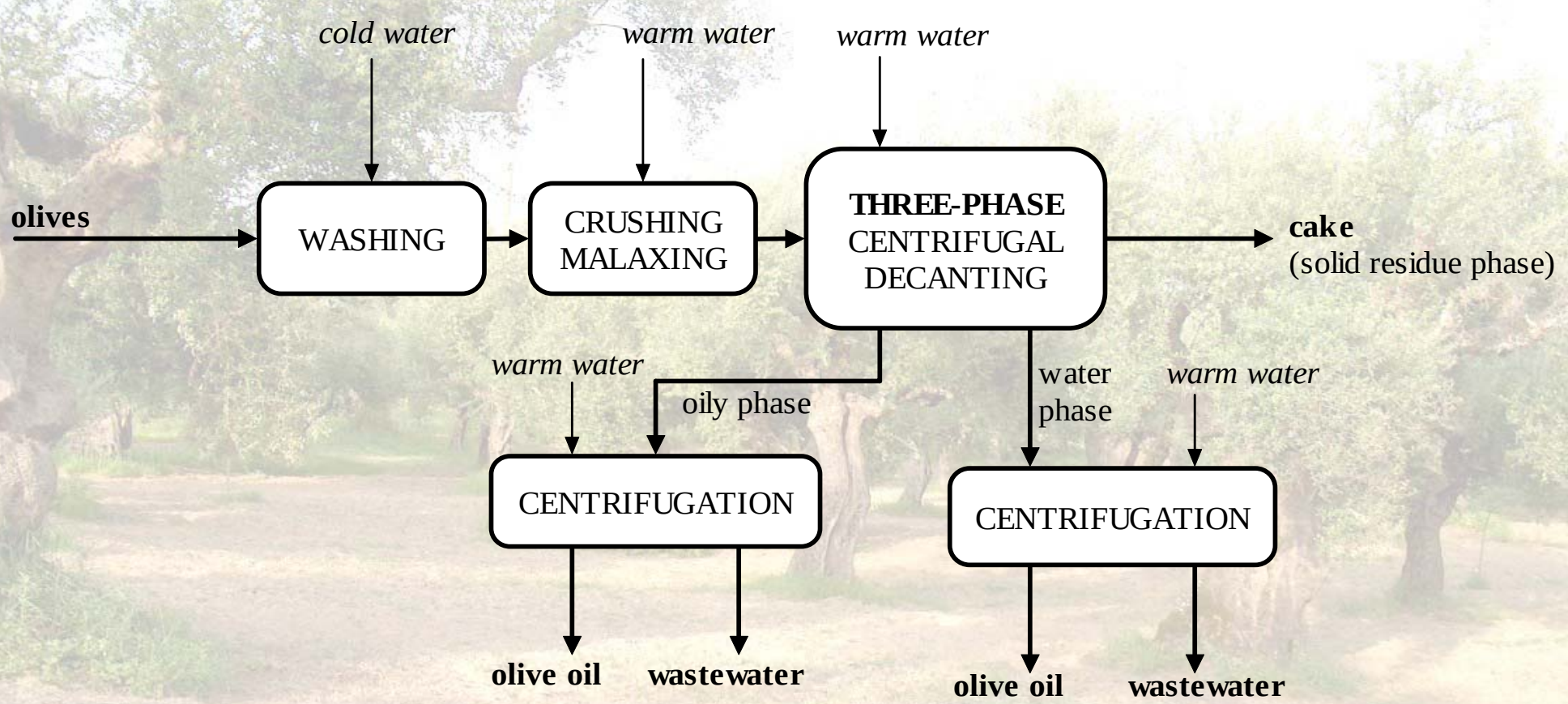
BIOTROLL industrial partners

- Eleourgiki Lipasmaton, A. Karathanasis S.A., Industrial Area of Kalamata, Greece
- Biocontractors A.S., Lyngby, Denmark

What is olive pulp?

