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3RD INTERNATIONAL CONFERENCE
on Sustainable Solid Waste Management

Performance and kinetic evaluation of different HRT application on complex substrates (winery waste) anaerobic digestion

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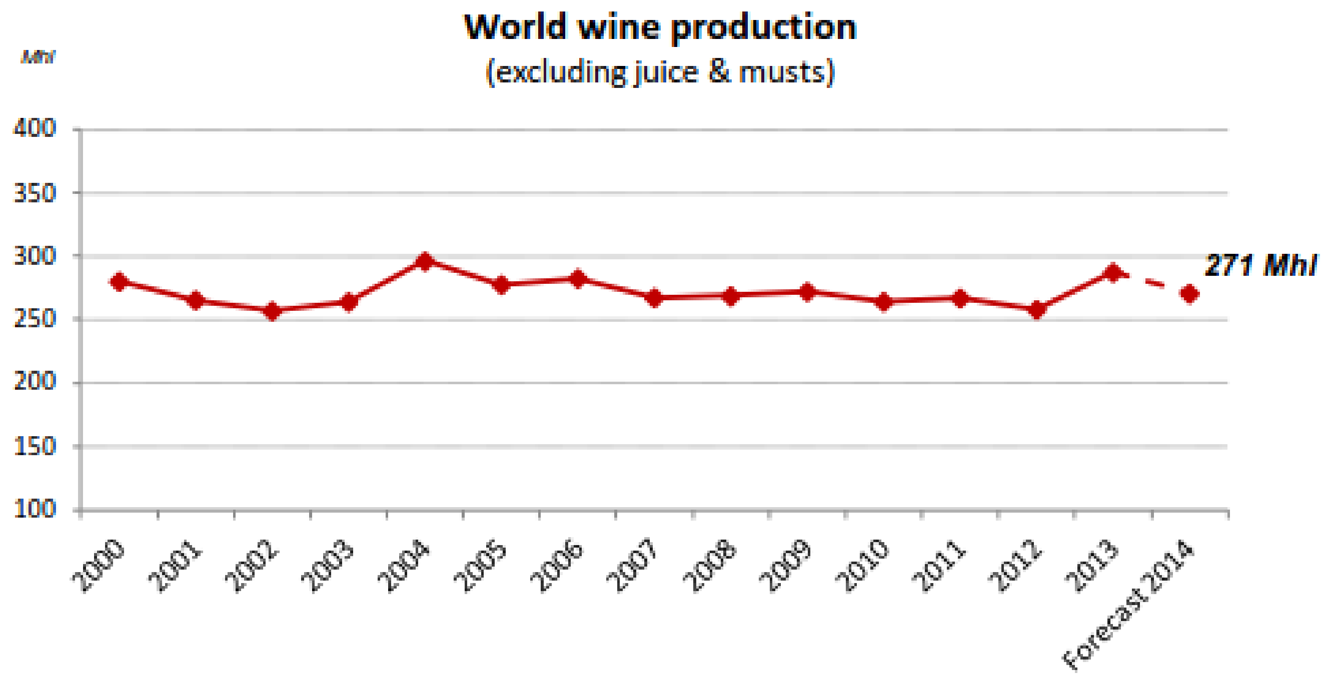
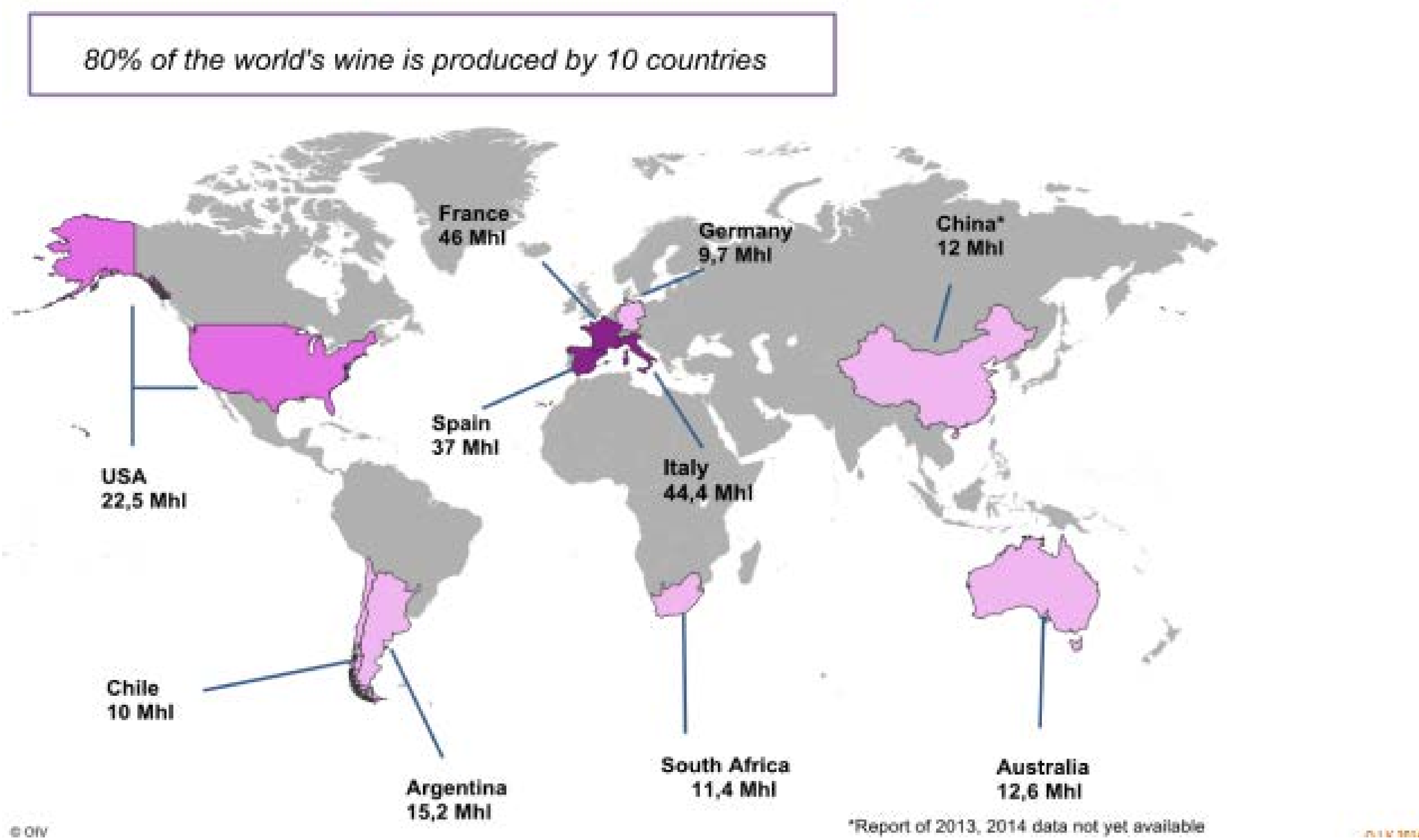
World wine production: stable production of 270 millions hL per year over the last 15 years



