Sustainable exploitation of wine lees for winemaking applications: a circular economy approach

E. Kokkinomagoulos[1], A. Stamkopoulos[1], A.M. Michaelidou[1], A.M. Goula[1], P. Kandylis[1,2]

[1] Department of Food Science and Technology, School of Agriculture, Aristotle University of Thessaloniki, P.O. Box 235, 54124 Thessaloniki, Greece
[2] Department of Food Science and Technology, Ionian University, Argostoli, 28100, Greece

Presenting author: ekokkinom@gmail.com

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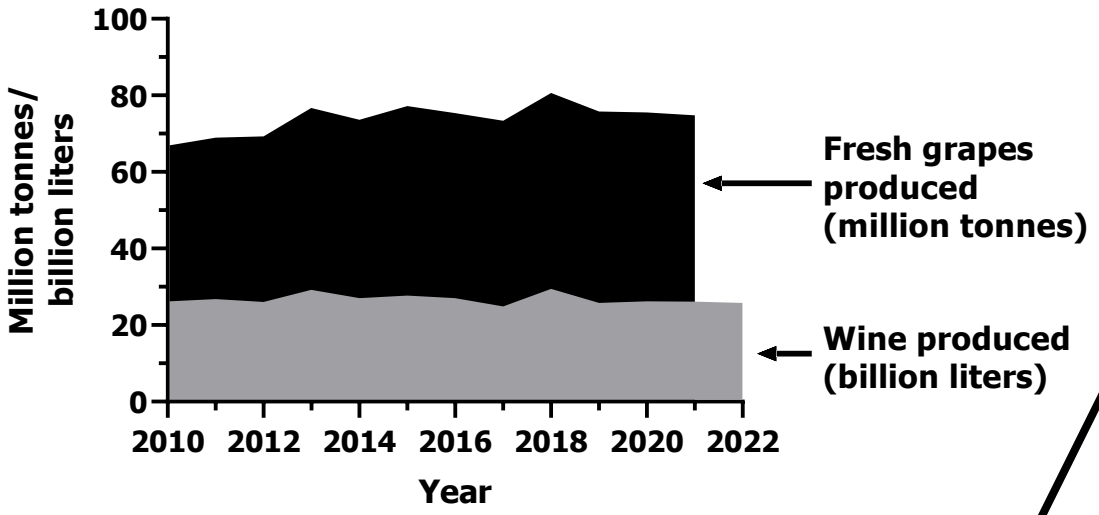
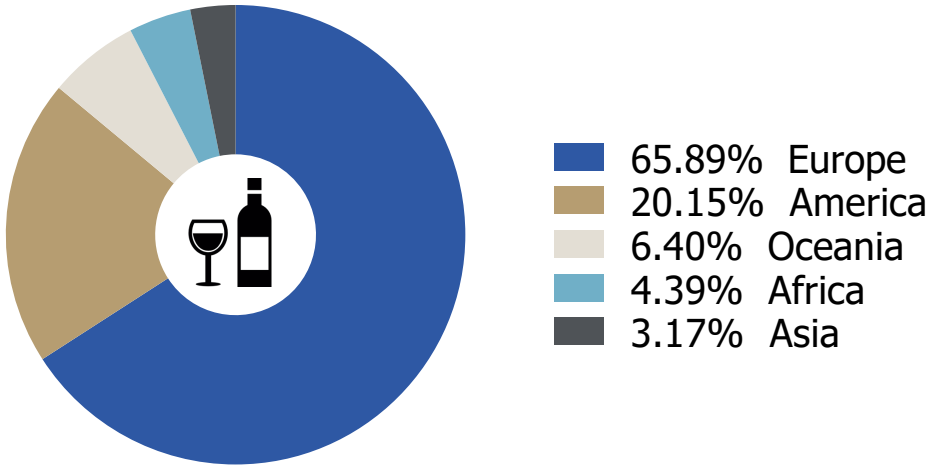
INTRODUCTION

Evolution of world production of fresh grapes and wine



2022 worldwide wine production by continent



(https://www.oiv.int/what-we-do/data-discovery-report?oiv)

INTRODUCTION

The world vitivinicultural year 2022 in a nutshell

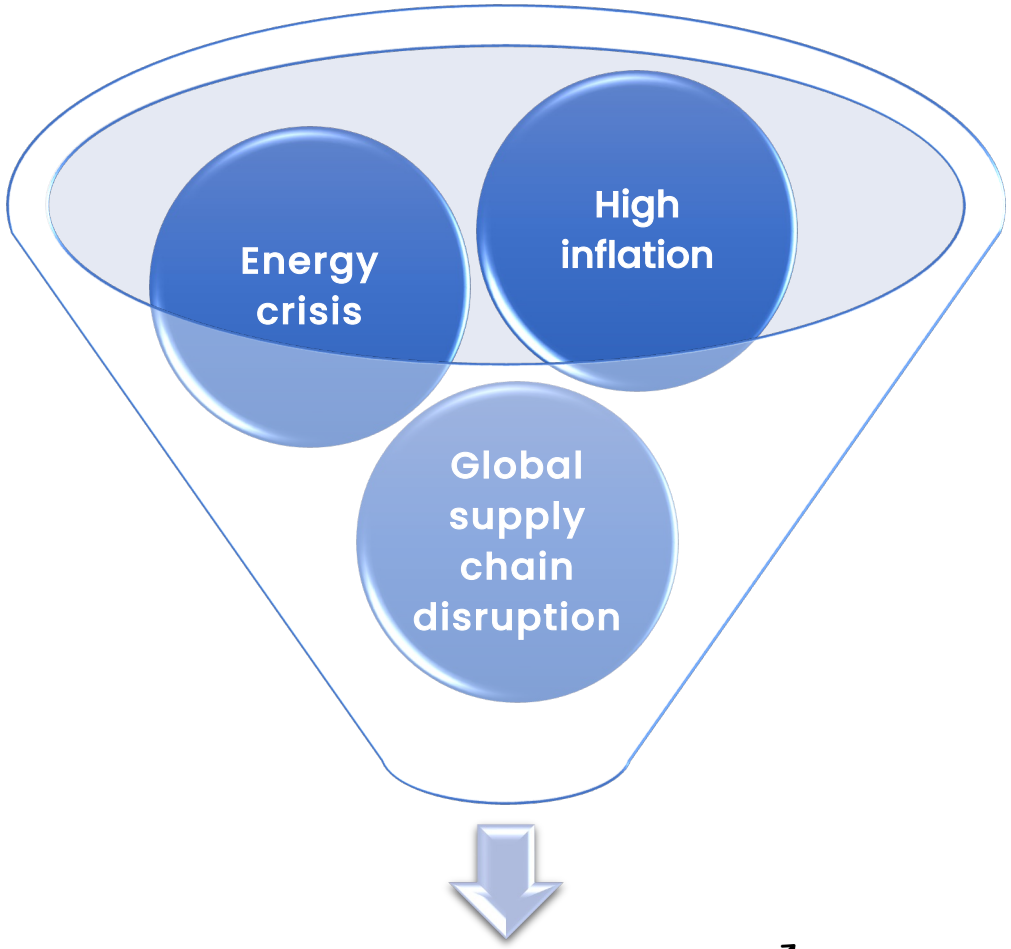
	2022	Compared to 2021
Vineyard surface (mha)	7.3	-0.4%
Wine production (mhl)	258	-1.0%
Wine consumption (mhl)	232	-1.0%
Wine exports (mhl)	107	-5.0%
Wine exports value (bn €)	37.6	+9.0%

Stable since 2017

All-time record high!!

