Toward Machine Learning Implementation in AI for Agro-Food Sustainability From Olive Oil Quality to Citrus Fruit Detection in the field

Francesca Venturini, Umberto Michelucci

TOELT LLC, Switzerland

Collaborators

Baptiste Paul Ernest Lucas
Safouane El Ghazouli
Arnaud Gucciardi
Alessandro Carella
Roberto Massenti
Riccardo Lo Bianco
Michael Baumgartner
Silvan Fluri
Ivo Herzig
Manas Mejari
Pablo Romero
Vanessa M. Martos

{/} TOELT RESEARCH

Politecnico di Torino

University of Ljubljana

UNIVERSIDAD DE GRANADA

UNIVERSITÀ DEGLI STUDI DI PALERMO

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

SustAInable FROM CROPS TO TABLE

Workshop at Alahambra Beer in Granada

Measurement Campaign at Granada

SSP lectures at UGR

Secondment at TOELT LLC (CH)

Secondments in Sicily (Palermo)

EVOO quality

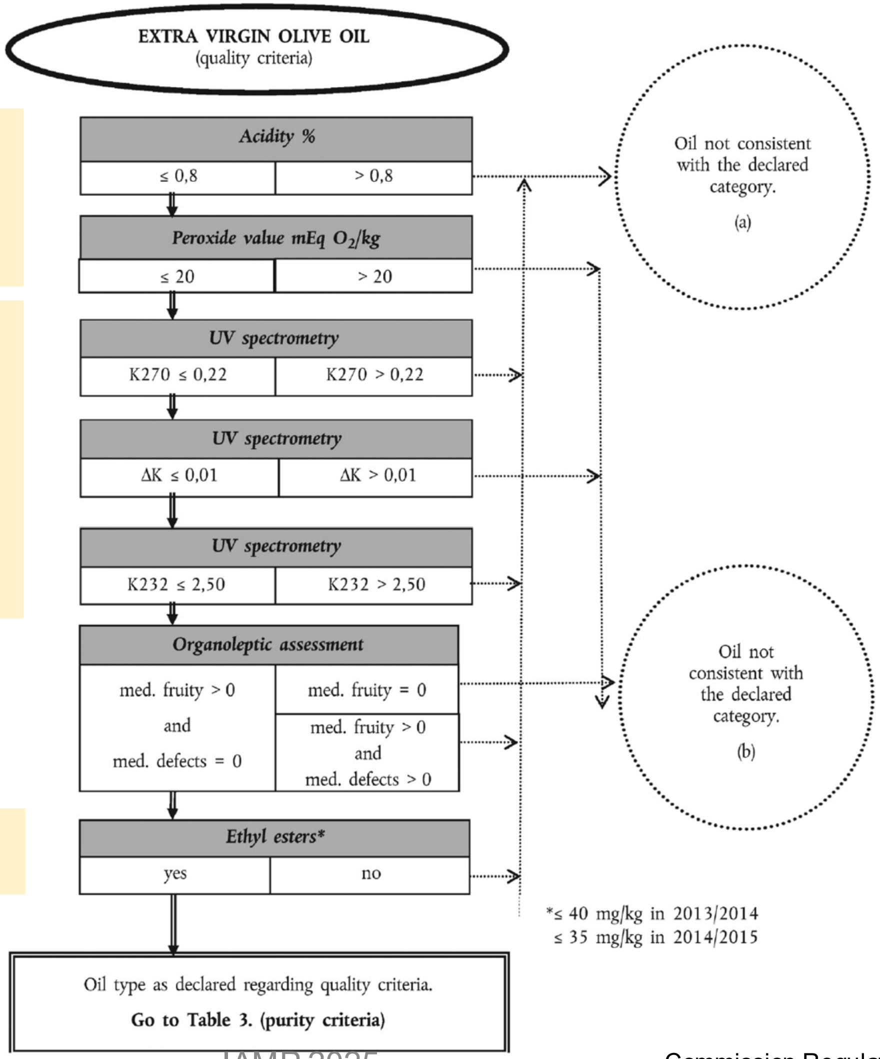
F. Venturini, francesca.venturini@zhaw.ch

Quality assessment of EVOO

Titration

Absorption spectroscopy

Gas chromatography

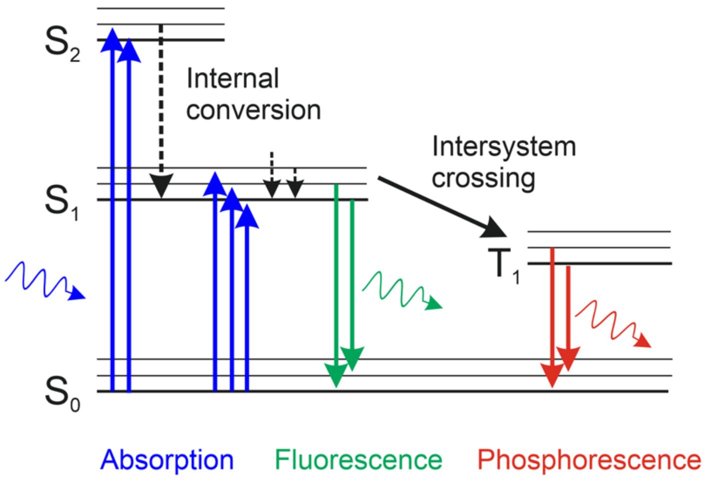


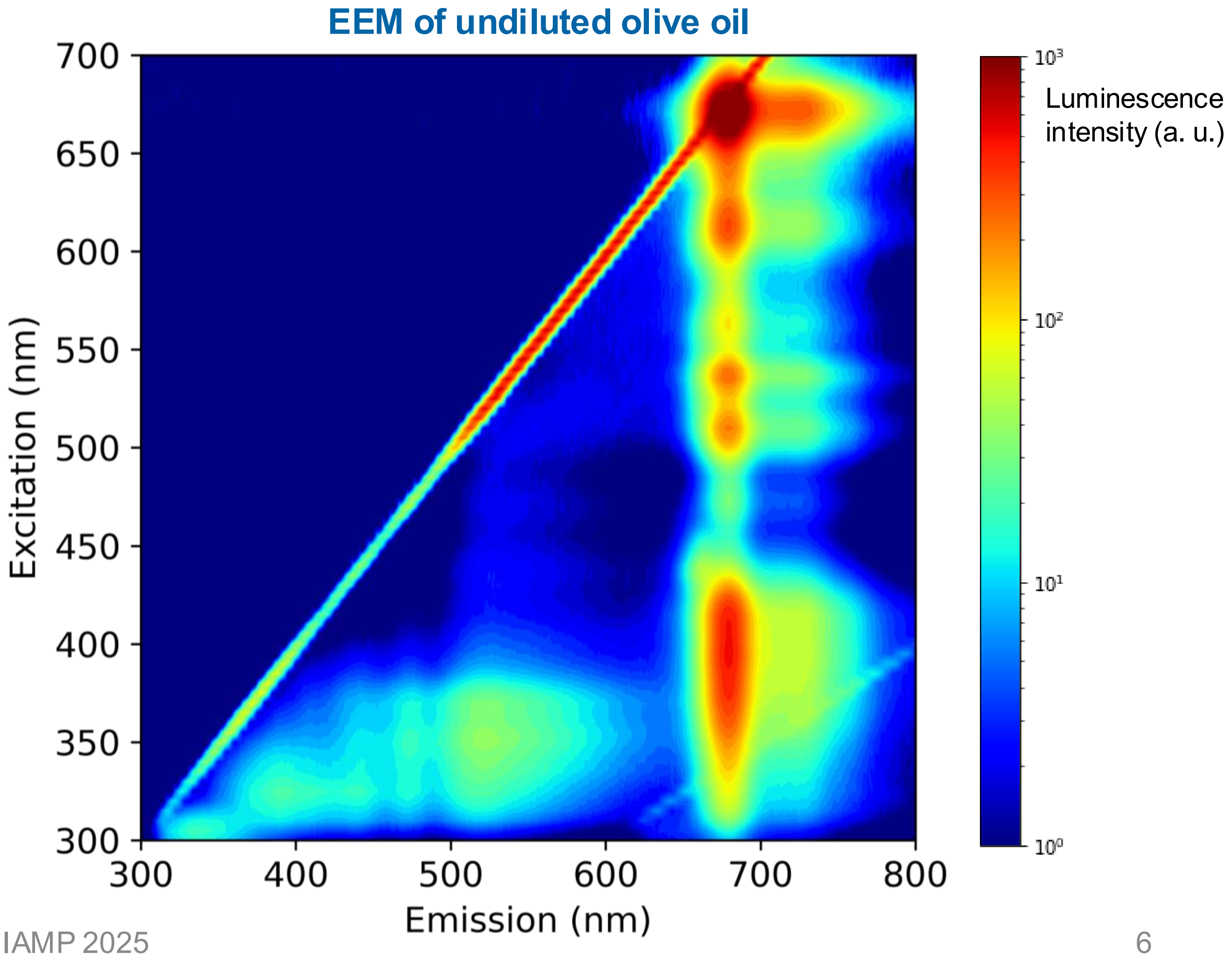
Commission Regulation EEC 2568/91,
Commission Implementing Regulation (EU) No 1348/2013

Why fluorescence?