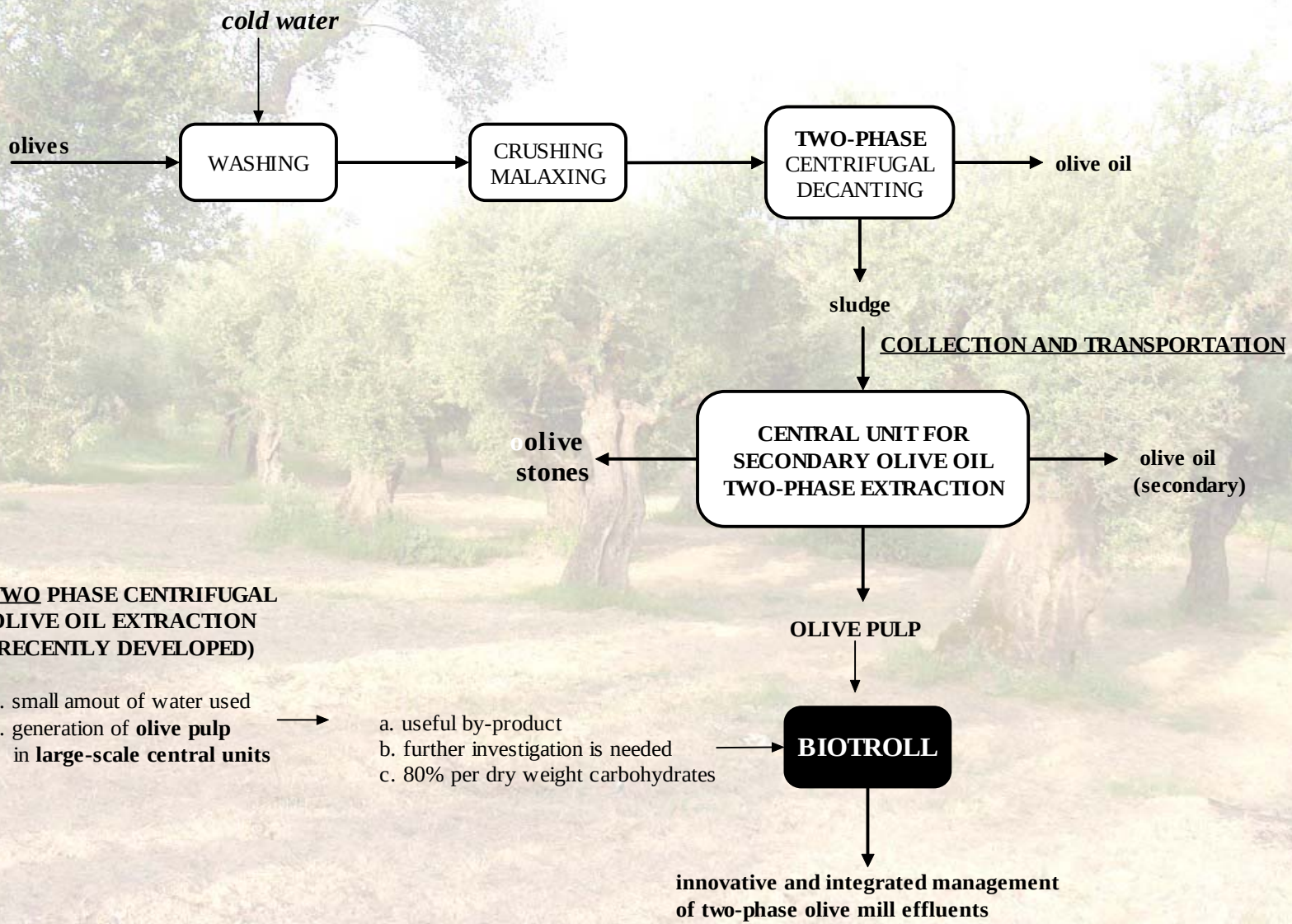
- Traditional three-phase olive oil producing industries
  - Consumption of water
  - Generation of olive-mill wastewater
- Two-phase olive oil producing industries
  - No addition of water
  - Generation of a semi-solid residue called **olive pulp**

Three-phase olive oil production



1. high amout of water used
2. generation of high organic content wastewater in **small scale olive mills** → wastewater treatment prohibitevely expensive → **pollution of surface and ground water**

