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VinePAT : Vineyard Management for Grape “Metabolomic Imaging” using Hyperspectral vis-NIR Spectroscopy

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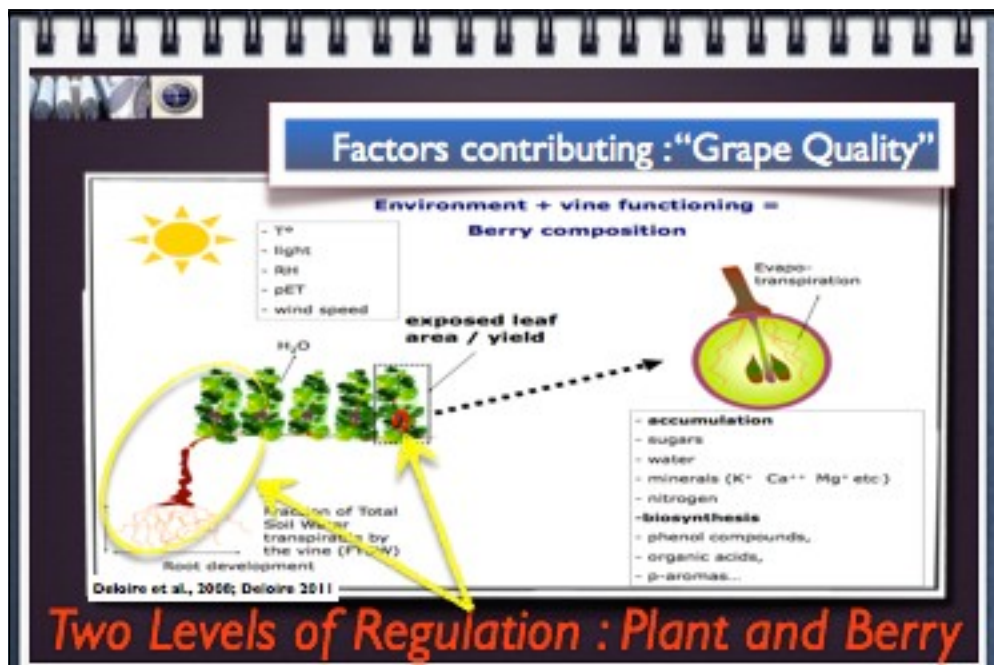
10 & 11 November 2011

Objectives

1. “Grape Quality” : Can we define it ? How to measure it ?
2. Spectroscopy – Holistic Measurement of Metabolism
3. Case Study : Hyperspectral Monitoring
4. “Harvest Forecasting ...”

Grape Composition: the Big Picture





Factors contributing : "Grape Quality"

- Which berry compound(s) to analyze to decide on an harvest date ?
- For which style of wine ?
- Which analytical method to chose ?

Deloire et al., 2006; Deloire 2011

Grape Maturity

1. Technical Maturity
2. Aromatic Maturity
3. Phenolic Maturity
4. Textual Maturity

WHEN ARE OF GRAPES READY FOR HARVEST?

How to follow grape maturity, a technical guide
Le Moigne et al Food Quality & Preference
2000, 19, 672-681



Four key parameters

(based on 30 attributes)

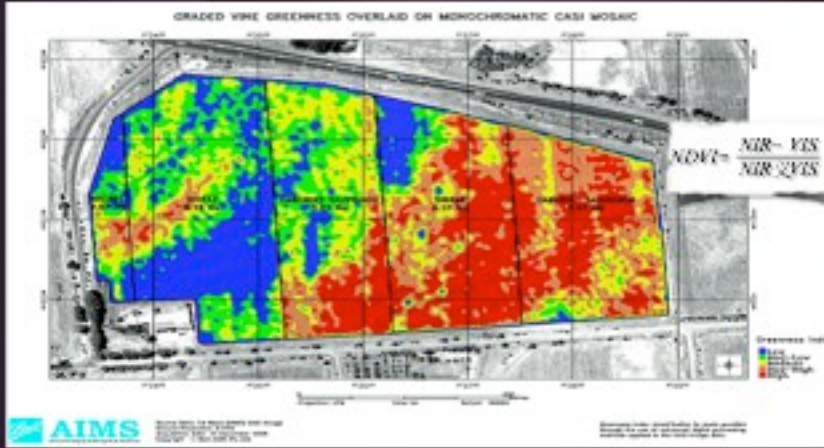
1. Technical maturity
2. Aromatic maturity
3. Phenolic maturity
4. Textual maturity

Le Moigne et al. Food Quality & Preference 2000, 19, 672-681

Strategies



Normalized Difference Vegetation Index (NDVI)



Factors contributing : "Grape Quality"

MACRO

- Latitude
- Altitude
- Relief

MESO

- Temperature
- Wind
- Rain
- Orientation
- Humidity

MICRO

- Aspect
- Leaf Cluster TIC

- Genotype
- Pest Control
- Soil Management
- Training System
- Harvest Date

Plant

Grape Metabolism

Soil

- Texture
- Water Regime
- Nutrients
- Rooting depth
- Temperature
- Light

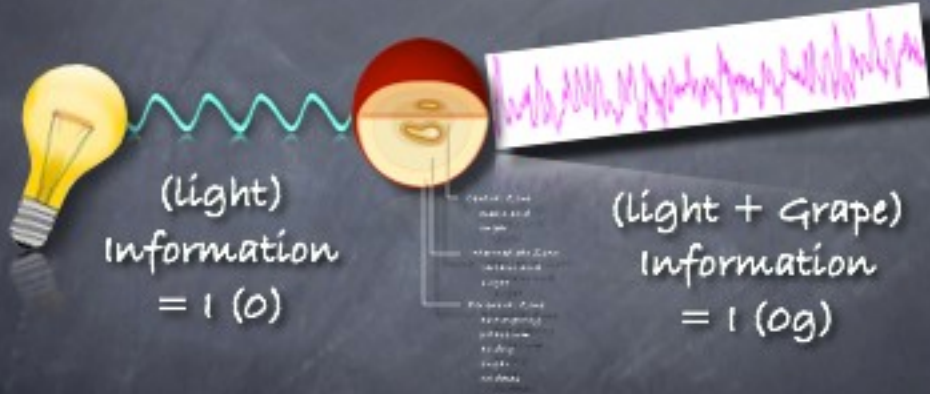
Jackson and Lombard / 1993

Electromagnetic Spectra

The visible portion of electromagnetic spectra is called light and can be types according to the frequency detected by the normal eye (380-750 nm).