Fluorophores naturally present in oil:

- Chlorophylls *a, b, d*
- Flavonoids, carotenoids
- Polyphenols
- Tocopherol, vitamin E
- Oxidation products





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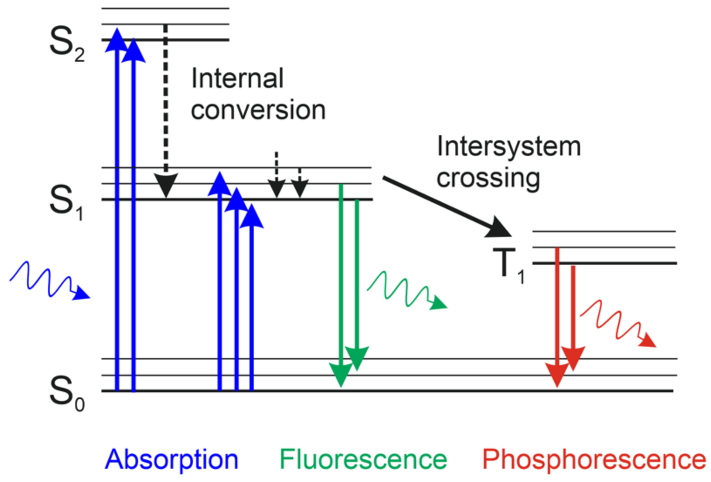

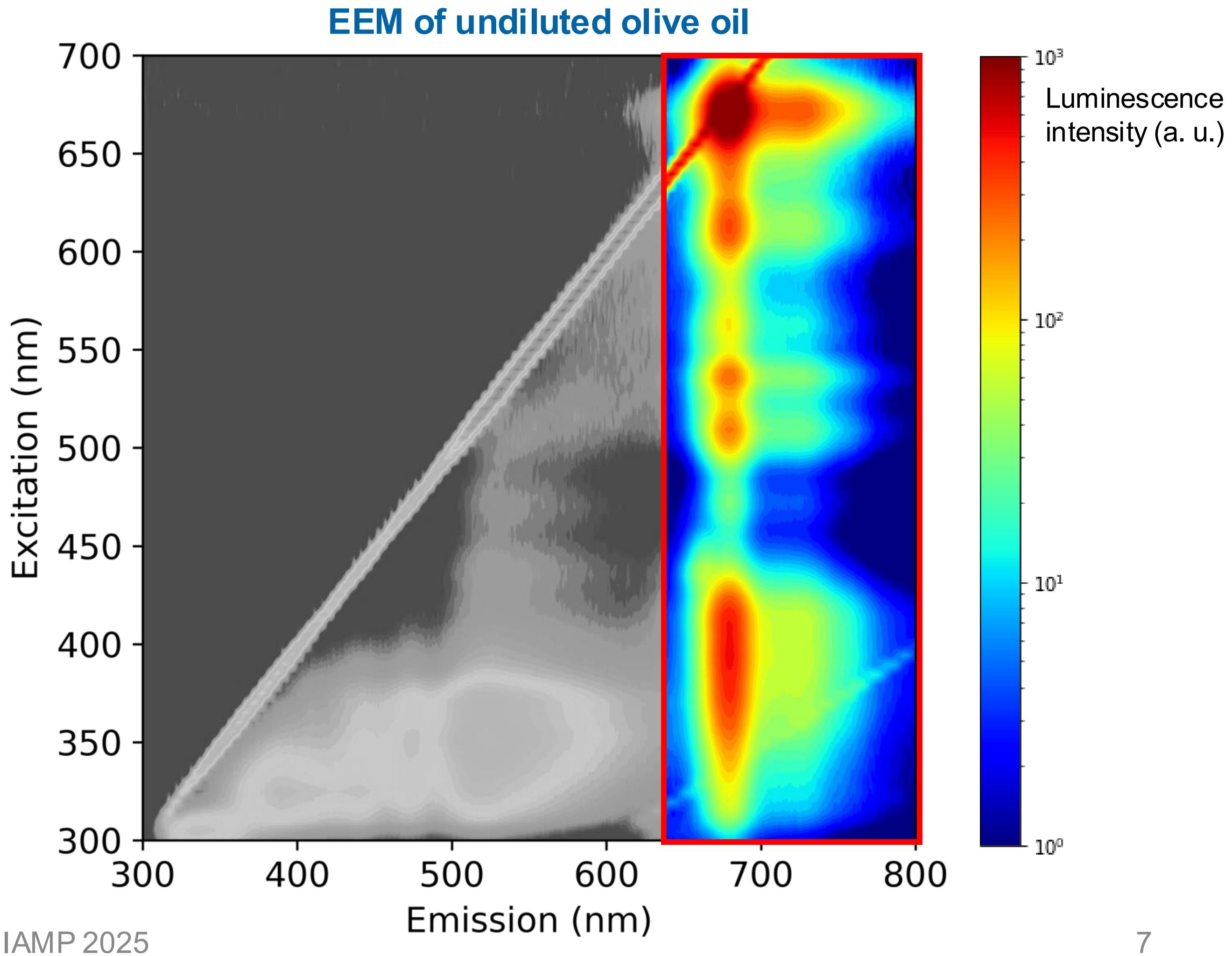

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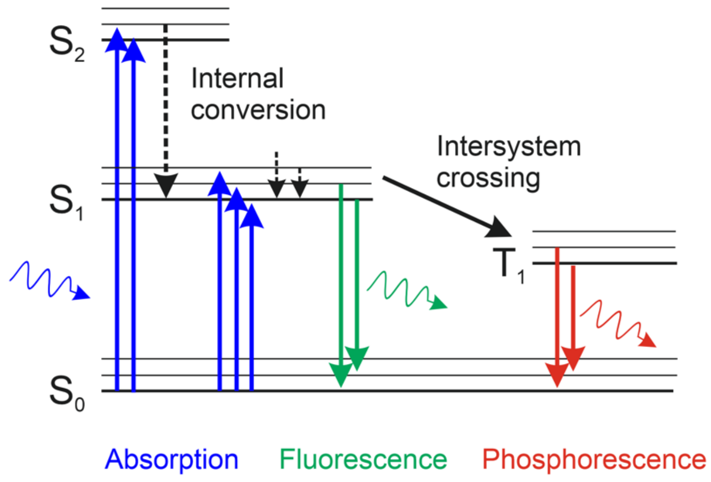

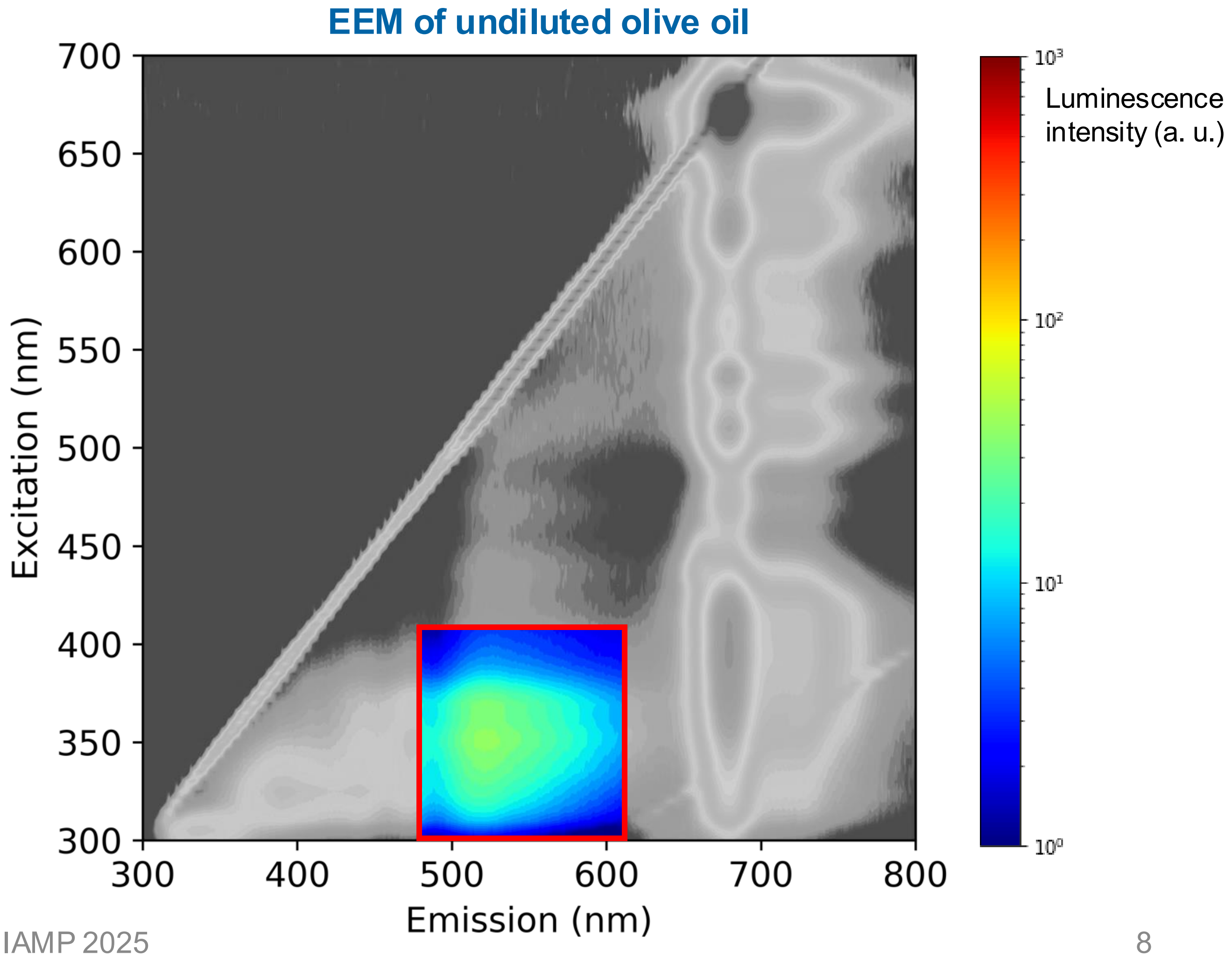

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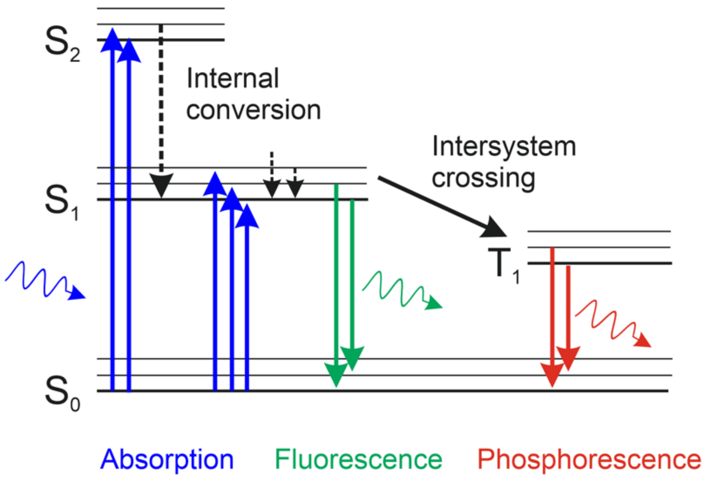

