

RECENT DEVELOPMENTS IN FOOD SCREENING BY NMR

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Food Scandals in recent years

http://www.khd-research.net/Food/LM_Skandale_4.html#AKTUELL

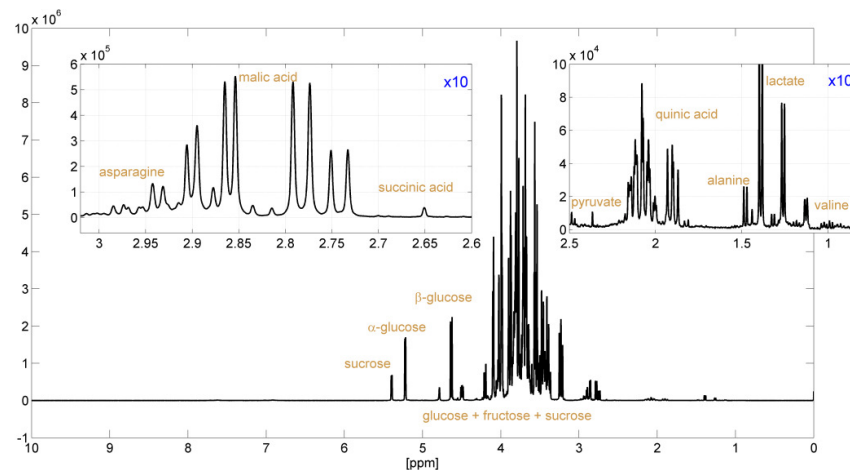


Red wine from the test tube	December 2005
Juices in Tetra-Paks polluted by ITX print chemical	January 2006
Benzene in fruit drinks	March 2006
Cheap Vodka poisons thousands in Russia	October 2006
Wine adulteration in Italy	March 2008
Milk scandal in Bavaria	June 2008
Adulteration of wine and champagne by glycerol	June 2008
Poisoned hard liquor in Turkey	March 2009
Artificial (analog) cheese rapidly increasing	April 2009
People died: cheese made from unpasteurized milk	January 2010
10 Mio. Liter falsified Chianti	May 2010
Bavarian mozzarella got blue	June 2010
Melamine in Chinese food	July 2010

Features of ^1H NMR based screening



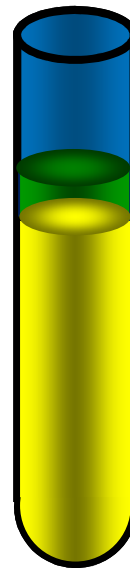
- All type of samples measurable : liquid, semi-solid, solid
- Quantitative detection of all proton-carrying molecules
- The spectrum corresponds to a **highly specific fingerprint**
- **Targeted** / **Non targeted** analysis in a single experiment



Example of an apple juice spectrum

Advantage of NMR

Minimal sample preparation



Buffer Solution
10%

Fruit juice / Urine
90%

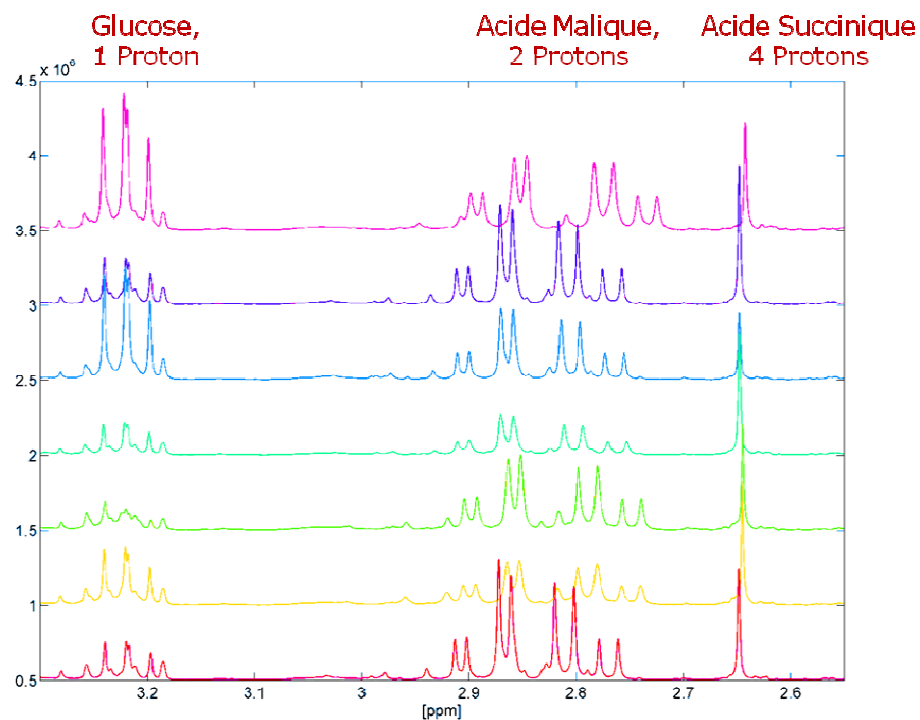
Total sample volume of 600 μ l
in NMR tubes of 5mm

