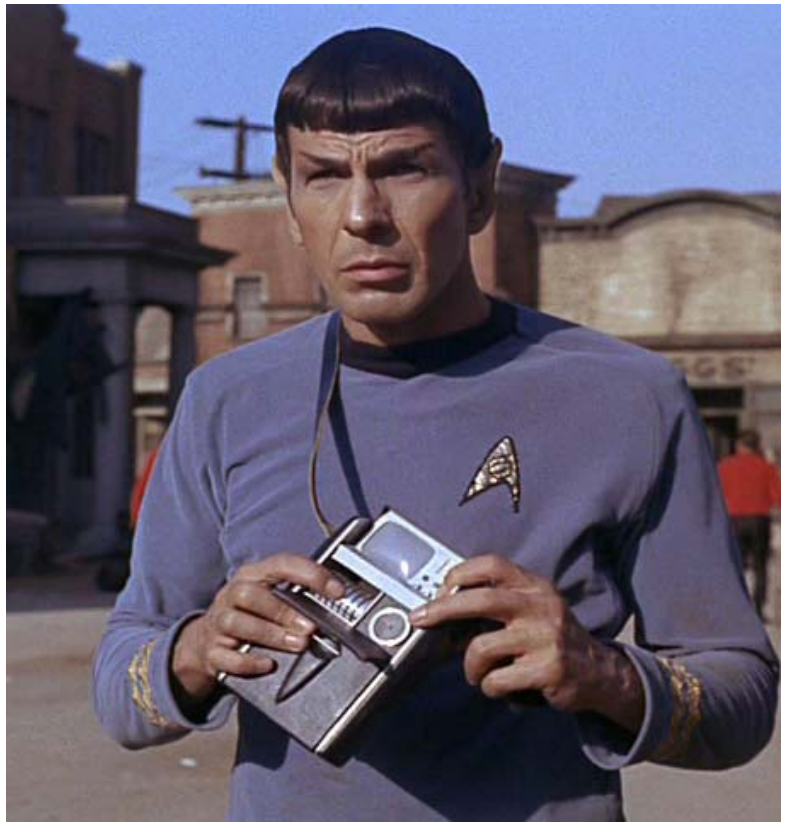
# Outline

- General concepts
- Instruments
- Applications
  - reflectance, absorption, fluorescence
- Non-conventional instruments for absorption spectroscopy
- Spectroscopy by mobile devices
- Raman spectroscopy
- The kitchen of the future

# Smartphone:
# the Swiss-knife of XXI century

# Smartphone – Startrek tricorder



# China and mobile phones

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## China's mobile phone users reach 1.11 billion

Updated: 2013-01-25 04:11
( Xinhua)

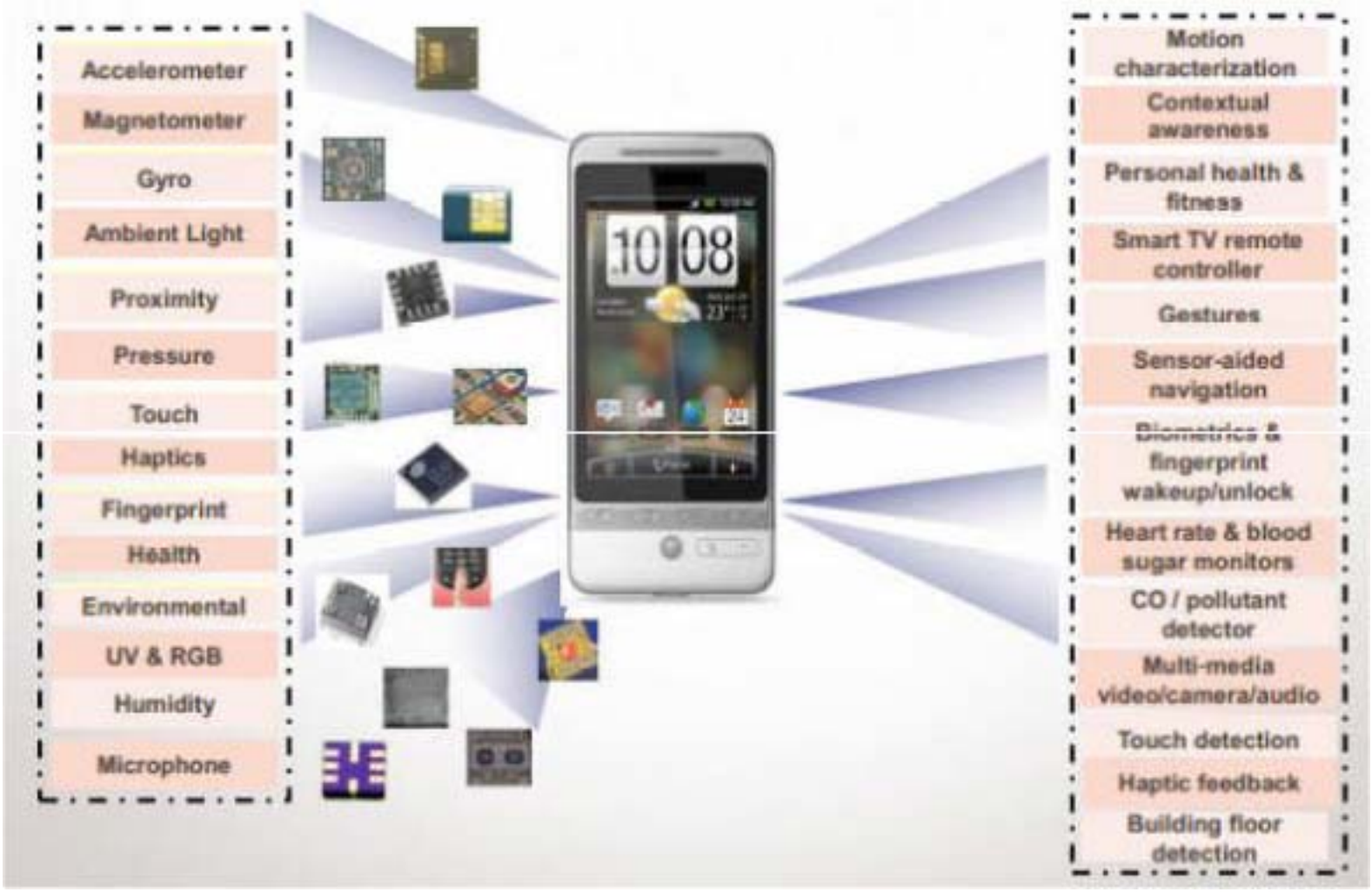
Comments | Print | Mail | Large Medium Small

BEIJING - The number of Chinese mobile phone users reached 1.11 billion as of the end of 2012, according to official data unveiled Thursday.

The Ministry of Industry and Information Technology (MIIT) said in a statement that mobile phone users represent 80 percent of all phones users in the country.

http://www.chinadaily.com.cn/china/2013-01/25/content_16172589.htm

# Trends


Accelerometer
Magnetometer
Gyro
Ambient Light
Proximity
Pressure
Touch
Haptics
Fingerprint
Health
Environmental
UV & RGB
Humidity
Microphone
Motion characterization
Contextual awareness
Personal health & fitness
Smart TV remote controller
Gestures
Sensor-aided navigation
fingerprint wakeup/unlock
Heart rate & blood sugar monitors
CO / pollutant detector
Multi-media video/camera/audio
Touch detection
Haptic feedback
Building floor detection

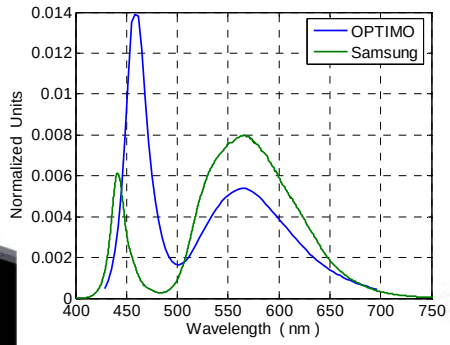
- Scenarios for smartphone-based sensors
  - Passive: info retrieval only
  - Plug-in sensors
  - Embedded spectroscopy

# Passive: info retrieval only

- Smartphone camera used to read QR or bar-code
- QR/bar-code pic sent through internet to a data warehouse where the info is stored
- Info retrieval using internet connection
- This approach implies that the info requested by the consumer has been acquired and is available


# Embedded spectroscopy

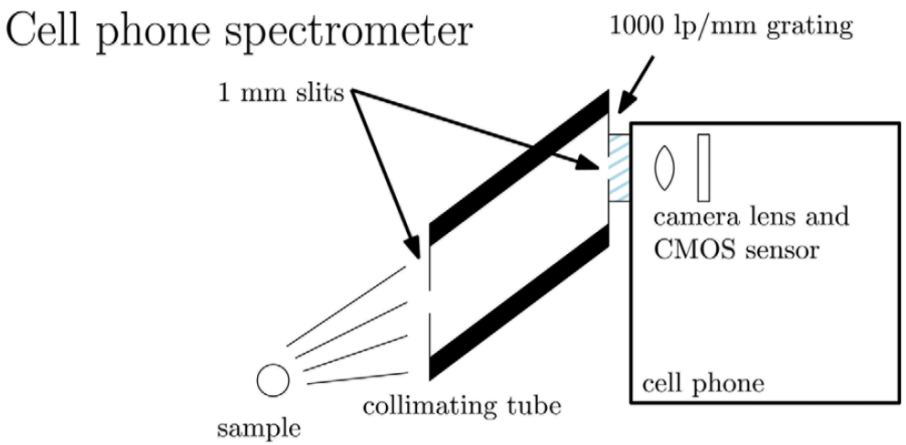
- White LED = source
- Camera = spectrometer
  - 3 channels only: RGB
  - Added chemometric functionalities  for a better exploitation of spectroscopic info