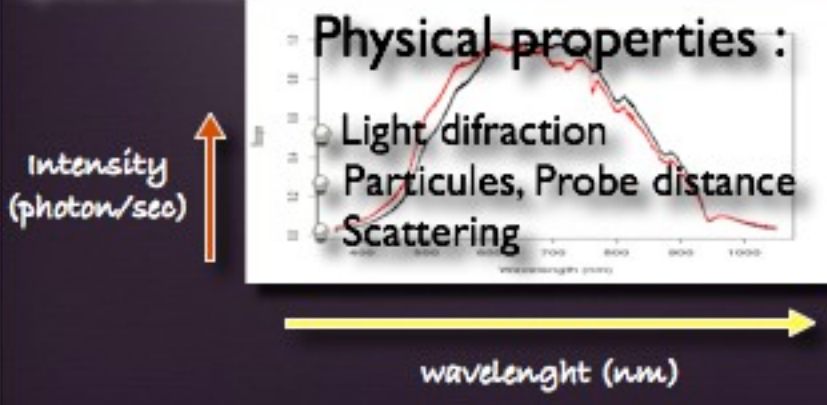
Photonics : Molecular Information



$$(Grape) \text{ Information} = I(Og) - I(O)$$

Photonics : Molecular Information

Spectral Information :



Photonics : Molecular Information

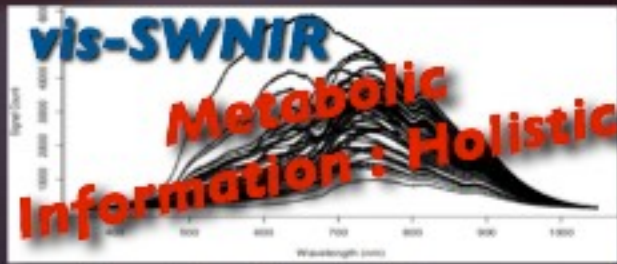
Spectral Information :

Chemical properties : "frequency changes"

- Absorption
- Fluorescence
- Resonance



Photonics : Molecular Information



Complex Fingerprinting :

- Convoluted Information
- Advanced Computational Signal Processing, Feature and Pattern Recognition



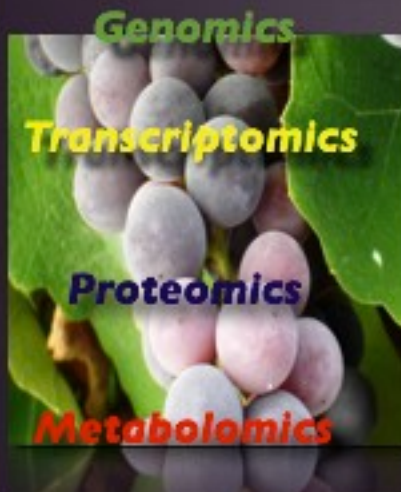
Central Zone
multicell
light

Intermediate Zone
cellular wall
sugar

Peripheral Zone
cellulose
pectin
acid
high
moisture



Information Complexity



Case Study : Target Approach

“Impact of Water into
Grape Quality ? ”

Selected Compounds ...

Glucose

Fructose

Malic Acid

Tartaric Acid

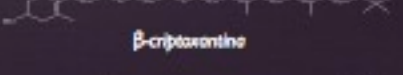
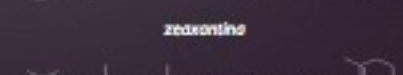
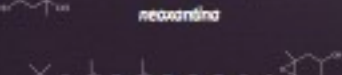
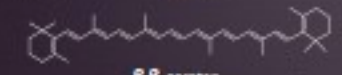
beta-carotene