The global wine production, excluding juice and musts, is likely to reach **271 millions hectolitres in 2014** – a decrease of 6% compared to 2013

2014 wine production in the 10 main producing countries



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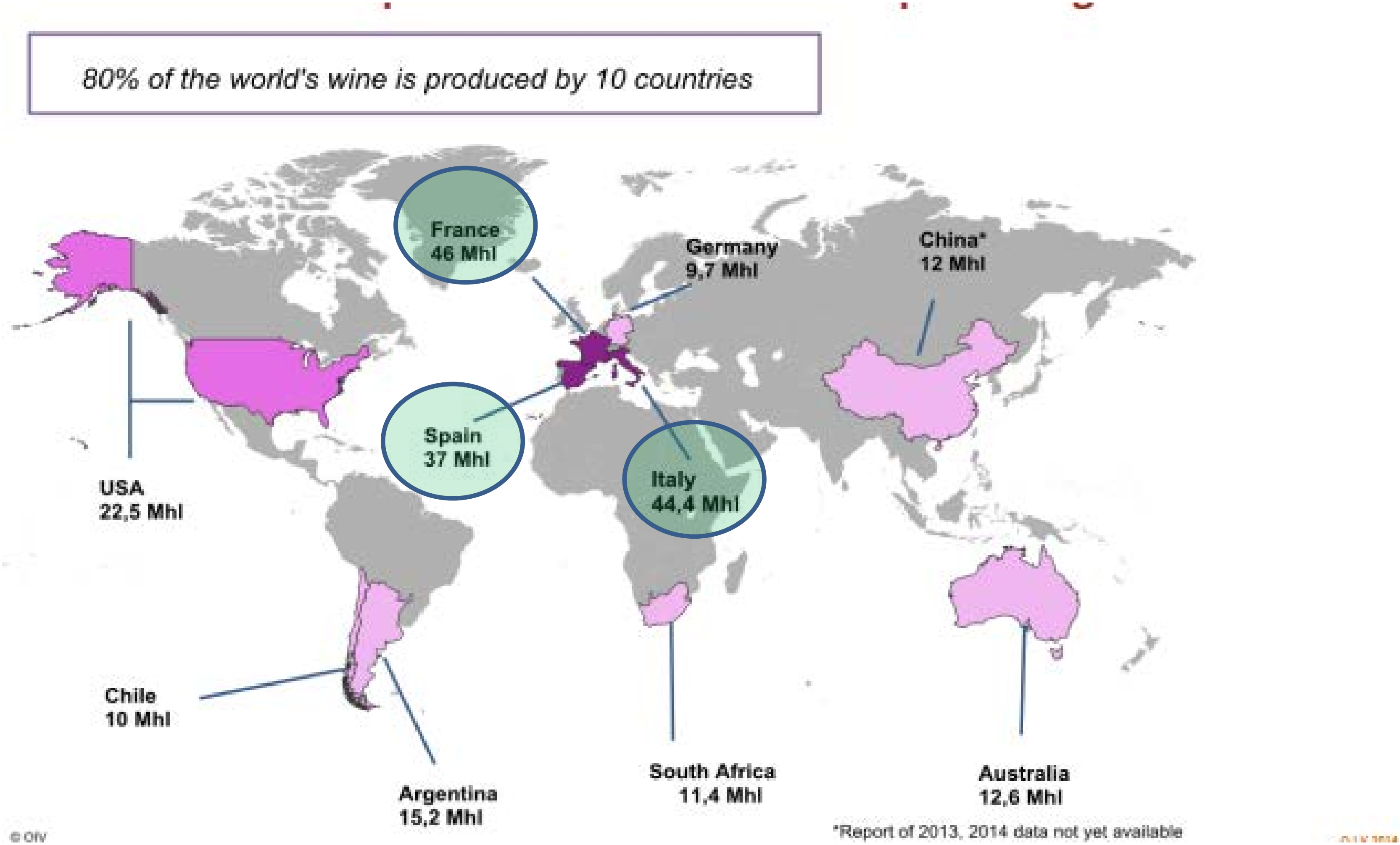
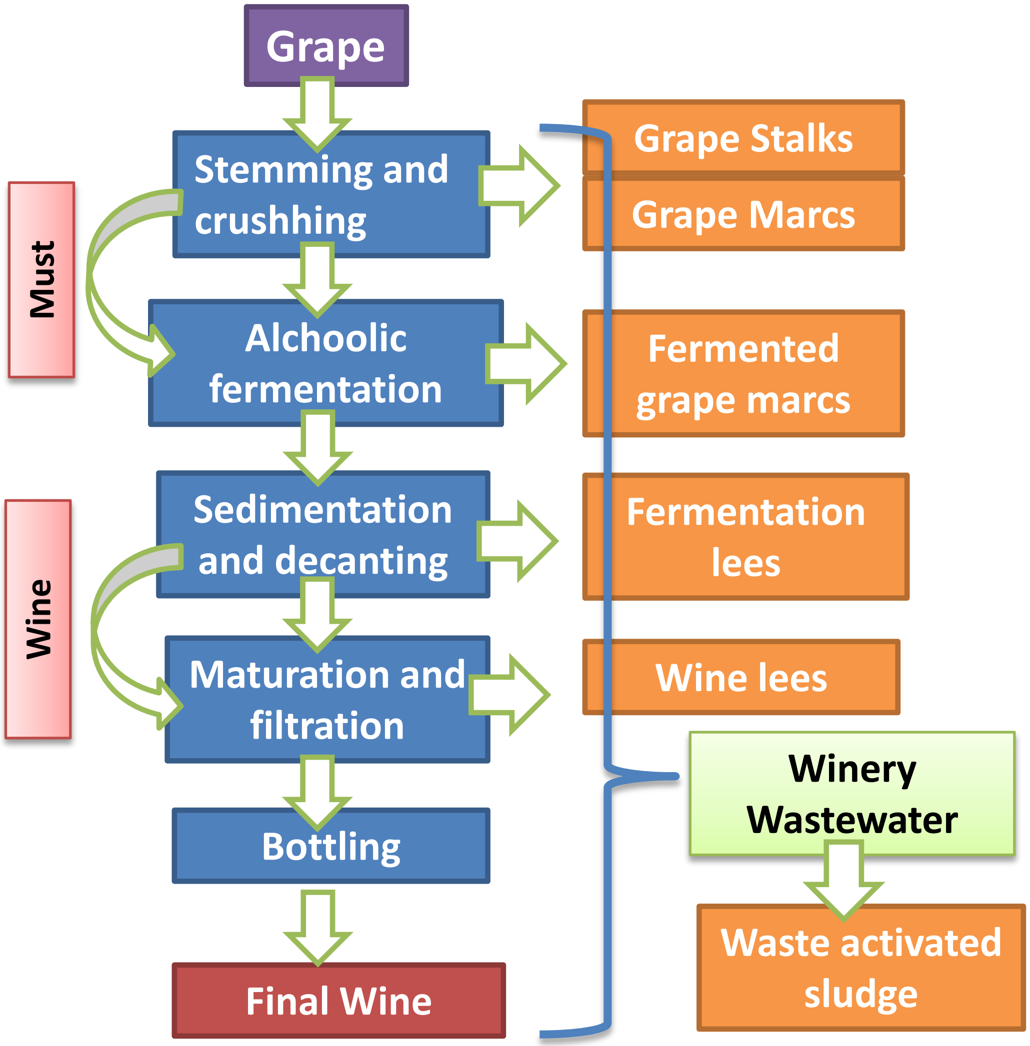