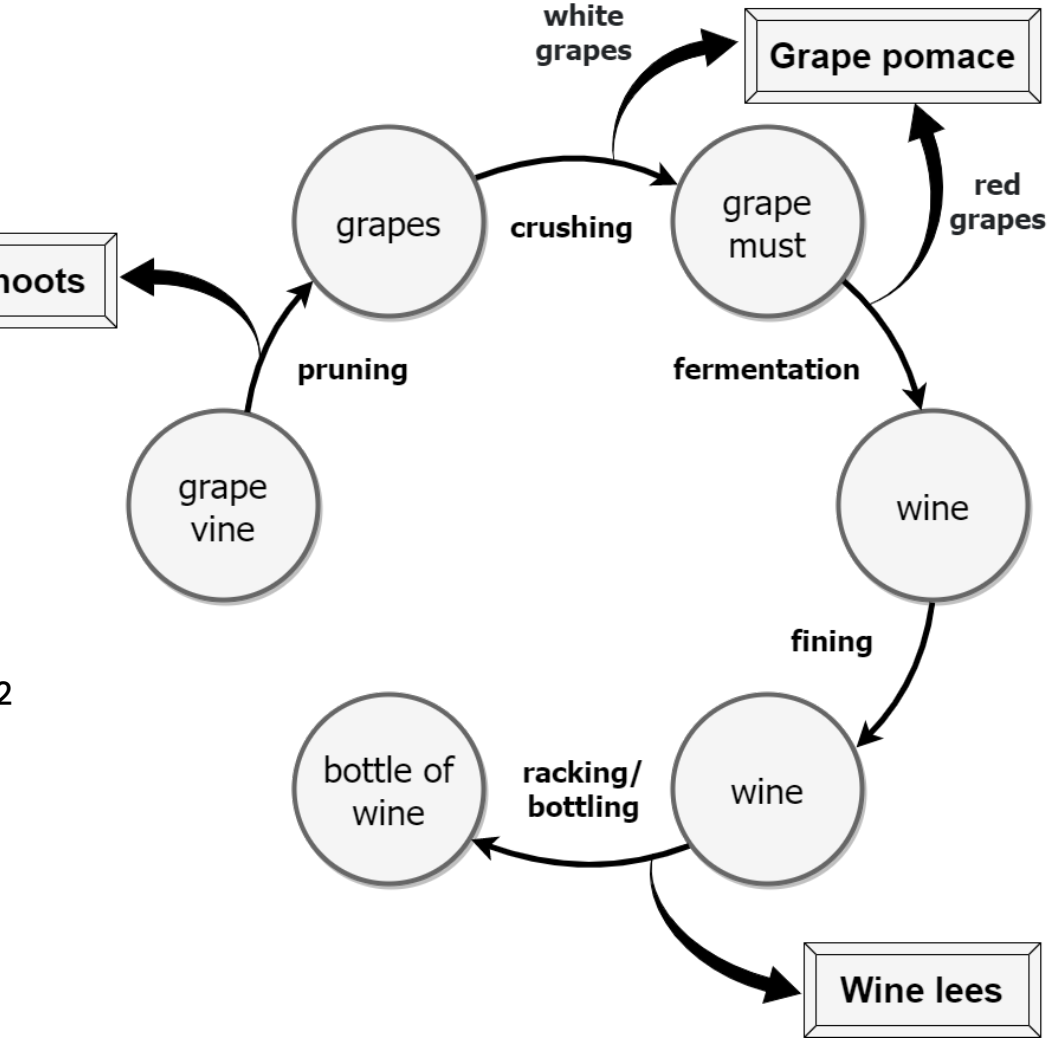
(OIV, 2023)

INTRODUCTION



INTRODUCTION

≈ 350 tonnes/km²



13-20% of grape

0.17 kg/L of wine

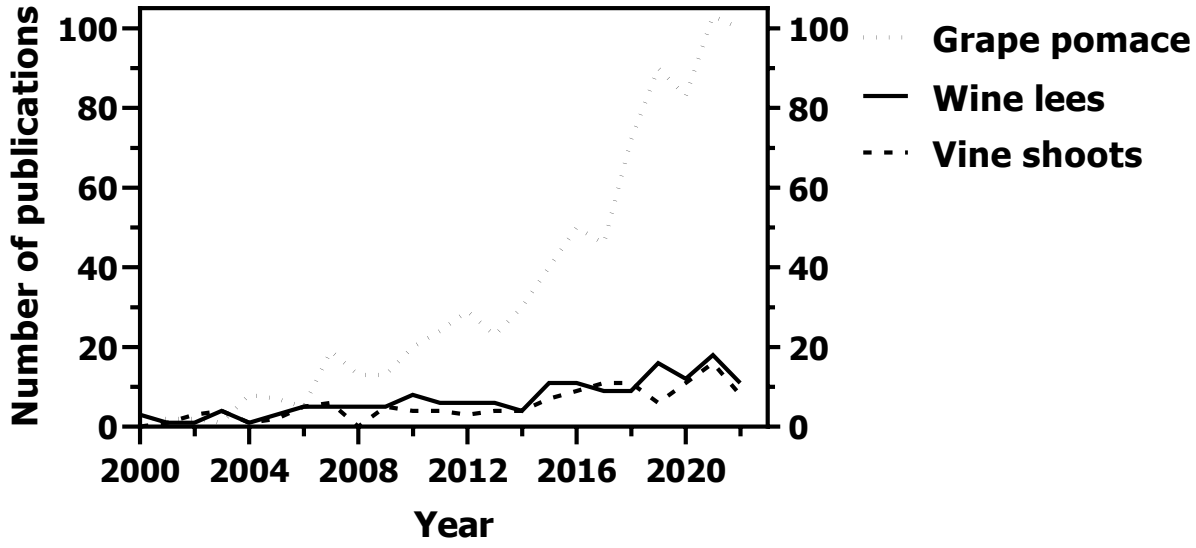
2-6% of wine

Yeast cells, tartrates, inorganic and phenolic compounds

(Mendívil et al., 2013)

INTRODUCTION

Publications on vitivinicultural by-products per year



Waste Framework Directive (2008/98/EC):
"Waste prevention should be the first priority of waste management and re-use and material recycling should be preferred to energy recovery from waste"

(https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_el
Web of Science Core Collection, https://www.webofscience.com/wos/woscc/basic-search)

INTRODUCTION

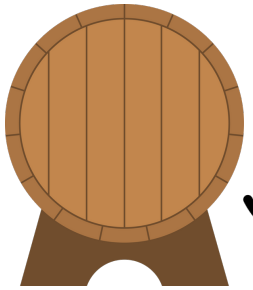
Chemical composition of main vitivinicultural by-products