Lutein

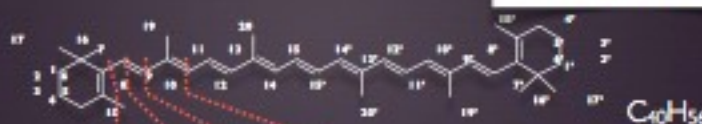
Pheophytin A

Pheophytin B

Aroma Precursors : Carotenoids



Norisoprenoids



non-Megastigma skeleton

Megastigma skeleton

2,2,6-Trimethylcyclohexanone
TOH

C9

β -cycloalral

C10

DHC

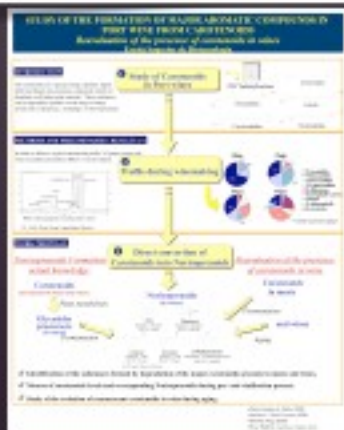
C11

C13

ionones

Damascones

Why Carotenoids in grapes, musts and wines



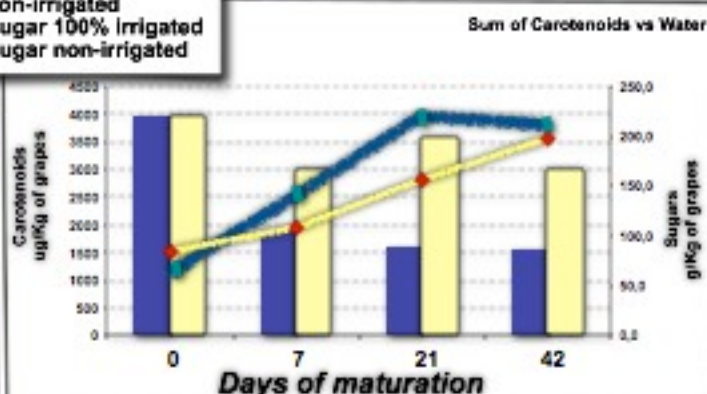
GUEDES DE ARAUJO, SORA FERREIRA, M. MENDES PAIRO, GOMEZ MENDEZ, J. e HOGG, T. Determination of carotenoid profiles in grapes, musts and finished wines from Douro varieties of Vitis vinifera. J. Agric. Food Chem. 2001, 49, 11, 5484-5488.

Why Carotenoids in grapes, musts and wines

It is well-known that carotenoid contents in plants are related to the metabolic processes of plant cells, which are dependent on climatic factors, agricultural practices, and plant variety ...

Irrigation effect on the grape carotenoid

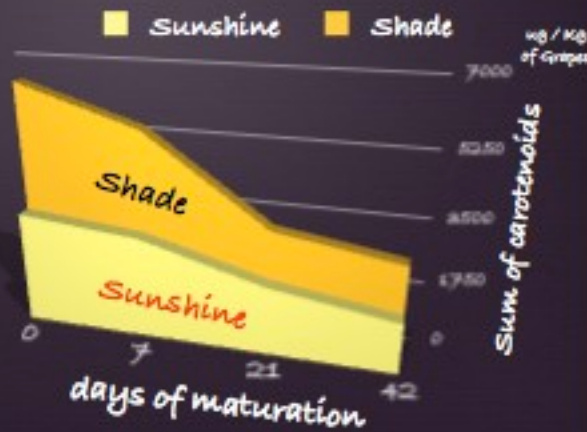
- 100% irrigated
- non-irrigated
- Sugar 100% irrigated
- Sugar non-irrigated



OLIVERIA, C. Sora Ferreira A. C., GONZALEZ, E., GONZALEZ, J. G. G. Efecto de riego y otros factores culturales en el perfil de carotenoides de uvas. J. Agric. Food Chem. 2004, 52 (17), 4178-4184.

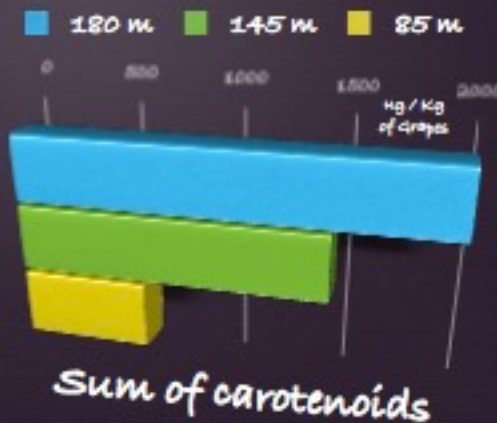
Effect of sunlight on the grape carotenoid

... higher levels in grapes protected from direct sunlight exposure than in those exposed to direct sunlight ...



Effect of altitude on the grape carotenoid

... Altitude strongly affect climatic conditions due to its direct impact on $T^{\circ}\text{C}$, humidity, and other environment factors that affect grape maturity ...



Case Study : Non-Target Approach

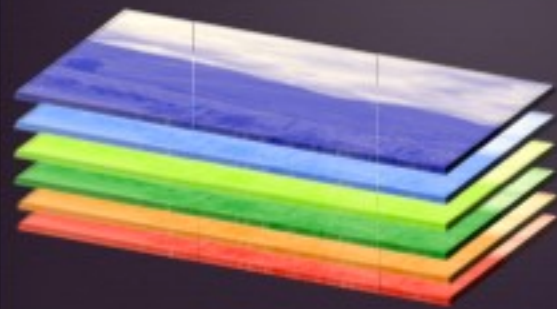
“High Resolution vis-SWNIR Imaging”

What is Hyperspectral Imaging?



Image = Set of pixels with x and y distribution

What is Hyperspectral Imaging?

