Olive stone wooden residues and olive pomace characterization –potential uses in co-composting with olive mill wastewater

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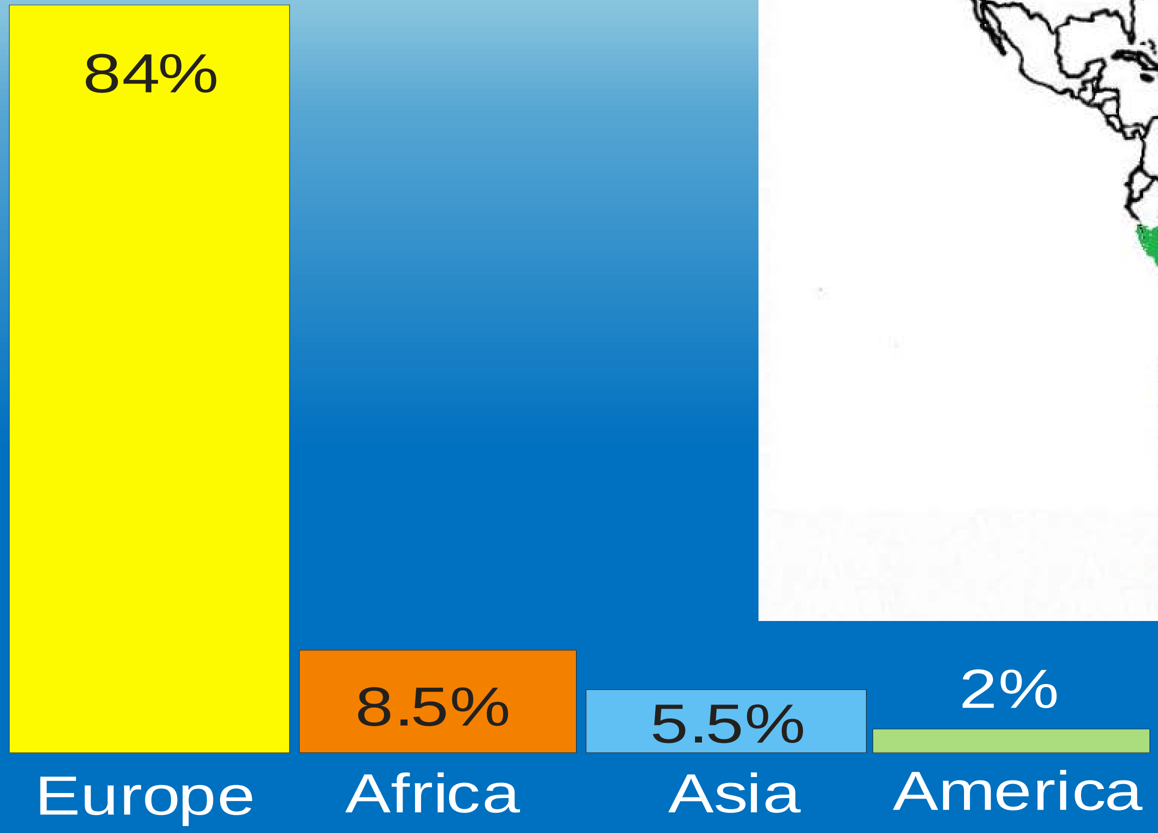
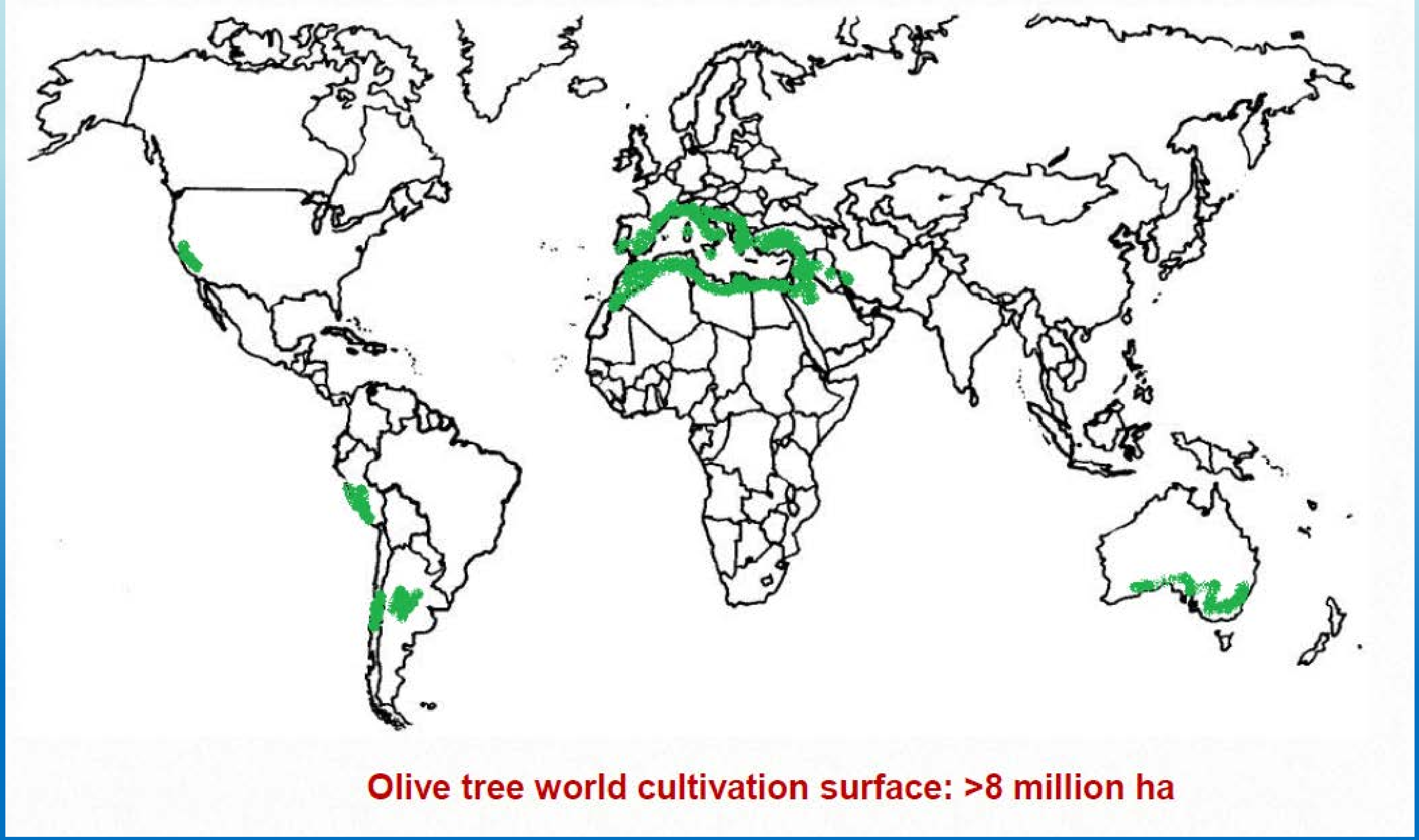
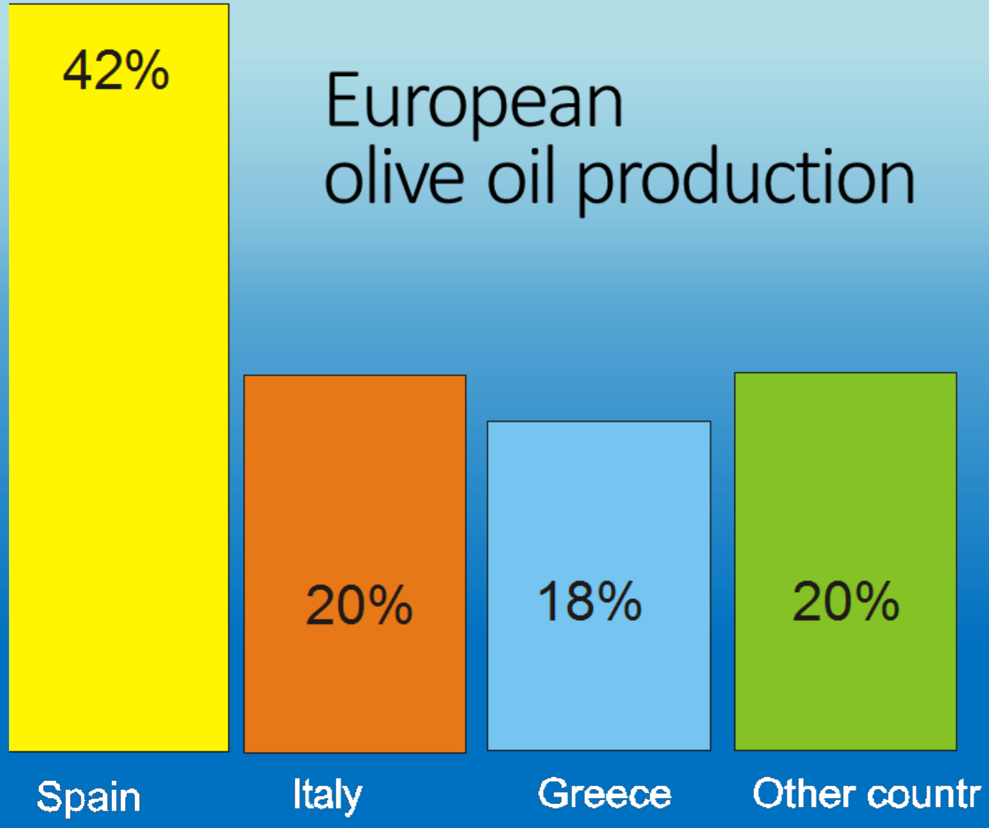
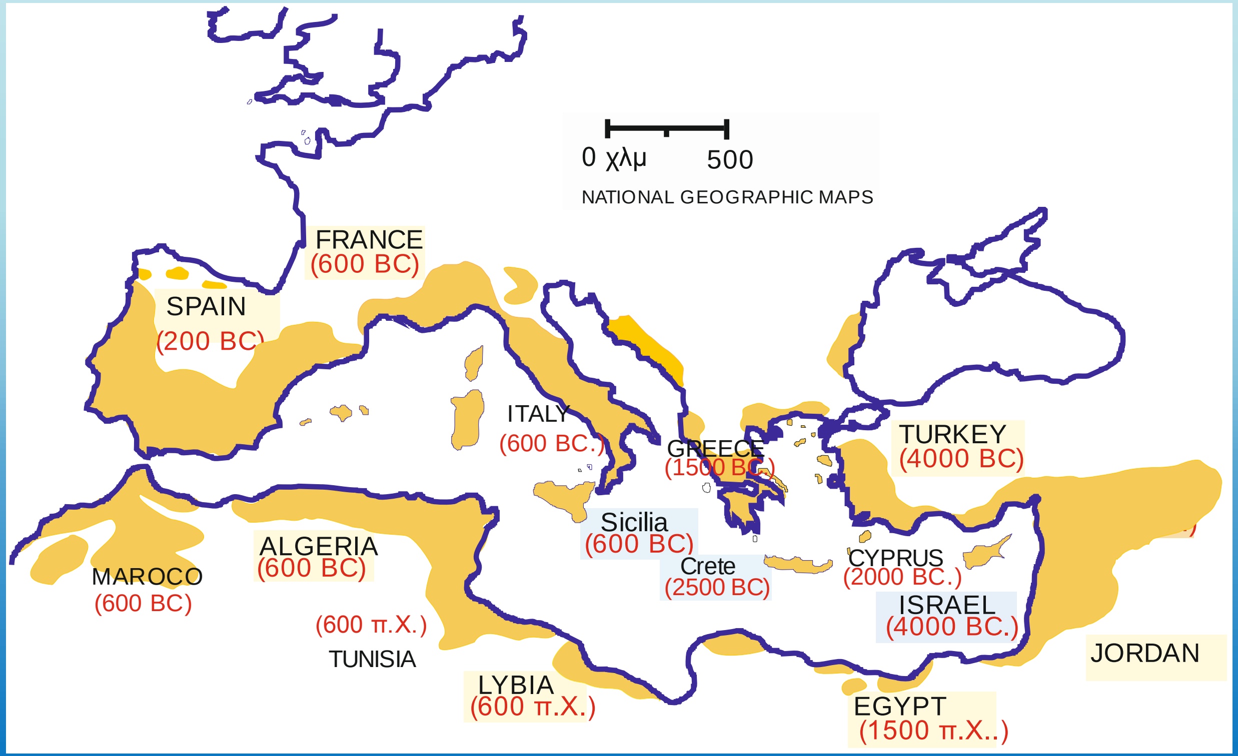
2-4 July 2015 – Tinos