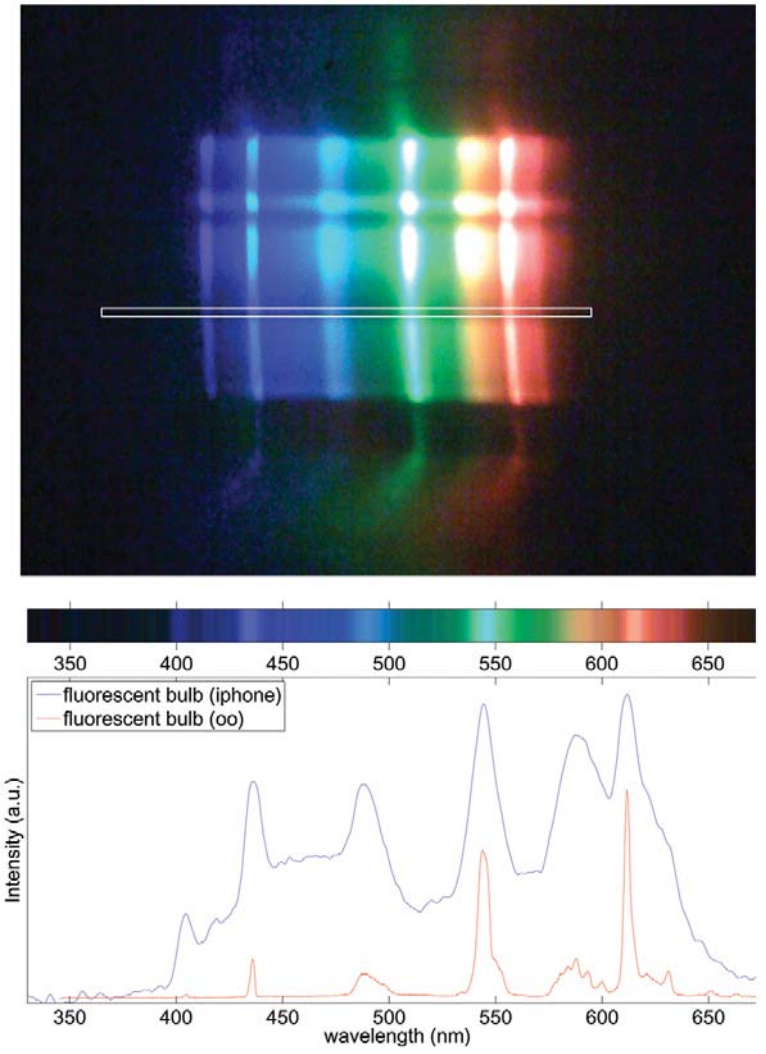



+ clip-on coupling and diffractive optics

# Embedded spectroscopy

## outside source




Smith et alii, *PLOS ONE,* vol. 6, 2011, e17150

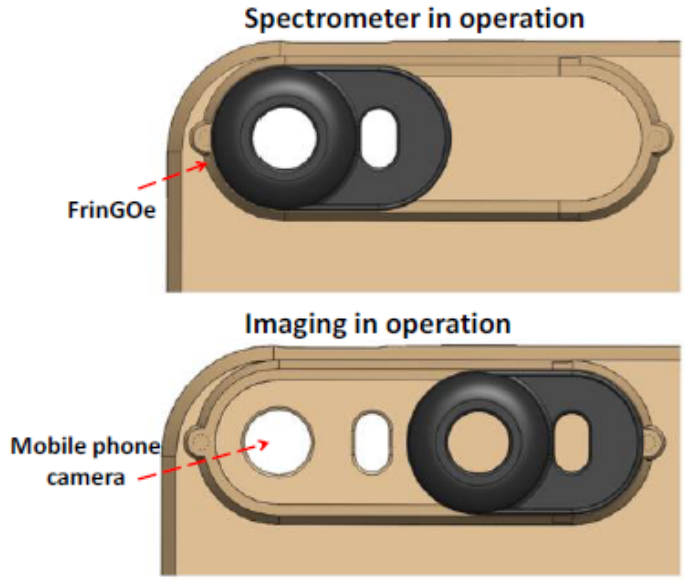
# Embedded spectroscopy

Shazam for materials..... & food

Advanced prototype - 3D printed

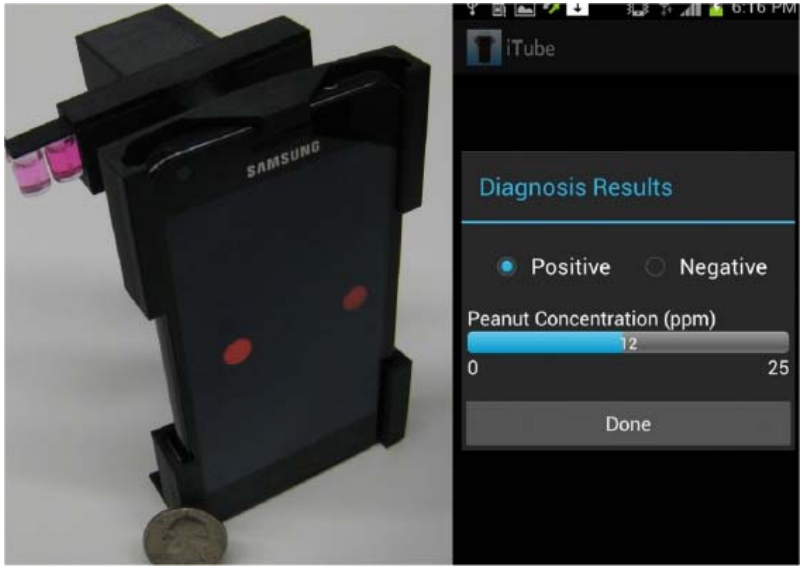

http://store.publiclab.org/products/smartphone-spectrometer

# Embedded spectroscopy
## by means of a special cover

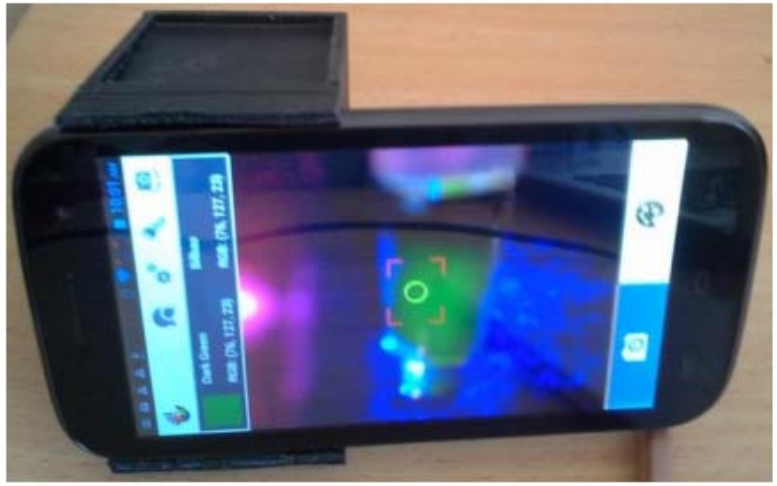



https://fringoe.com/

# Lab in a phone




http://innovate.ee.ucla.edu/welcome.html



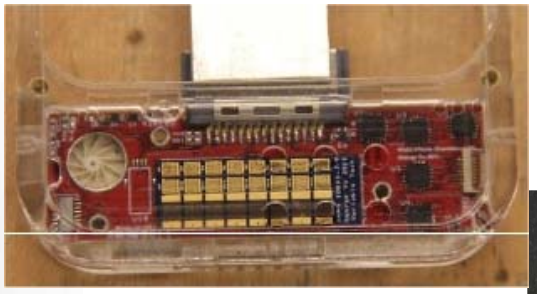
http://www.iplaustralia.com/

https://phonebloks.com/plan/ - http://www.dscout.com

motorola
a Google company

# Smartphone sensors

- External unit with sensors
  - Plug-in through socket
  - Blue-tooth connection for stand-alone units

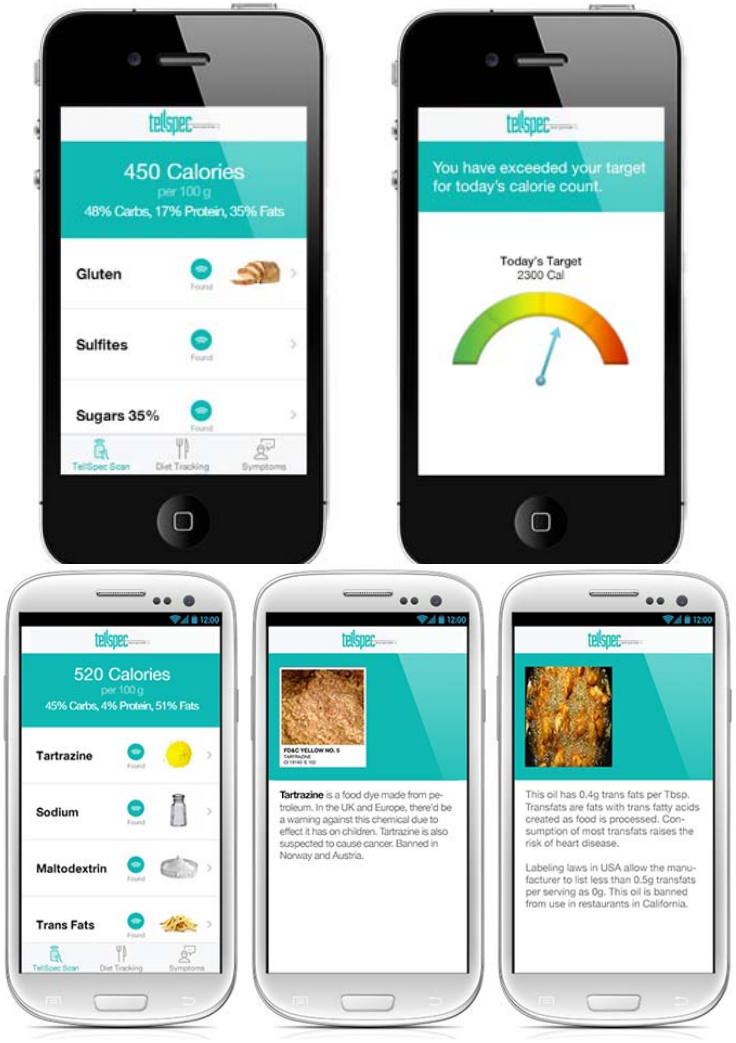


http://www.mydario.com/#Device
J. Li et alii, *IEEE Sensors Conf.* 2012
http://www.sensorcon.com/sensordrone/