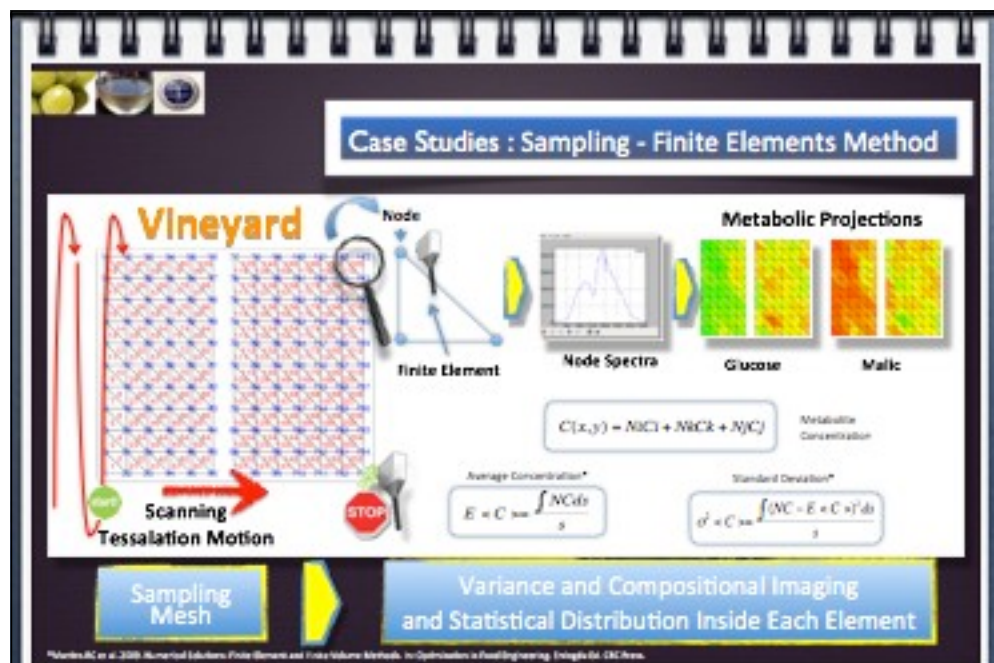
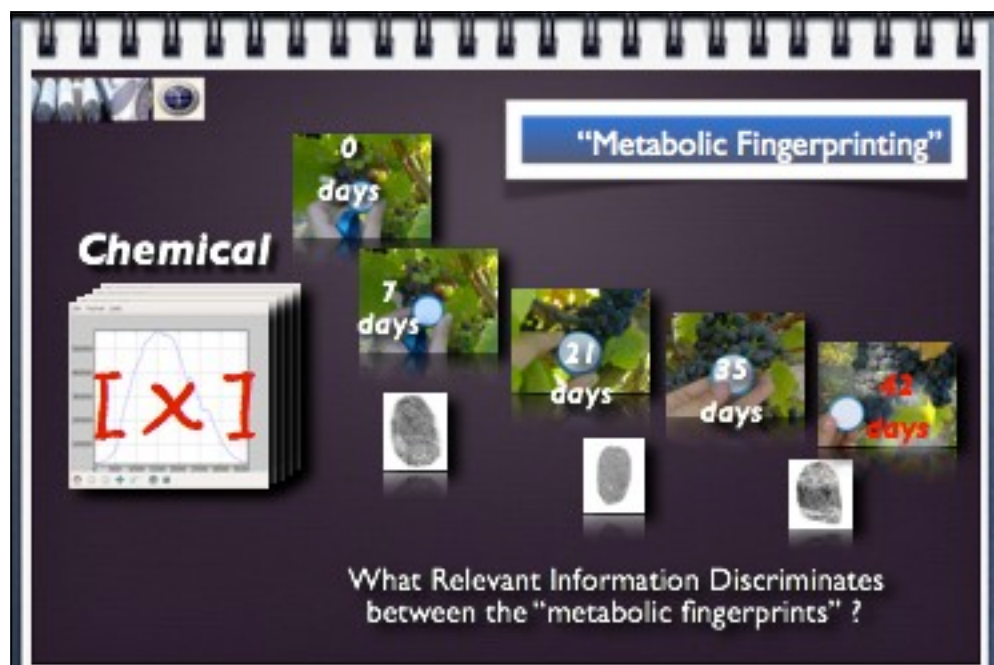
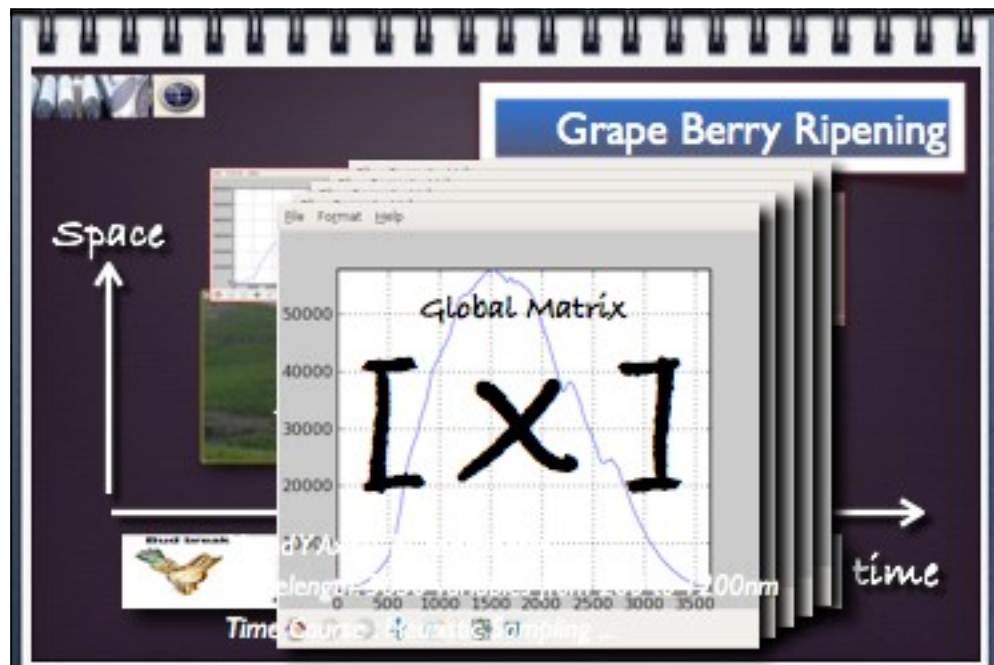