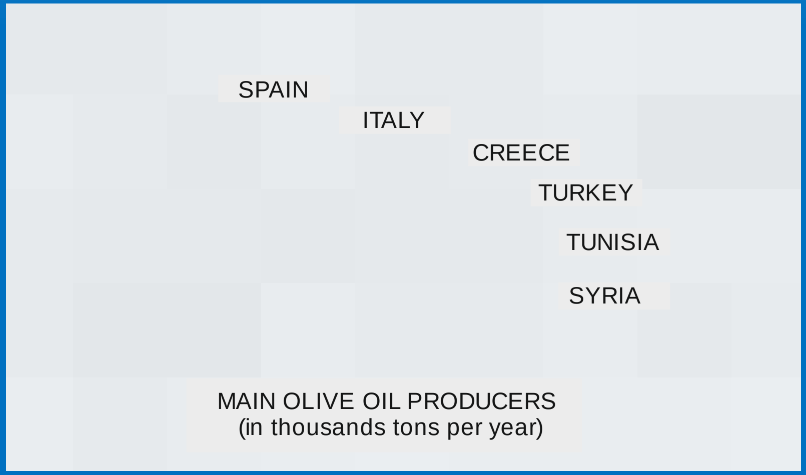
World wide olive oil production





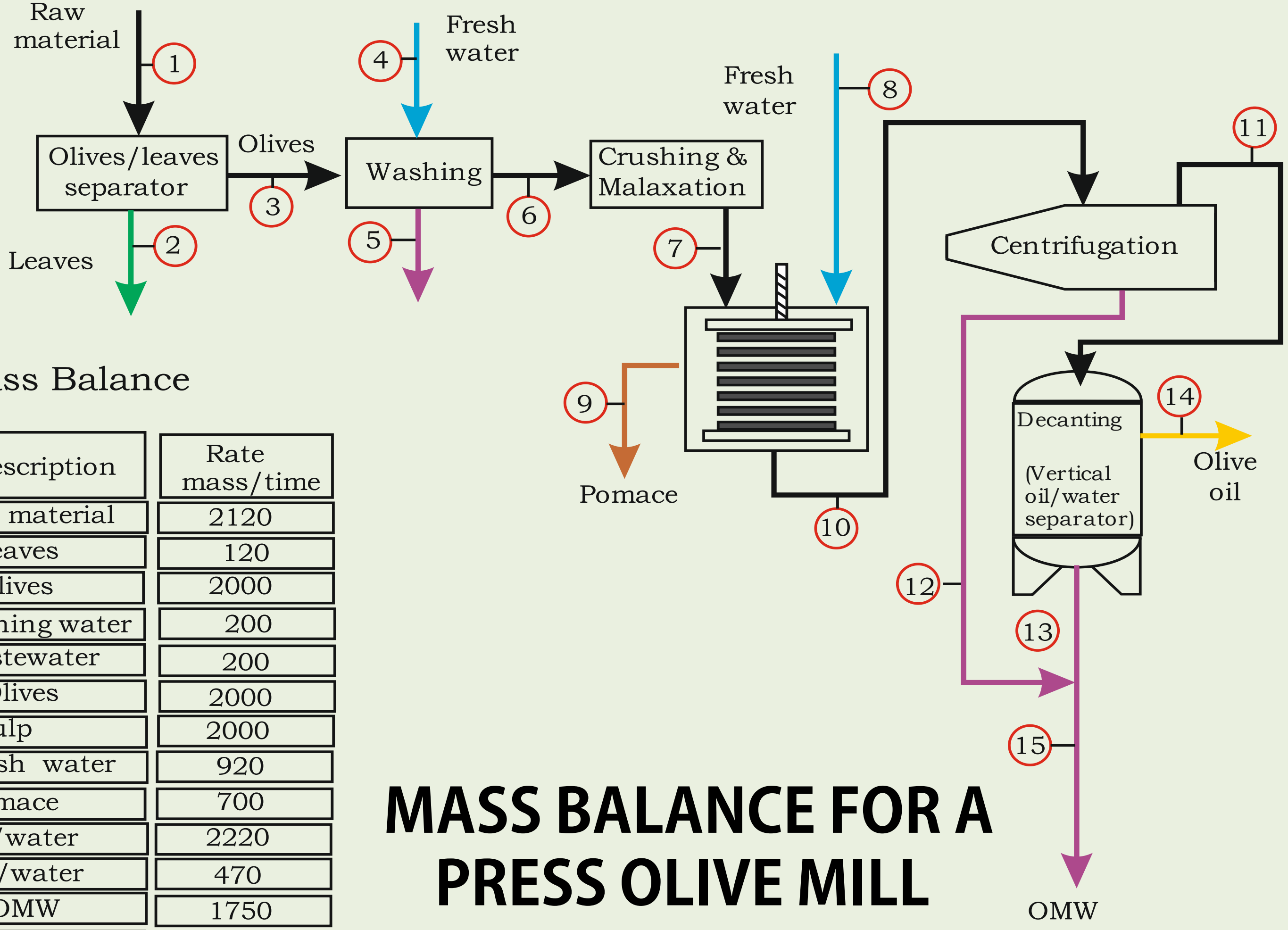

European
olive oil production
42%
20%
18%
20%
Spain
Italy
Greece
Other countr


0 χλμ 500
NATIONAL GEOGRAPHIC MAPS
FRANCE
(600 BC)
SPAIN
(200 BC)
ITALY
(600 BC.)
GREECE
(1500 BC)
TURKEY
(4000 BC)
Sicilia
(600 BC)
Crete
(2500 BC)
CYPRUS
(2000 BC.)
ISRAEL
(4000 BC.)
JORDAN
MAROCO
(600 BC)
ALGERIA
(600 BC)
(600 π.Χ.)
TUNISIA
LYBIA
(600 π.Χ.)
EGYPT
(1500 π.Χ..)