Two-phase olive oil production



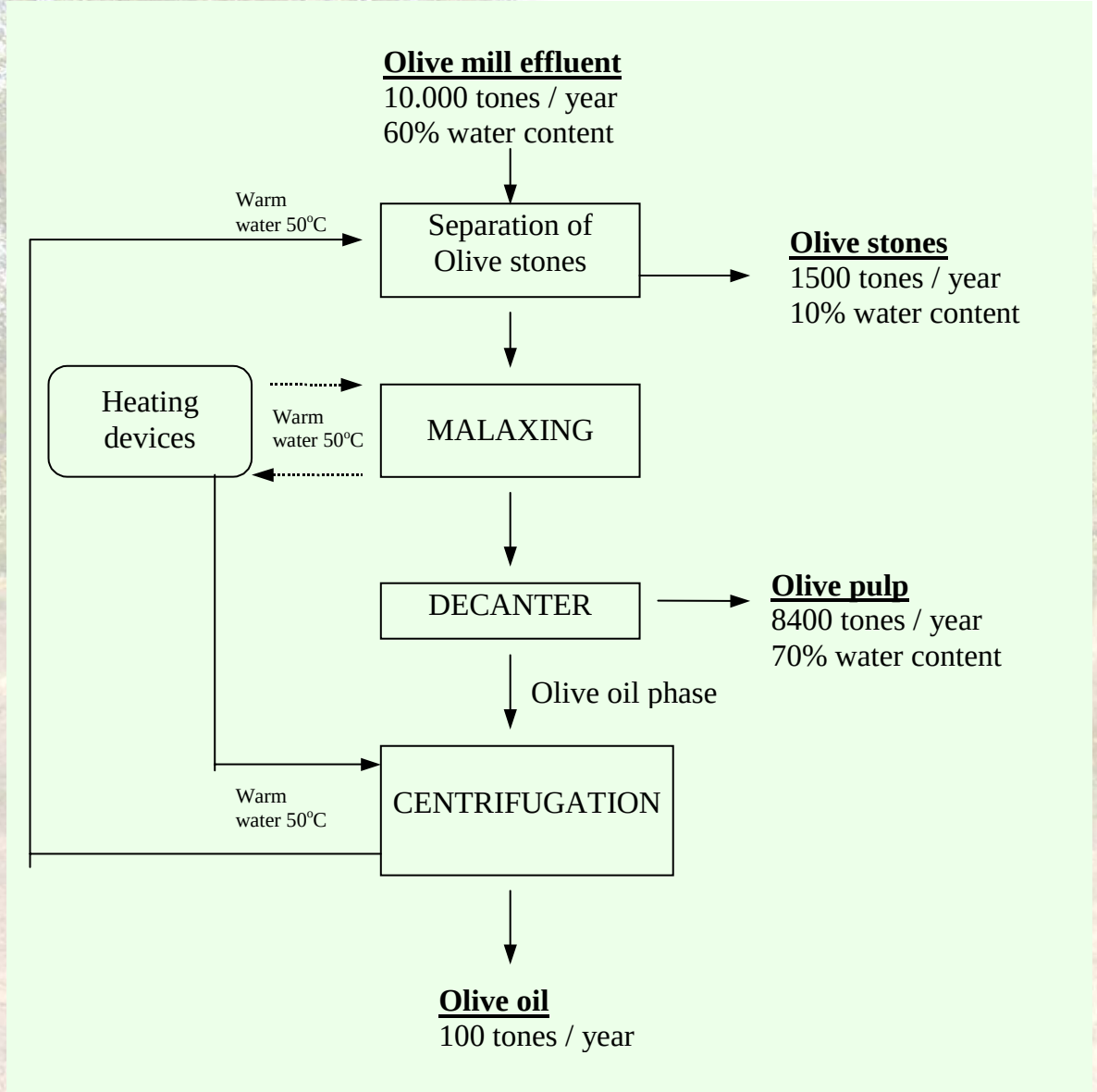
TWO PHASE CENTRIFUGAL OLIVE OIL EXTRACTION (RECENTLY DEVELOPED)

1. small amout of water used
2. generation of **olive pulp** in **large-scale central units**