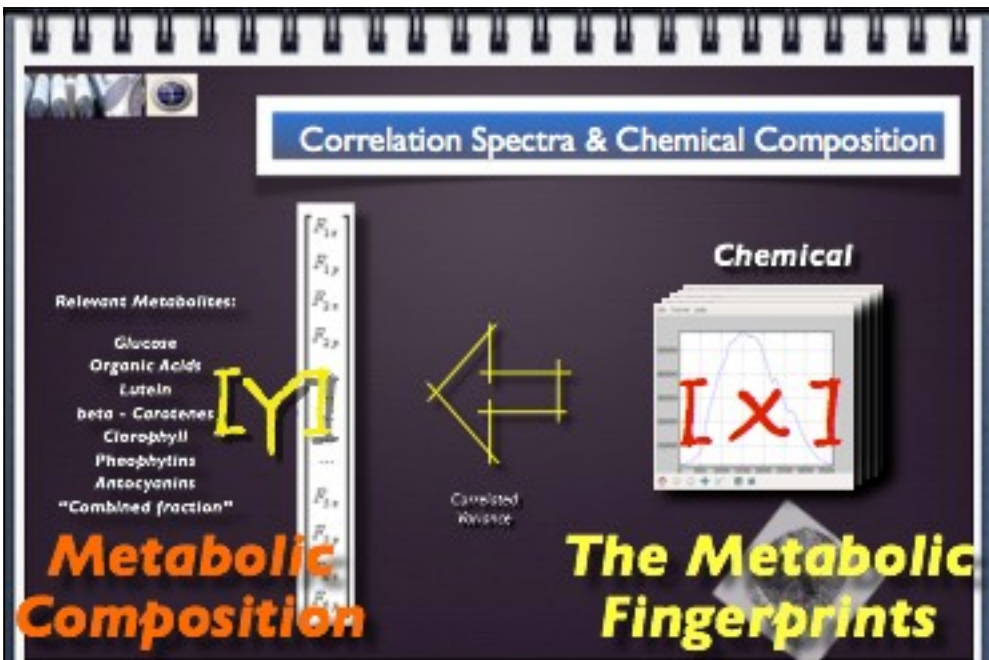
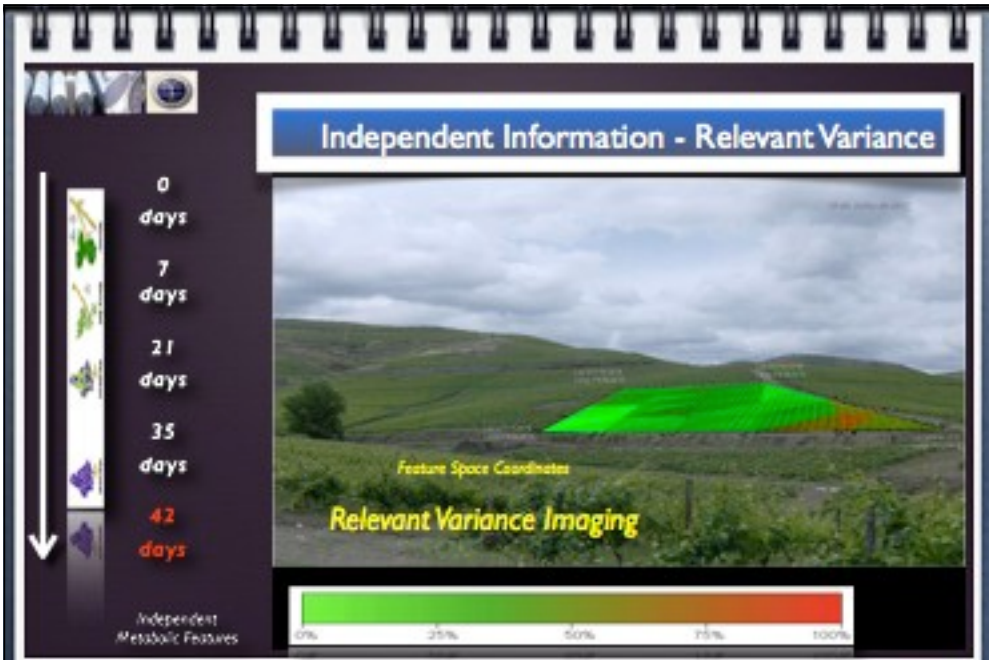
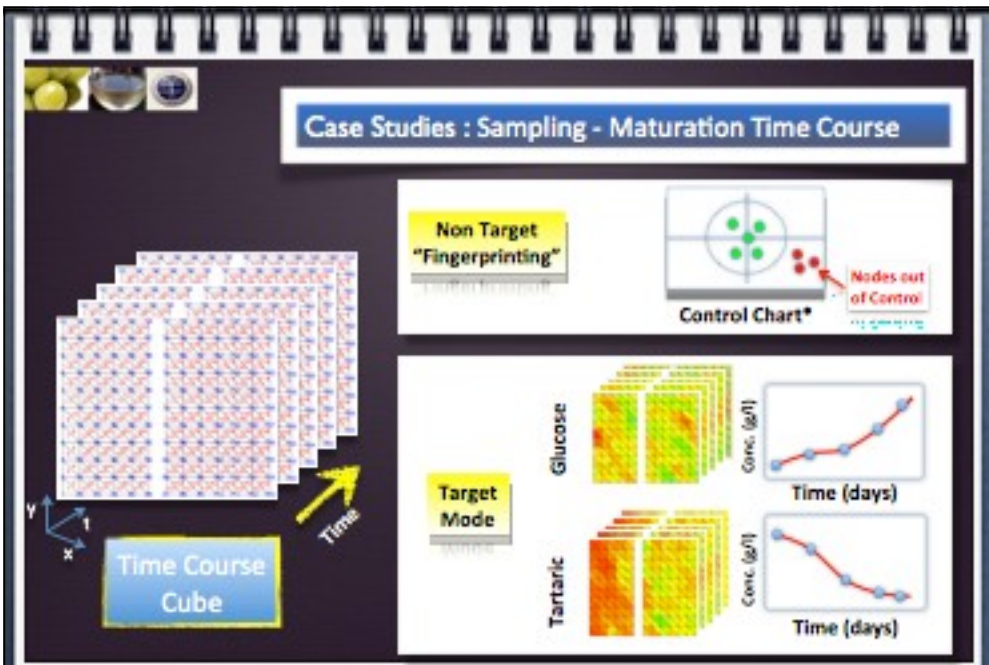
- Spatial Information for each time,
- Time Course Resolution,
- Each point of the field is a spectra,
- Allows high discrimination,
- Maturation Monitoring...