SPAIN
ITALY
CREECE
TURKEY
TUNISIA
SYRIA
MAIN OLIVE OIL PRODUCERS
(in thousands tons per year)

Greek situation

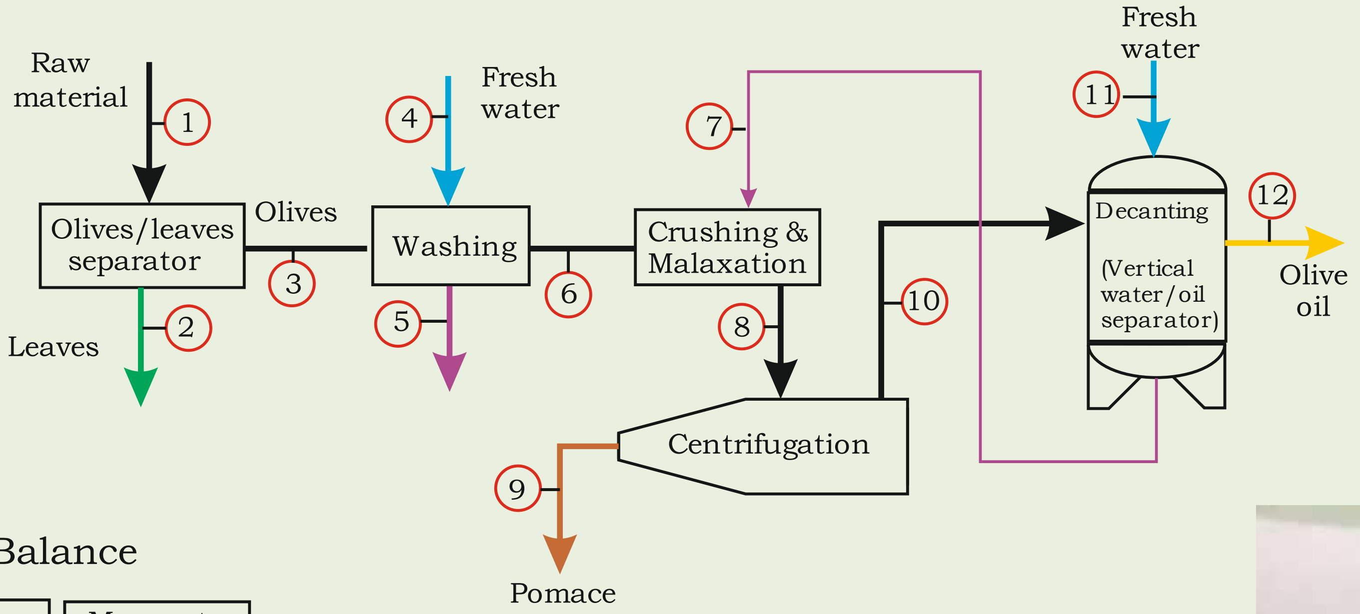
- The olives and olive oil are inextricable part of Greek culture
- In Greece there are 150.000.000 olive trees cultivated in 765.000 hectare
- The annual production of each tree rises up to 300 kg of olives
- The 1/3 of Greek farmers are working on cultivation of olives
- Olives and olive oil production in Greece rise up 1.750.000 tn and 400.000 tn respectively



Mass Balance

Line	Description	Rate mass/time
1	Raw material	2120
2	Leaves	120
3	Olives	2000
4	Washing water	200
5	Wastewater	200
6	Olives	2000
7	Pulp	2000
8	Fresh water	920
9	Pomace	700
10	Oil/water	2220
11	Oil/water	470
12	OMW	1750
13	OMW	50
14	Olive oil	420
15	Total OMW	1800

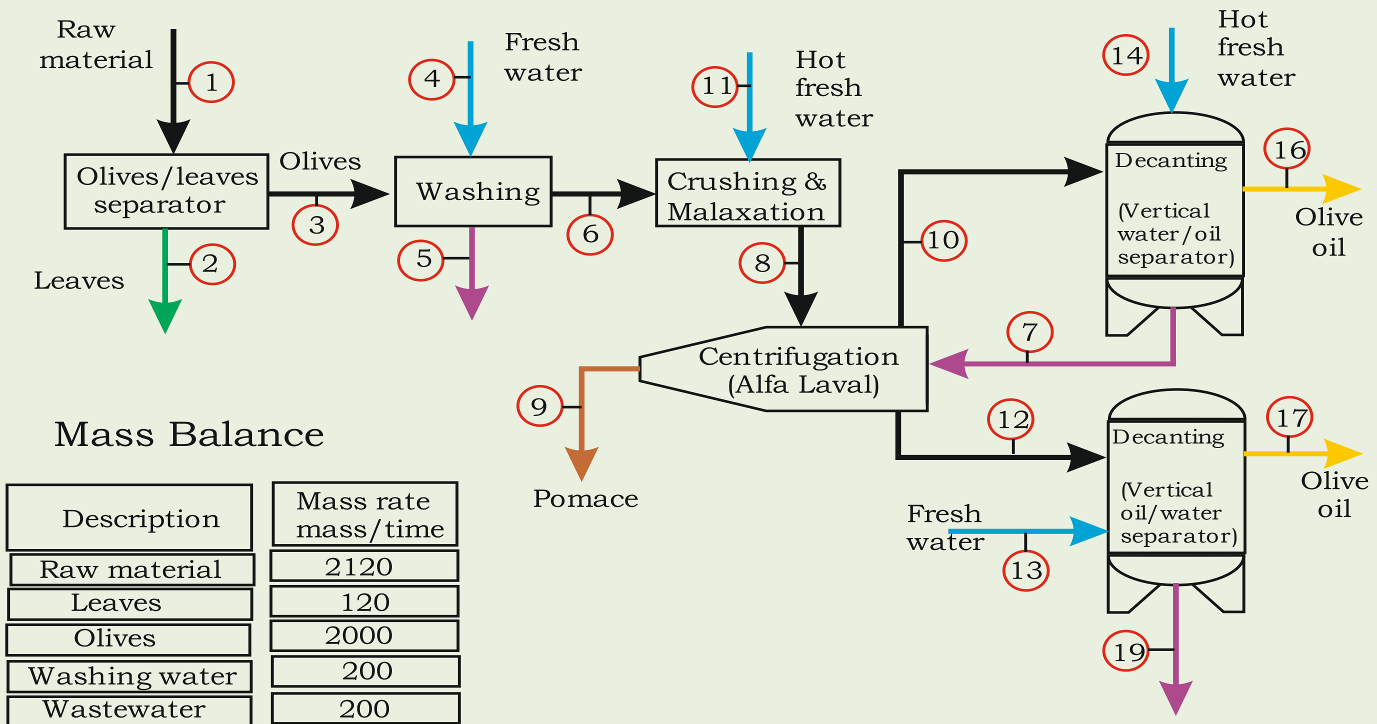
MASS BALANCE FOR A PRESS OLIVE MILL



MASS BALANCE FOR A II-PHASE OLIVE MILL

Mass Balance

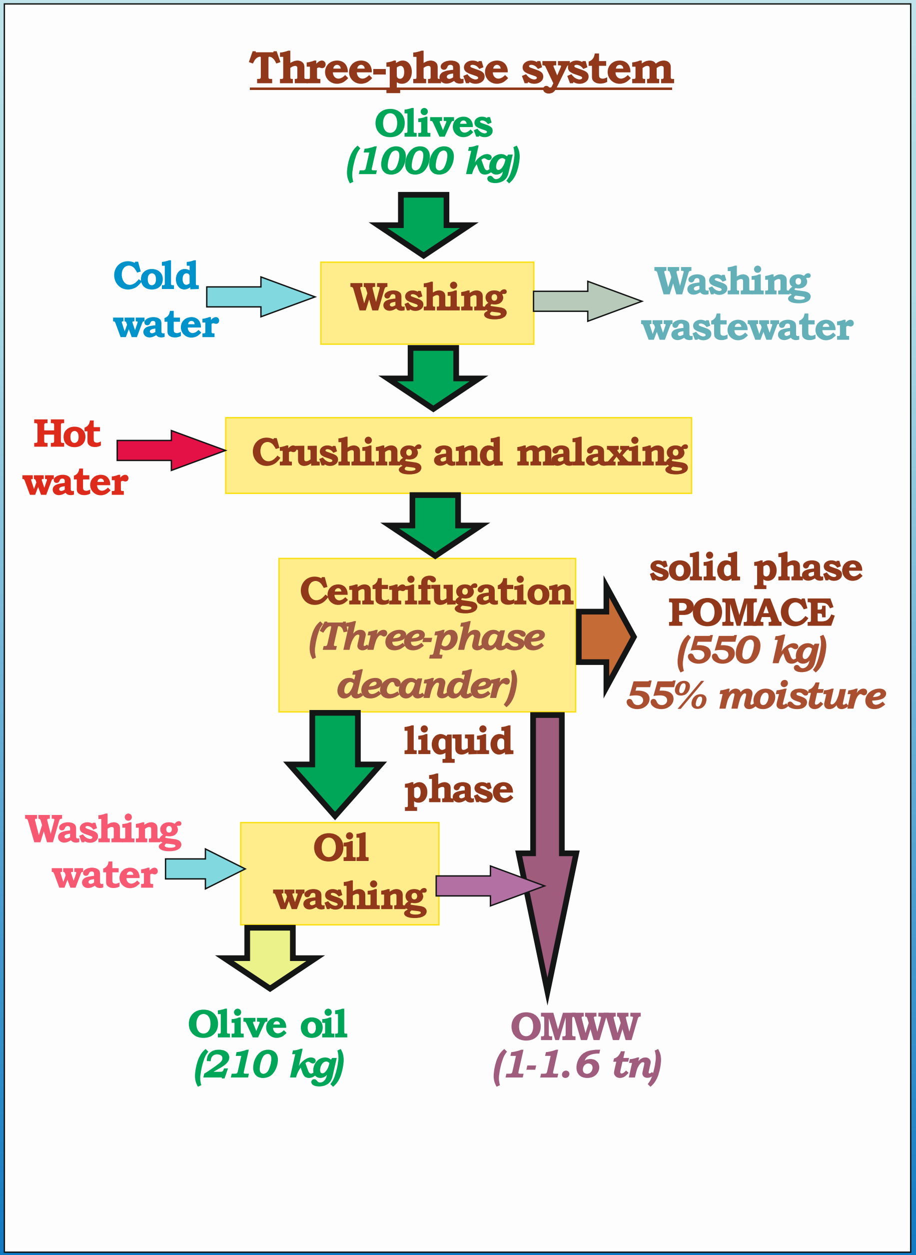
Line	Description	Mass rate mass/time
1	Raw material	2120
2	Leaves	120
3	Olives	2000
4	Washing water	200
5	Wastewater	200
6	Olives	2000
7	OMW	50
8	Pulp	2050
9	Pomace	1000
10	Oil/water	500
11	Hot water	50
12	Olive oil	400