→

a. useful by-product
b. further investigation is needed
c. 80% per dry weight carbohydrates

CENTRAL UNIT FOR SECONDARY OLIVE OIL TWO-PHASE EXTRACTION



Research scope

To combine production of olive oil with the treatment of the generated olive pulp for the production of bioenergy (in the form of CH_4, H_2 and ethanol) and fertilizer

OLIVE OIL

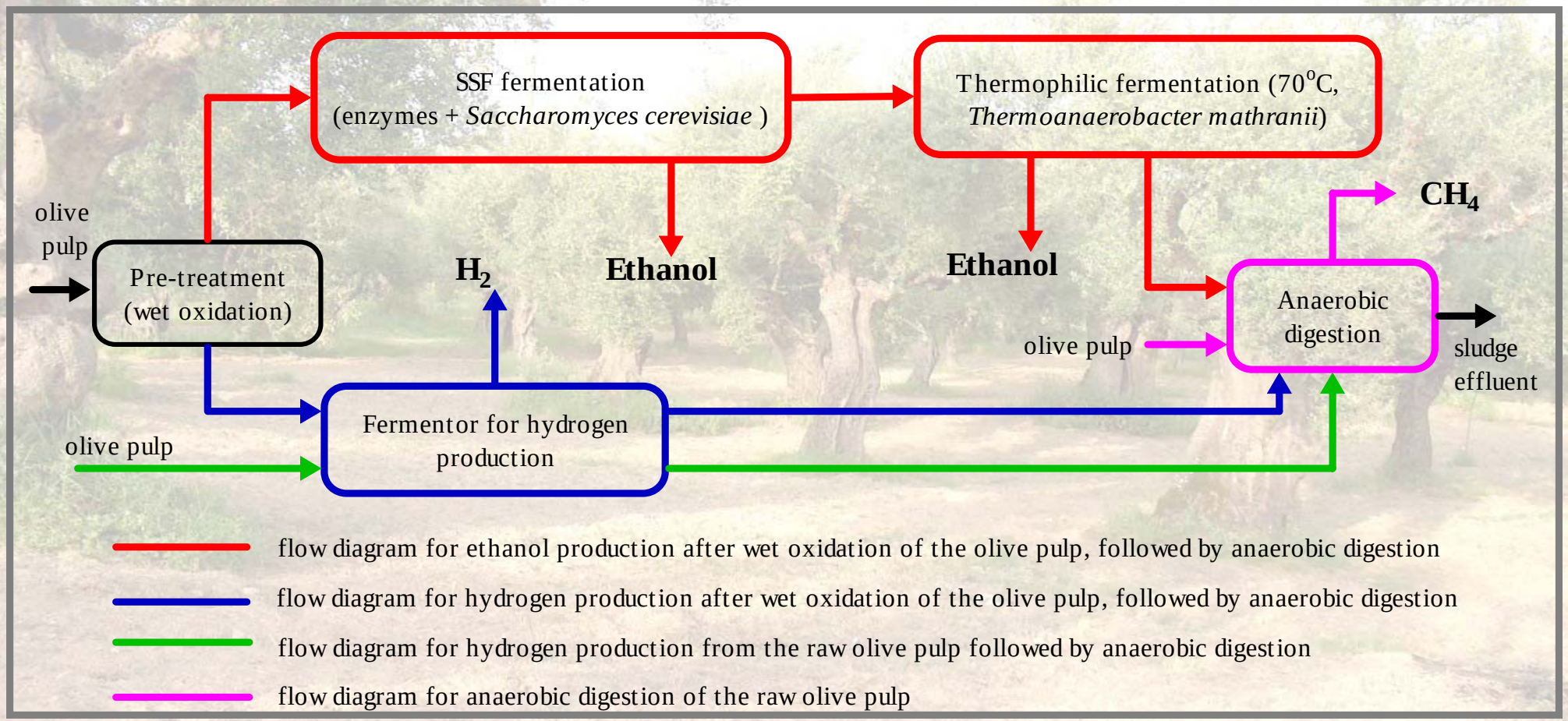