# Mobile spectroscopy + cloud computing

# TellSpec

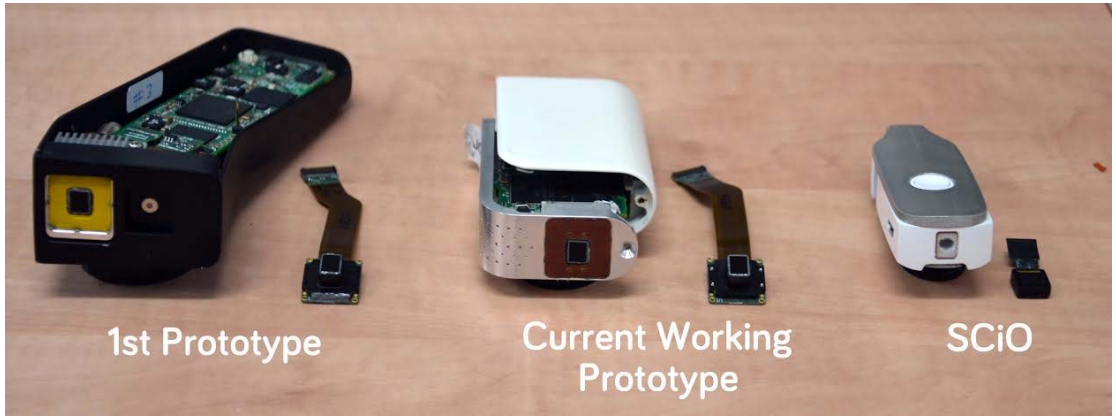
http://www.tellspec.com

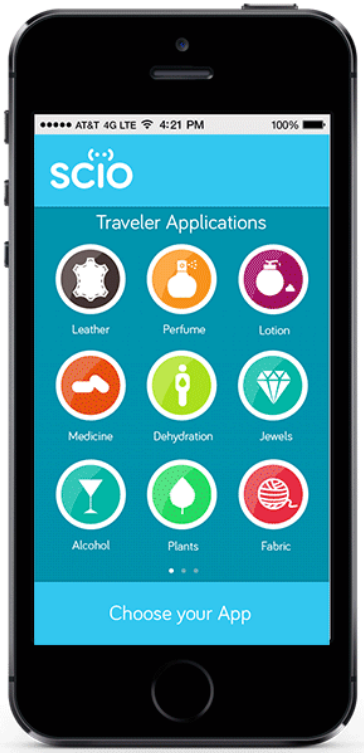


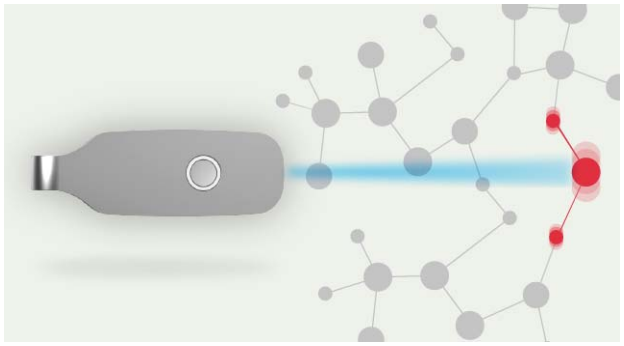


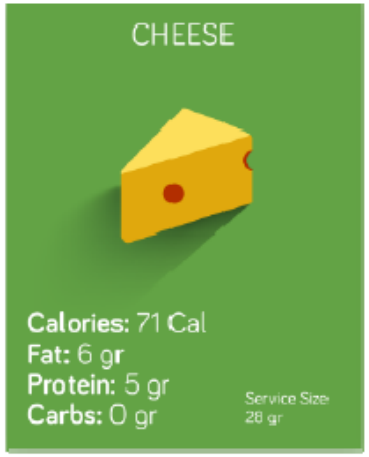
# SCiO

http://www.consumerphysics.com

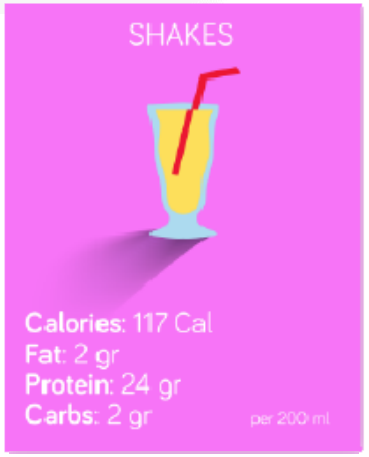


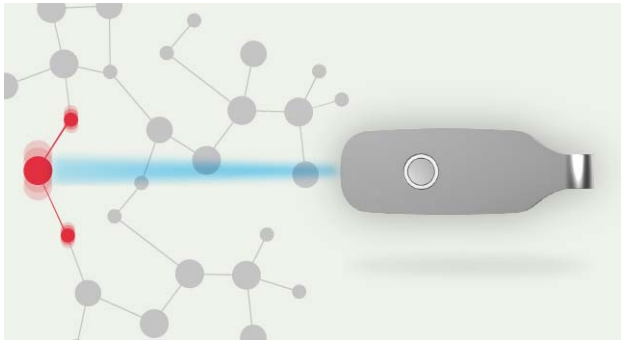


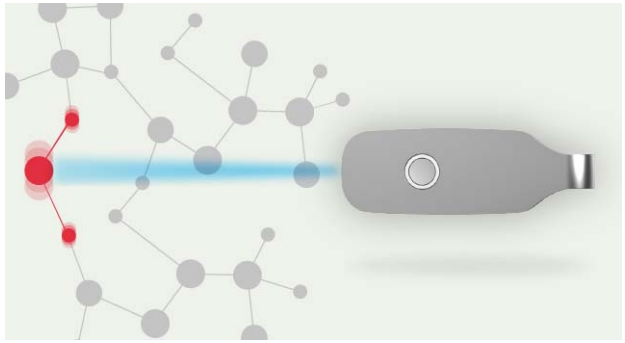




# SCiO

http://www.consumerphysics.com





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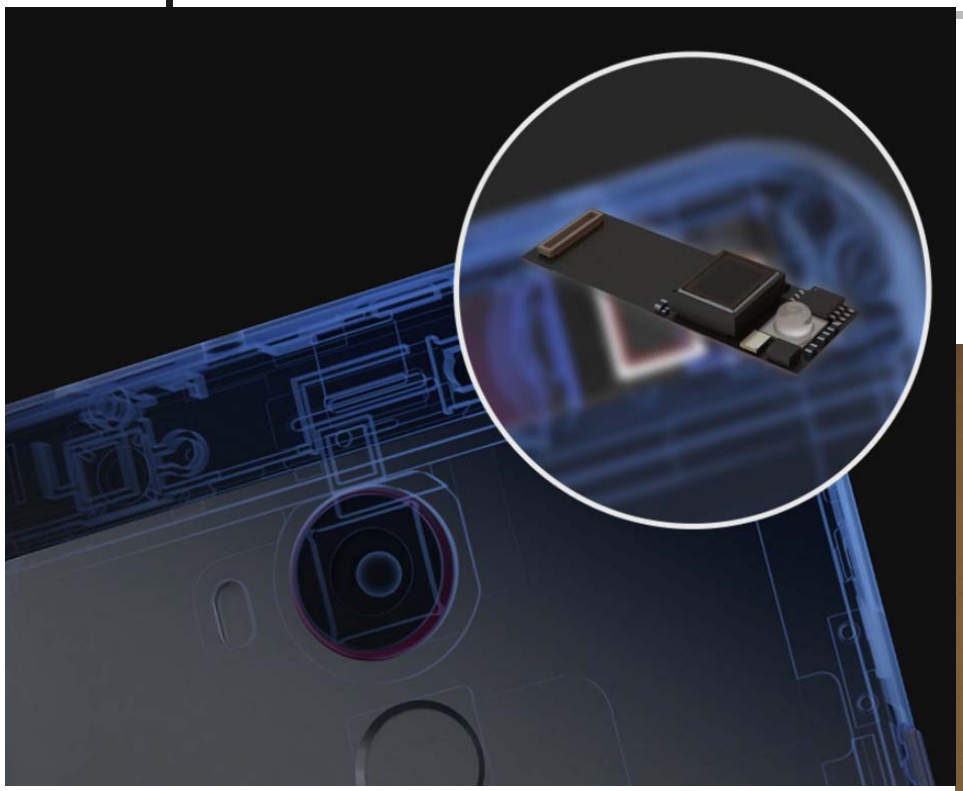
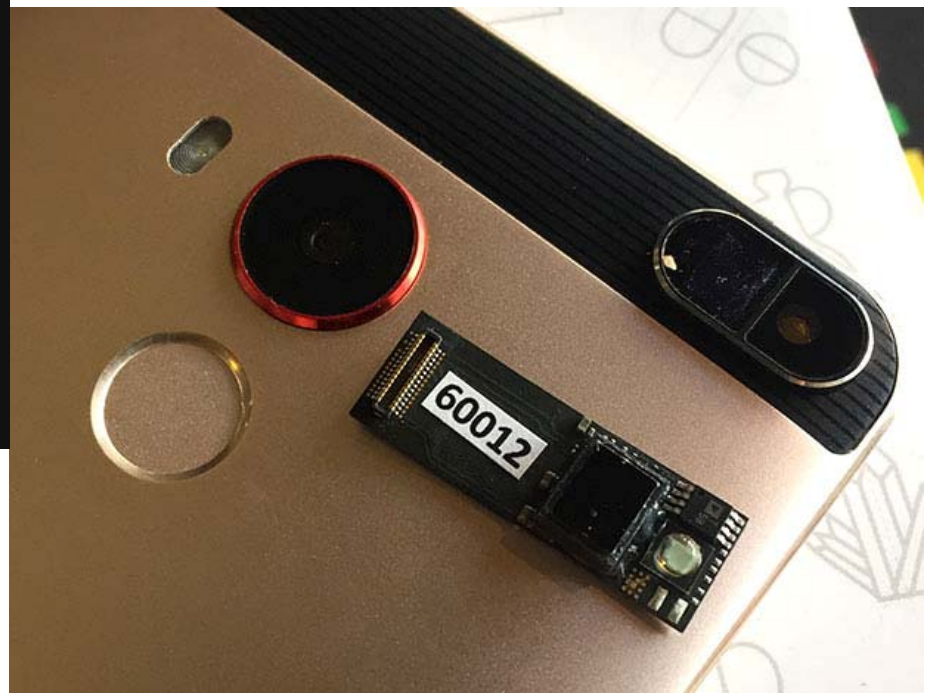
http://www.consumerphysics.com





# Outline

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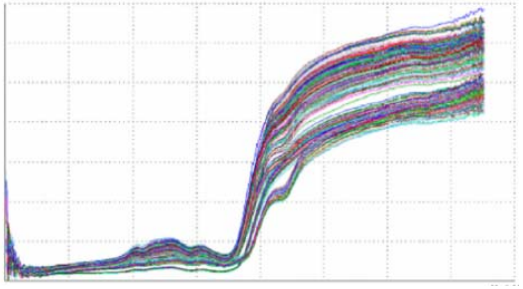
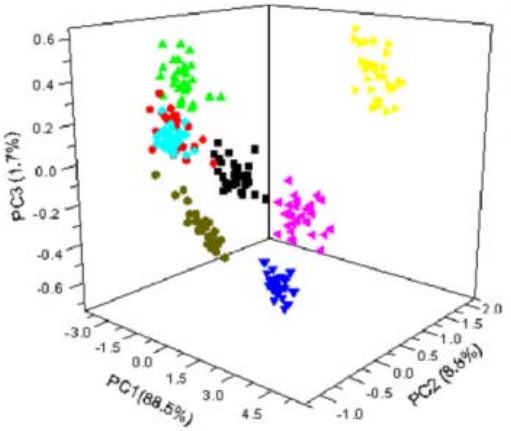
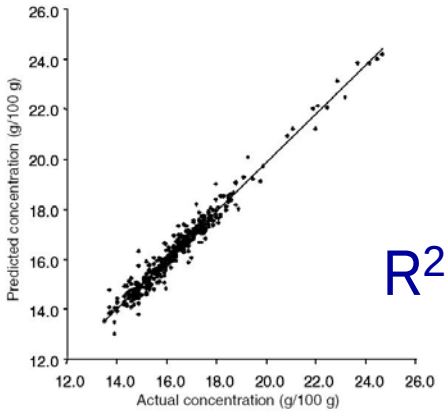
- Raman spectroscopy
- The kitchen of the future