Winery wastes



From 1000kg of grape

- 700 liters of wine
- 22-30 kg of stems
- 120-130 kg of marcs
- 36-50 kg of wine lees
- 1.43-1.65 m^3 of winery wastewater

ANPA, 1999
Oliverira & Duarte, 2014

Environmental impacts of wine production ….
Waste «pressure» …..

Wastewater (and then sludge)

Wastewater
(and then sludge)

Grape pomace

Wastewater (and then sludge)

Grape pomace

Stalks

Wastewater (and then sludge)

Grape pomace

Stalks

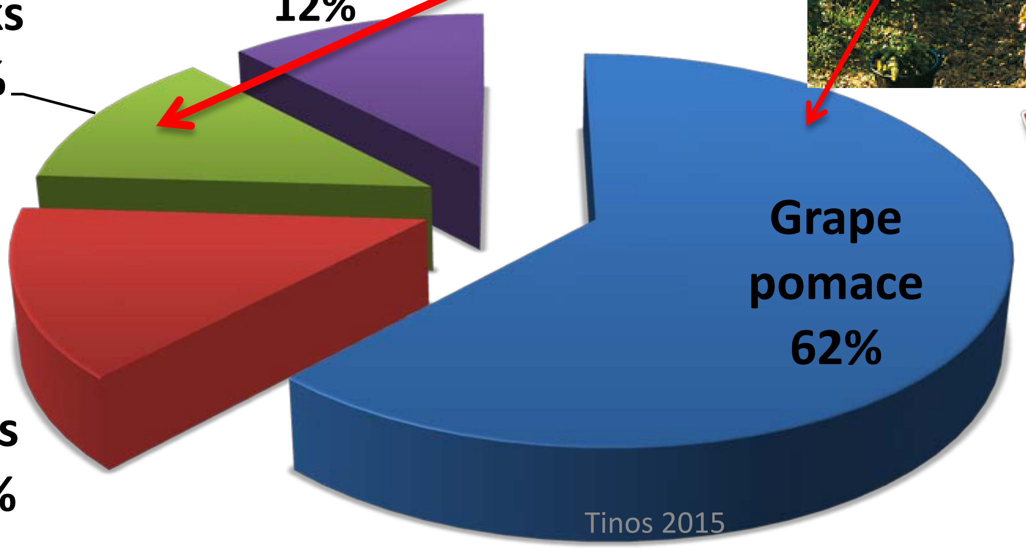
Lees

Winery Organic Wastes

(80% of total wastes)

Organic waste:

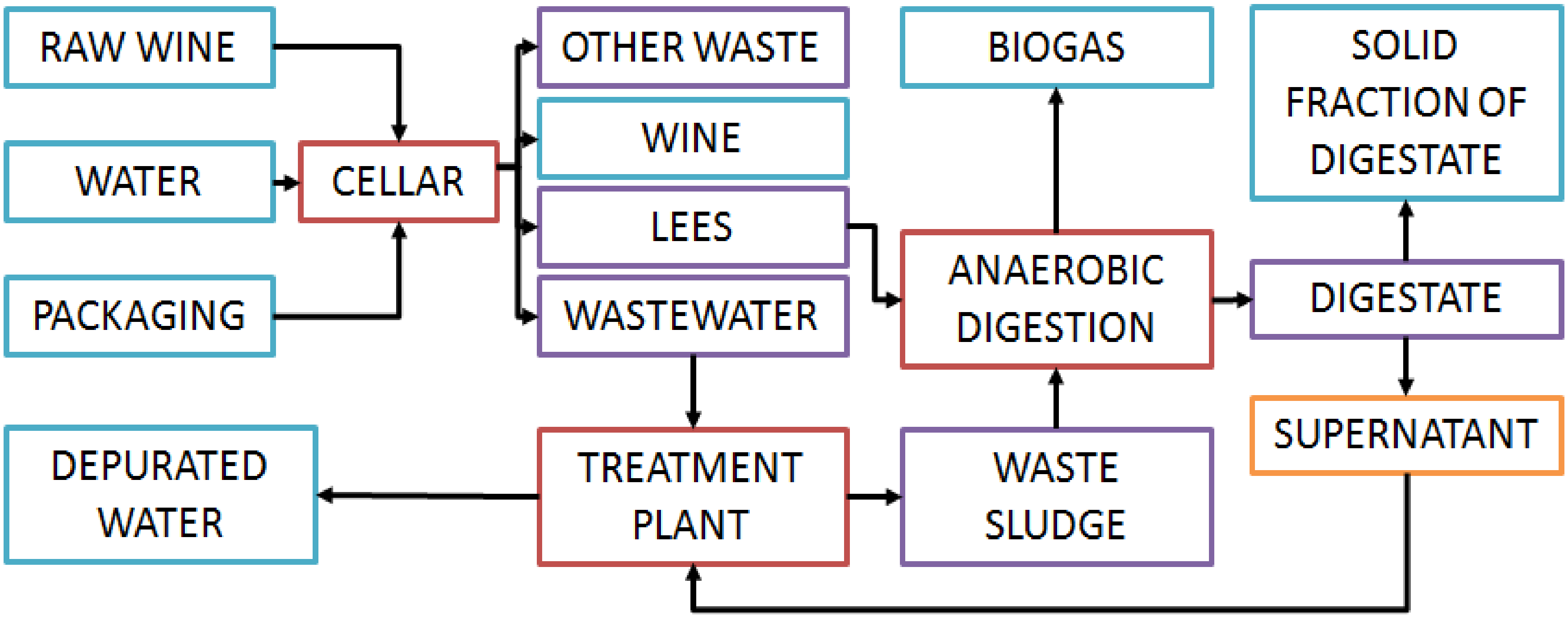
40-60 kg/hl of wine produced



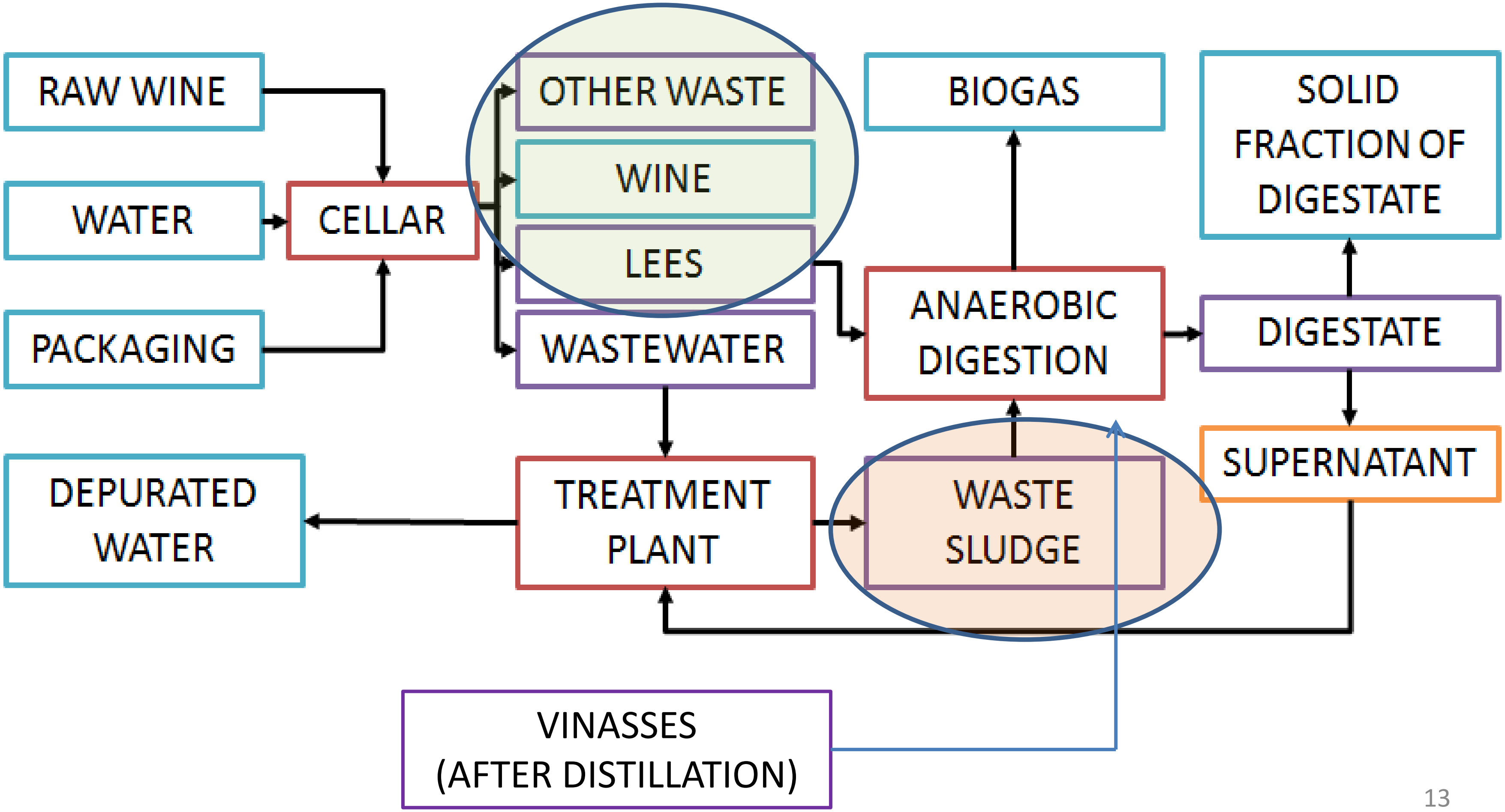
Ruggieri et al., 2009

Vintage period

Integrated treatment of winery wastes by **ANAEROBIC DIGESTION**



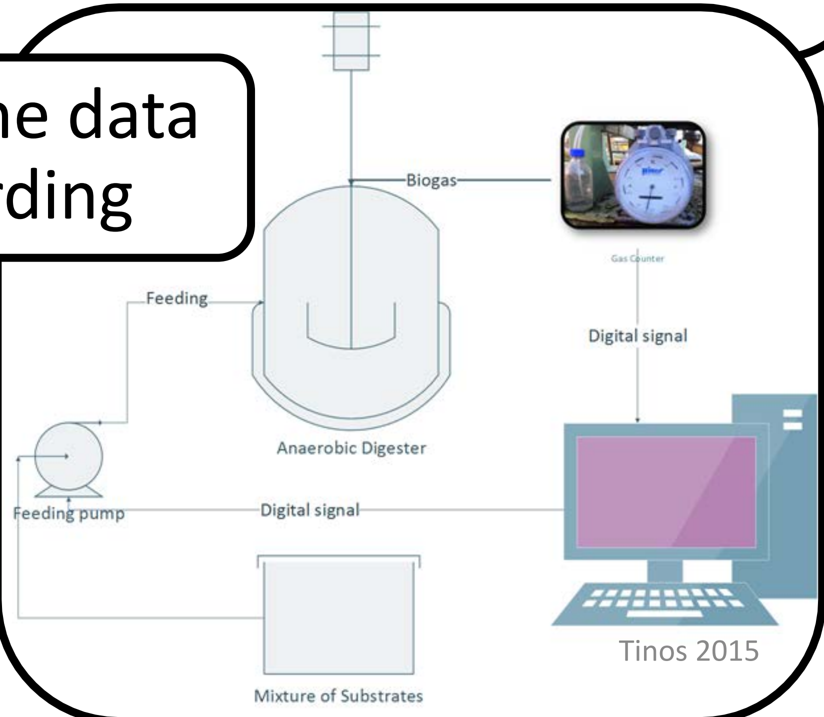
Integrated treatment of winery wastes by **ANAEROBIC DIGESTION**