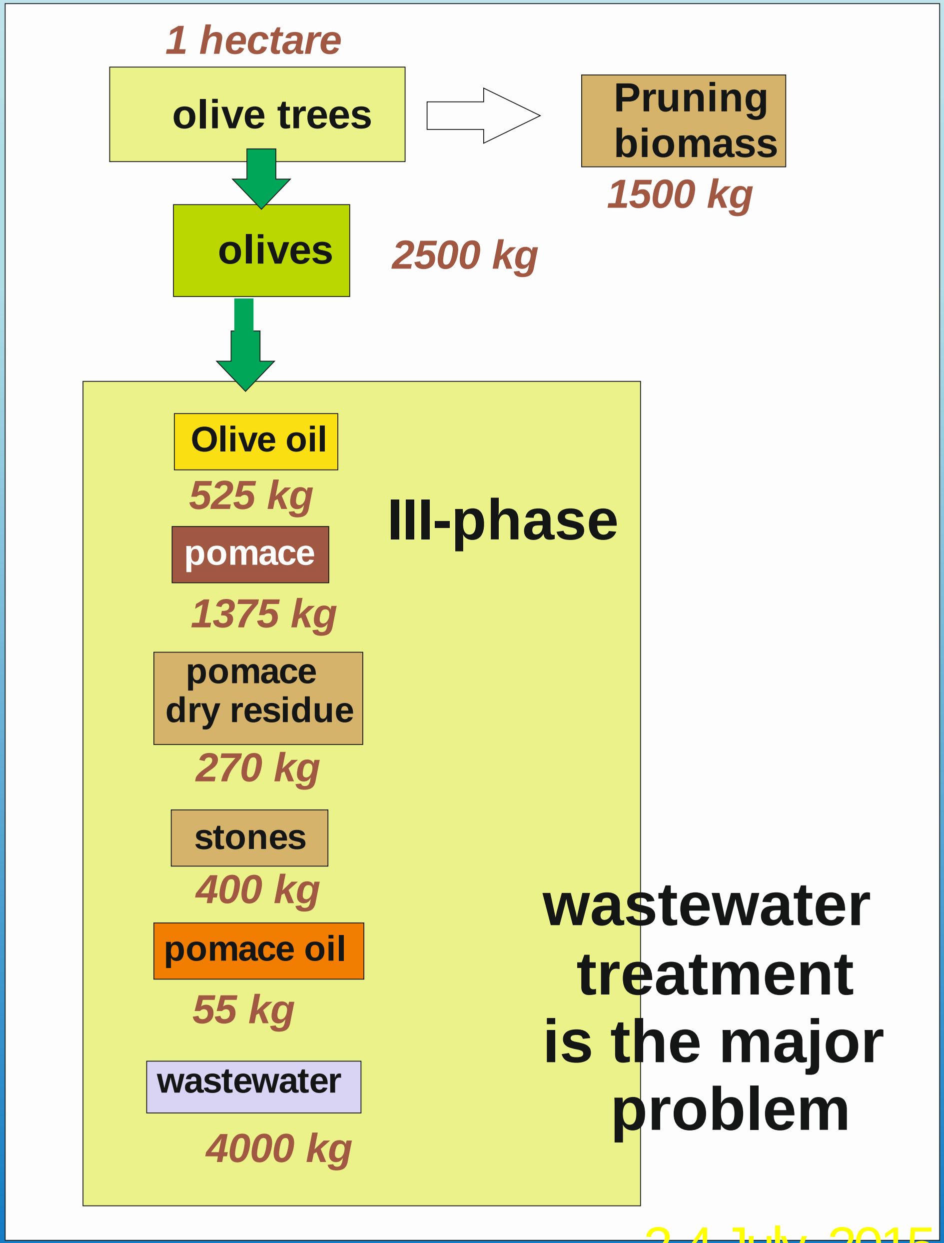


Mass Balance

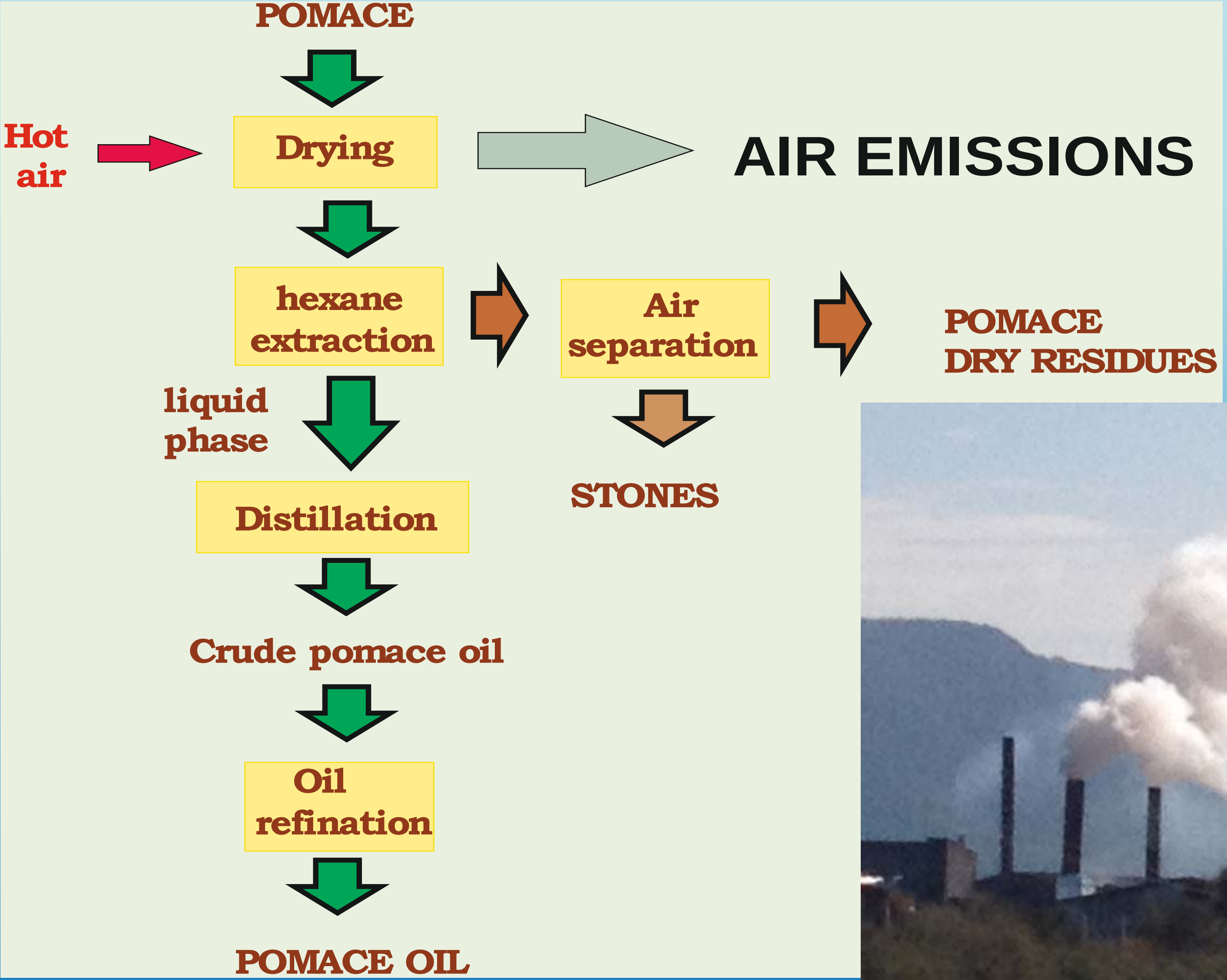
Line	Description	Mass rate mass/time
1	Raw material	2120
2	Leaves	120
3	Olives	2000
4	Washing water	200
5	Wastewater	200
6	Olives	2000
7	OMW	740
8	Pulp	2050
9	Pomace	1000
10	Oil/water	700
11	Hot water	50
12	Oil/water	1040
13	Hot water	350
14	Hot water	400
16	Olive oil	360
17	Olive oil	40
19	Total OMW	1400