# ..... Steps towards multicomponent analysis

- Spectroscopy
- Chemometrics
- Classification maps
- Library of ref. spectra / analytical data
- Model for prediction of quality indicators
- Validation

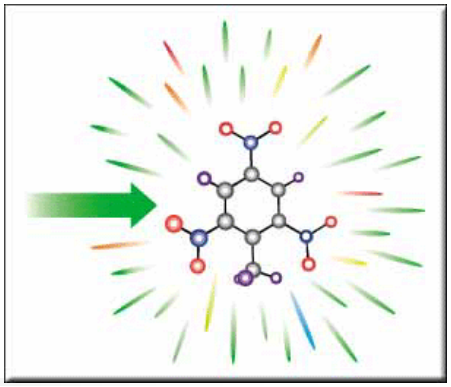


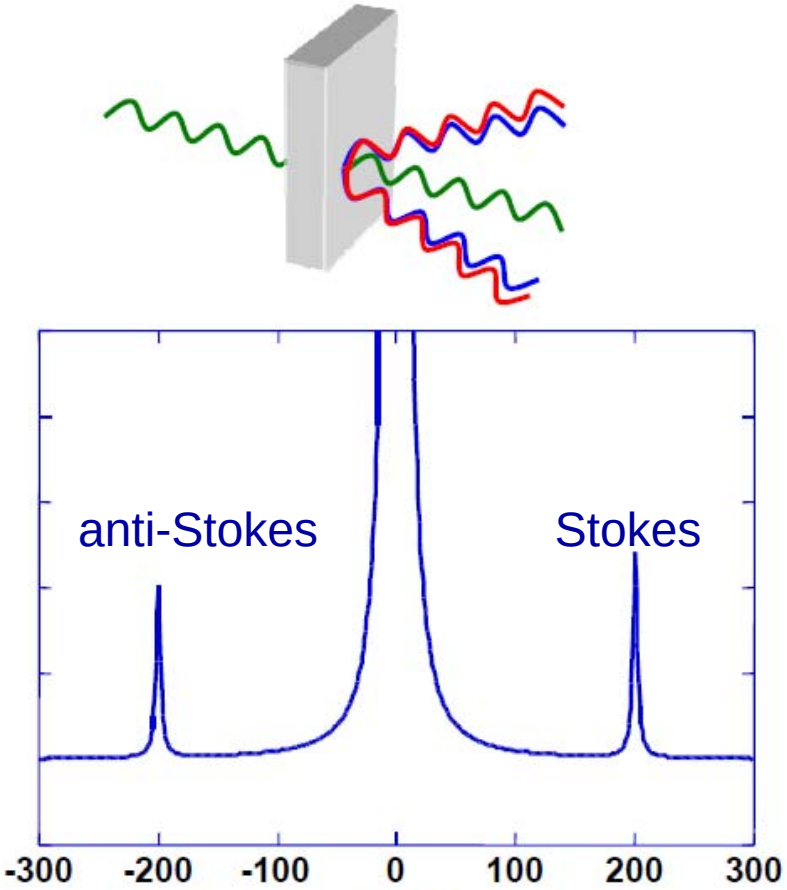



$R^2$

# Raman spectroscopy



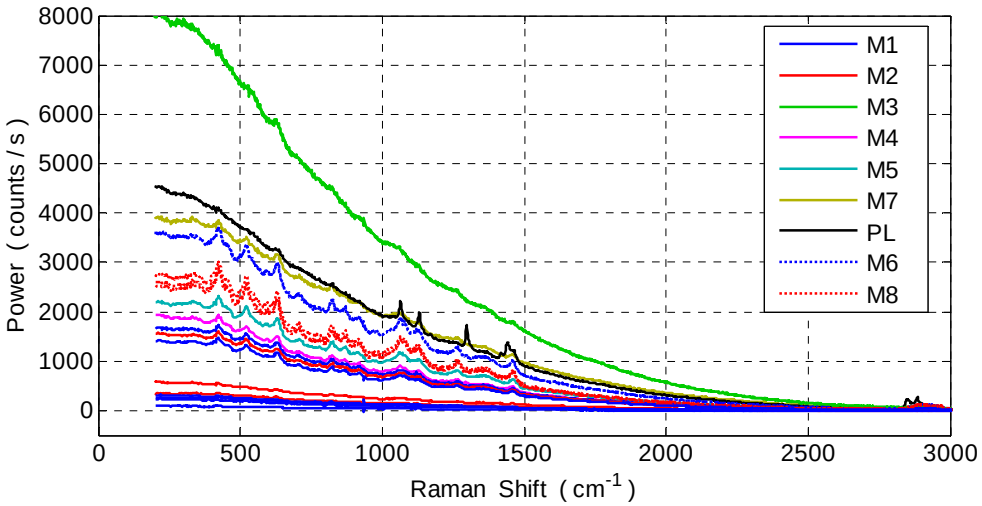



- Most of the scattered light has the same frequency/energy as that of the incident light (scattering Rayleigh)
- A slight fraction of the incident light donates or receives energy to contribute to a change in the vibrational and rotational state of molecules.
- The change in the photon energy as a result of inelastic scattering of light with molecules is the “Raman shift”