Pilot scale anaerobic reactors

- Volume reactors: 230 l
- Organic load: 3.2 kgCOD/m^{3}d
- Temperature: 37°C
- **HRT: 23 d & 40 d**

real-time data recording



Waste activated sludge & wine lees

MATHER

Parameter	Unit	Waste Activated Sludge			Wine Lees		
		average	std.dev	range	average	std.dev	range
TS	gTS/kg_{ww}	158.9	49.3	22.7-267.8	62.0	27.9	12.3 -120.0
VS	gVS/kg_{ww}	143.5	41.6	20.7 – 237.3	33.6	15.1	10.3 -73.0
VS/TS	%	88%	3	79- 93%	57%	13%	29 - 86%
COD	mg/g TS	868	69.4	749-1008	559	151	312 – 919
sCOD	g/l	nd	nd	nd	167	45	111 -204
TKN	mg N-NH_4^+/g TS	52.7	16.3	14.5 -80.3	30.3	12.7	9.7 -68.7
NH_4^+	mg N NH_4^+/l	nd	nd	nd	33.9	22.7	6.7 – 95.3
P_{tot}	mg P-PO_4^{3-}/g TS	7.3	2.0	2.5 -10.7	6.2	2.9	2.6 - 14.3
Polyphenols	mg HGal/l	nd	nd	nd	1537	1189	260-3,980

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Process performances

Parameter	Unit	HRT 23 d	HRT 40 d
SGP	m^3/kgCOD	0.386± 0.049	0.378 ± 0.036
TS removal	%	28%	22%
VS removal	%	40%	36%
COD removal	%	76%	77%
Polyphenols removal	%	94%	92%

In the anaerobic digestion of winery wastes the application of longer HRT did not improve biogas production or organic matter removal.

Digestates characteristics

Parameter	Unit	HRT 23 d	HRT 40 d
TS	gTS/kg	24.3 ± 2.9	33.4 ± 2,43
VS		14.2 ± 1.7	21.7 ± 1.1
COD		640 ± 46	752 ± 73
sCOD	mg COD/l	360 ± 152	349 ± 74
TKN	mg N-NH_4^+/gTS	36.3 ± 4.5	52.8 ± 3.3
N-N…	…+/l	400 ± 56	638 ± 49
Ptot	mg P-PO_4^{3-}/gTS	8.8 ± 1.6	8.4 ± 0.8
pH	-	7.46 ± 0.19	7.51 ± 0.07
Total Alkalinity	mg $CaCO_3$/l	2248 ± 200	3,332 ± 124
Polyphenols	mgGAE/l	26 ± 7	56 ± 26

Reduction of flow rate and increase of solid concentration in the feed mixture

Minor dilution effect

Kinetic study

Degradation of different substrate fractions

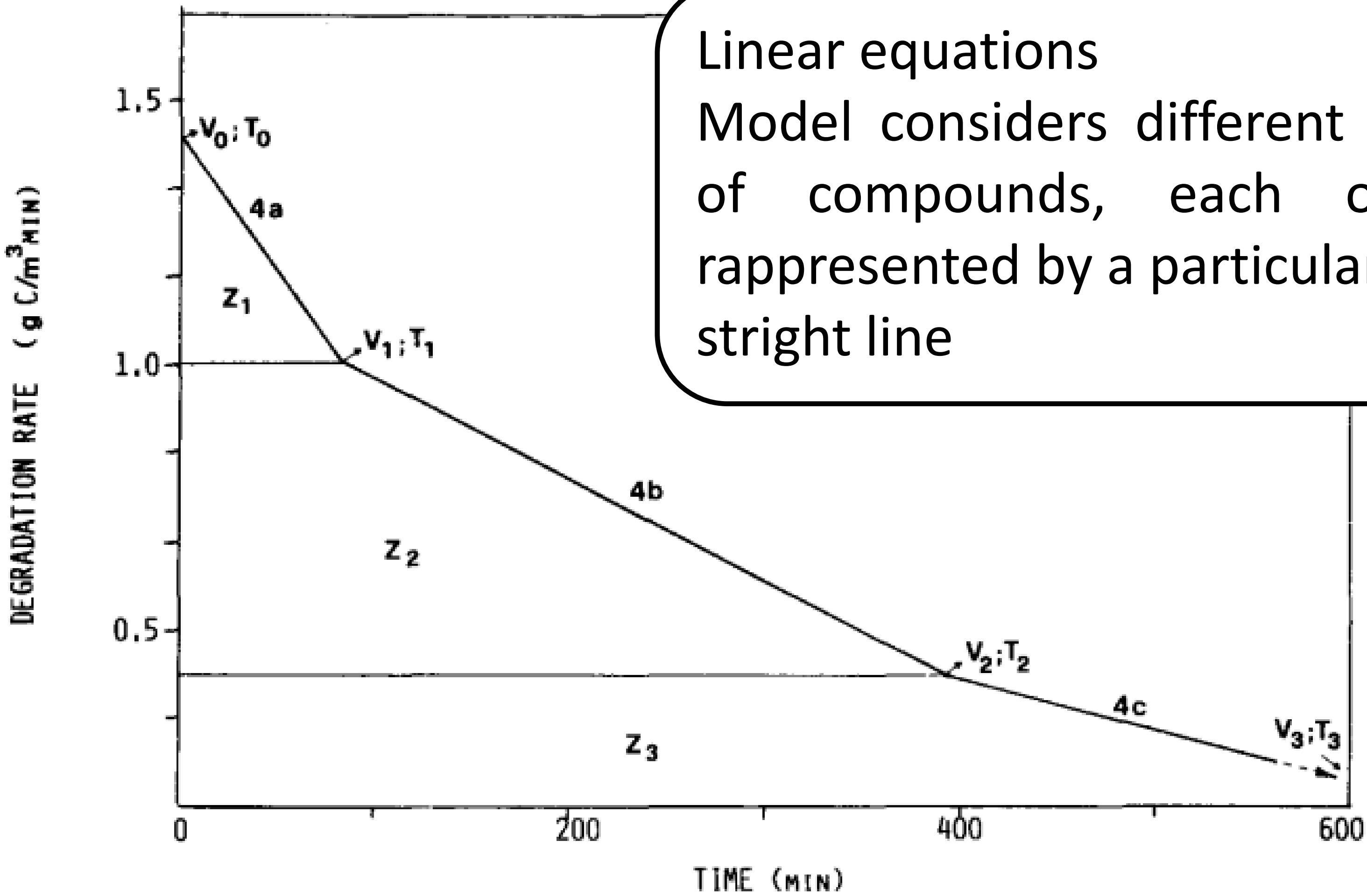
Kinetic study

a) Step-diffusional model (Mata-Alvarez and Cecchi, 1980s)