&

BIOENERGY

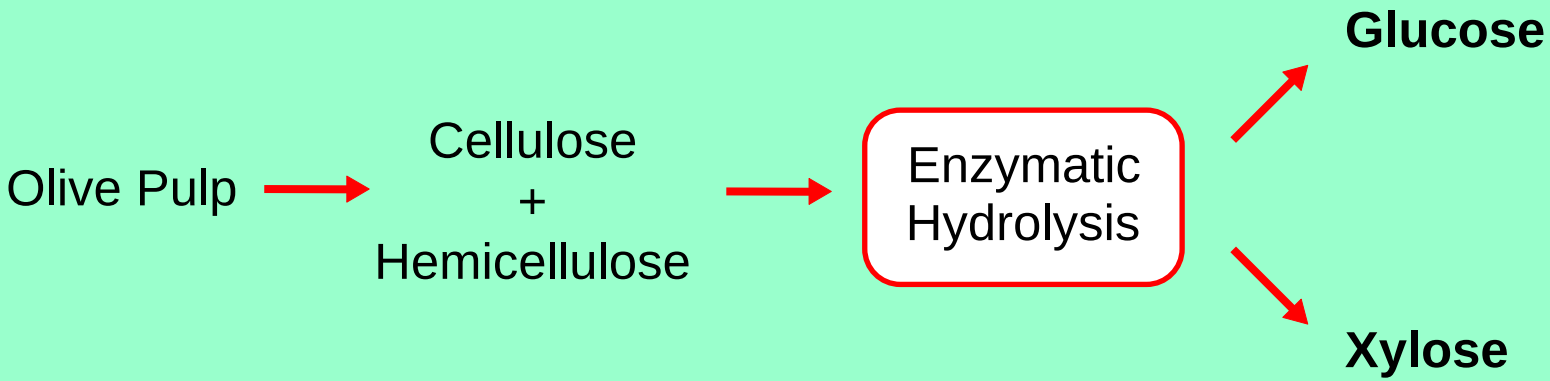
Characteristics of the olive pulp

Olive stones, %	8.9 ± 0.2
Water, %	70.5
TS, %	29.5 ± 1.2
Total carbohydrates, g / 100 g TS	24.5 ± 5.6
Chemical Oxygen Demand, g / 100 g TS	158.0 ± 10.1
Lignin, g / 100 g TS	38.4

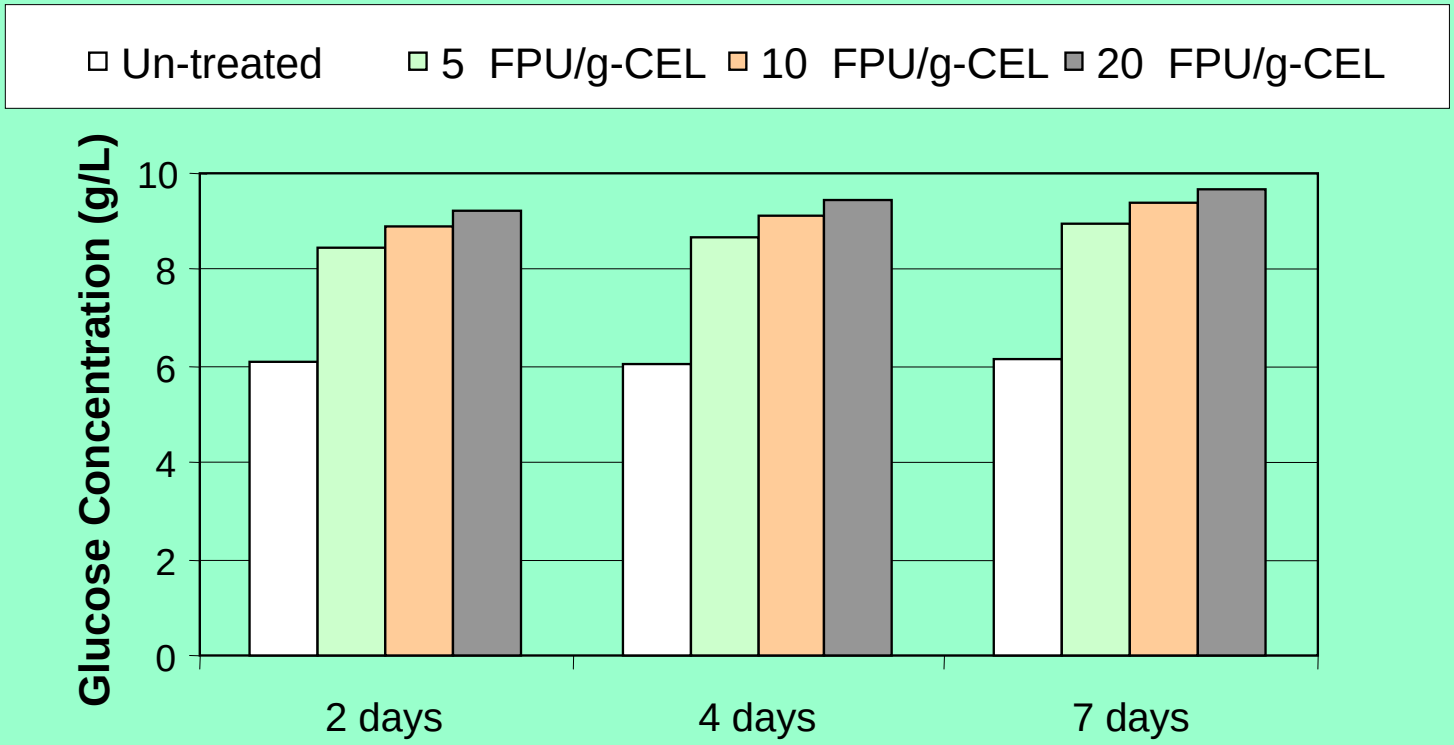
BIOTROLL project: innovative management of two-phase olive mill effluents