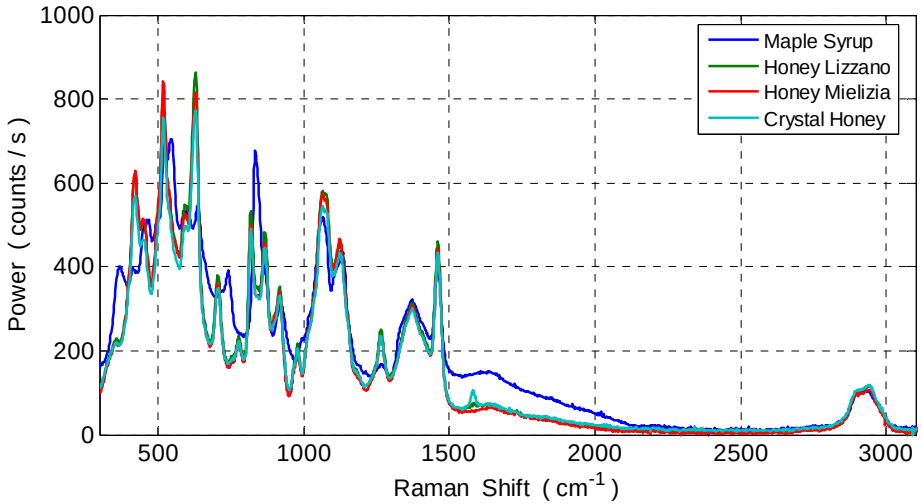
$$I_{Raman} \propto 1 / \lambda^4$$

# Raman @785nm VS @1064nm

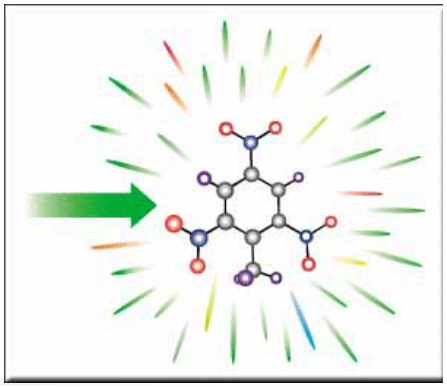
@ 785nm

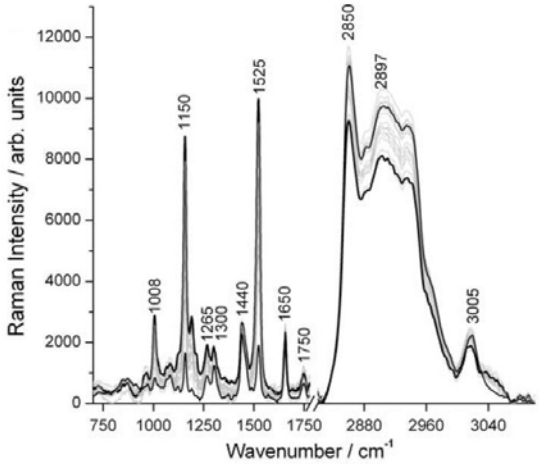



@ 1064nm

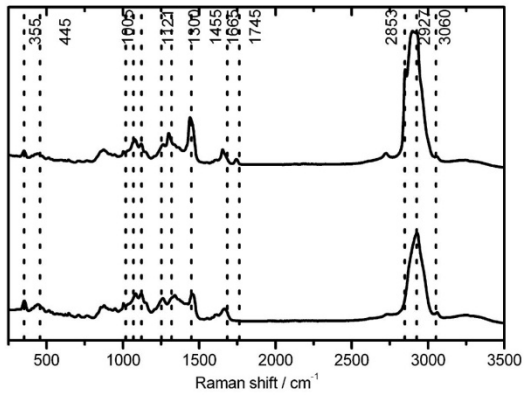


# **Raman** – food fingerprints

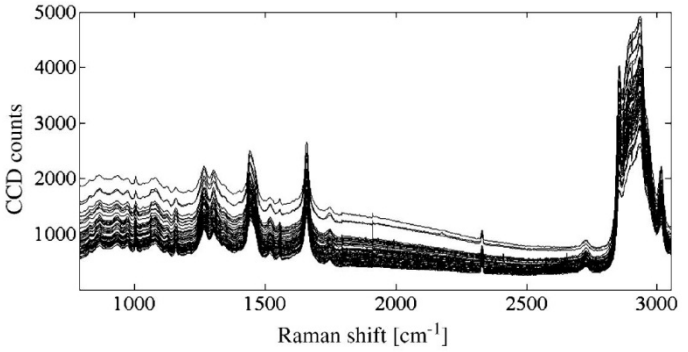




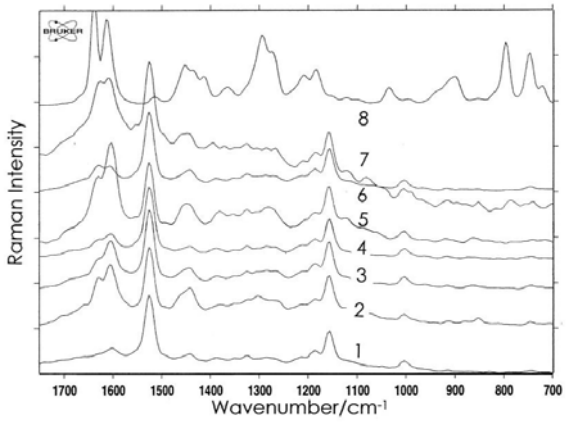

olive oil
different brands




powder milk
whole and skim



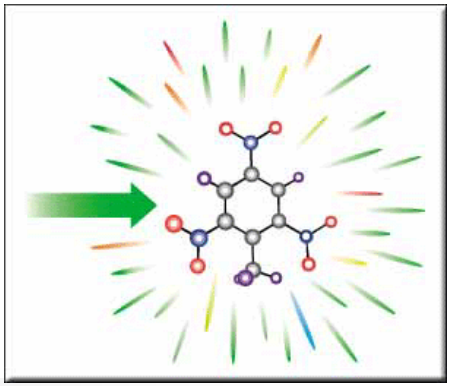

salmon

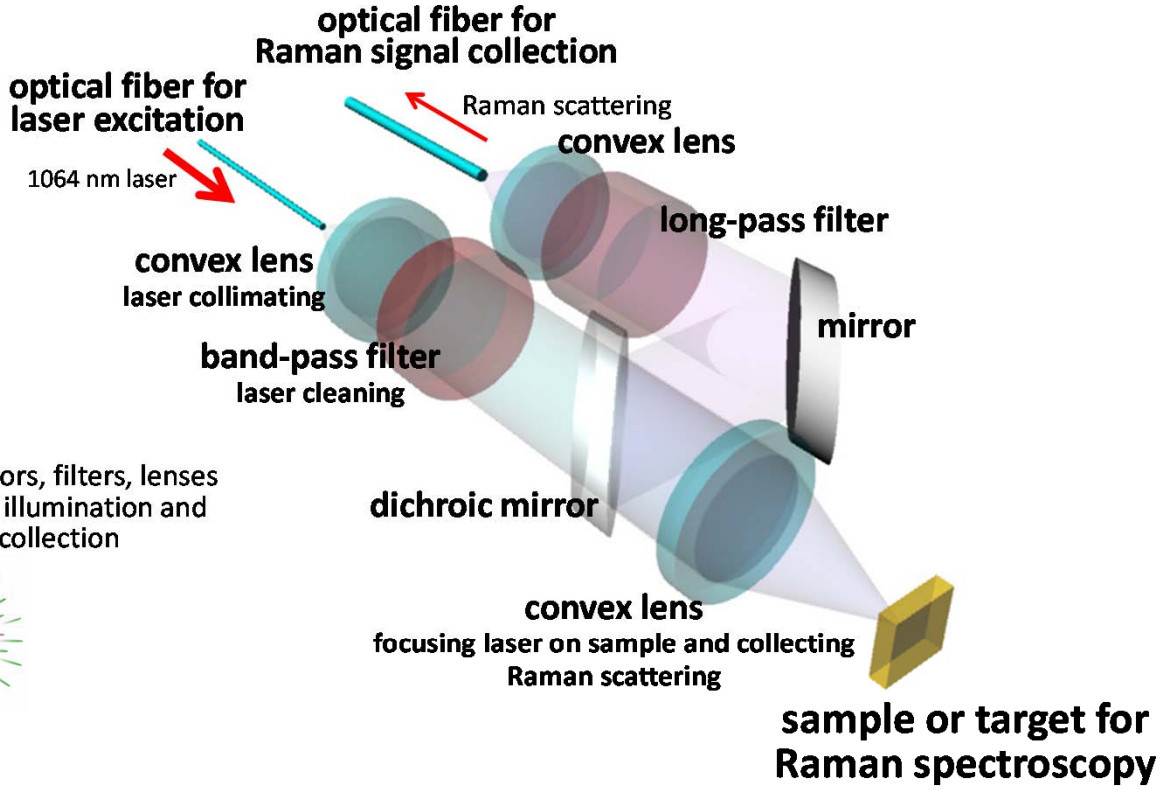


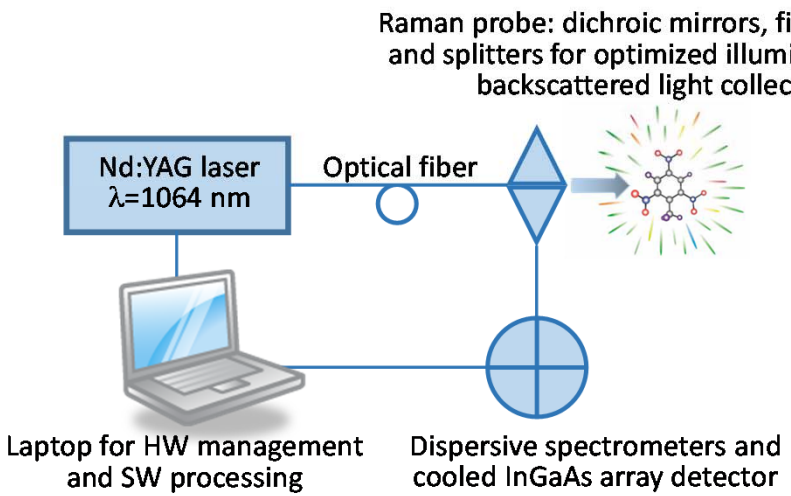

fresh herbs

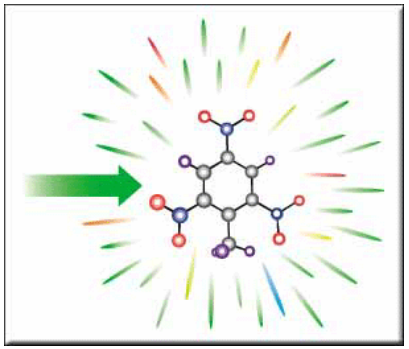

R.M. El-Abassy et alii, *JAOCS*, vol. 86, 2009, pp. 507-511
C.M. McGoverin et alii, *Anal. Chim. Acta*, vol. 673, 2010, pp. 26-32
N.K. Afseth et alii, *Anal. Chim. Acta*, vol. 572, 2006, pp. 85-92
B. Schrader, *J. Mol. Str.*, vol. 480-481, 1999, pp. 21-32

# Raman spectroscopy @ 1064 nm





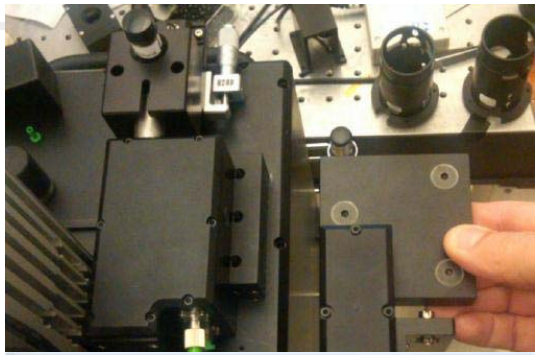





# Raman spectroscopy @ 1064 nm

Laser power: 400 mW
Detector cooling: - 55°C

RamSpec-1064nm-HR
BaySpec Inc., San Josè CA
www.bayspec.com



www.bayspec.com

www.rigakuraman.com

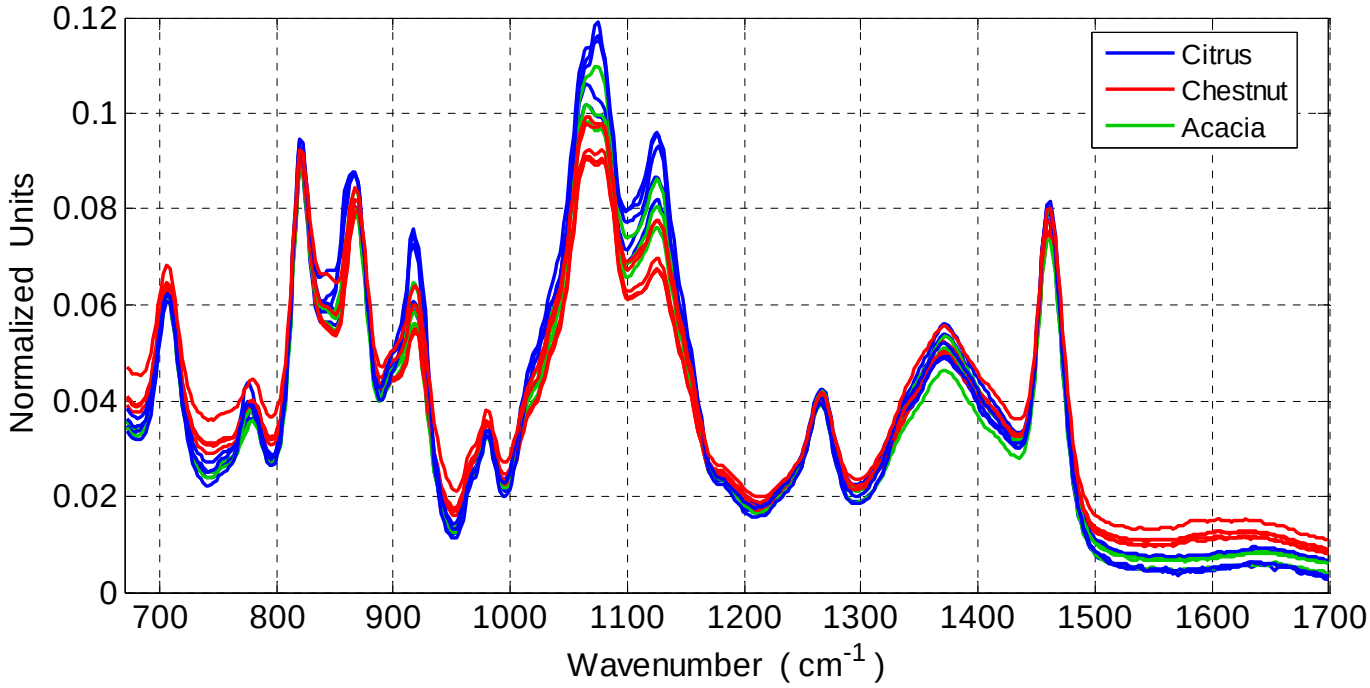
www.wysri.com

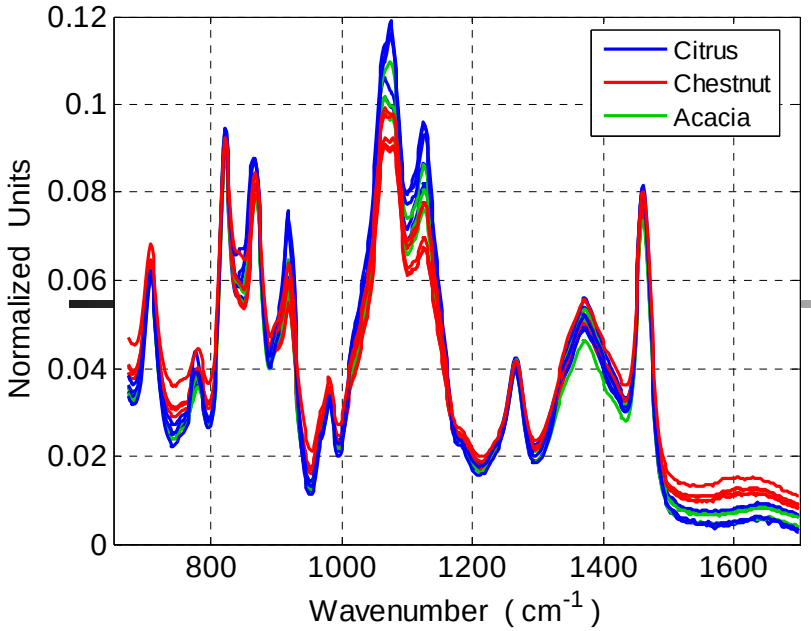
www.metrohm.com

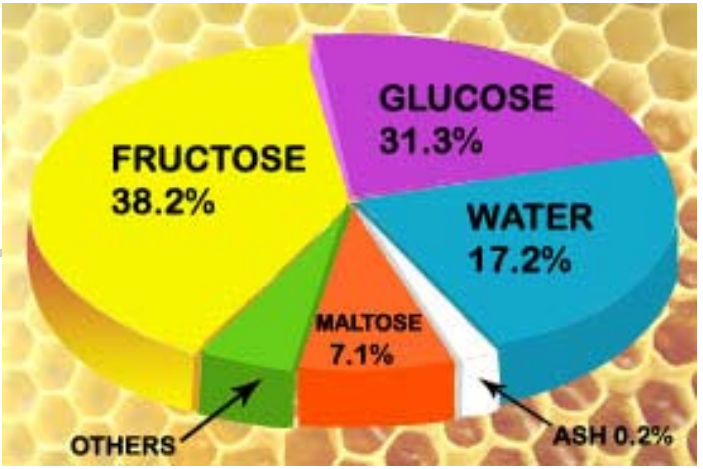
# Raman spectroscopy for honey applications: the collection of honeys from Calabria