Advantage of NMR

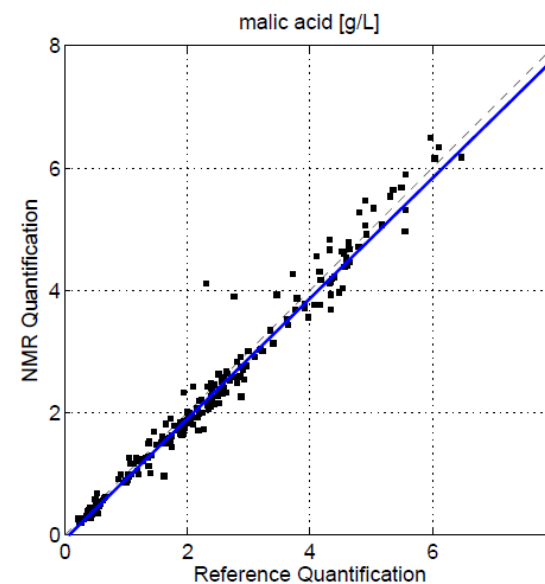
NMR is quantitative



- NMR is inherently quantitative



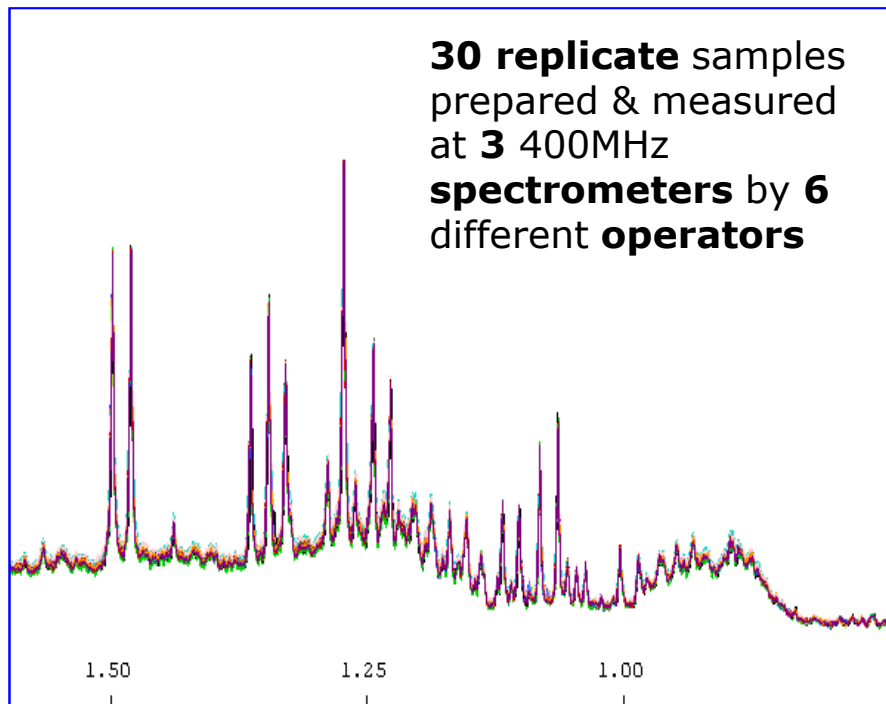
- ✓ Integral of a signal is directly proportional to molar concentration
- ✓ Only one calibration for the quantification of all compounds in a mixture