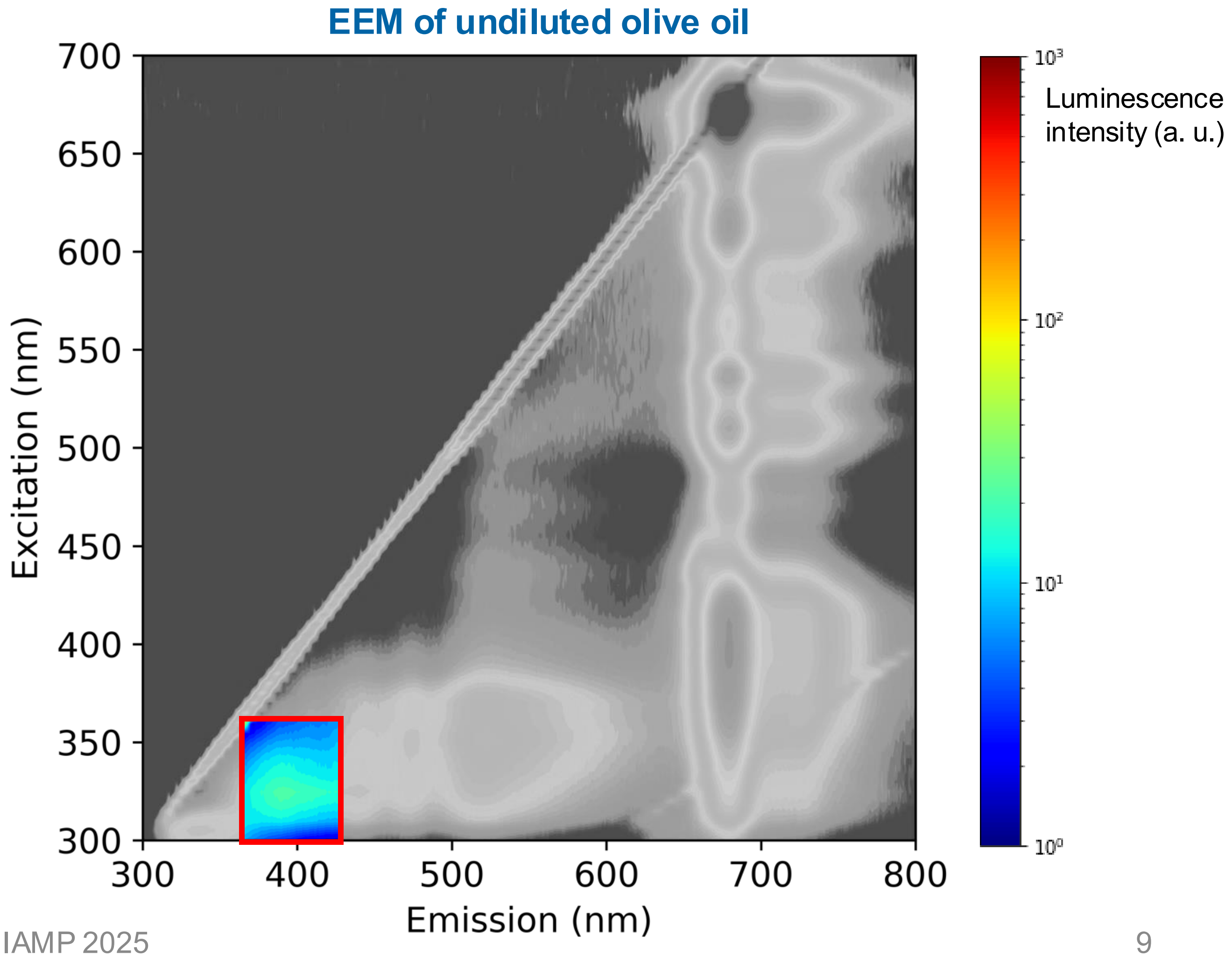

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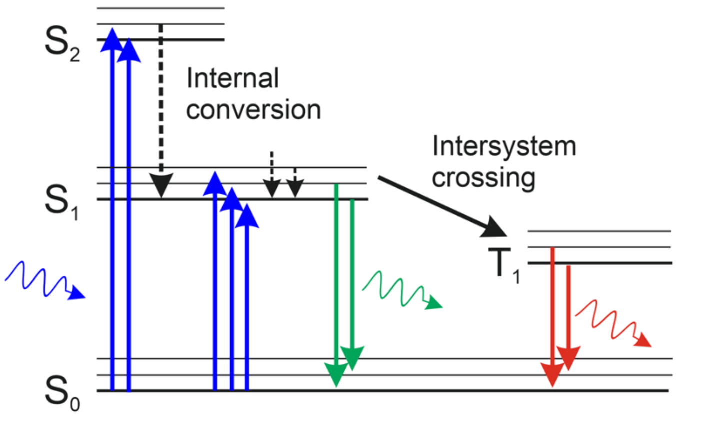
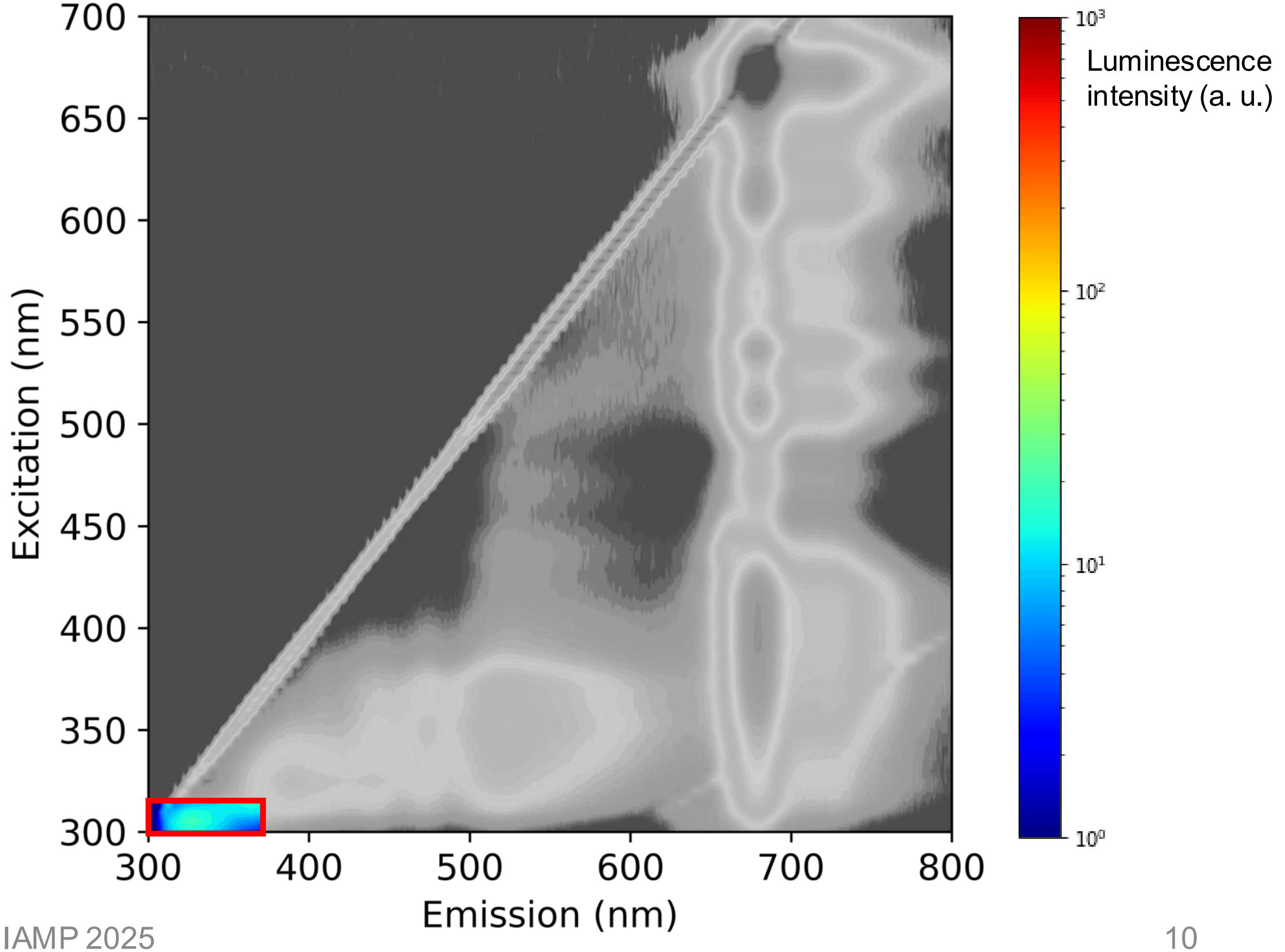