MASS BALANCE FOR A III-PHASE OLIVE MILL

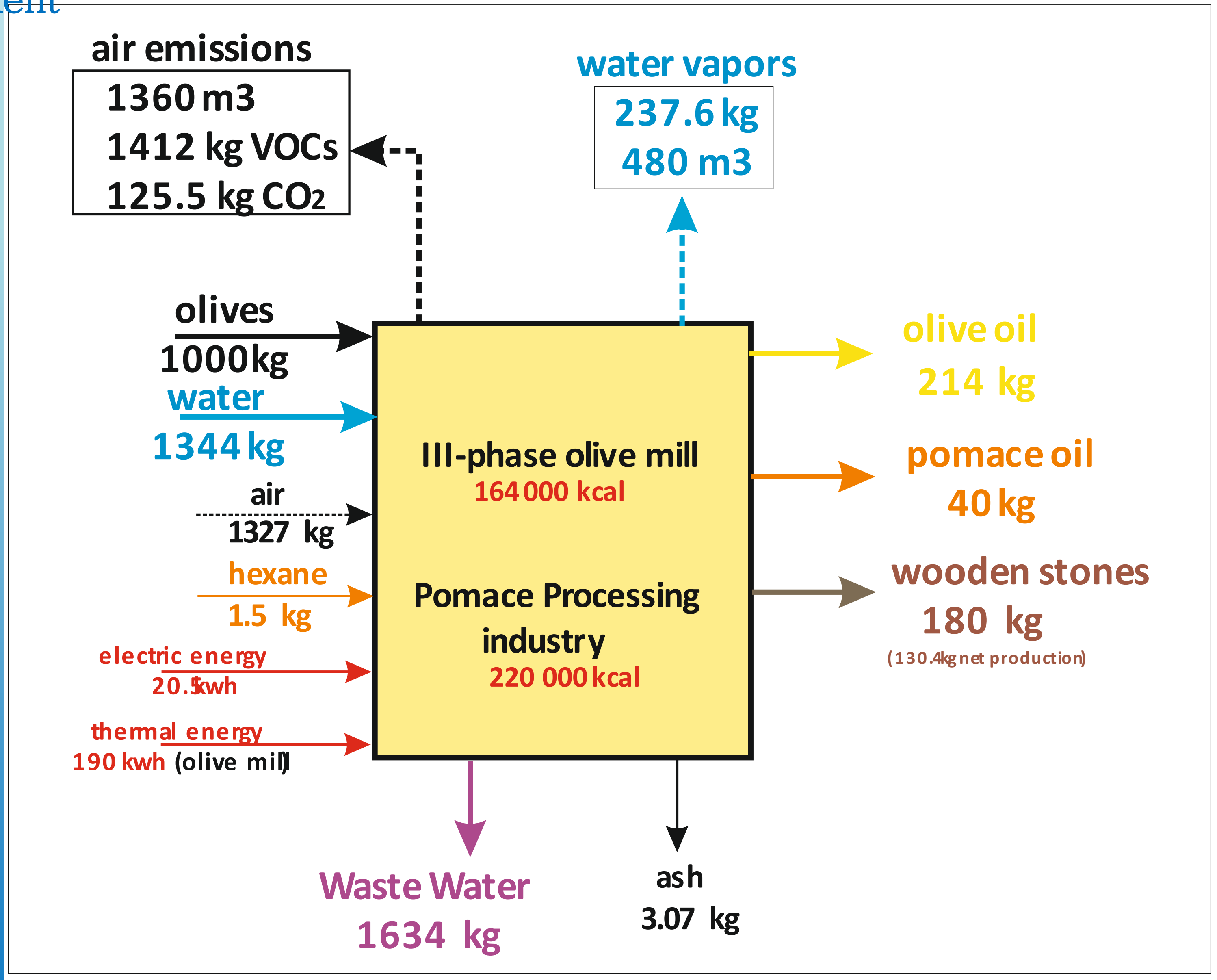

Three-phase system
Olives
(1000 kg)
Cold water
Washing
Washing wastewater
Hot water
Crushing and malaxing
Centrifugation
(Three-phase decander)
solid phase
POMACE
(550 kg)
55% moisture
liquid phase
Washing water
Oil washing
Olive oil
(210 kg)
OMWW
(1-1.6 tn)


1 hectare
olive trees
Pruning biomass
1500 kg
olives
2500 kg
Olive oil
525 kg
III-phase
pomace
1375 kg
pomace dry residue
270 kg
stones
400 kg
pomace oil
55 kg
wastewater
4000 kg
wastewater treatment is the major problem

POMACE PROCESSING INDUSTRIES



III phase & press pomace



TOTAL MASS & ENERGY BALANCE

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Greek situation

- There are 2.633 olive oil mills
    - 2,152 centrifugal systems (mostly III-phases)
    - 481 traditional (pressure squeezing)

- There are 20 pomace processing plants

21.4 tn olive oil

100 tn olives

24 tn water

OLIVE MILL
III-phases

49.6 tn pomace

Dry mater (DM)	22.4 tn
Total Organic Carbon (TOC)	9.5 tn
kernel oil	1 tn

74.4 tn OMWW wastewater

Total Solids (TS)	63.5 g/l
Total Suspended Solids (TSS)	2.8 g/l
Total Volatile Solids (TVS)	57.37 g/l
Ash	6.13 g/l
Total Organic Carbon (TOC)	39.82 g/l
Total Organic Nitrogen (TKN)	0.76 g/l
Total Phosphorus (P_2O_5)	0.53 g/l
pH	4.8
BOD_5	45.5 g/l
COD	92.5 g/l
olive oil	15 g/l
Conductivity	12 mmhos/cm
Total Phenolic Compounds (TPCs)	10.65 g/l
Potasium (K_2O)	2.37 g/l

18 tn

OSWR

Olive Stone Waste Residue

$$\frac{OMWW}{OSWR} = 4.1$$

Physical and Chemical Characteristics of OSWR

Moisture ,%	13,50
Fats and oils ,% of TS (total Solids)	1,85
Nitrogen content substances ,% of TS	7,39
Total sugars, % of TS	2,13
Cellulose, % of TS	37,39
Hemicellulose, % of TS	17,04
Ash, % of TS	3,66
Ether extraction substances, % of TS	8,61
Lignin, %of TS	21,97
Kjendahl Nitrogen content, % of TS	1,093
Phosphorous content as P_2O_5, % of TS	0,113
Potassium content as K_2O, % of TS	0,83
Calcium content as CaO, % of TS	0,95
Total Carbon content, % of TS	56,13
C/N ratio	51,34
C/P ratio	1137

Characteristics of OMWW

Characteristics	Value ($mg\ L^{-1}$)
pH	4.2
BOD_5	25850
COD	80250
Total Suspended Solids	4580
Volatile Suspended Solids	4024
Total Phosphorus	870
Total Kjeldahl Nitrogen	1150
Total Phenolic Compounds (TPC)	14250

Treatment methods applied as case studies in Greece

Physical methods

Evaporation ponds
Land disposal

Biological methods

Anaerobic digestion
Aerobic digestion
Nitrogen fixation

Physicochemical methods

Membrane's technology
Wet oxidation Evaporation
Electrochemical oxidation
Evaporation

Combined methods

Wet oxidation following by membrane technologies (EHO method)
Nitrogen fixation following by aerobic digestion (Bio-wheel method)

Evaporation ponds

- This is the common used method of OMW treatment in Greece
- There are about 400 installations in Greece

Advantages
- Simplicity
- Low fixed and operational cost (5 c/kg olive oil)

Disadvantages
- Air emissions and odorous especially in summer time
- Leakages
- Farther needs for treatment of solids residues

Land disposal (irrigation method)

Advantages

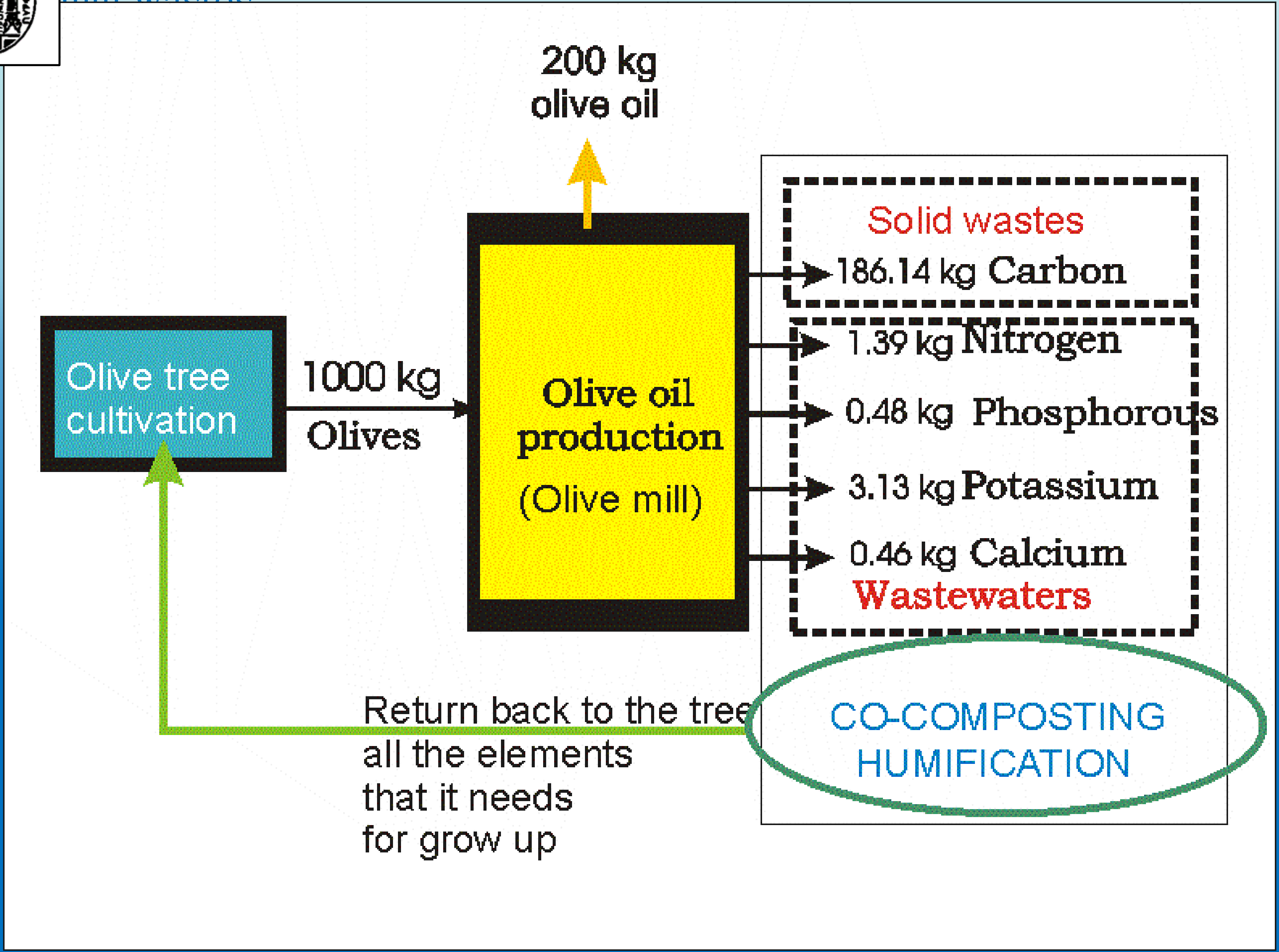
Simplicity
Low fixed and operational cost (about 5 c/kg olive oil) excluding the sludge treatment cost and the proper expectation by case for non contamination of ground waters and the soil.