- Distinguishing the botanic origin
- Predictive models for sugar profile
- Potassium as important nutraceutic indicator

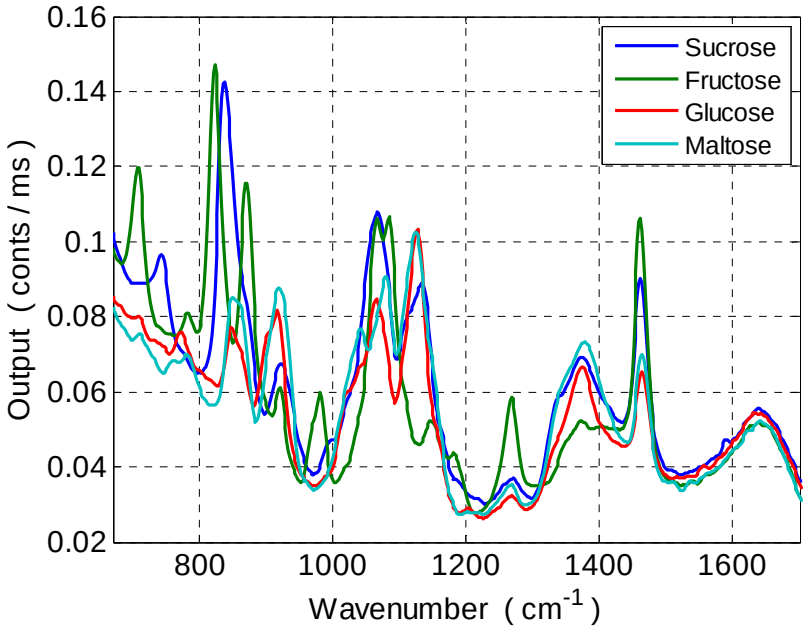
# Raman spectra





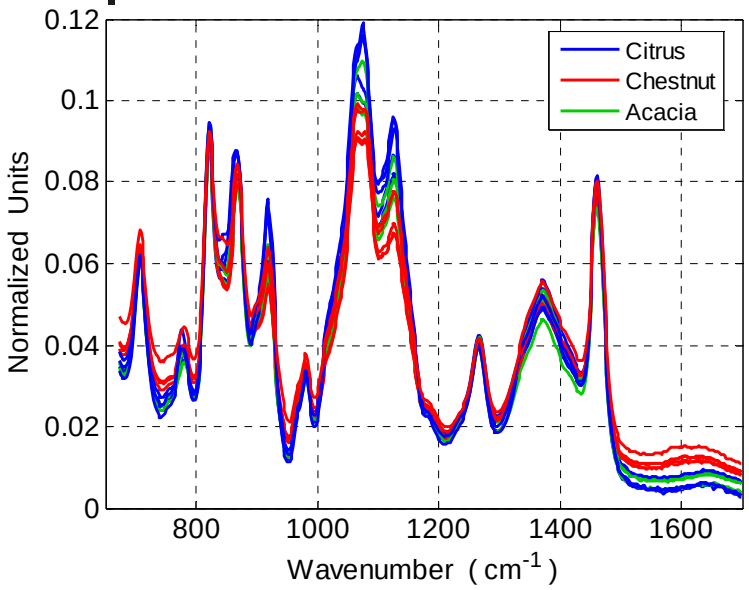




Concentration = 20% w/w

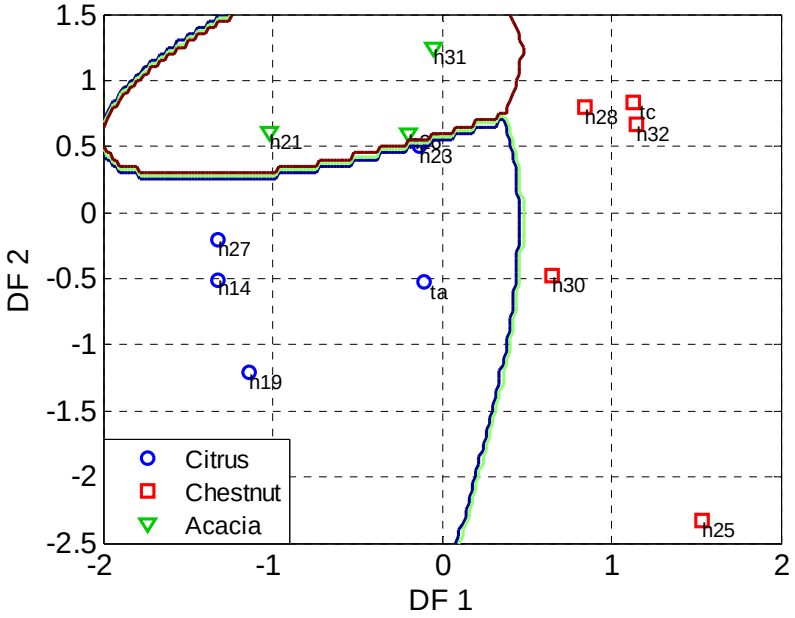



| Raman band ($cm^{-1}$) | Main contribution | Secondary contribution |
|---|---|---|
| 707 | Fructose | |
| 821 | Fructose | |
| 867 | Fructose | Glucose |
| 917 | Glucose | Maltose |
| 1060-1080 | Fructose | Glucose |
| 1127 | Glucose | Maltose |
| 1267 | Fructose | Glucose |
| 1372 | Glucose | Maltose |
| 1460 | Fructose | Glucose |