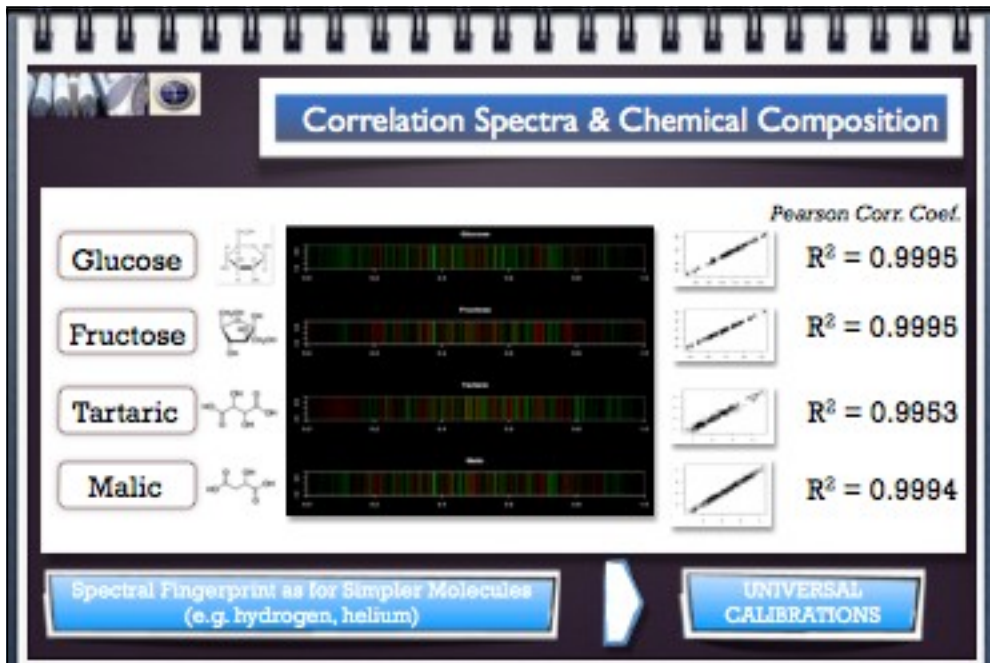
Workflow...

Imaging : vis-SWNIR









Correlation Spectra & Chemical Composition

Metabolite	# Sp Samples	Error	Limit of Detection	R^2 (Pearson)
Glucose (g/l)	271 800	2.2	22	0.9995
Fructose (g/l)	271 800	2.5	25	0.9995
Tartaric Acid (g/l)	271 800	0.18	1.6	0.9953
Malic Acid (g/l)	271 800	0.12	1.2	0.9994
Lutein (ug/kg)*	12 610	15	115	0.9705
Pheophytin A (ug/kg)*	12 610	23	230	0.9602
Pheophytin B (ug/kg)*	12 610	22	220	0.9756
Neoxanthin (ug/kg)*	12 610	4	40	0.9871
Zeaxanthin (ug/kg)*	12 610	6	60	0.9561

* Touriga Nacional only.

Validation of calibrations are performed accessing High-Throughput LARGE DATA SETS!

Universal Calibrations Bias-Free Band Extraction!