Grape pomace	Wine lees	Vine shoots
pH: 3.4–5.4	pH: 3.6–7.2	Moisture: 7.9–8.4% (DM)
Polyphenols: 0.09–1.36% (DM)	Polyphenols: 0.19–1.63% (DM)	Ash: 3.0–3.8% (DM)
Dietary fiber: 19–38% (DM)	Protein: 14.5–15.7% (DM)	Holocellulose: 64.2–69.6% (DM)
Total nitrogen: 1.0–1.7% (DM)	Lipids: 5.0–5.9% (DM)	Lignin: 19.3–21.8% (DM)
Sugars: 15–33% (FM)	Sugars: 3.5–4.8% (DM)	Pentosans: 18.4–23.6% (DM)
Lipids: 0.4–1.0% (FM)	Tartaric acid: 24.5–24.7% (DM)	Lipids: 2.4–6.7% (DM)
Ash: 1.8–2.4% (FM)	Ash: 10.5–10.6% (DM)	Protein: 4.0–5.3% (DM)
COD: 610 g O_2 kg^{-1}	COD: 72–323 g kg^{-1}	

DM: Dry Matter; FM: Fresh Matter; COD: Chemical Oxygen Demand

(Kokkinomagoulos & Kandylis, 2020)

INTRODUCTION



wine racking

<u>Wine lees</u>

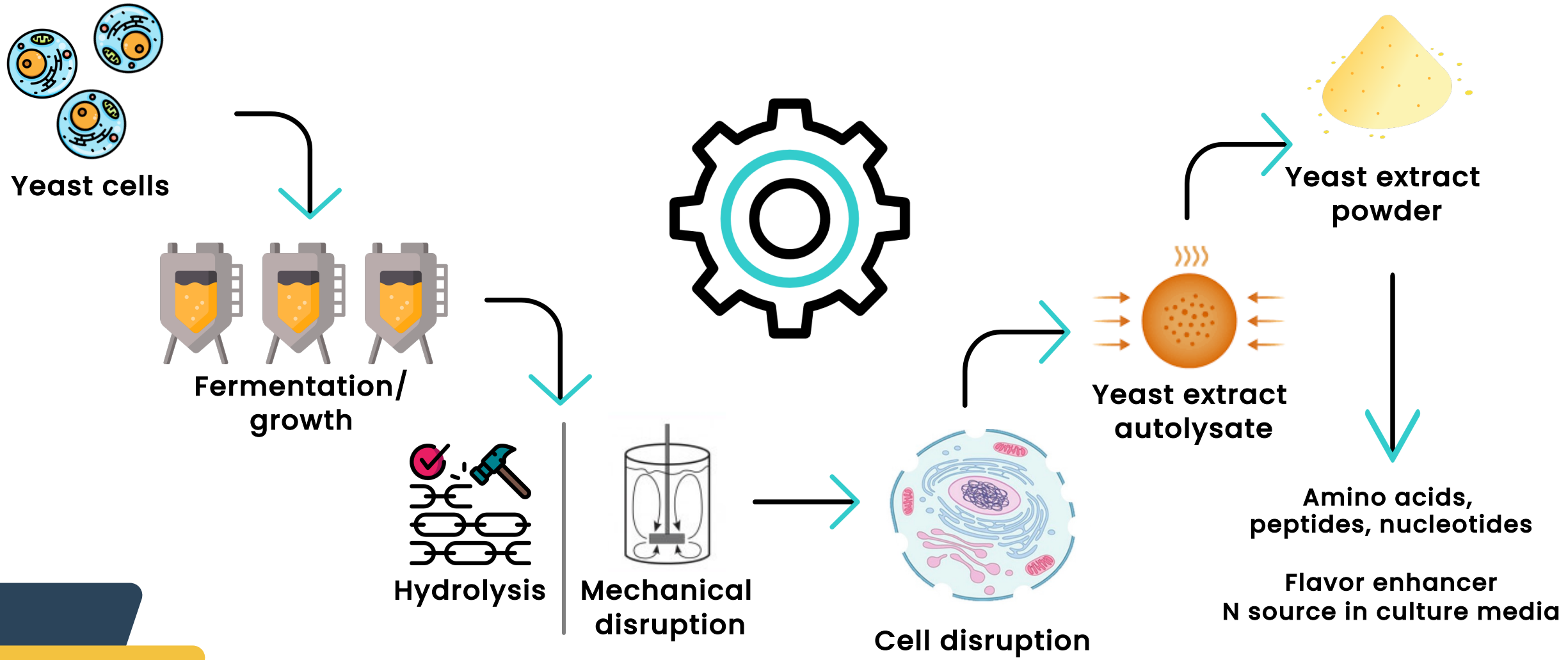
“The muddy residue accumulating in wine vessels after fermentation or during the storage of wine, dried or not”

Mainly contains dead yeast cells and other compounds.

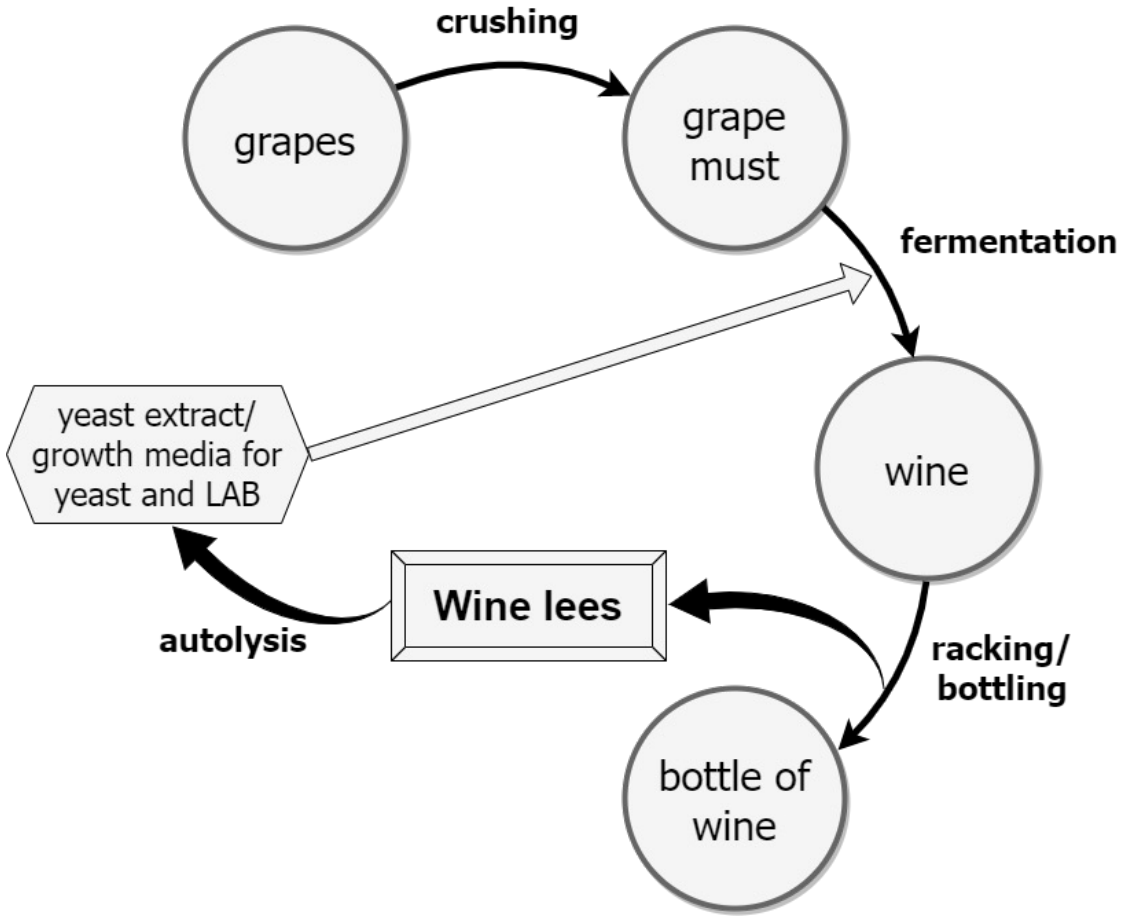
Production of a commercial yeast extract substitute