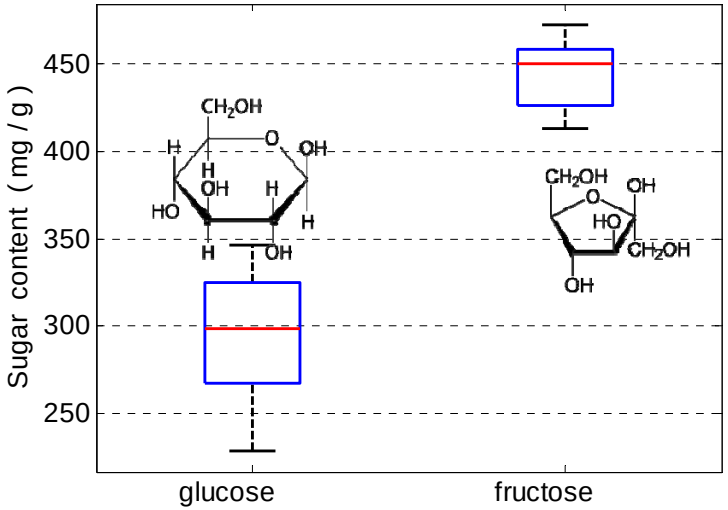
# Distinguishing the botanic origin

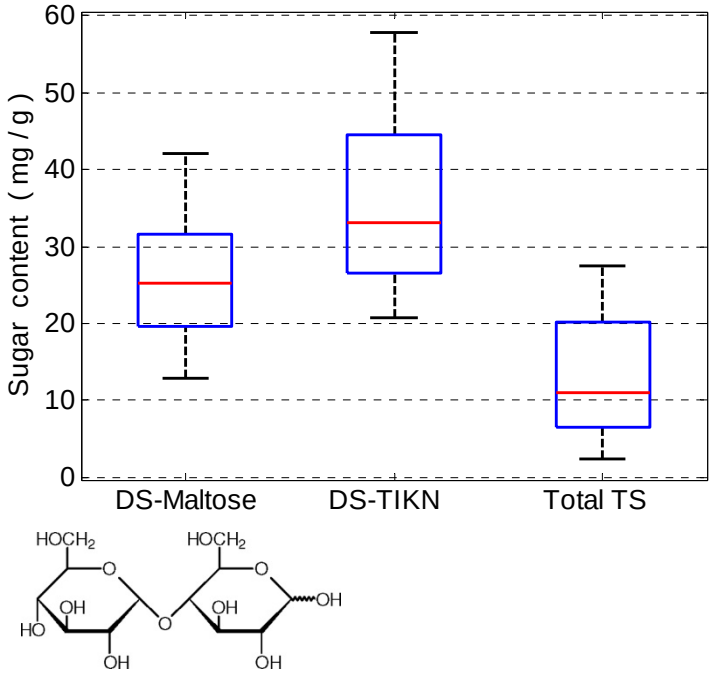



**PCA + LDA + KNN**

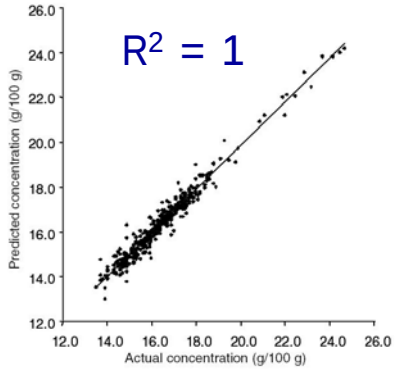


# Sugar profile



# Results of PLS predictive models for sugars & potassium

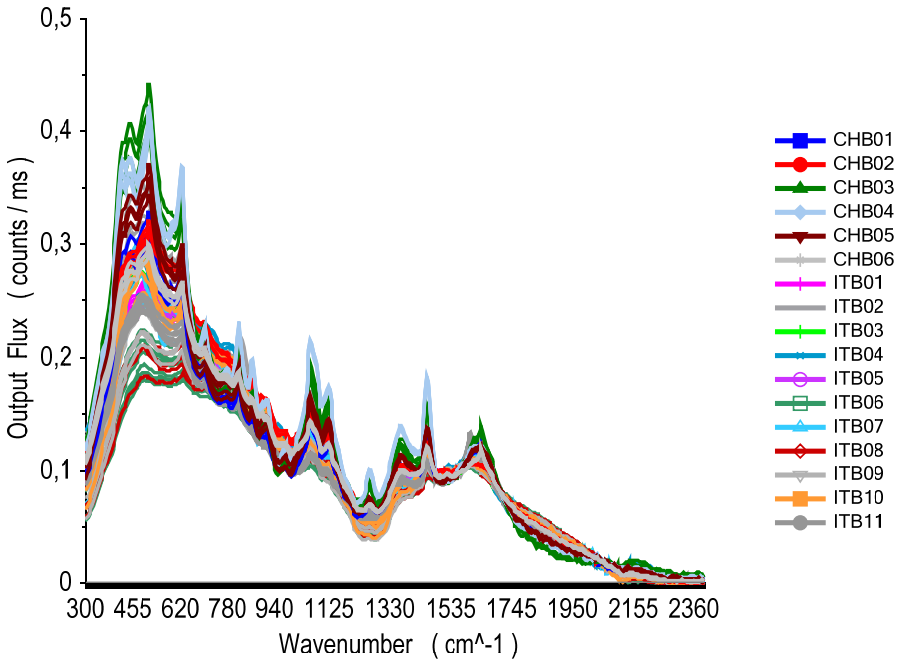


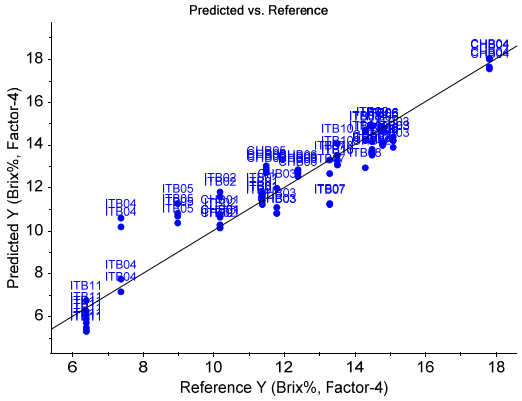

| Analyte | | | RMSEC | $R^2$ (cal) | RMSECV | $R^2$ (val) |
|---|---|---|---|---|---|---|
| SUGARS | Monosaccharides (mg/g) | Glucose | 7,3 | **0,96** | 11 | **0,92** |
| | | Fructose | 5,5 | **0,89** | 7,6 | **0,82** |
| | Disaccharides (mg/g) | Maltose | 3,5 | **0,83** | 5,3 | **0,66** |
| | | Trehalose+Isomaltose +Kojibiose+Nigerose | 2,3 | **0,91** | 3,6 | **0,83** |
| | Trisaccharides (mg/g) | Erlose+Isomaltotriose +Panose | 2,6 | **0,89** | 3,9 | **0,80** |
| **POTASSIUM (μg/g)** | | | 0,3 | **0,97** | 0,5 | **0,94** |

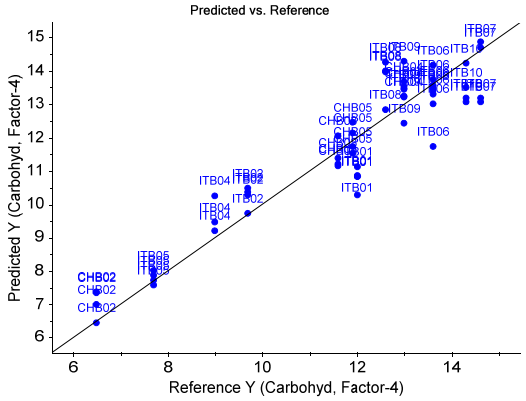
A.G. Mignani *et alii*, IEEE-JLT, 2016

# Raman fingerprints of blueberry juices

## Brix and Carbohydrates

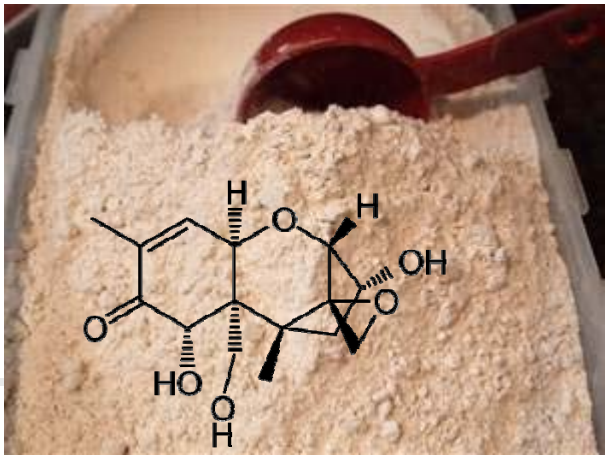



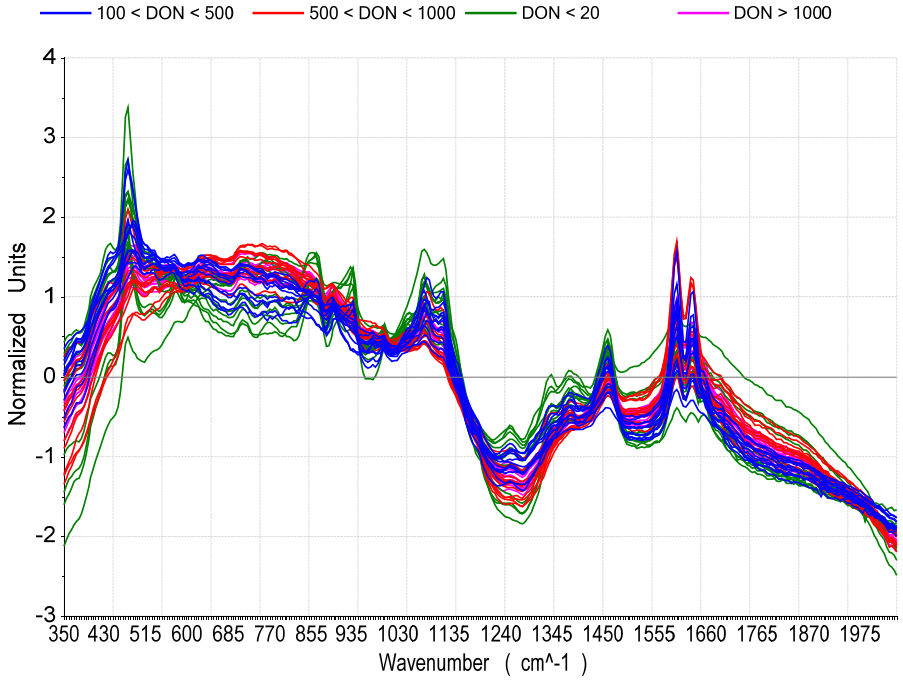



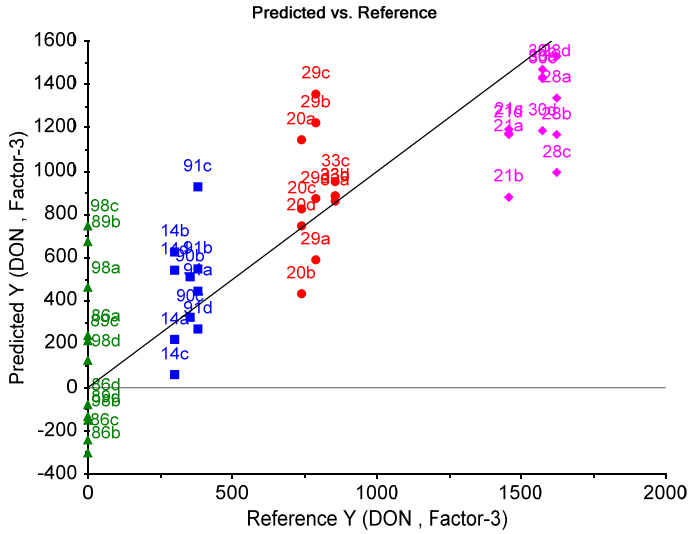

| Parameter and model results | Carbohydrates | BRIX degrees |
|---|---|---|
| RMSEC | 0,80 g/hg | 0,97% |
| RMSCV | 0,97 g/hg | 1,1% |
| $R^2$ (cal) | 0,887 | 0,9 |
| $R^2$ (val) | 0,840 | 0,88 |

# Mycotoxins in wheat flour

## DON – Raman spectra and predictive model



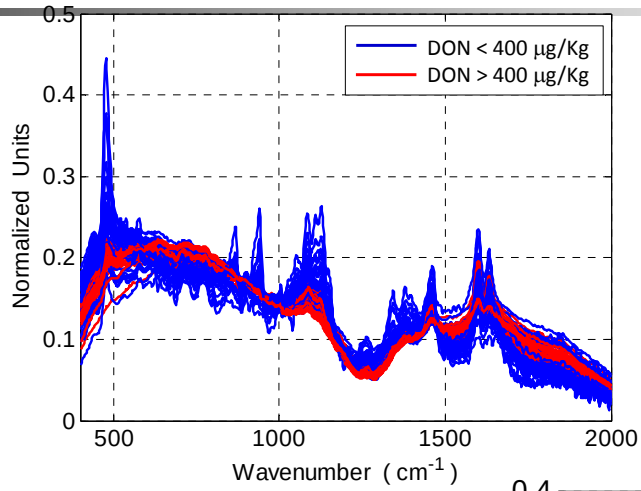

4 levels of contamination:

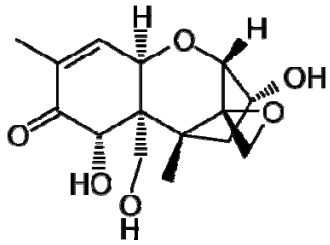
1) < 20 ppb
2) 100-500 ppb
3) 500-1000 ppb
4) > 1000 ppb

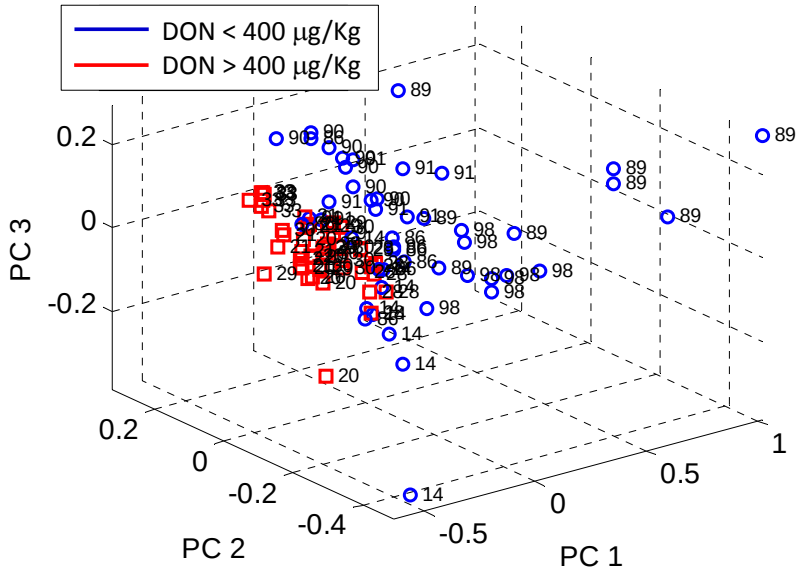
| Parameter | Calibration | Cross-validation (LOO) |
|---|---|---|
| RMSE (ppb) | 313 | 357 |
| R squared | 0,72 | 0,65 |