EEM of undiluted olive oil



Method: fluorescence

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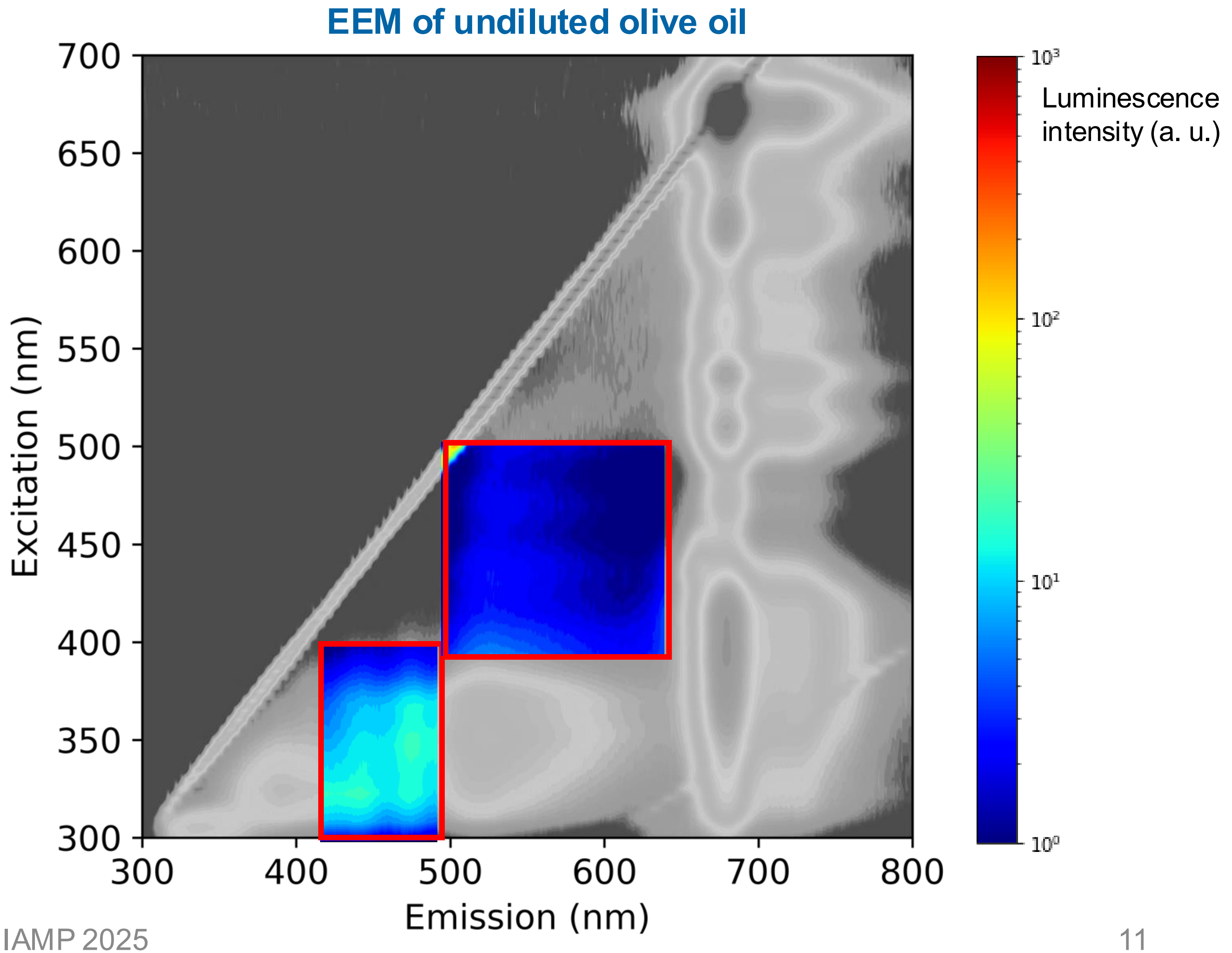
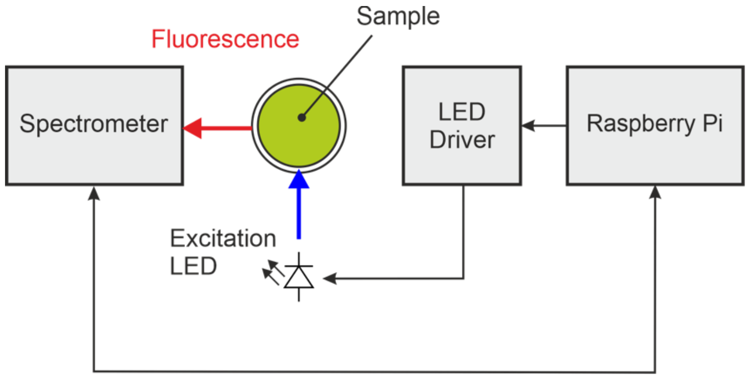
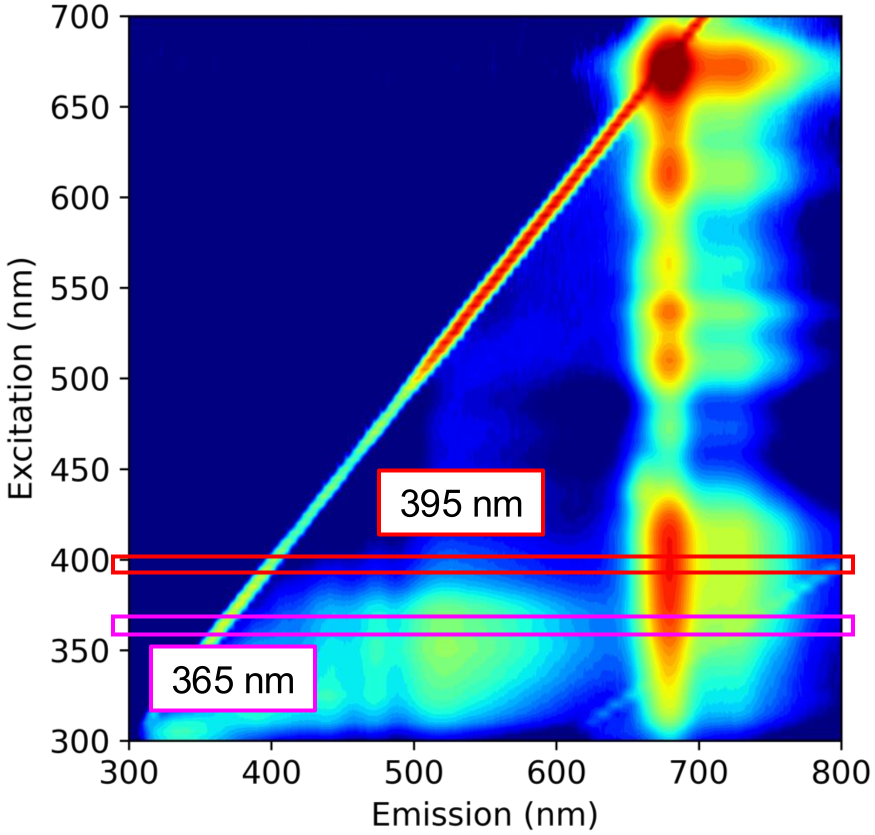
➢ Fluorescence is very specific of the molecules contained in the sample
→Fluorescence can be used for quantitative assessment



Extraction of quality parameters with fluorescence: instrument

- Single spectra
- Compact and cost-effective design
- No optical filters, lenses
- Fast acquisition (<1s)
- Easy to use

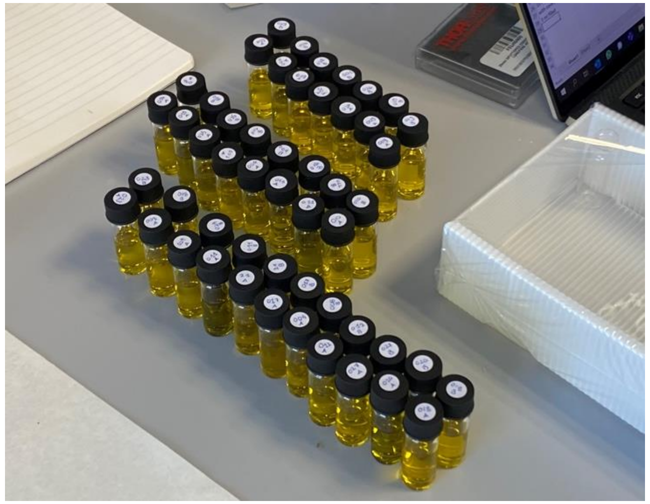




Venturini, F. *et al.*, *Foods* 2021, *10*, 1010

Dataset of olive oils

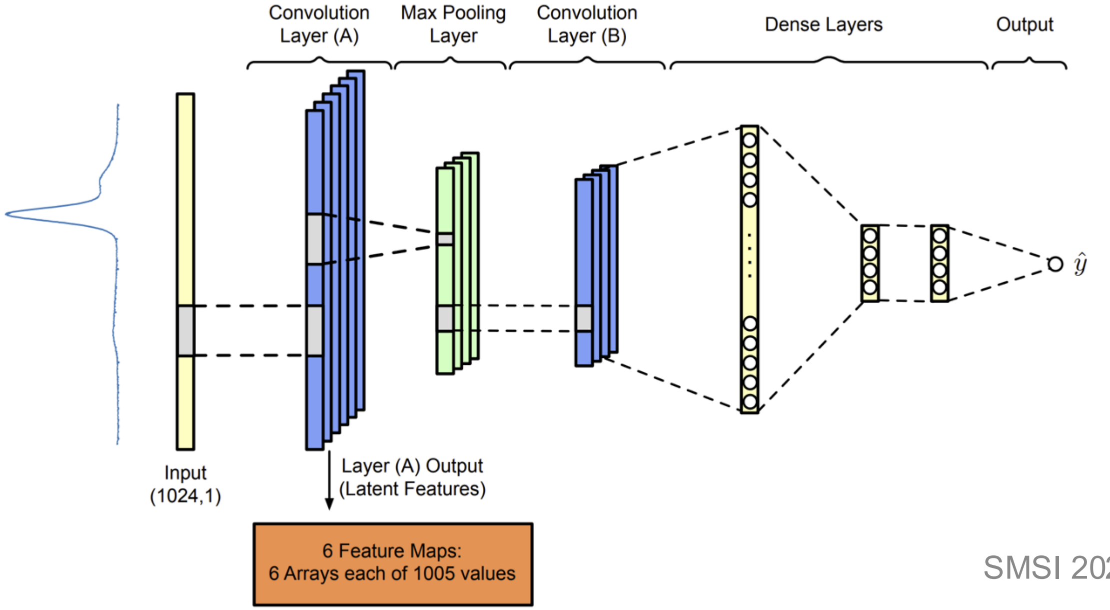
- Oils from single producer, 3 different quality levels: EVOO, VOO, LOO
- Complete chemical analysis for all oils