INTRODUCTION

Industrial production of yeast extract



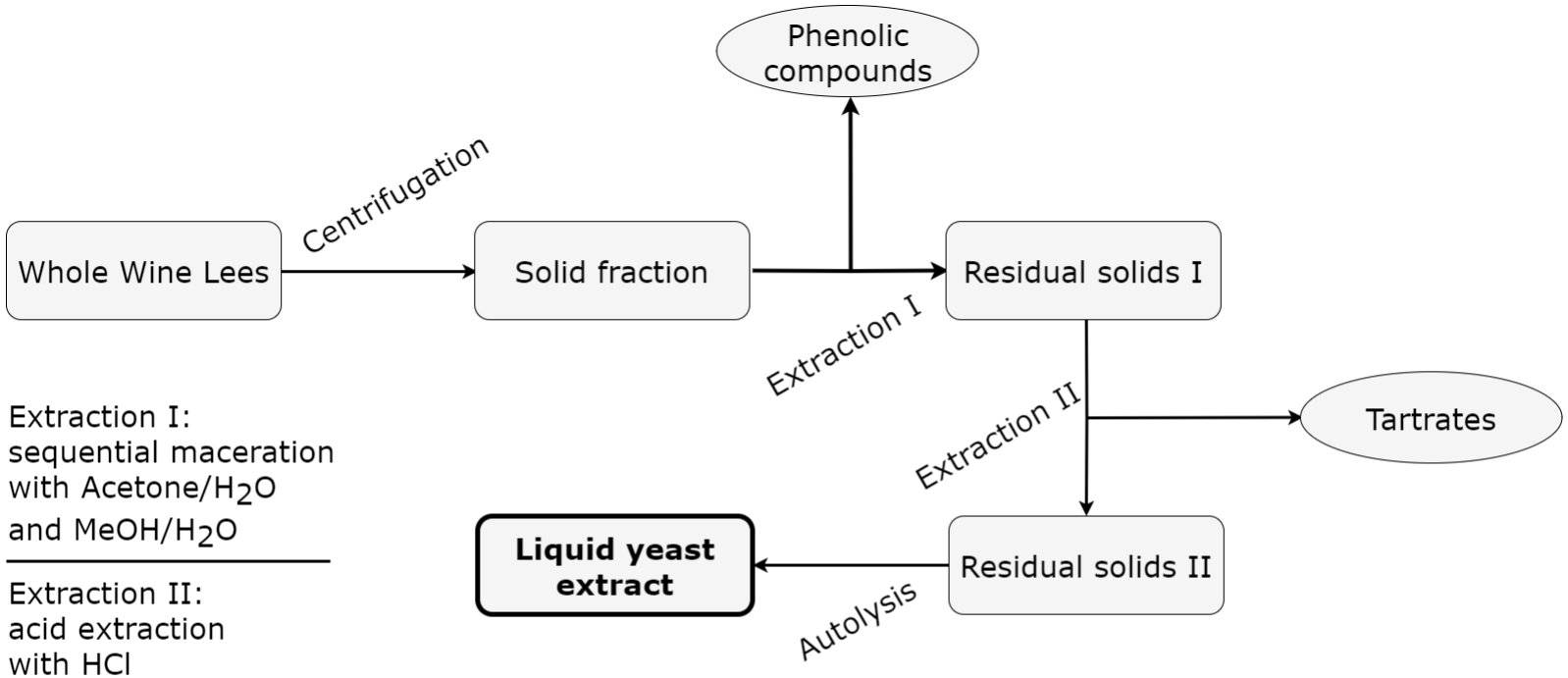
METHODOLOGY



Autolysis

- Naturally-occurring process (self-digestion)
- Cell membrane disruption by endogenous enzymes
- Release of intracellular material

METHODOLOGY



pH: 4.0 - 9.0
T: 40 - 65 ^{o}C
Solid concentration: 50 - 400 g/L

Autolysis yield:
Free α-amino nitrogen formation

Ninhydrin spectrophotometric method

(Chira et al., 2009; Lie, 1973; Salgado et al., 2010)

METHODOLOGY

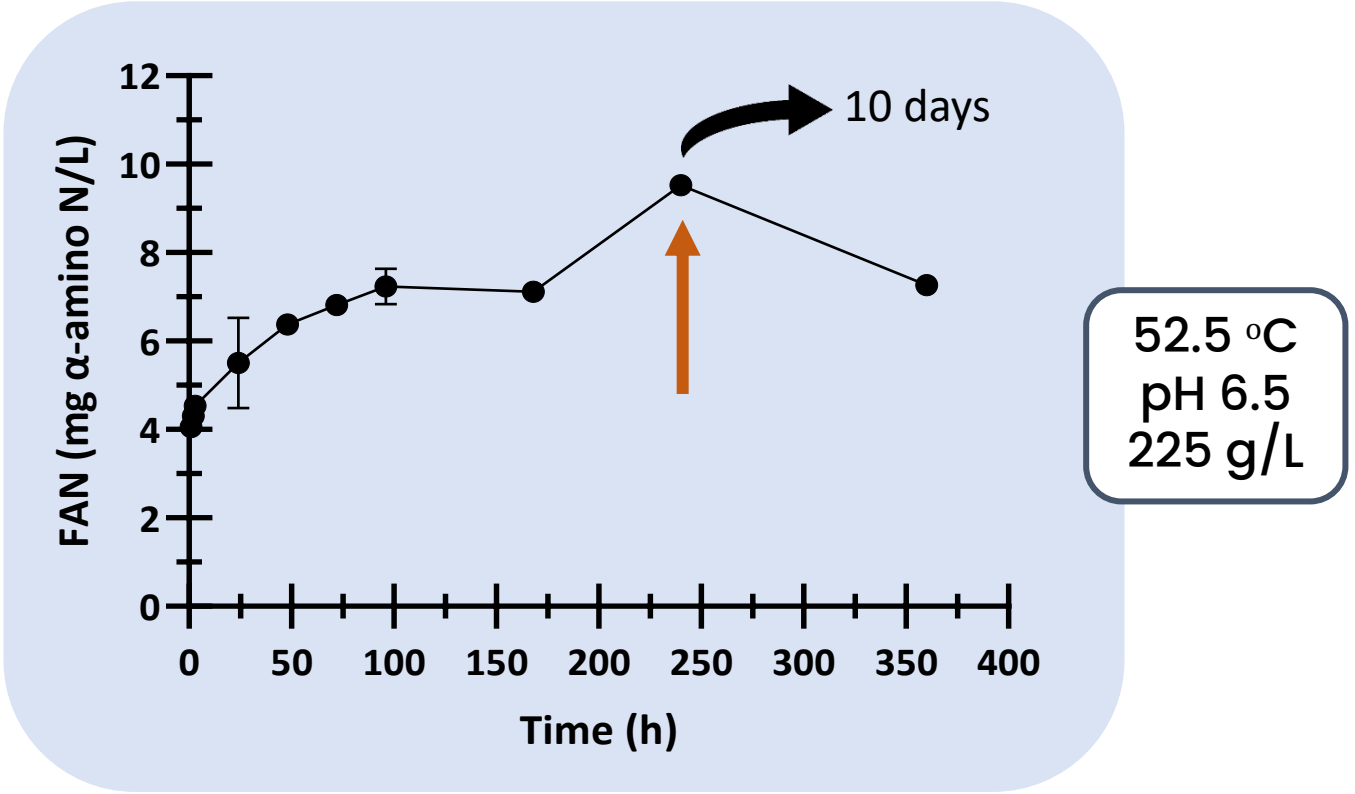
Enzyme	Optimum T (°C)	Optimum pH
Chitinase	40-55	5.0-7.5
β-glucanase	50-65	4.0-5.5
protease	40-60	5.0-9.0
cellulase	40-65	4.0-9.0