Bioethanol production from olive pulp



Enzyme hydrolysis of olive pulp



	Increase in Glucose 4 days	Increase in Xylose 4 days
5 FPU/g-CEL	**43%**	**15%**
10 FPU/g-CEL	**50%**	**22%**
20 FPU/g-CEL	**56%**	**27%**

Process efficiency

$C_6H_{12}O_6 \longrightarrow C_2H_5OH$

Enzyme loading (FPU/g-CEL)	Biomass Concentration (g-DM/L)	Ethanol Production (g/L)	Ethanol Yield (g-ETOH/g-GLU)
5	100	3.16	0.44
10		3.07	0.41
25		3.49	0.44
5	150	4.50	0.43
10		4.77	0.42
25		5.21	0.45
5	200	6.35	0.45
10		6.55	0.44
25		6.99	0.45

Hydrogenogenic CSTR

Active volume: 500 ml

Operating conditions

Temperature	35 or 55 °C
HRT (h)	14 - 30
Flow rates (ml/d)	300 - 1600
Loading rates (g TS/d)	20 - 90

Hydrogen production from batch and CSTR experiments with raw olive pulp

Batch experiments	mmole H_2 / g TS olive pulp
Olive pulp, 1:4	1.54 ± 0.30
Olive pulp, 1:20	1.61 ± 0.19