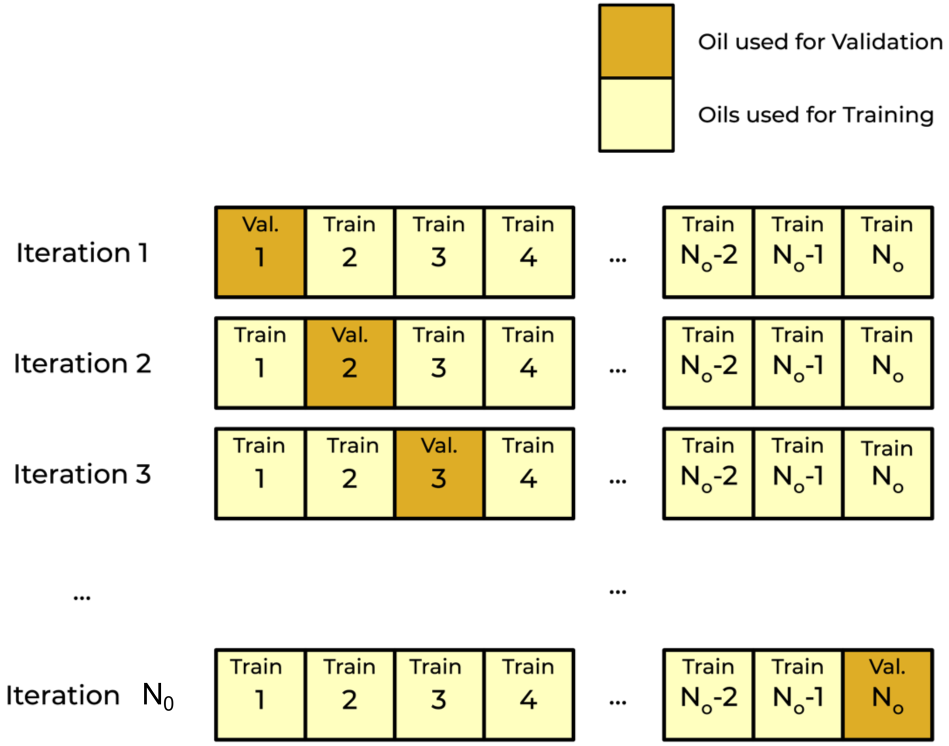


Label	Acidity (%)	Peroxide value (mEq O_2/kg)	K_{270}	K_{232}	Ethyl esters (mg/Kg)	Quality
D03	0.35	8.4	0.123	1.435	26	VOO
D04	0.34	8.6	0.108	1.403	40	VOO
D05	0.36	10.3	0.112	1.44	18	VOO
D06	0.31	9.2	0.151	1.484	18	VOO
D07	0.50	8.9	0.150	1.537	47	VOO
D08	0.40	8.5	0.158	1.546	25	VOO
D19	0.25	4.9	0.13	1.540	10	EVOO
D20	0.26	4.6	0.14	1.540	10	EVOO
D35	0.17	6.4	0.12	1.63	8	EVOO
D38	0.16	6.4	0.12	1.63	9	EVOO
D45	0.17	4.9	0.12	1.63	7	EVOO
D46	0.18	5.0	0.13	1.63	8	EVOO
D47	0.18	5.2	0.13	1.64	16	EVOO
D49	0.9	9.9	-	-	-	LOO
D51	2.16	-	-	-	-	LOO
D52	1.78	22	-	-	-	LOO
D53	0.7	8.7	-	-	-	LOO
D64	0.2	7.1	0.13	1.63	29	VOO
D73	0.2	8.9	0.14	1.66	15	EVOO
D77	0.24	10.4	0.13	1.74	26	VOO
D81	0.16	4.9	0.12	1.63	9	EVOO
D92	0.18	5	0.17	1.91	15	EVOO

Design of the 1D-CNN

- Design using **physical** information:
  - Number of filters → number of the expected features
  - Size of filters → resolution of the spectrometer
- **Supervised** learning
- Cross validation → **Leave-one-out**

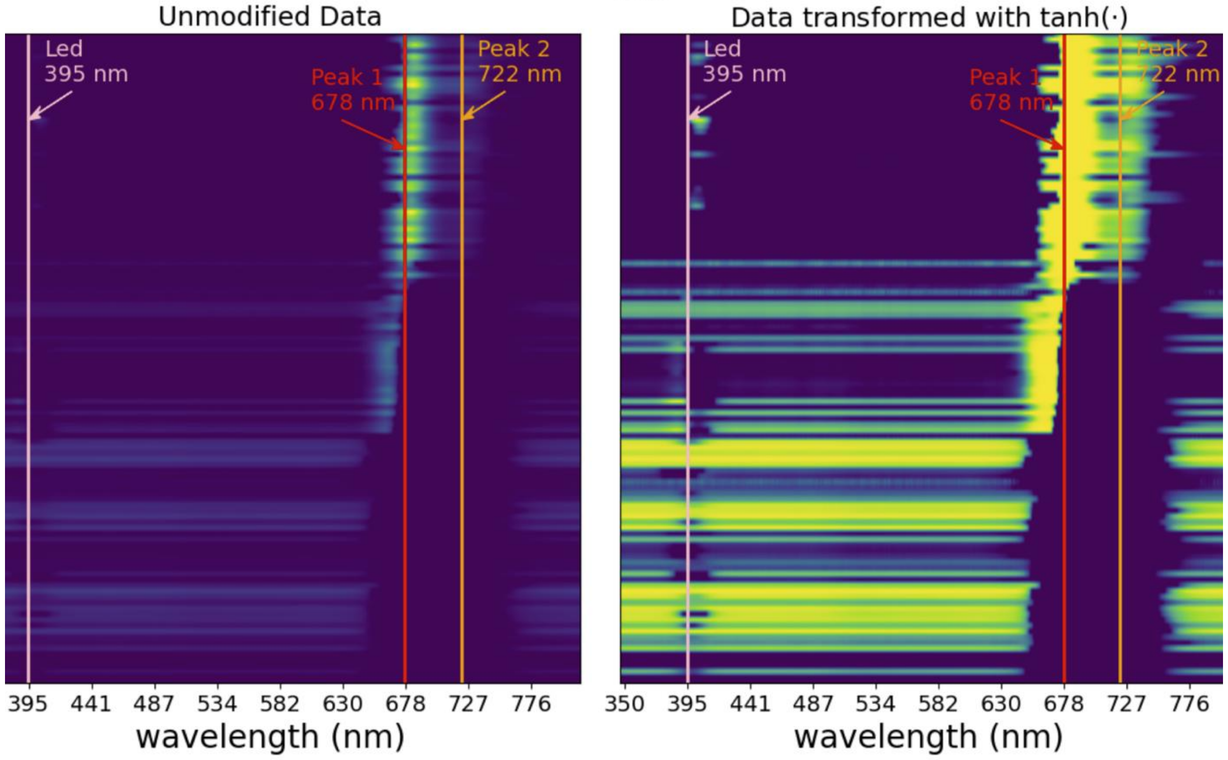


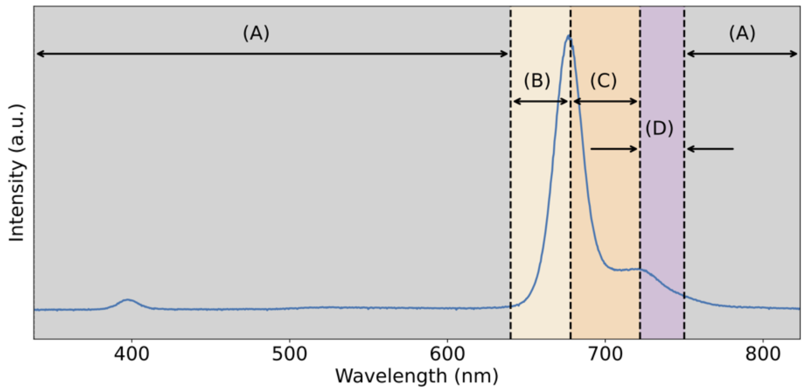


Explainability results

Feature maps for all the oils

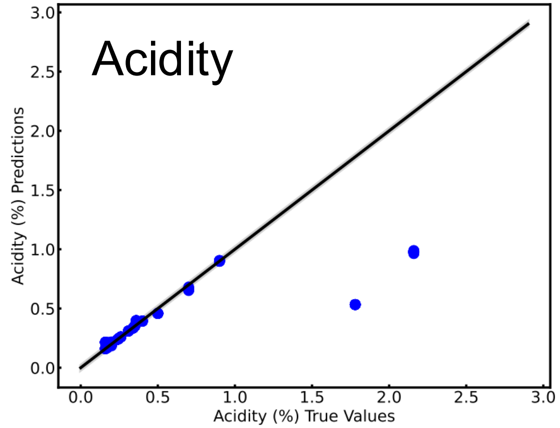
K_{232}

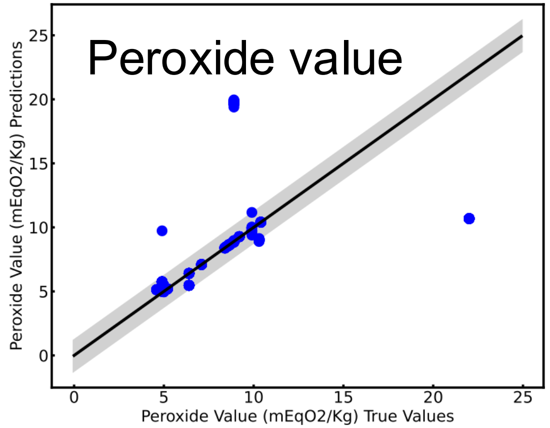


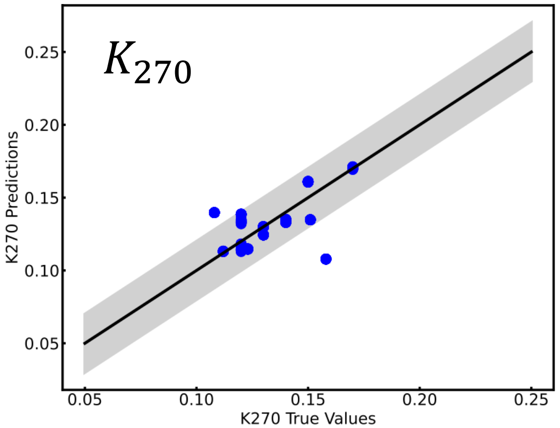


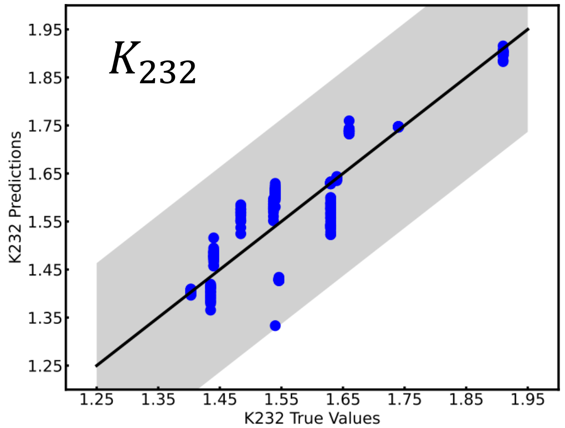
- There 1D-CNN identifies tha **spectral regions** relevant for the prediction
- The 1D-CNN learns from the **same** regions of the spectra for **all oils** → results are **robust**
- The 1D-CNN identifies the spectral features which are physically meaningful → **trust** the results

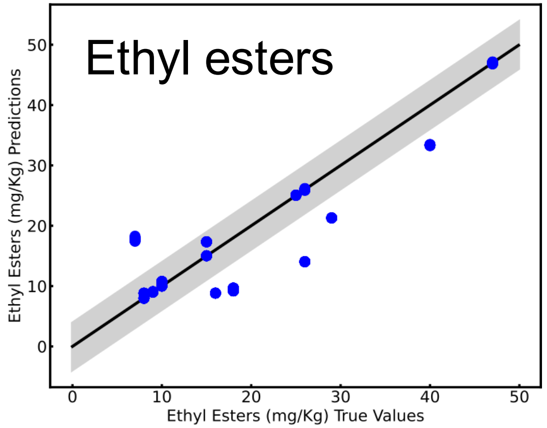
Results: extraction of quality parameters