T: 40 – 65 °C
pH: 4.0 – 9.0

	T (°C)	pH	Solid concentration (g/L)
1	52.5	6.50	400.00
2	45.1	5.01	120.94
3	59.9	5.01	120.94
4	45.1	7.99	120.94
5	52.5	6.50	225.00
6	40.0	6.50	225.00
7	52.5	6.50	225.00
8	52.5	6.50	225.00
9	52.5	4.00	225.00
10	45.1	5.01	329.06
11	59.9	7.99	329.06
12	52.5	6.50	225.00
13	59.9	7.99	120.94
14	52.5	6.50	225.00
15	52.5	6.50	50.00
16	59.9	5.01	329.06
17	45.1	7.99	329.06
18	52.5	6.50	225.00
19	52.5	9.00	225.00
20	65.0	6.50	225.00

RESULTS

Optimization of autolysis duration of treated wine lees



RESULTS

- Higher autolysis yields: mid-low and highest temperatures.
- Increase of pH and solid concentration within the examined ranges appears to negatively affect autolysis efficiency.

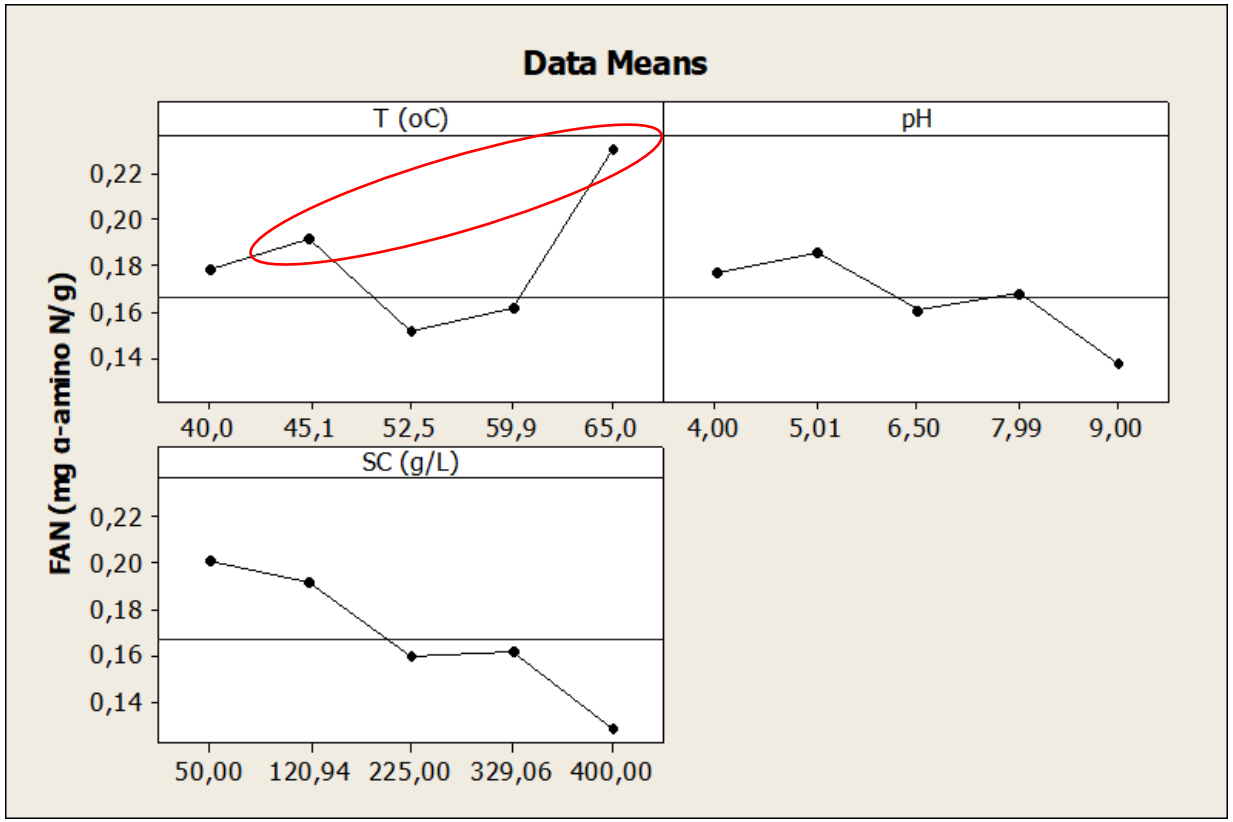


Figure 1. Main Effects Plot of temperature, pH and solid concentration on autolysis efficiency of treated wine lees (FAN).

RESULTS

- Max. yield: 0.236 mg α-amino N/g (@45.1 ºC, pH 5.01, 120.94 g L^{-1})
- Max. FAN increase: 476%
- T, T*T and SC: significant factors
- R^2=79.86%