Compounds	Equations	Substrate concentration
Group A: Acetate, methanol, ethanol	$-\frac{dS}{dt} = v_0 - \frac{4a(t-t_0)}{2}$	$S = S_0 - v_0 t + \frac{4at^2}{4}$
Group B: VFA > C3, lactic acid	$-\frac{dS}{dt} = v_1 - \frac{4b(t-t_1)}{2}$	$S = S_1 - v_1(t-t_1) + \frac{4b(t-t_1)^2}{4}$
Group C: Complex soluble organic matter	$-\frac{dS}{dt} = v_2 - \frac{4c(t-t_2)}{2}$	$S = S_2 - v_2(t-t_2) + \frac{4c(t-t_2)^2}{4}$
Group D: Particulate organic matter	$-\frac{dS}{dt} = v_3$	$S = S_3 - v_3(t-t_3)$

b) First order model $dS/dt = -kS$ $S = S_0 e^{-kt}$

Kinetic study: Step-diffusional model



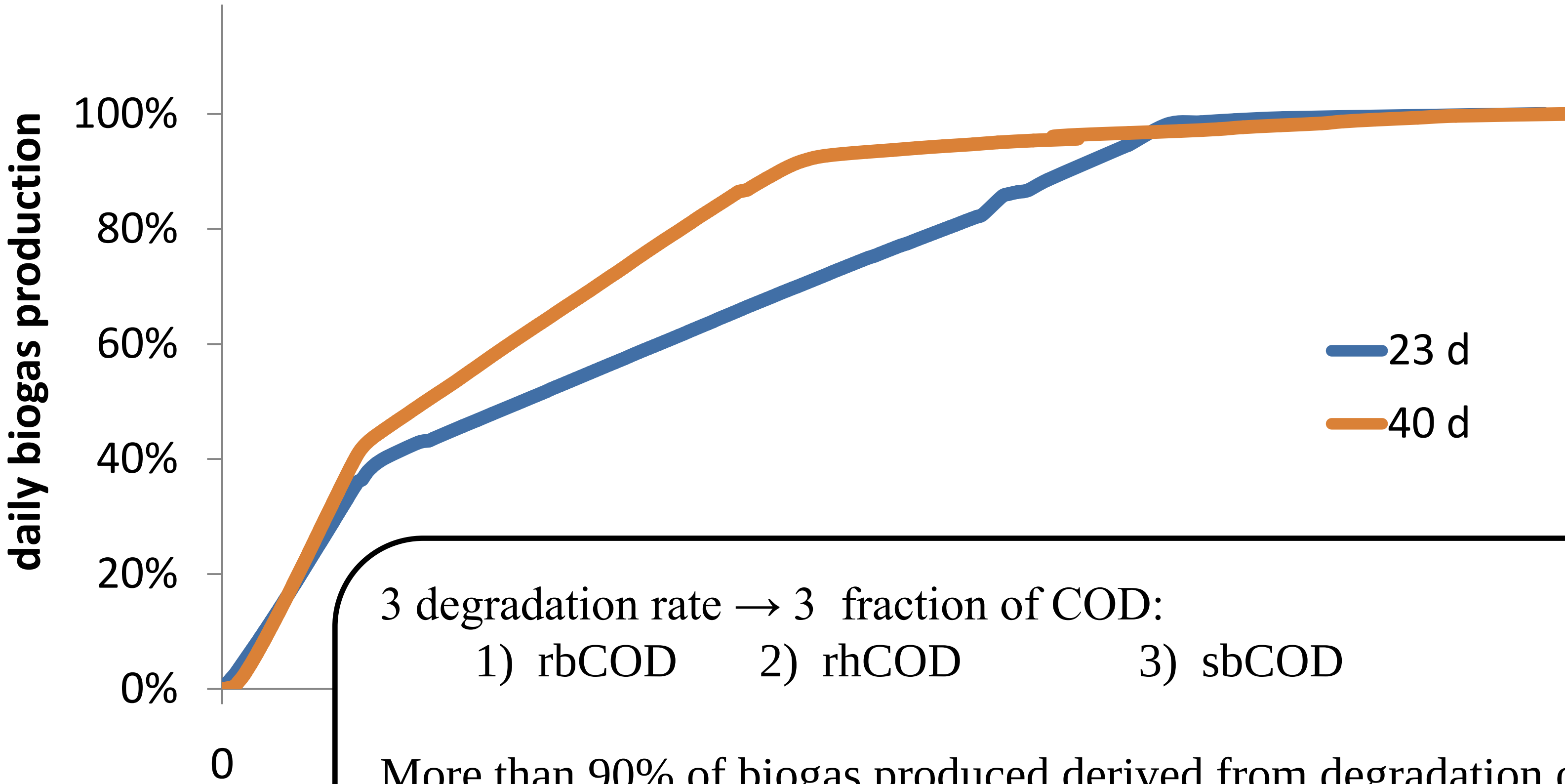
Linear equations

Model considers different groups of compounds, each one is rappresented by a particular single stright line