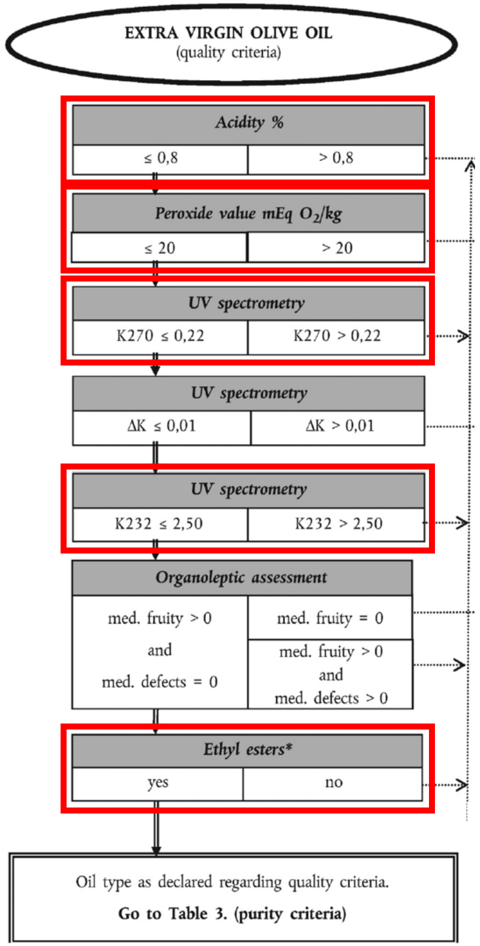








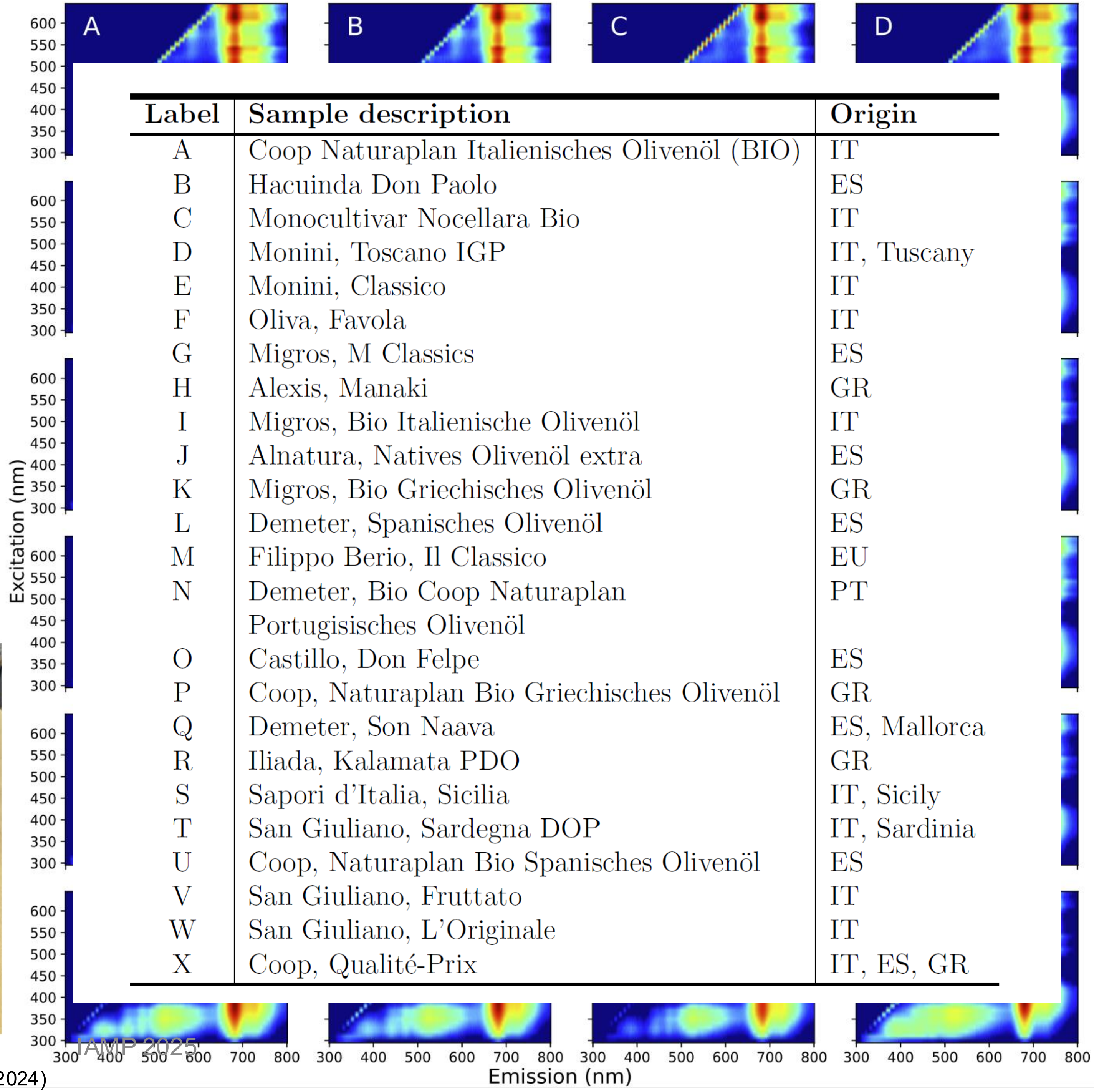




Venturini, F. et al., Journal of Food Engineering 336, 111198 (2023)

Ageing of EVOO

- 24 commercial EVOO
- Heterogenous geographical origin (Italy, Spain, Portugal, Greece, and unspecified Europe) and price
- 3 samples per oil and ageing step
- 10 ageing steps at 60°C, dark, sealed vials
- 720 EEMs



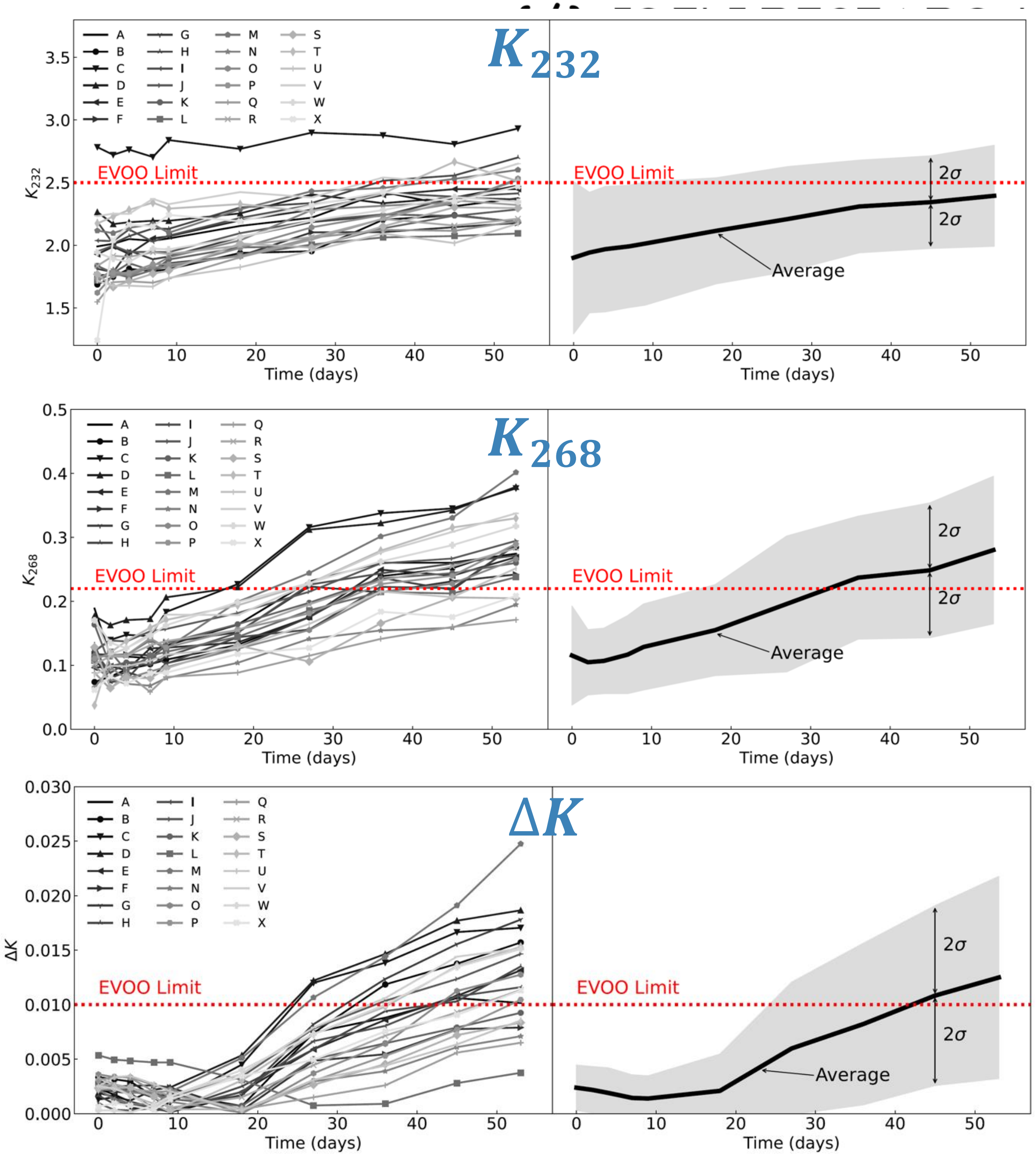
Label	Sample description	Origin
A	Coop Naturaplan Italienisches Olivenöl (BIO)	IT
B	Hacuinda Don Paolo	ES
C	Monocultivar Nocellara Bio	IT
D	Monini, Toscano IGP	IT, Tuscany
E	Monini, Classico	IT
F	Oliva, Favola	IT
G	Migros, M Classics	ES
H	Alexis, Manaki	GR
I	Migros, Bio Italienische Olivenöl	IT
J	Alnatura, Natives Olivenöl extra	ES
K	Migros, Bio Griechisches Olivenöl	GR
L	Demeter, Spanisches Olivenöl	ES
M	Filippo Berio, Il Classico	EU
N	Demeter, Bio Coop Naturaplan Portugisisches Olivenöl	PT
O	Castillo, Don Felpe	ES
P	Coop, Naturaplan Bio Griechisches Olivenöl	GR
Q	Demeter, Son Naava	ES, Mallorca
R	Iliada, Kalamata PDO	GR
S	Sapori d'Italia, Sicilia	IT, Sicily
T	San Giuliano, Sardegna DOP	IT, Sardinia
U	Coop, Naturaplan Bio Spanisches Olivenöl	ES
V	San Giuliano, Fruttato	IT
W	San Giuliano, L'Originale	IT
X	Coop, Qualité-Prix	IT, ES, GR