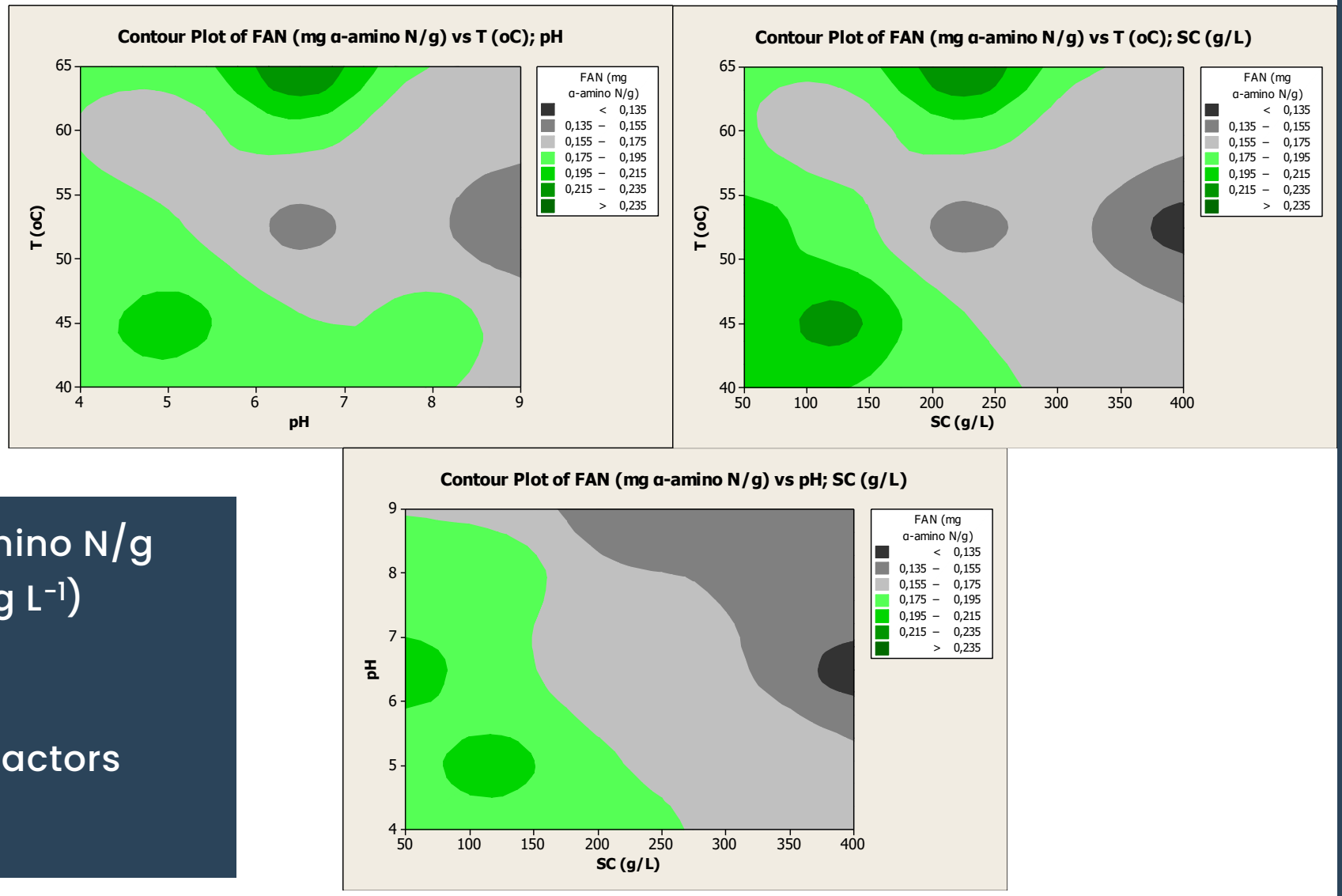


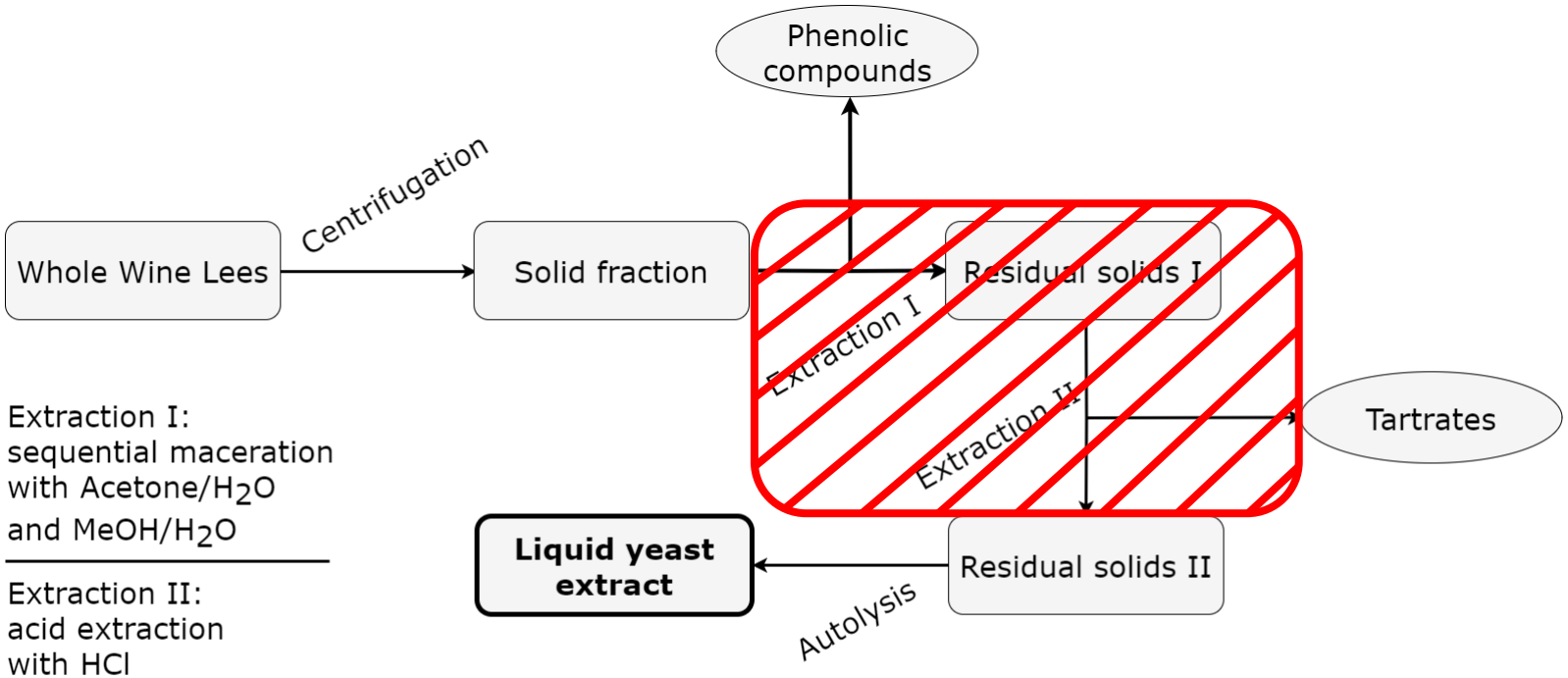
Figure 2. Effect of temperature, pH and solid concentration on autolysis efficiency of treated wine lees (FAN).

RESULTS

Quantification of free amino acids in treated wine lees autolysates by RP-HPLC-FL

T (oC)	pH	SC (g/L)	% FAN increase	FAN (mg α-amino N/kg)	mg/kg												
					asp	glu	ser	arg	gly	ala	pro	val	ile	leu	lys	his	sum
45.1	5.01	120.94	476.5	236.2	3.0	3.0	5.5	14.8	7.9	3.8	12.5	2.5	0.7	2.9	16.7	5.4	78.8
45.1	5.01	329.06	389.8	169.9	2.4	2.5	3.8	13.3	5.2	2.0	12.2	2.7	0.4	1.9	15.1	3.7	65.3
45.1	7.99	120.94	338.0	206.4	4.5	2.6	3.8	9.9	7.1	3.8	10.7	2.5	0.8	3.0	12.4	1.3	62.4
45.1	7.99	329.06	330.7	153.1	2.3	2.3	2.4	10.0	5.2	2.0	8.7	1.3	0.7	2.3	11.3	1.0	49.6
59.9	5.01	120.94	334.6	165.8	117	4.3	7.2	34.9	12.0	9.5	20.9	7.4	5.2	10.6	39.5	6.1	169.2
59.9	5.01	329.06	390.0	170.0	14.3	5.4	7.1	37.5	12.8	10.7	19.8	7.9	4.0	12.7	51.3	4.8	188.3
59.9	7.99	120.94	259.1	158.2	11.3	16.4	9.6	24.6	12.2	12.6	21.4	8.2	5.0	12.3	29.5	1.3	164.3
59.9	7.99	329.06	330.4	153.0	9.6	5.8	8.8	5.3	7.3	9.9	17.6	5.3	2.0	6.6	14.8	-	93.0
Initial																	
	5.01	120.94		49.6	8.2	4.5	5.8	28.8	6.2	11.1	24.3	7.4	3.7	10.4	42.9	7.5	160.9
	5.01	329.06		43.6	7.1	5.1	4.1	29.9	4.8	9.6	21.8	7.9	3.9	9.3	43.9	8.0	155.4
	7.99	120.94		61.1	7.9	5.3	5.7	31.9	6.8	12.0	26.1	8.1	4.2	11.4	43.3	5.3	168.0
	7.99	329.06		46.3	7.1	4.9	4.0	29.4	4.8	9.5	21.6	7.4	3.6	9.5	40.7	6.3	148.8
Commercial yeast extract (1 g/L)					10563.9	31657.2	14689.0	18874.2	7465.1	34531.4	9445.8	22818.9	13982.1	35737.6	15544.4	680.3	215990.0