Disadvantages

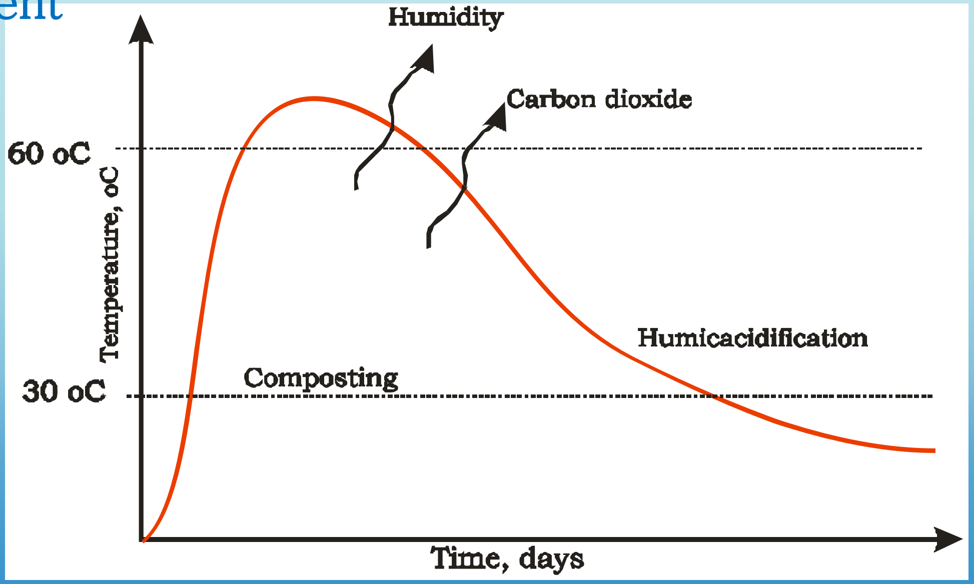
Air emissions and odorous especially in summer time
Dangerous for ground waters contamination
Farther needs for R & D
Farther treatment for pretreatment sediments
Difficulties for standardization of the method
The method doesn’t meet the National EQSs for land application

The potassium in the soil is increased
The phenolic compounds in the soil are increased
The microbial activity in the soil is decreased

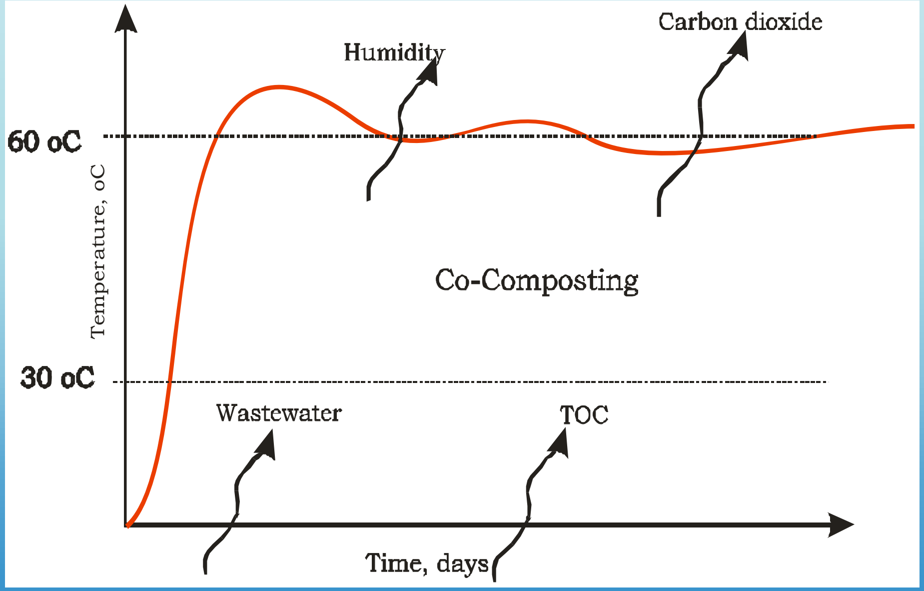
Institute for Olive tree and Subtropical plants of Chania, Crete



Basic concept for sustainability of olive cultivation

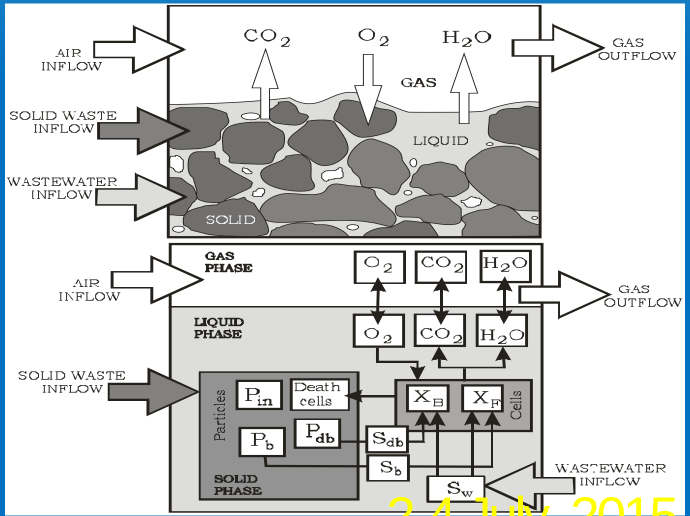


Typical operation of a composting pile

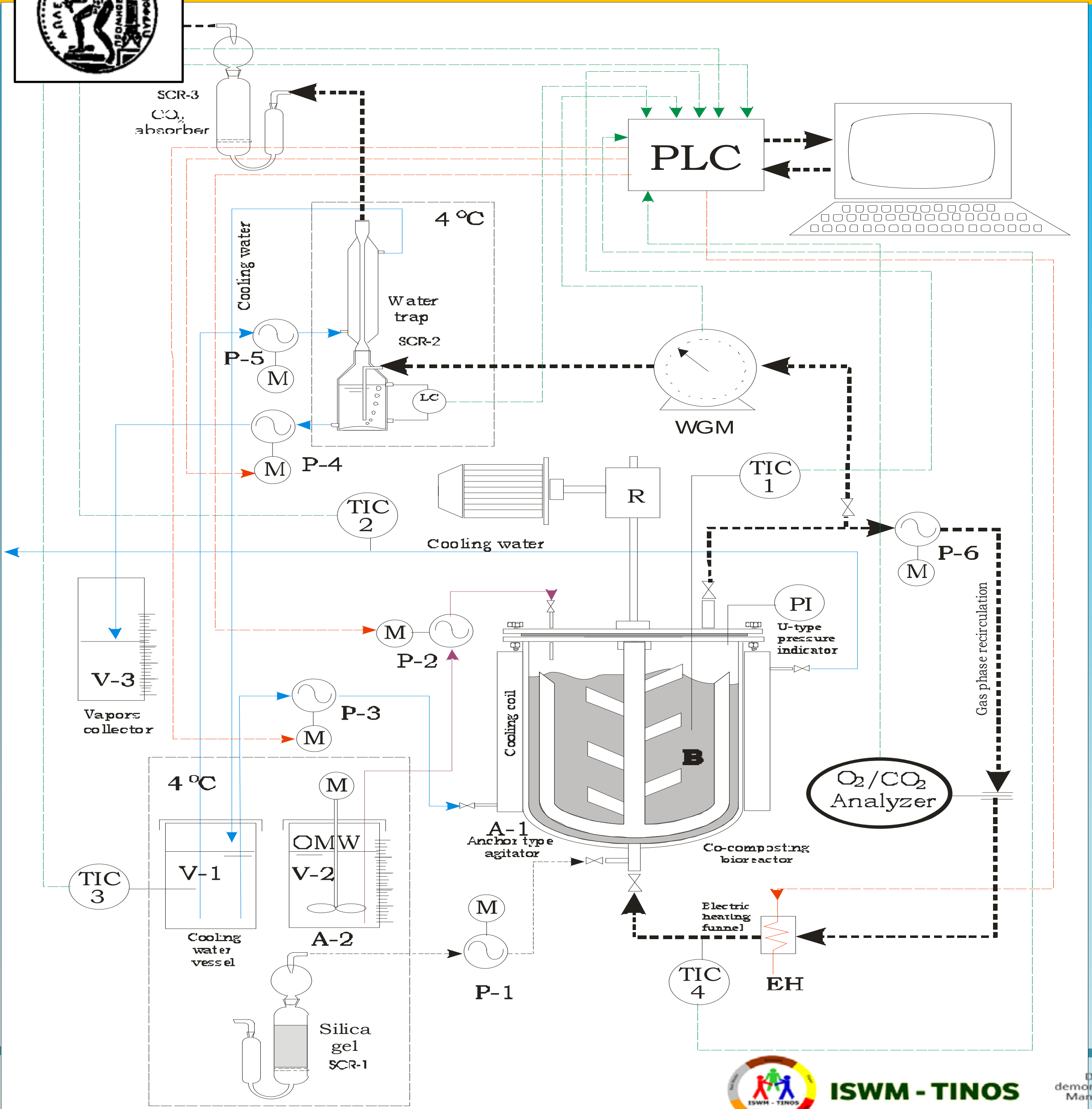


Basic Concept for a success wastewater treatment using co-composting

Moisture (45-60%)
Biodegradable Carbon content in the substrate (>30%)
C/N ratio (30-17/1)
C/P ratio (<500/1)
Partial Oxygen Pressure inside the bulking material (5-20%)