- CSTR efficiency: 0.32 mmole H_2 / g TS

Methanogenic CSTR

Active volume: 3 L

Operating conditions

Temperature	35 or 55°C
HRT	20 d
Flow rate	150 ml/d
Loading rate	7 g TS/d

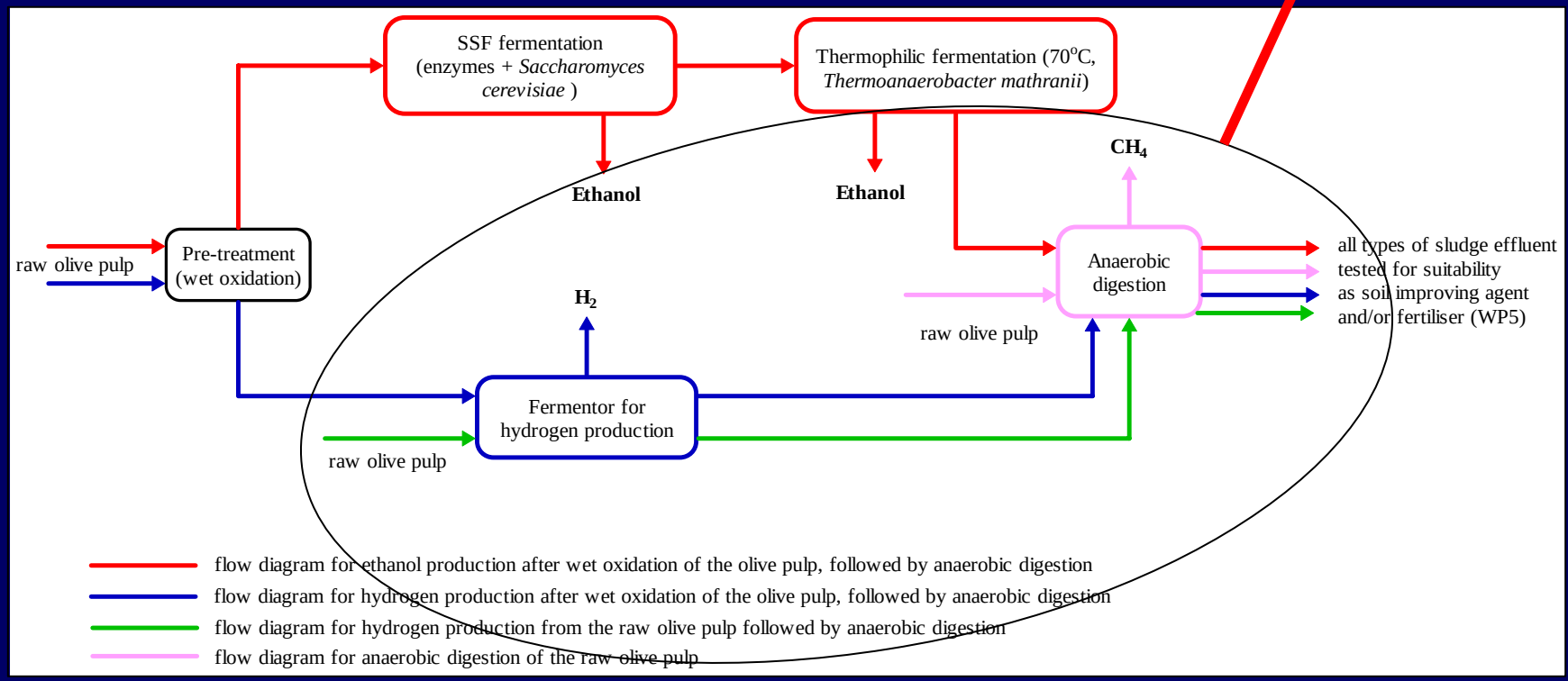
Methanogenic potential of the raw olive pulp and of the H_2-CSTR effluent

	mmole CH_4 / g TS	% TS removal
Raw olive pulp	18.5 ± 0.4	55.9 ± 7.9
H_2-CSTR effluent	19.0 ± 0.2	61.3 ± 6.8