Correlation Spectra & Sensory data

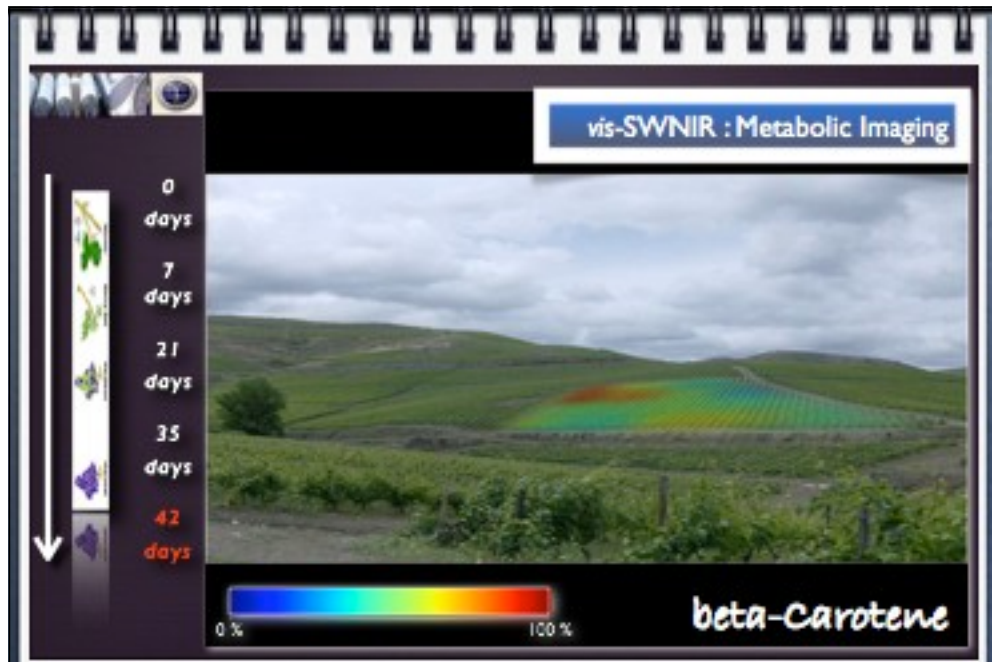
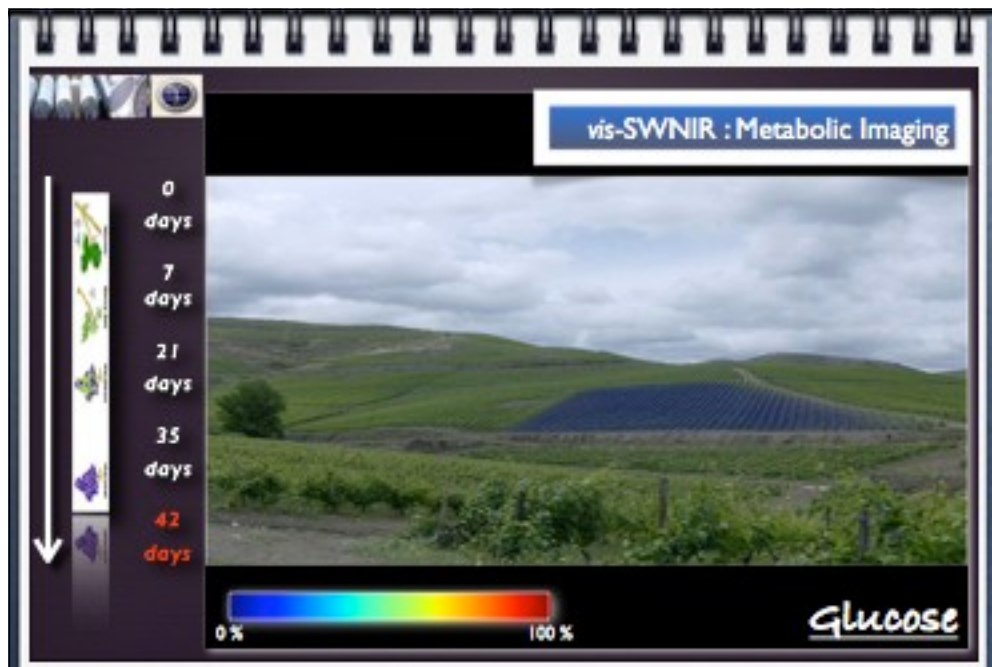
Hedonic Scale (0 to 4)

Sensory	No. Samples	Error	Detec. Lim.	R^2 (Pearson)
Sugars/Acids ratio*	3000	0.15	1.5	0.7235
Pulp score*	3000	0.10	1.0	0.7749
Skin score*	3000	0.08	0.8	0.6222
Seed score*	3000	0.14	1.4	0.7361

* Touriga Nacional and Tinta Roriz only.

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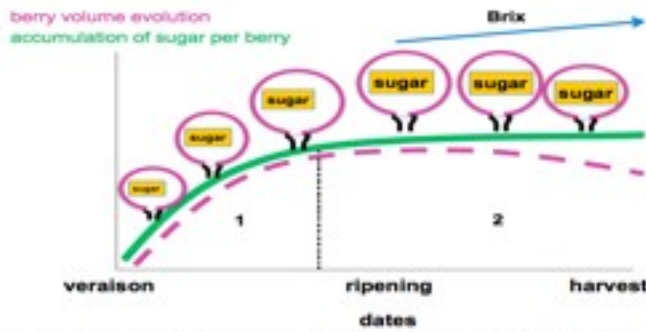


“Harvest Forecast”

This slide features three small icons in the top left corner: a yellow lemon, a glass of red wine, and a globe. The main text is “Harvest Forecast” in a large, white, serif font centered on a dark background.

Model : Berry Aromatic Sequence (BAS)

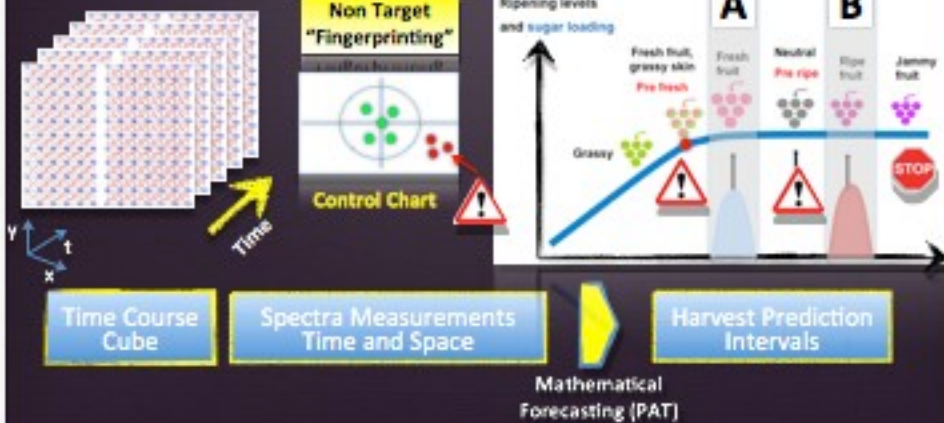
Berry sugar loading needs to plateau to achieve the ripening process



When sugar per berry plateaus, the volume of the berry could decrease by water loss and therefore the brix will increase