Semi-batch operating lab scale co-composting unit



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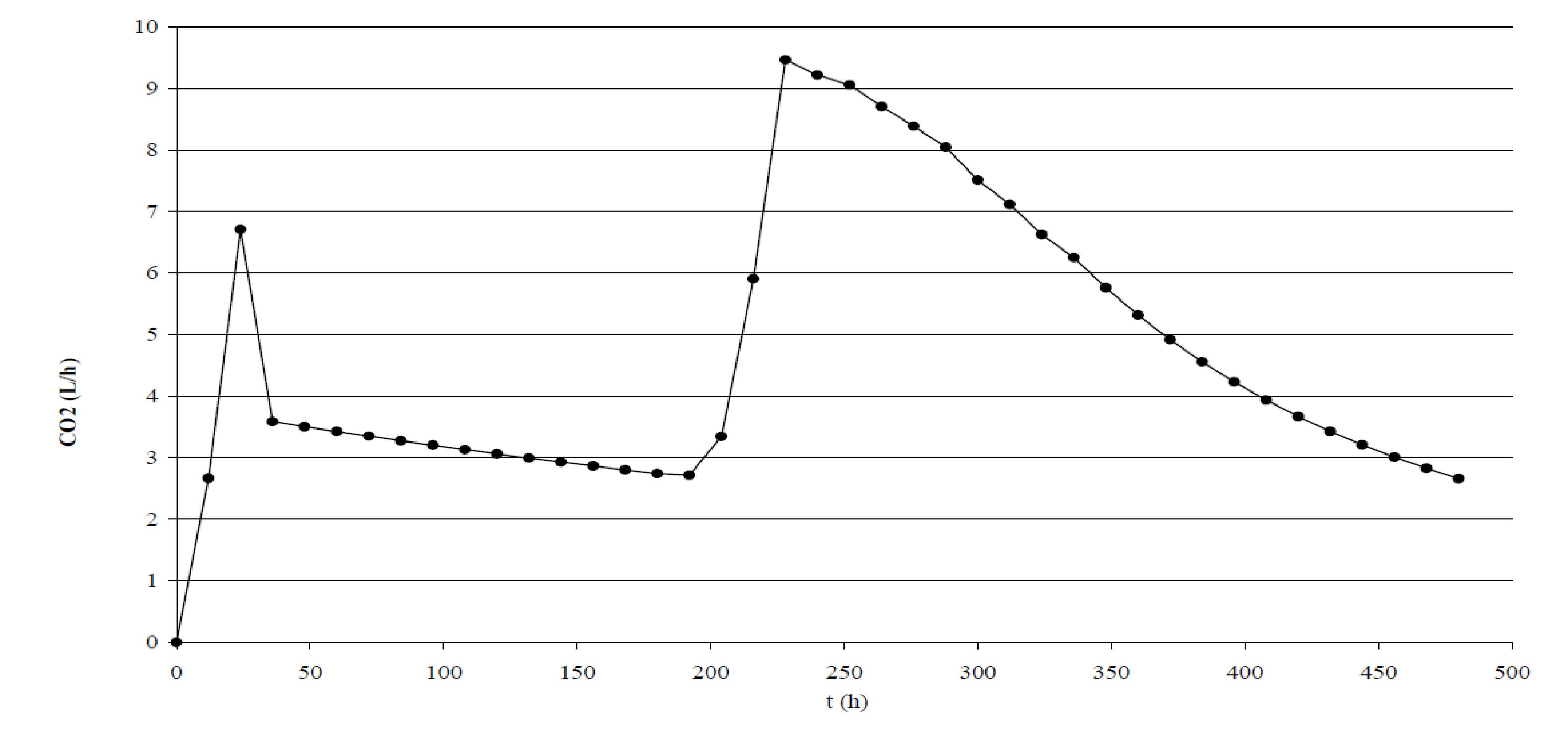
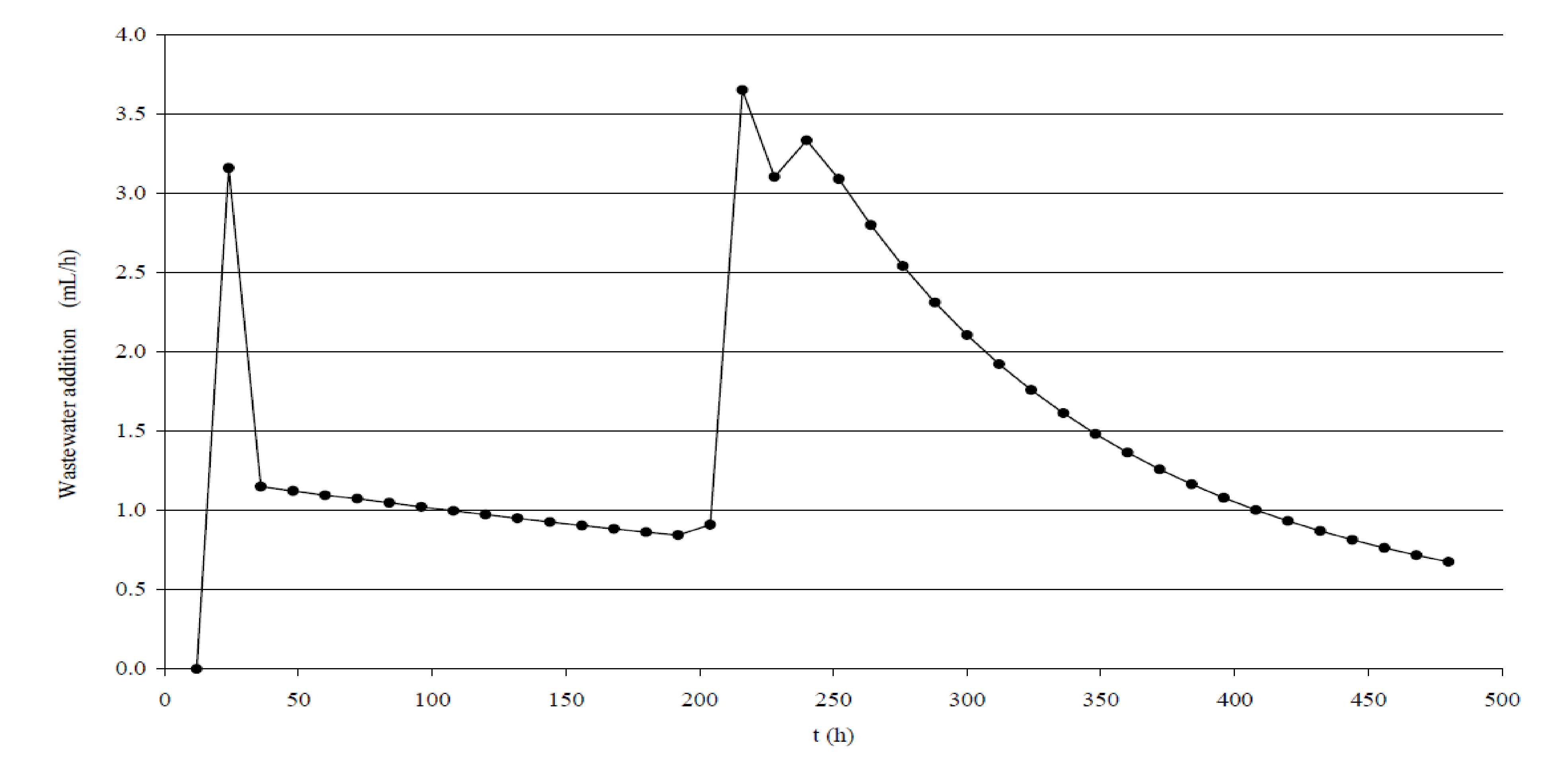
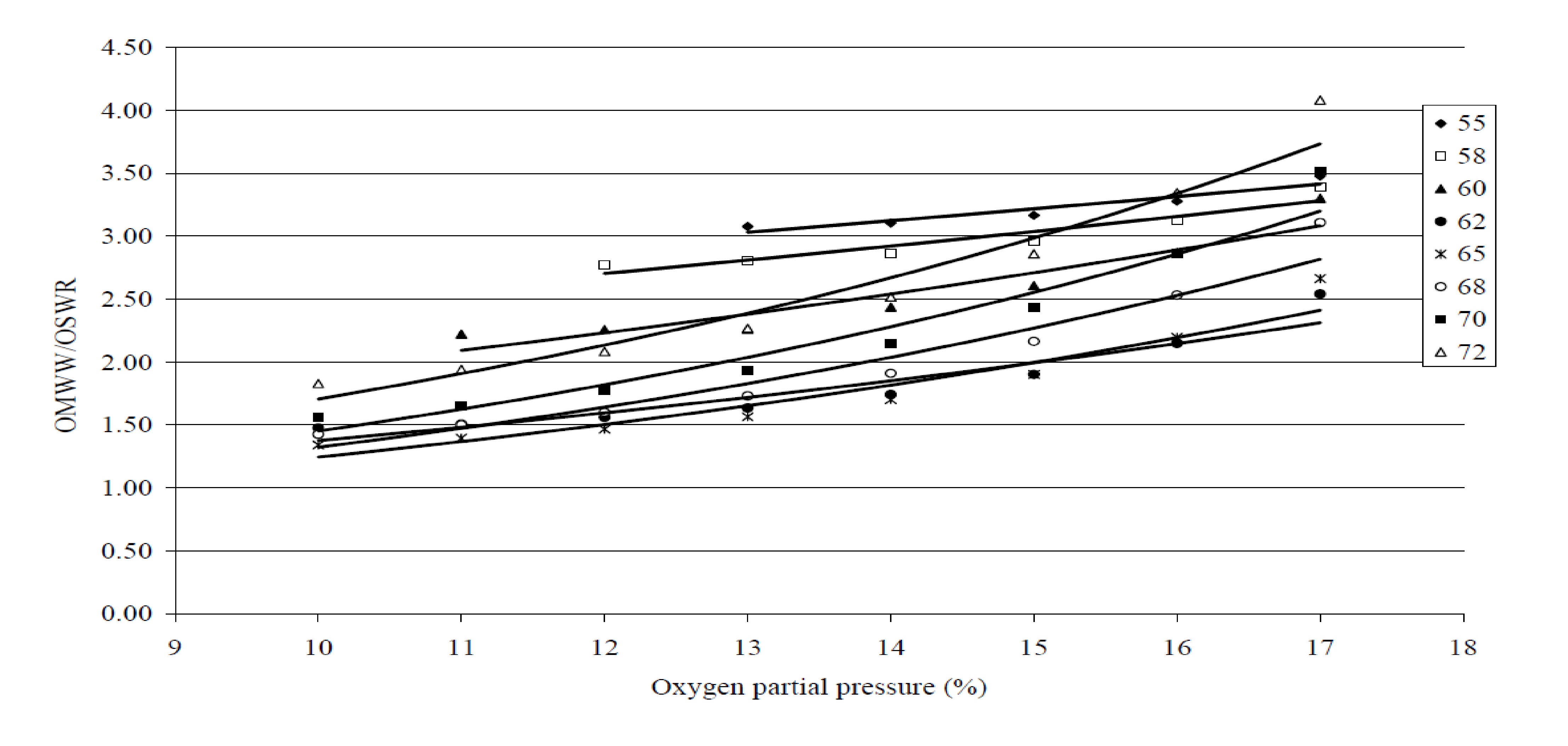
Carbon dioxide production during a typical experiment