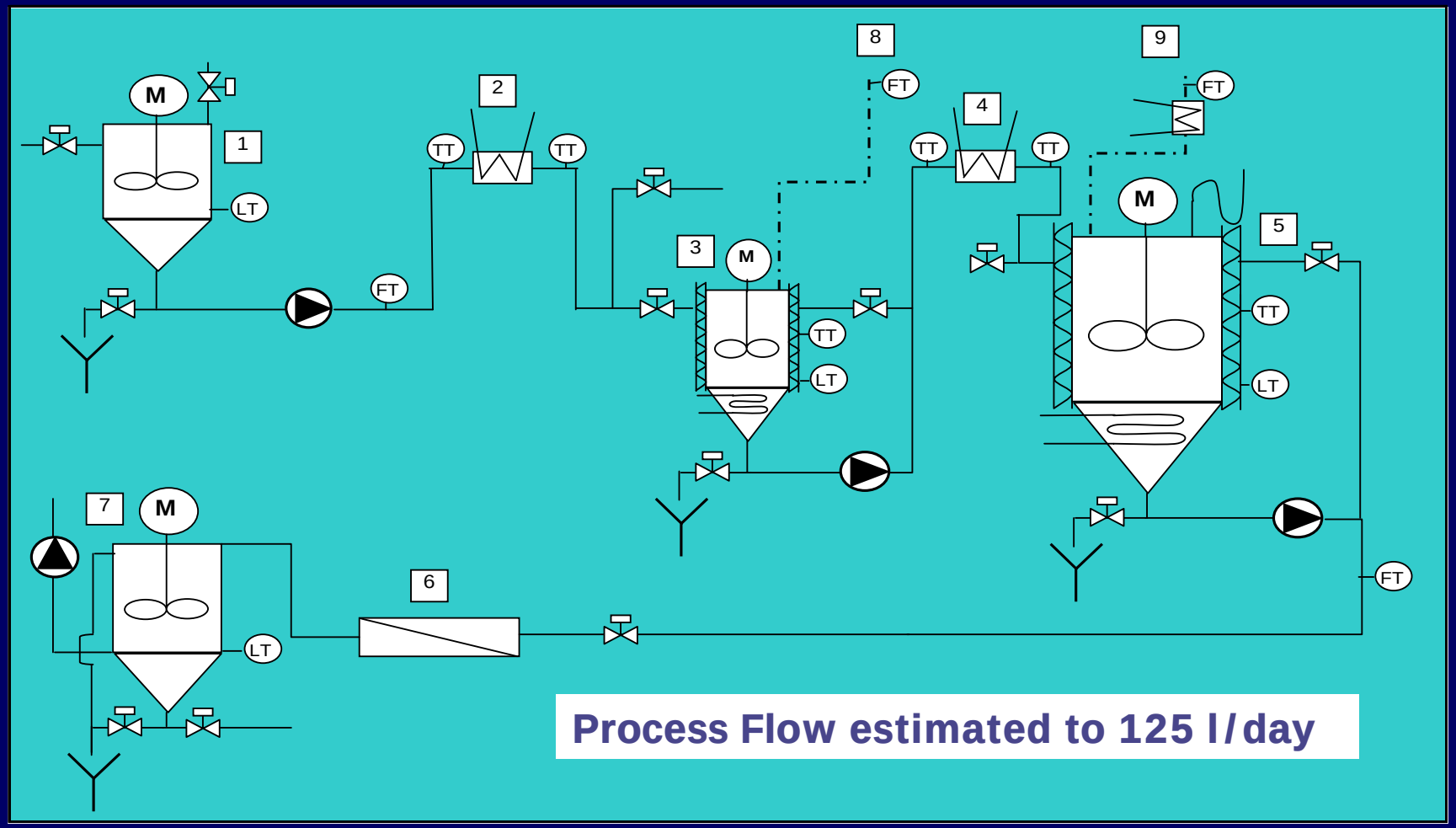
- CSTR efficiency: 14.1 mmole CH_4 / g TS raw olive pulp

  39 % TS removal

Processes evaluated to be feasible for Pilot Testing



Flow diagram – Pilot Plant



Estimation of the fertilizer value (Euro) of raw olive pulp and pretreated olive pulp

Element	Olive Pulp		Effluent from Hydrogen		Effluent from Methane	
	Conc. (kg/ton)*	**Euro**	**Conc.** (kg/ton)	**Euro**	**Conc.** (kg/ton)	**Euro**
N	6.4	8-16	3.9	4.8-9,6	2.5	2.6-5.2
P_2O_5	9.7	7.8-11.6	10.5	8.4-12.6	11.8	9.4-14.2
K_2O	5.7	1.7-2.3	4.0	1.2-1.4	3.0	0.9-1.2
TOTAL amount of **macronutrients** and value per ton	**21.8**	**17.5-29.9**	**18.4**	**14.4-23.6**	**17.3**	**12.9-20.6**

*kg of element per ton of fresh material.

Conclusions

- Olive pulp is a very promising biomass for production of biofuels
  - 0.42 m^3 CH_4 / kg TS
  - 0.13 m^3 CH_4 / kg olive pulp
- The final sludge effluent can be used as soil improving agent enhancing the process sustainability since the nutrients will be recirculated