METHODOLOGY



Extraction I:
sequential maceration
with Acetone/H_2O
and MeOH/H_2O

Extraction II:
acid extraction
with HCl

pH: 4.0 - 9.0
T: 40 - 65 ^{o}C
Solid concentration: 50 - 400 g/L

Autolysis yield:
Free α-amino nitrogen formation

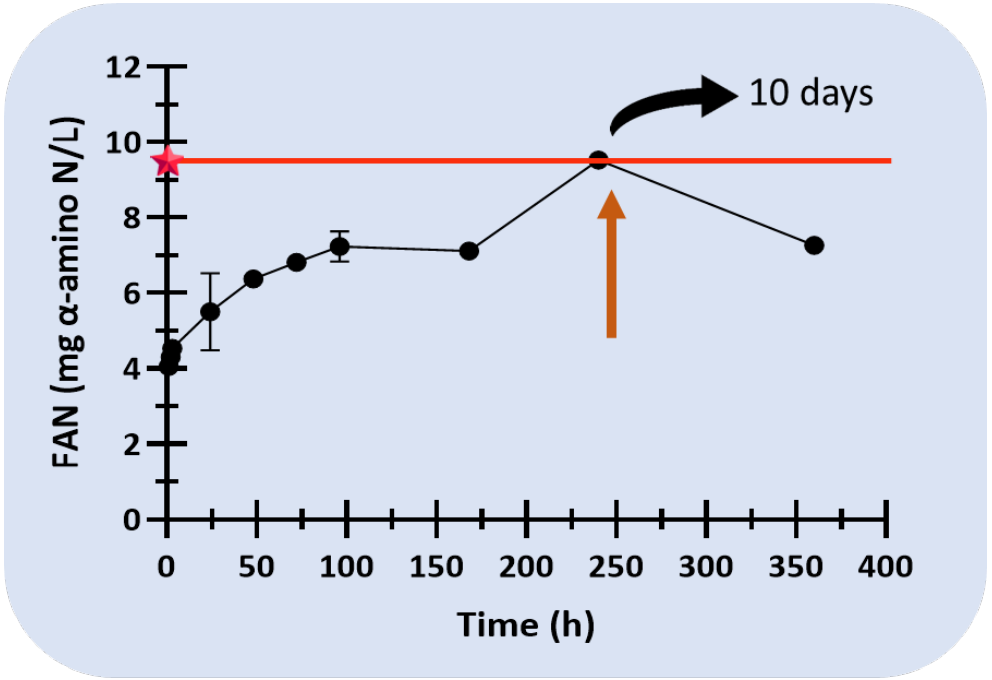
Ninhydrin spectrophotometric method

(Chira et al., 2009; Lie, 1973; Salgado et al., 2010)

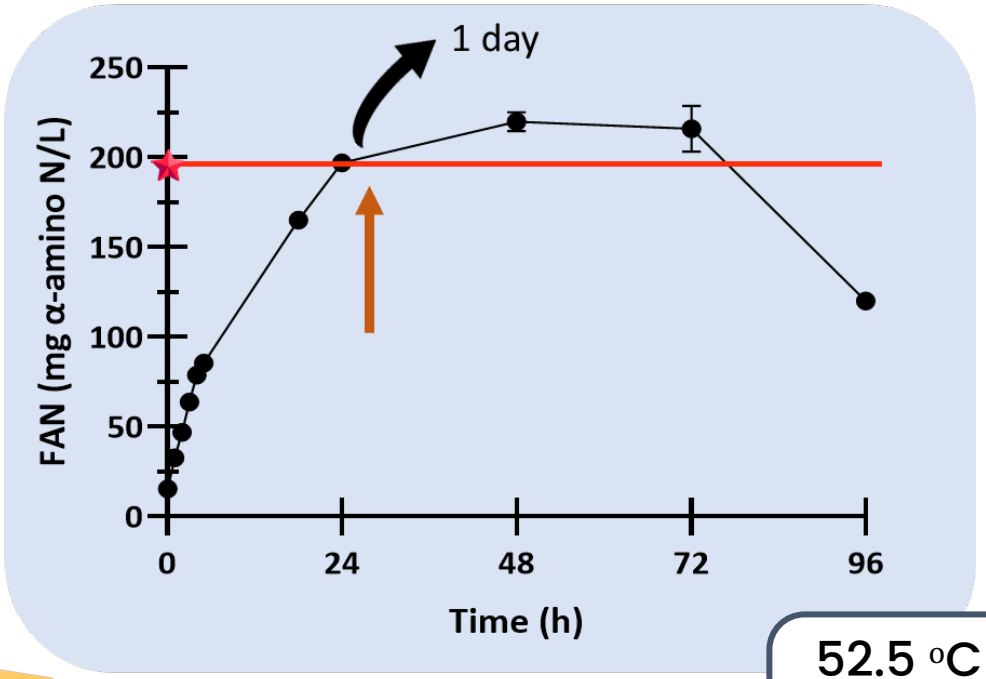
RESULTS

Optimization of autolysis duration of wine lees

Treated



Untreated



52.5 °C
pH 6.5
225 g/L

RESULTS

- Similar pattern with treated wine lees for pH and solid concentration.
- Increase of temperature within the examined ranges appears to **negatively affect** autolysis efficiency.