Venturini, F. et al., LWT 191, 115679, (2024)

Quantitative assessment of ageing: UV spectroscopy

- Ageing assessed through quality parameters: K_{232}, K_{268}, ΔK

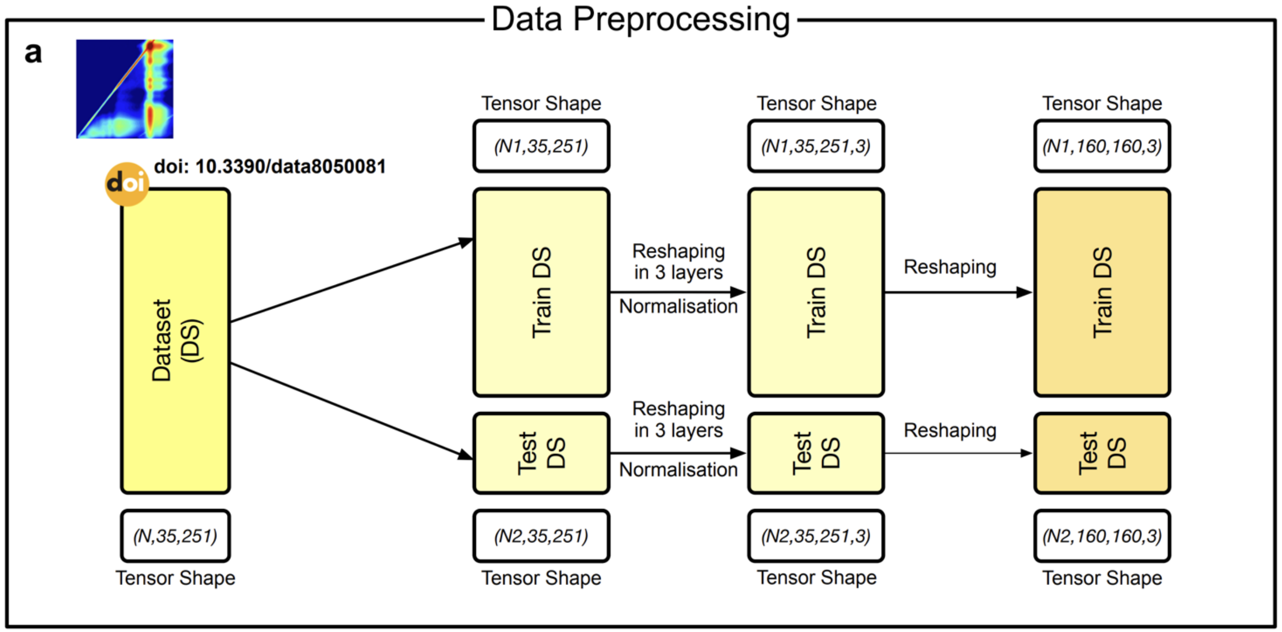
Commission Regulation EEC 2568/91,
Commission Implementing Regulation (EU) No 1348/2013

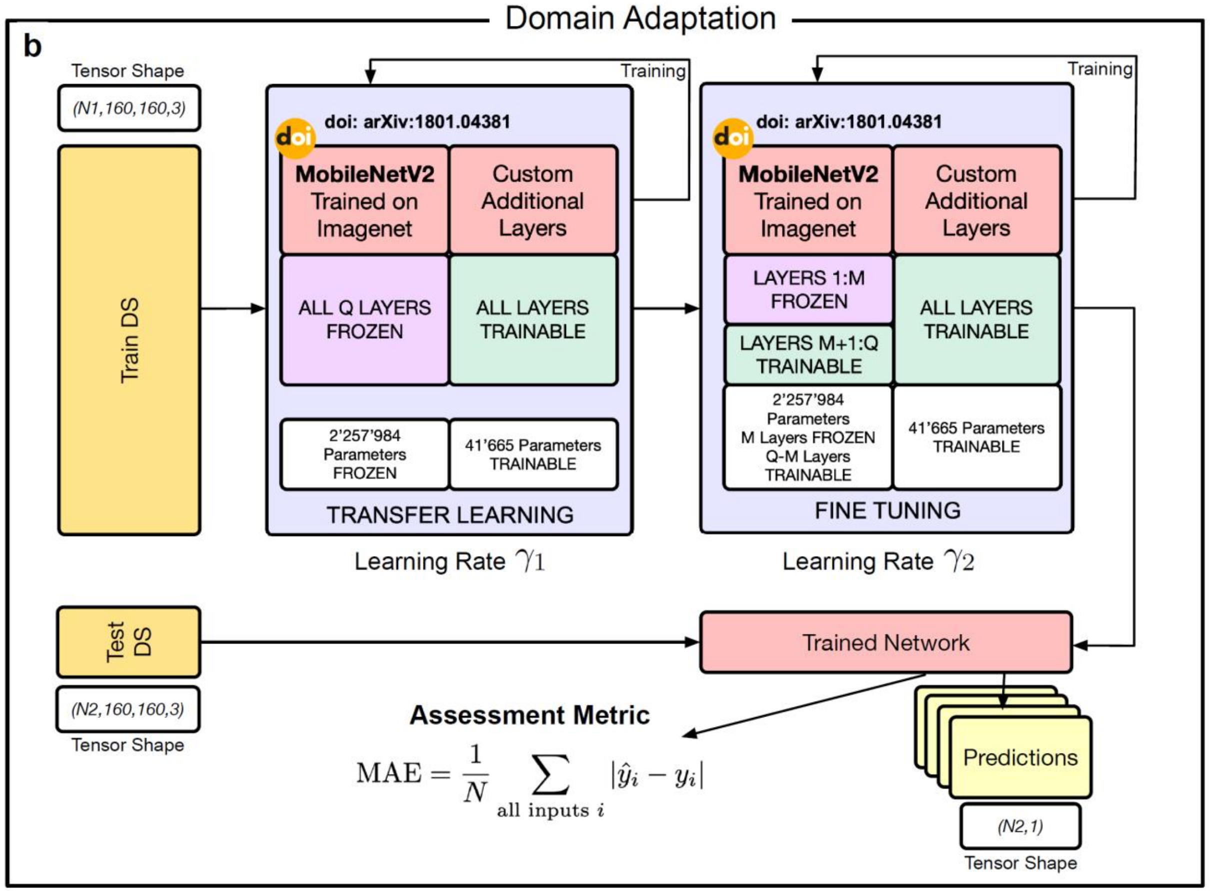


<u>Observations:</u>

- Similar trends for all oils despite heterogeneity
- $\boldsymbol{K_{232}}$: total change 26% → weak
- $\boldsymbol{K_{268}}$: total change 143% →strong
- $\boldsymbol{\Delta K}$: Behaviour similar to K_{268}

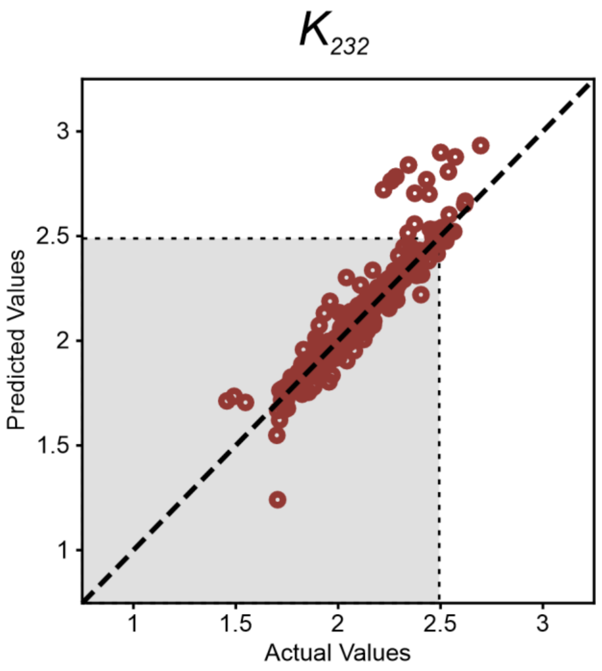
Deep learning approach

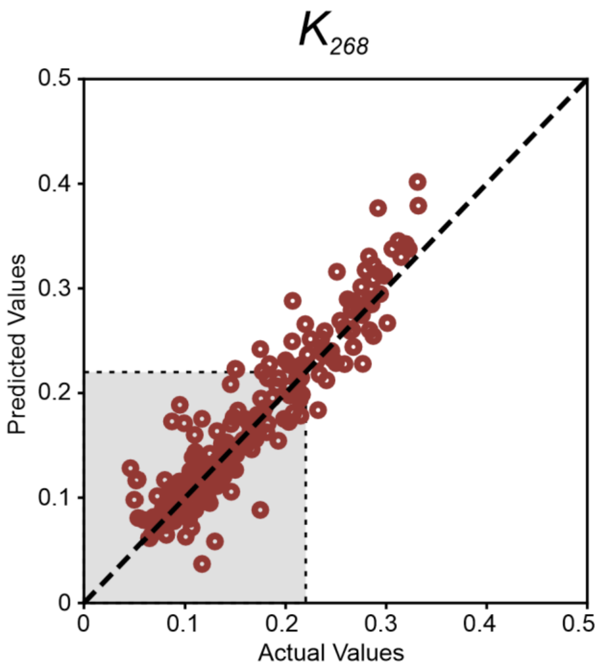




Michelucci, U., Venturini, F. *Sci Rep* **14**, 22291 (2024)