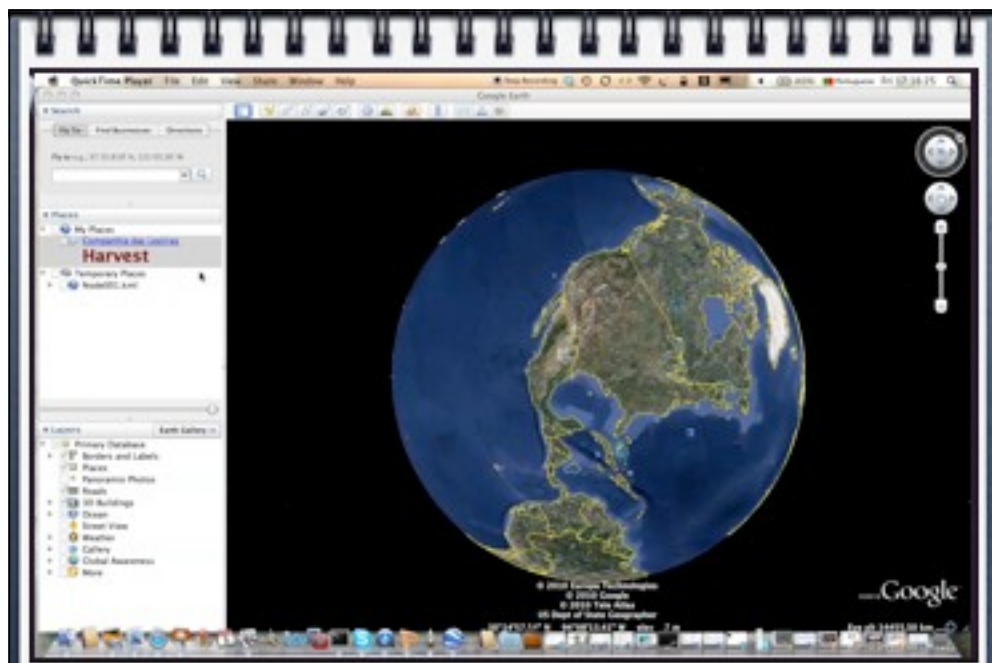
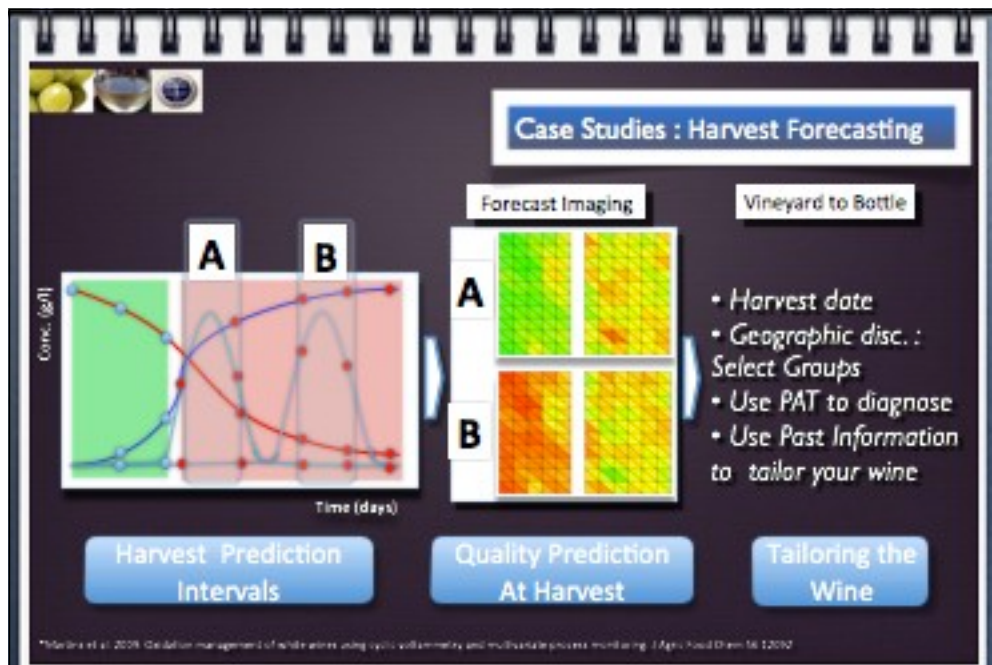
Deloire et al., 2006; Deloire 2011

Harvest Forecast - Choosing the Maturation Properties



Harvest Forecast - Choosing the Maturation Properties





- ### Conclusion
- Non destructive Spectroscopy techniques coupled with signal processing are ideal tools for management of “grape quality” ;
 - Non targeted approach enables the “glass to vineyard” sensory perspective ;
 - Hyperspectral monitoring allows optimization and consistence in final wine quality.



Dankie !!!



VinePAT

Facing the Complexity of Quality Management and Delivering a High-Throughput Device

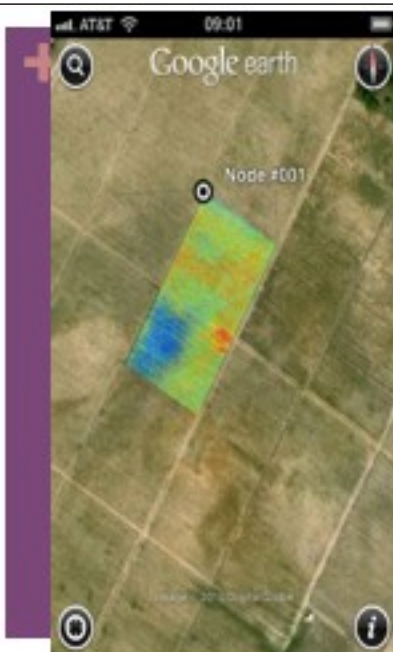


Globally Recognized Technology

1st Place Engineering Prize

Idea To Product Global
University of Texas - Austin
2010

International Patent Pending



VinePAT

Is a Data-driven High-Throughput biophotonics system for facing the complexity of grape quality management