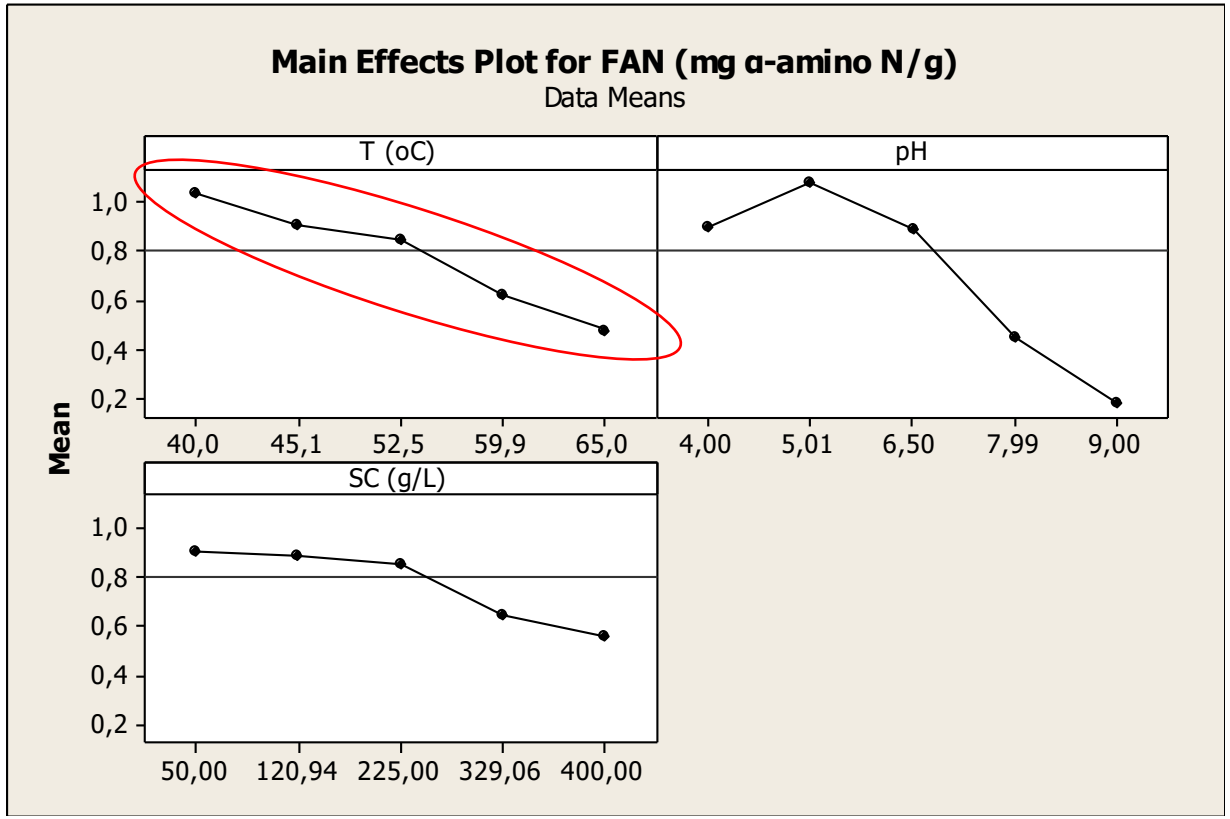


Figure 3. Main Effects Plot of temperature, pH and solid concentration on autolysis efficiency of untreated wine lees (FAN).

RESULTS

- Max. yield: 0.236 ➔ 1.393 mg α-amino N/g
- Max. FAN increase: 476 ➔ 833%
- pH*pH: significant factor
- R^2=91.75%

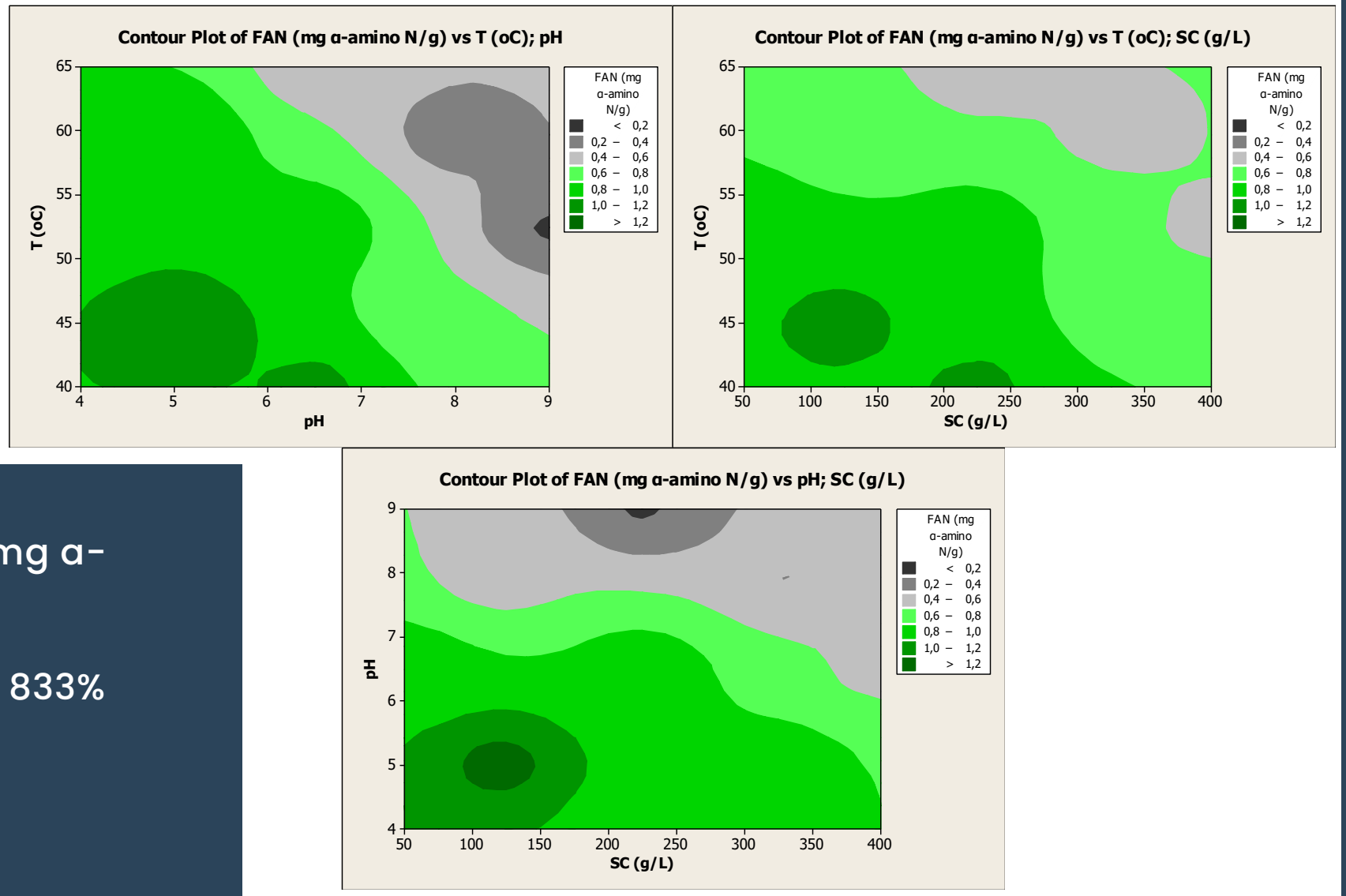


Figure 4. Effect of temperature, pH and solid concentration on autolysis efficiency of untreated wine lees (FAN).

ONGOING RESEARCH

- Effect of commercial enzyme consortia addition on autolysis yield.
- Production of yeast extract powder through freeze-drying of autolysates
- Substitution of commercial yeast extract in synthetic media and effect on winemaking yeast and LAB growth

CONCLUSIONS

- Autolysis of wine lees increased free α-amino nitrogen by up to 833%.
- Results are promising towards the production of a novel, yeast extract substitute.
- Further investigation is required in order to produce a stable powder, with possible uses within the food industry and winemaking.

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