The additional amounts of wastewater feeding during a typical experiment



The optimum temperature in relation of OMWW/OSWR ratio and Oxygen Partial pressure



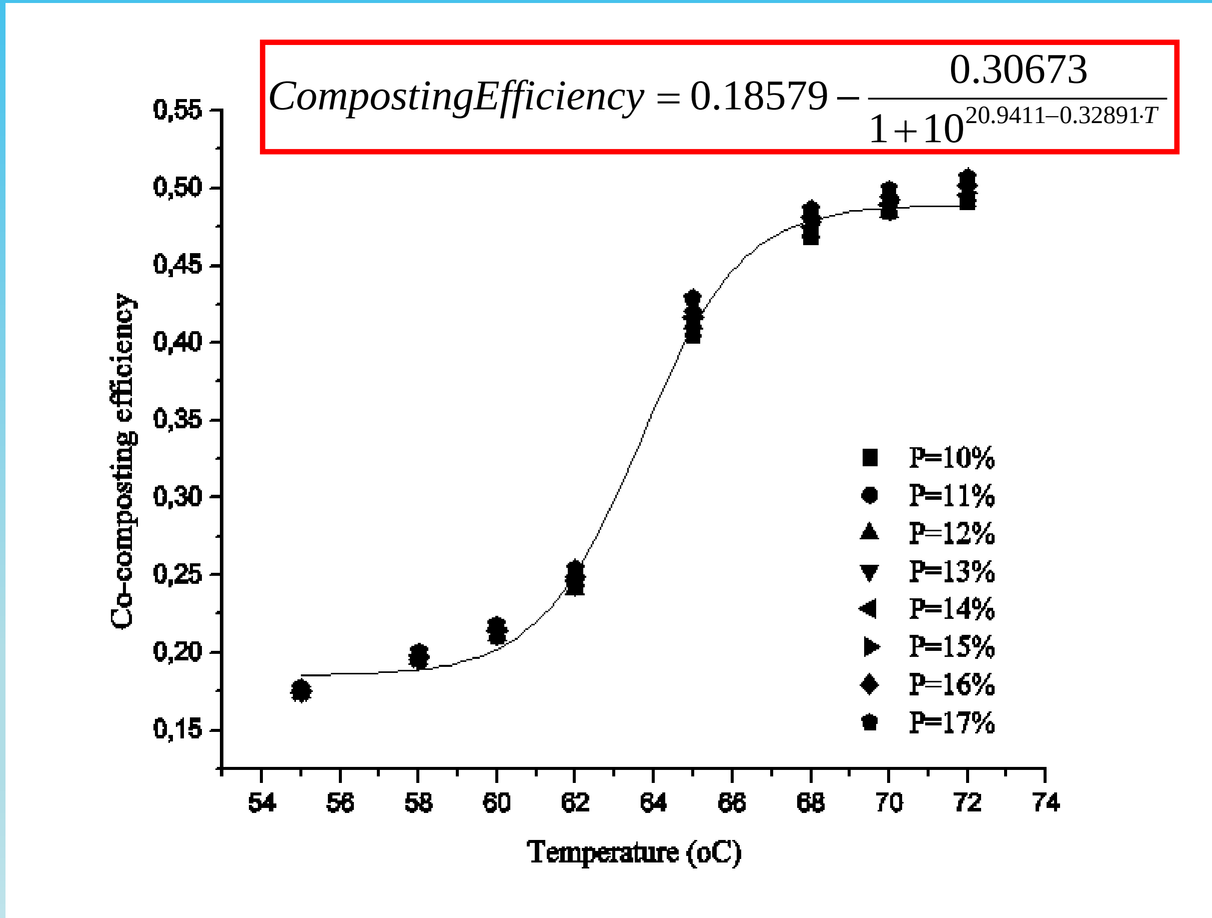
Optimization Parameter

Composting Efficiency = C-CO_2/Total Biodegradable Carbon

Limitation Parameter

OMWW/OSWR = 4.1

Effect of co-composting temperature and Oxygen partial Pressure on the co-composting efficiency



T= 55oC $\frac{OMWW}{OSWR} = 2.0578e^{0.0298 \cdot P}$

T= 58oC $\frac{OMWW}{OSWR} = 1.698e^{0.0388 \cdot P}$

T= 60oC $\frac{OMWW}{OSWR} = 1.0275e^{0.0646 \cdot P}$

T= 62oC $\frac{OMWW}{OSWR} = 0.6559e^{0.0741 \cdot P}$

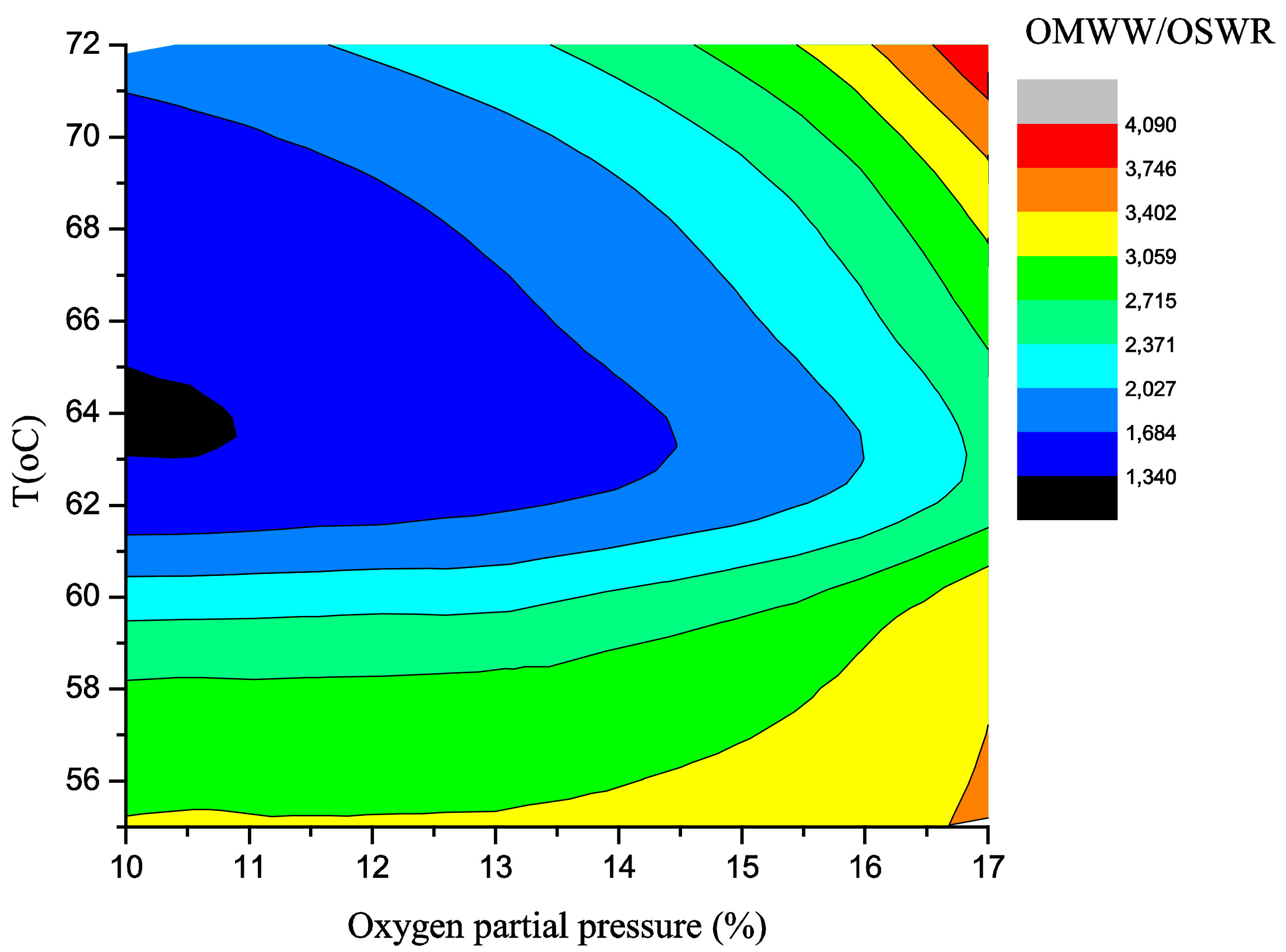
T= 65oC $\frac{OMWW}{OSWR} = 0.4841e^{0.0945 \cdot P}$

T= 68oC $\frac{OMWW}{OSWR} = 0.449e^{0.108 \cdot P}$

T= 70oC $\frac{OMWW}{OSWR} = 0.4695e^{0.1129 \cdot P}$

T= 72oC $\frac{OMWW}{OSWR} = 0.5575e^{0.1119 \cdot P}$

Effect of Temperature and air oxygen content on OMWW/OSWR ratio



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T= 72oC $\frac{OMWW}{OSWR} = 0.5575e^{0.1119 \cdot P}$

Pilot scale unit in National Technical University of Athens

Conclusions

- The co-composting of the OSWR with the OMWW is an effective treatment method for OMWW
- The efficiency of the co-composting depends on composting temperature and the initial ratio of OMWW/OSWR but it is independed on oxygen partial pressure.
- The optimal composting conditions for OMWW/OSWR=4.1 were determined for T=68oC and P=16%
- The final composting product is a good soil conditioner with enough fertility

Thank you for your attention