Cecchi et al., 1990

MATHERIALS &METHODS

Kinetic study: biogas production



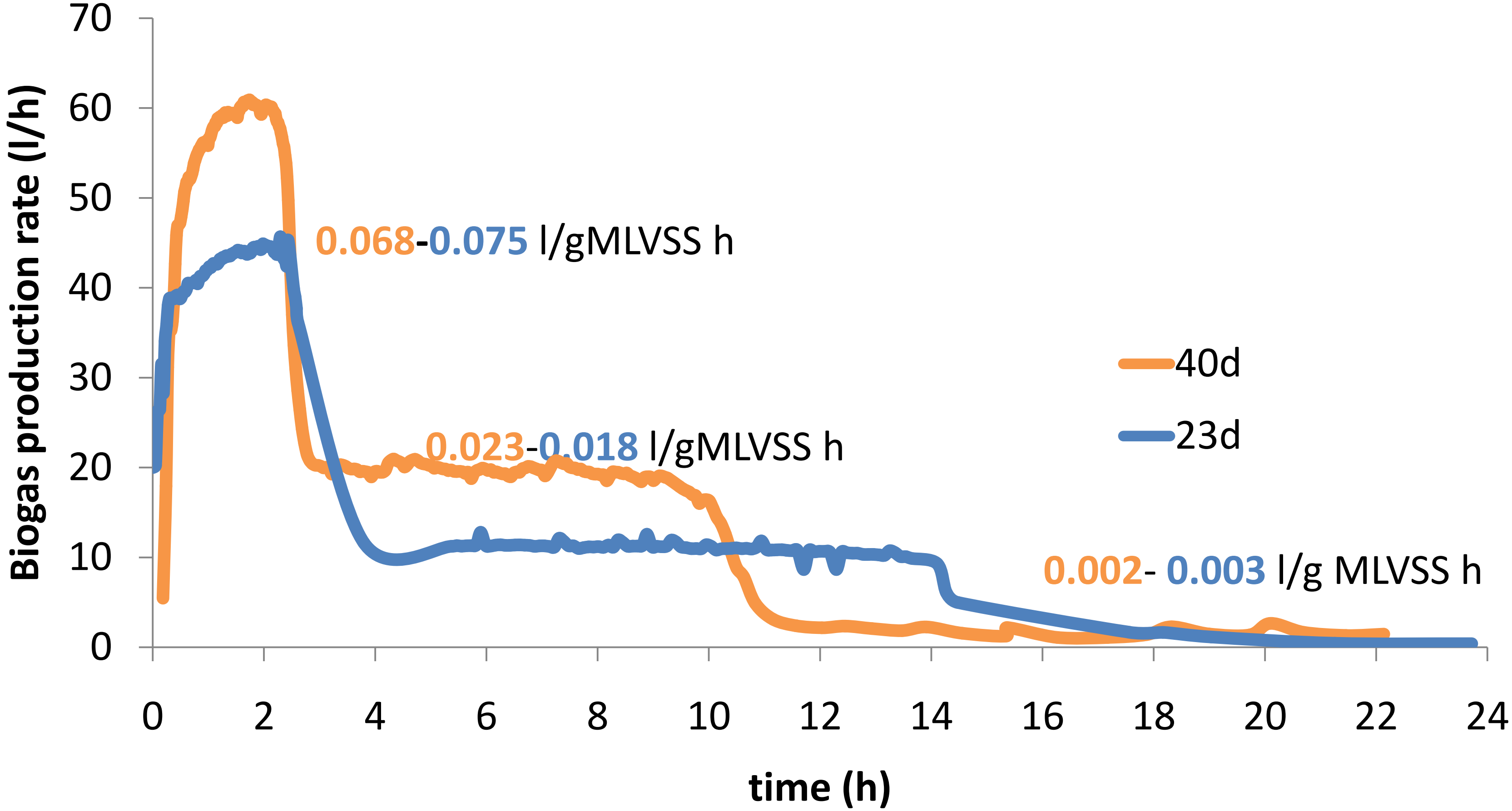
3 degradation rate → 3 fraction of COD:

1) rbCOD 2) rhCOD 3) sbCOD

More than 90% of biogas produced derived from degradation of rbCOD and rhCOD

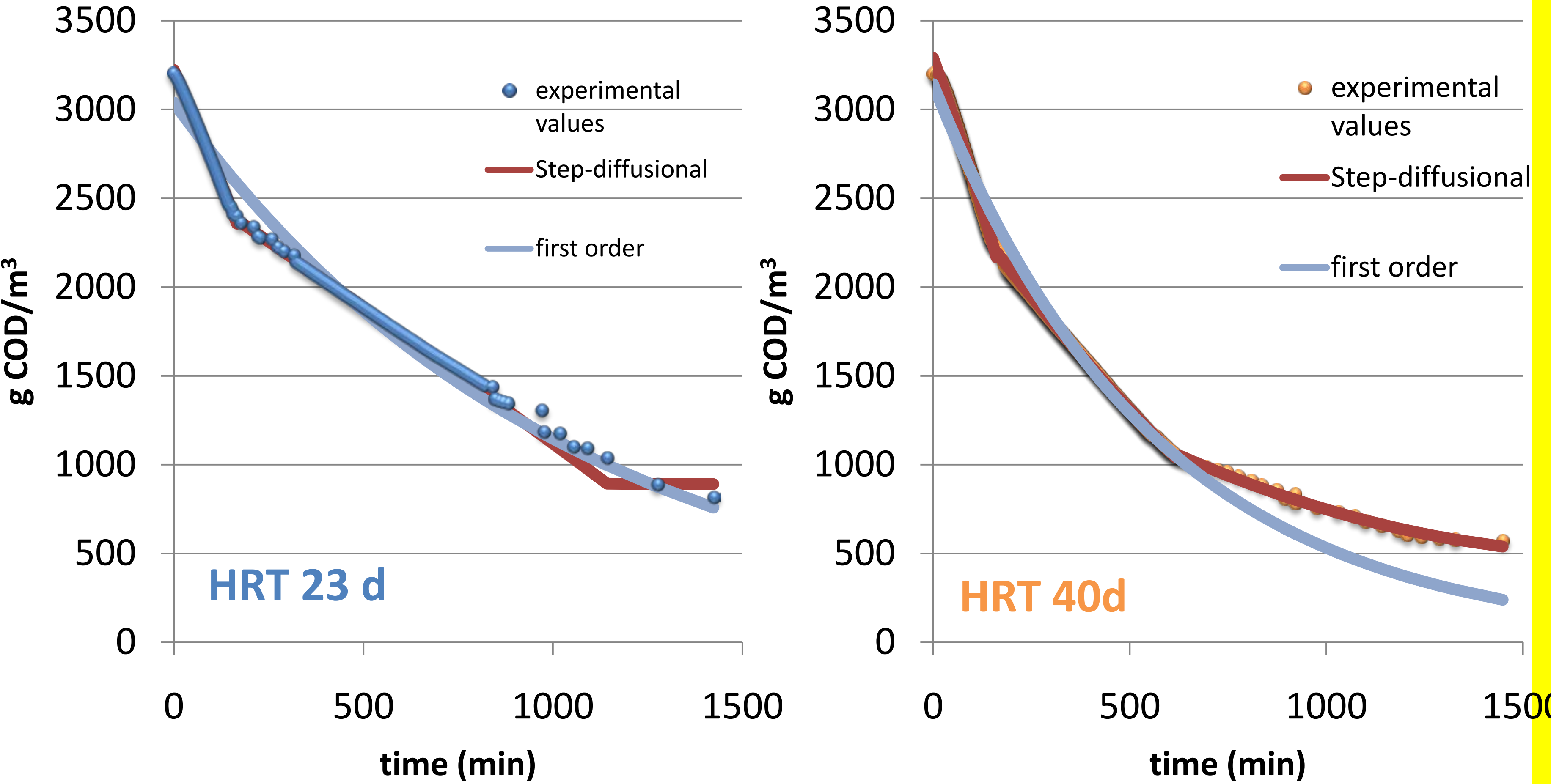
HRT affect mainly degradation rate of second fraction of organic matter