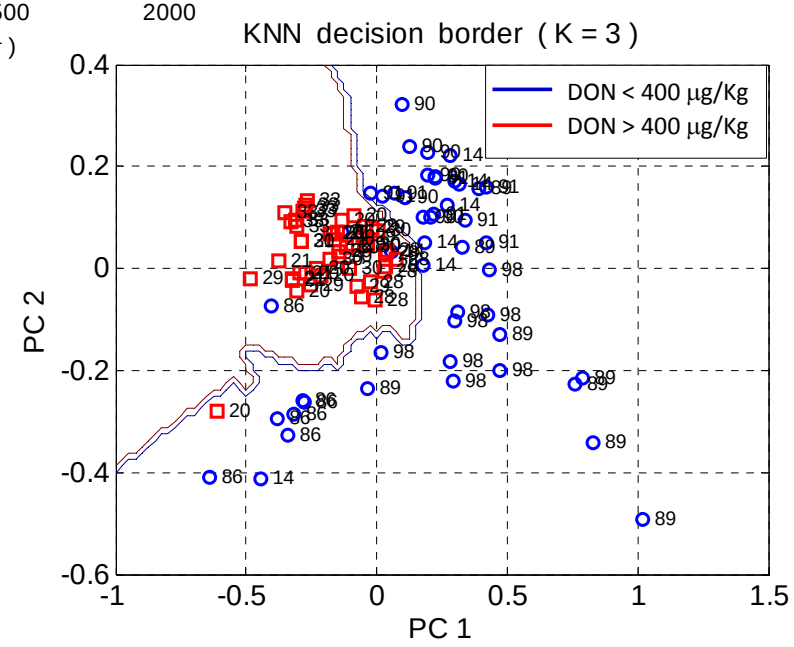
# Mycotoxins in wheat flour

## DON – Raman spectra and predictive model



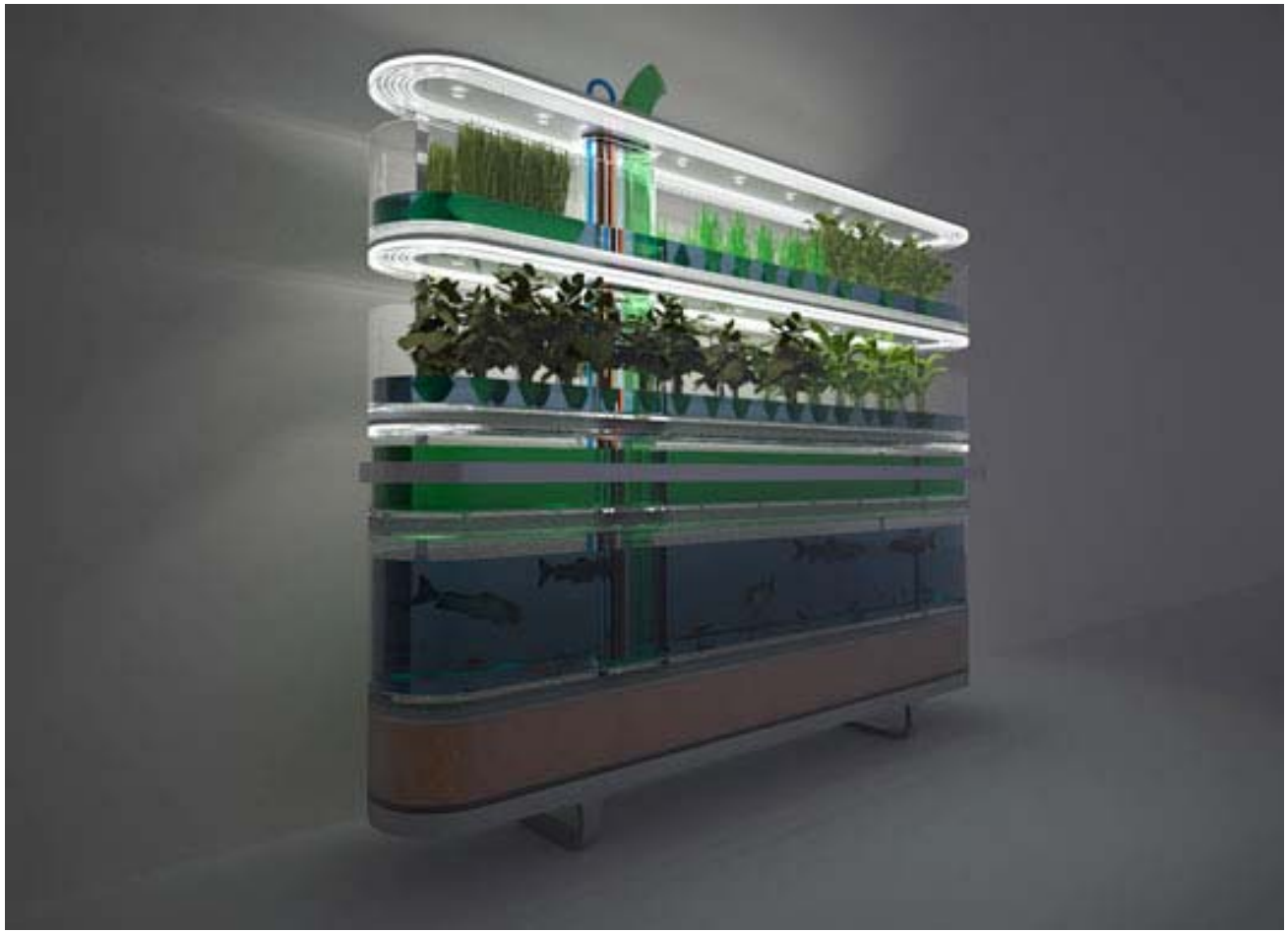



# Outline

- General concepts
- Instruments
- Applications
  - reflectance, absorption, fluorescence
- Non-conventional instruments for absorption spectroscopy
- Spectroscopy by mobile devices
- Raman spectroscopy
- The kitchen of the future

# Home farming



http://www.nextnature.net/2009/10/food-design-in-the-21th-century/

https://www.alamy.com/indoor-soil-free-gardens-with-herb-plants-and-vegetables-producing-food-on-display-at-the-consumer-electronics-show-ces-in-las-vegas-nv-usa-image221407345.html

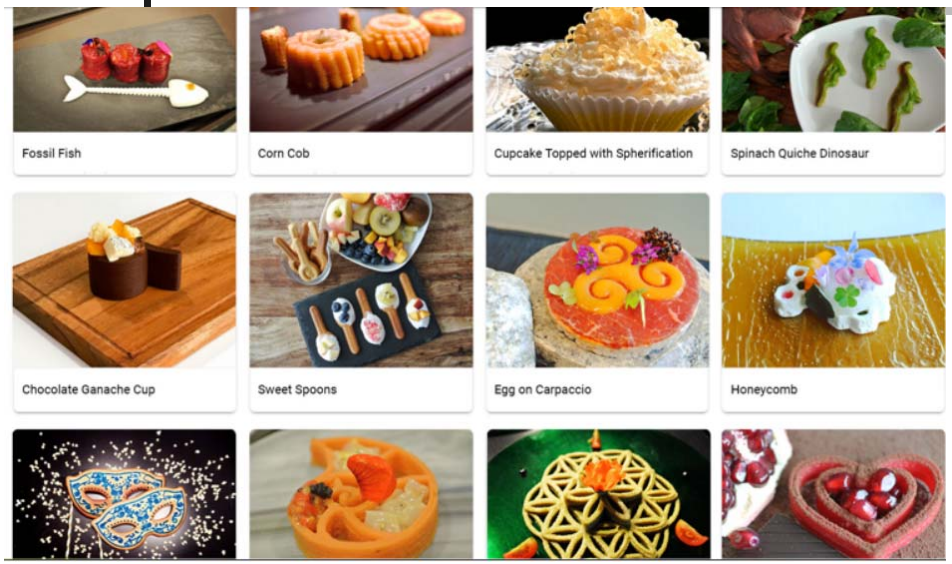
# Home farming @ CES 2019


# Digital gastronomy

http://www.nextnature.net/2010/01/digital-gastronomy/

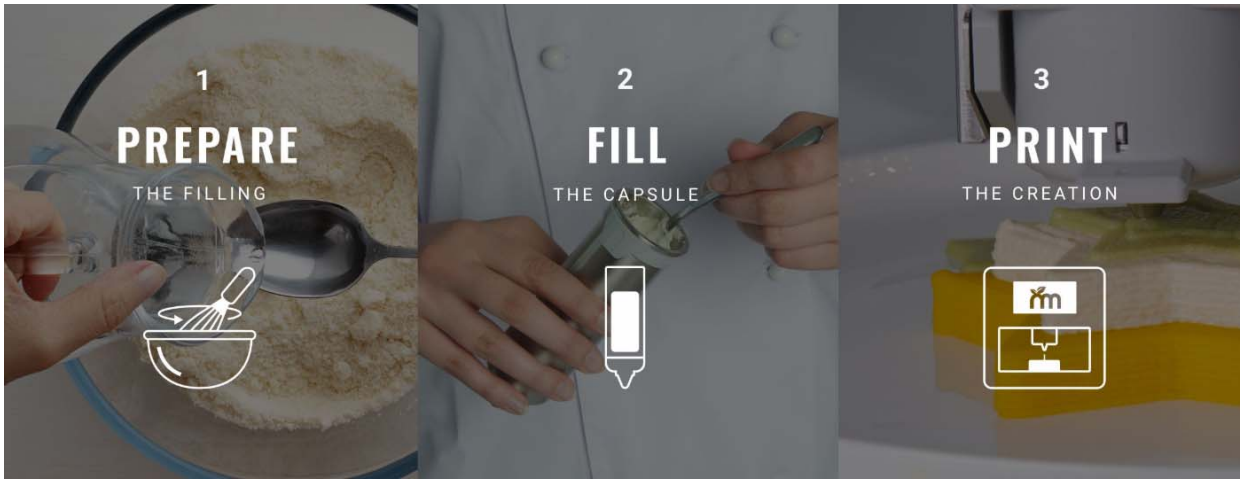
http://www.nextnature.net/2010/05/nano-product-the-food-printer/

# Digital gastronomy





https://www.naturalmachines.com/foodini/



# Curiosity and gadgets


http://situscale.com/

https://nimasensor.com/

# The Internet of Things - IoT

# The kitchen of the future


http://www.digitaltrends.com/home/heck-internet-things-dont-yet/

# The fridge of the future – a family hub


http://koreabizwire.com/from-ai-to-iot-home-appliances-get-tech-treatment/99404

# The fridge of the future – a community hub


https://pulsenews.co.kr/view.php?year=2017&no=565012

# What's next in food

## ?? Edible electronics ??

## ?? Edible photonics ??

https://www.youtube.com/watch?v=oaaHLu77pQc