Results: extraction of quality parameters



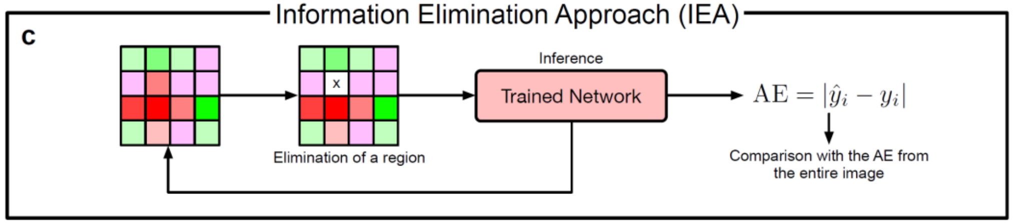


Quality parameter	MAE	Label error	EU limits
K232	0.066	0.06	2.5
K268	0.010	0.02	0.22

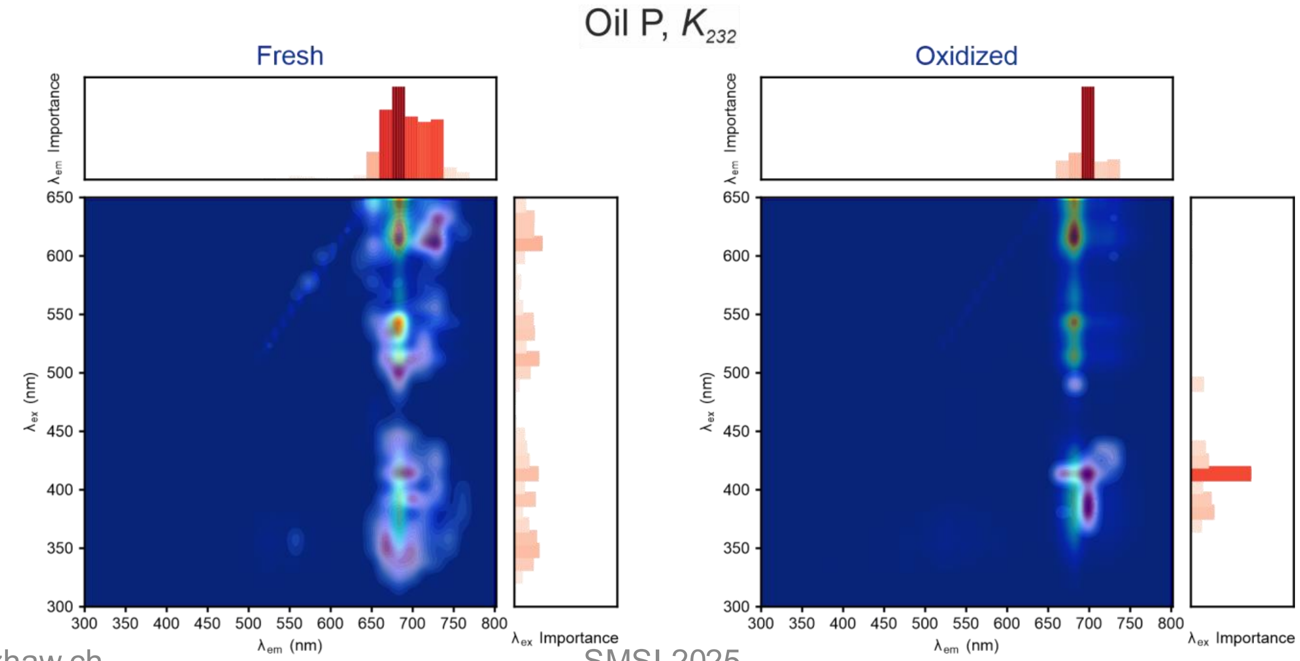
- Fluorescence intensity can be used to predict UV quality parameters

Explainability approach

- Method: Information elimination approach

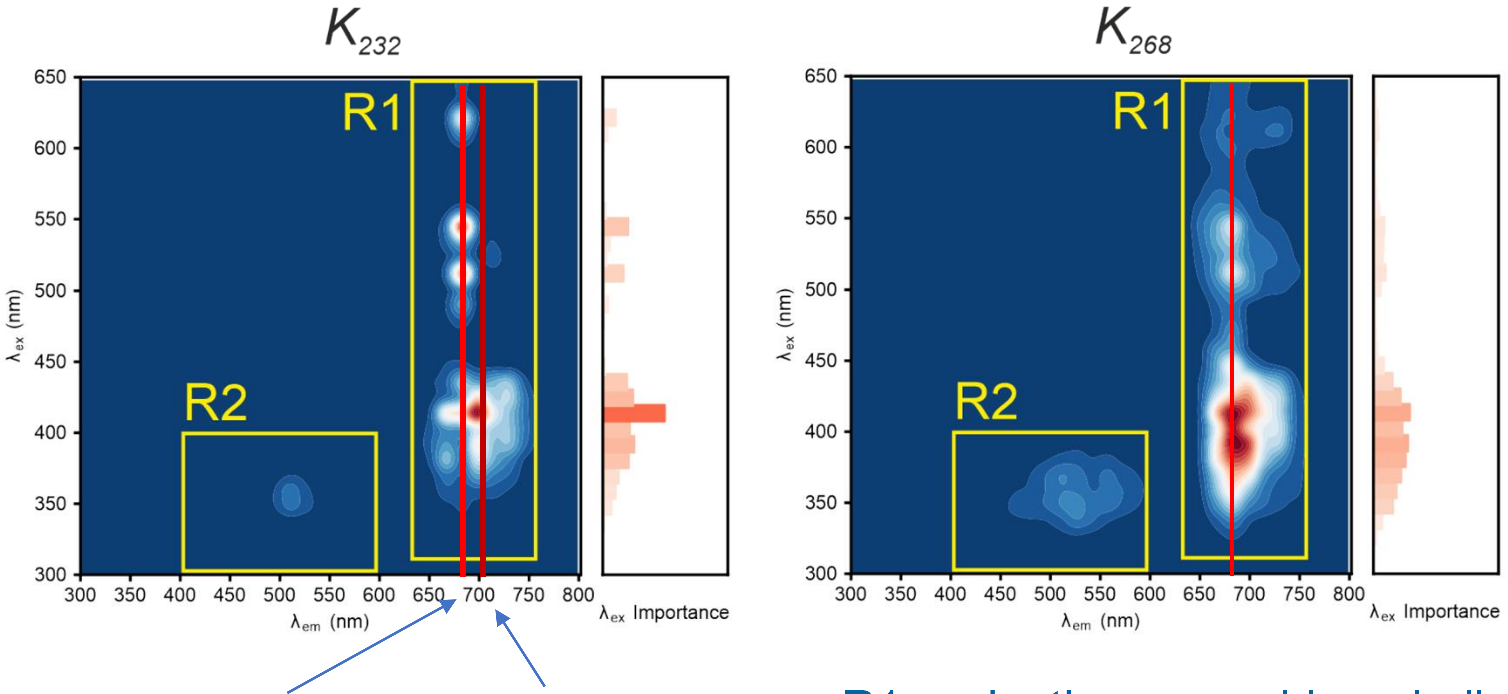


- Heatmap of the AE (absolute error) when eliminating a spectral region → identification of spectral regions contributing to the prediction



Results: heatmap of the spectral regions relevant for prediction

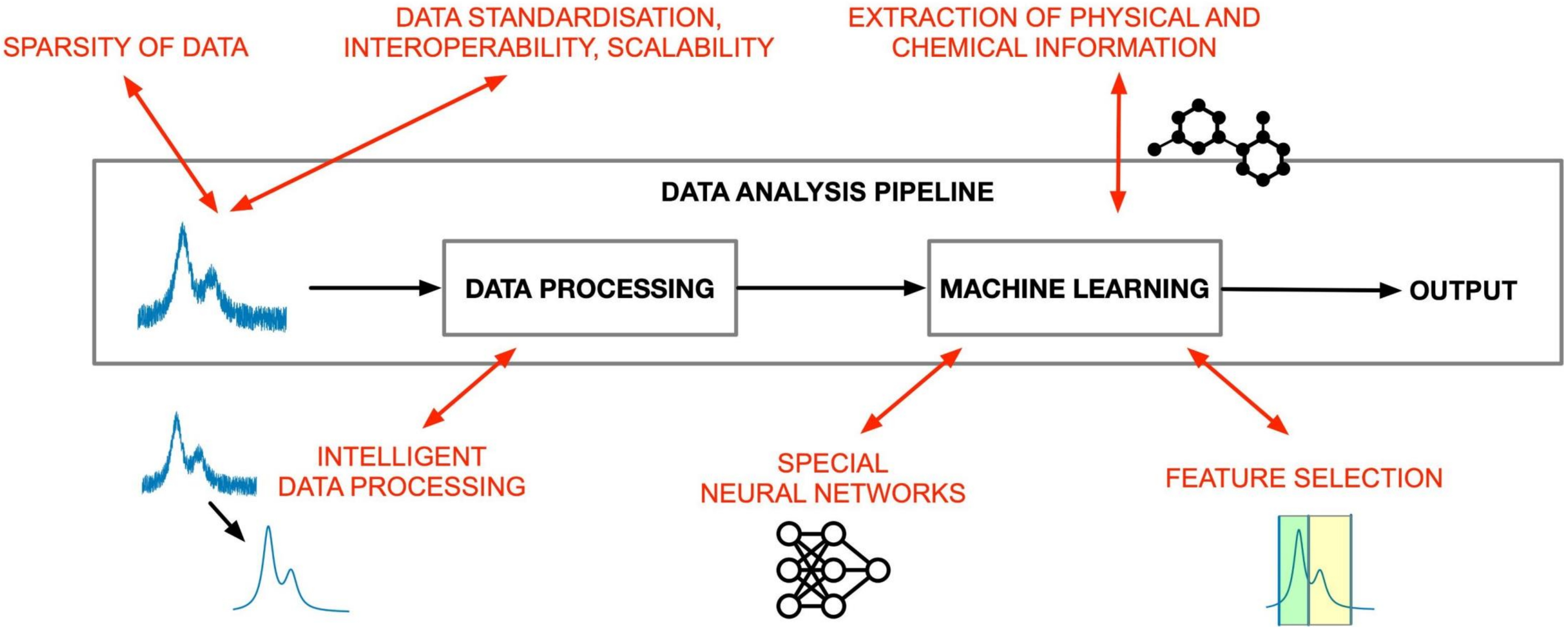
➢ Identification of spectral regions affected during the ageing (the oxidation process)



R1: chlorophylls → pheophytins

R1: reduction conc chlorophylls
R2: reduction conc carotenoids

No free lunch: challenges in application of ML



Smeesters, L., Venturini, F., et al., 2025 photonics for agrifood roadmap. Journal of Physics: Photonics (2025)