Kinetic study: biogas production rate



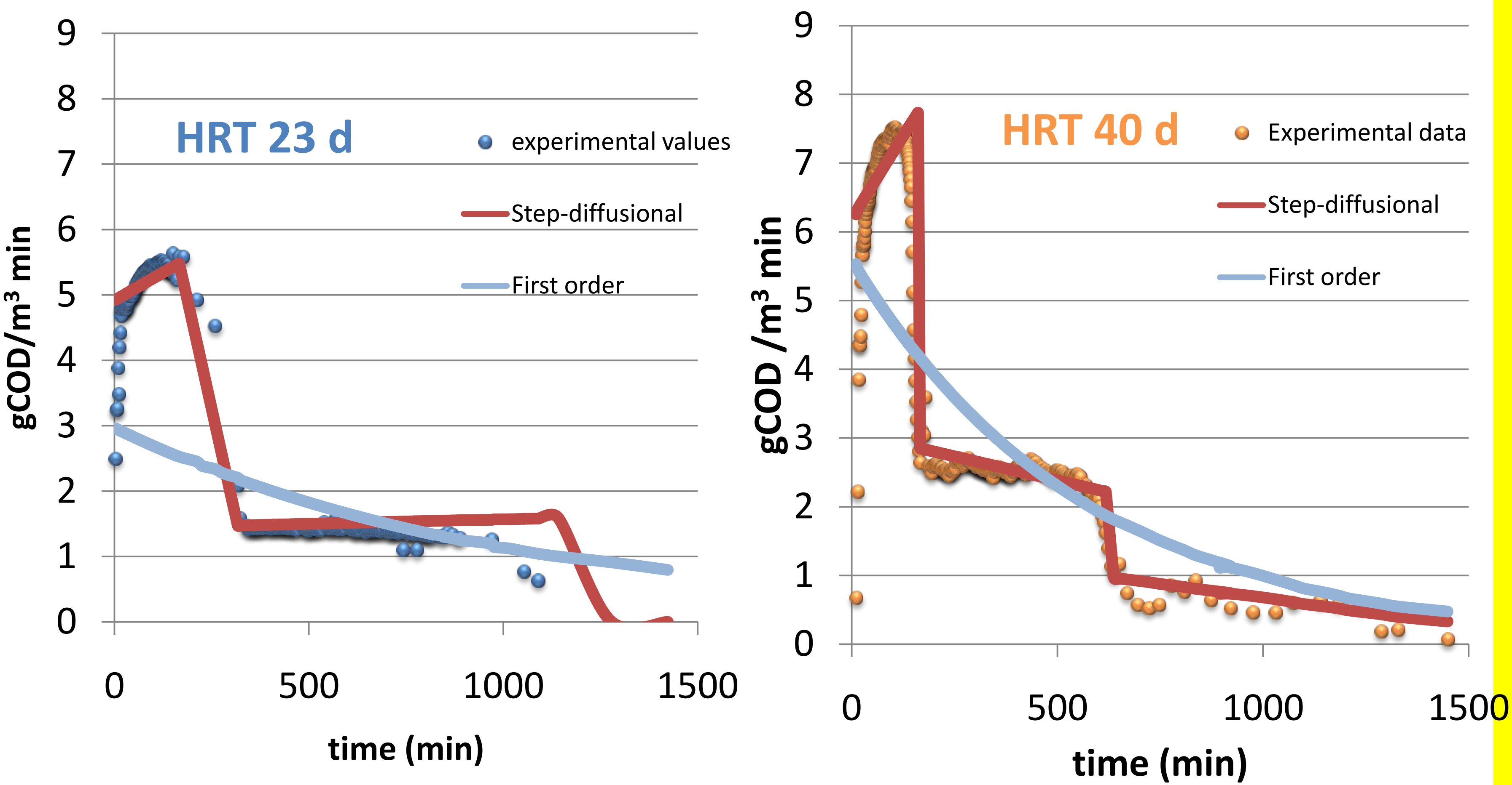
Kinetic study: first-order and step-diffusional models

Substrate use



RESULTS & DISCUSSION

Kinetic study: first-order and step-diffusional models Biogas production



RESULTS & DISCUSSION

		HRT 23 d	HRT 40 d
First-order model			
k	d^{-1}	1.40	2.56
R^2		**0.90**	**0.84**
Lack of fit		679	772
		3.31	2.55
Step diffusional model			
v_0	mgCOD/l min	4.92	6.20
v_1	mgCOD/l min	1.45	2.85
	COD/l min	2.11	0.97
	COD/l min²	-0.007	-0.191
	COD/l min²	0.000	0.003
4c	mgCOD/l min²	0.020	0.002
R^2		**0.99**	**0.94**
Lack of fit		21	216
Average lack of fit		0.10	0.72

Degradation rates were affected by HRT (OLR, VS….)

Constant *«a»* has negative values because of increasing of degradation rate during the first hours after feeding

Conclusions

- Mixture of **winery waste** rappresents a **complex substrates** for **anaerobic digestion**, and the process behaviour is difficult to predict. However, the outcome is still of interest from both an environmental and energy perspective

- Changing the HRT from 23 d to 40 d didn't affect the process performances (SGP of **0.386** and **0.378** $\mathbf{m^3/kgCOD_{fed}}$).

Conclusions

- Longer HRT increased absolute biodegradation rates.
- Three degradation rates were detected corresponding to three fraction of COD (rbCOD, rhCOD and sbCOD) characterising wine lees
- Step-diffusional model could described better than first order model the COD consumption (R^2 0.94 vs 0.99)