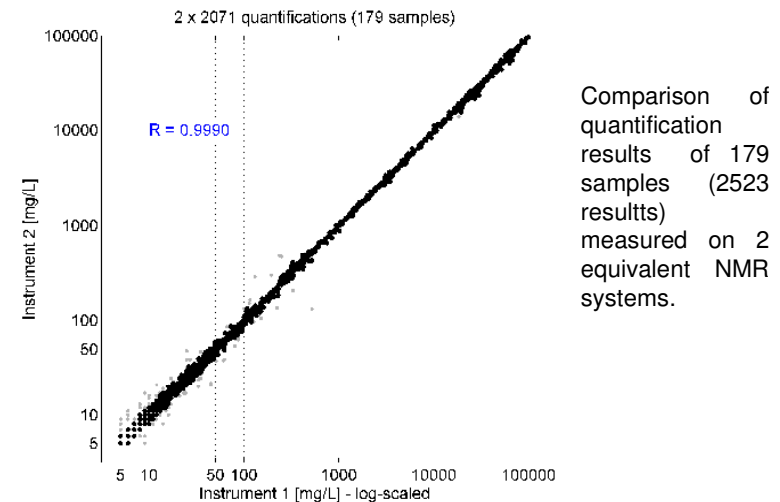
Advantage of NMR Highest Reproducibility



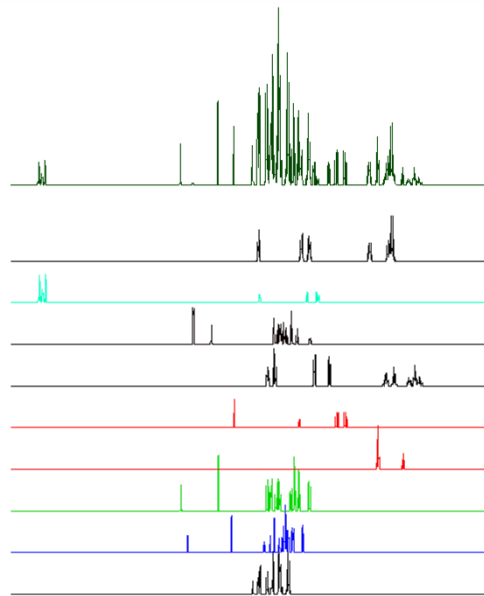
- Highest reproducibility → allows to detect even the smallest variations in concentration of all relevant compounds



- Inter-instrumental reproducibility (at same magnetic field strength)

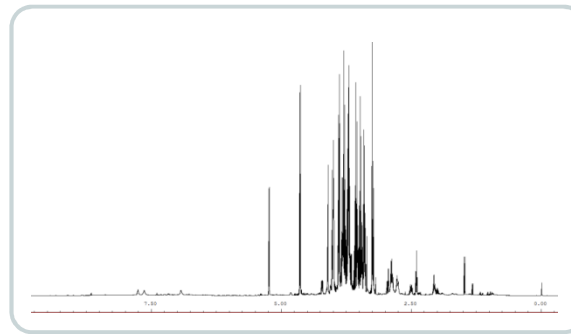


Applications of ^1H NMR screening

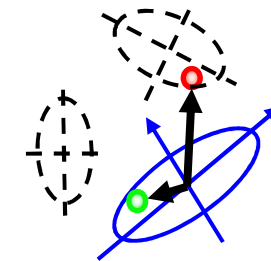
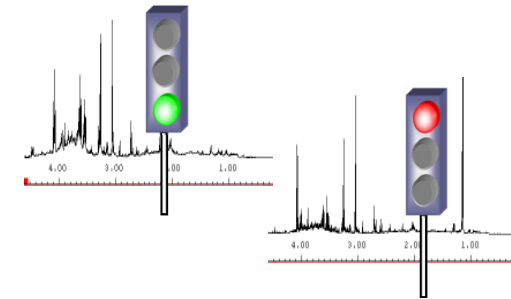


Targeted

Identification & quantification of targeted compounds



Fingerprint/profile



Non targeted

Statistical models for classification and verification of samples

NMR as Pre-Screening Method



Each Sample:

NMR Profiling



Results Summary

Type of Analysis	Analysis ID	Result	Values	Status
Classification Models				
Similarity Analysis	1000/2	OS-KS-BRS ¹	-	-
Global Model	1500/3	OS/MN ²	0.86	-
Orange / Mandarin	2101/3	OS ³	0.91	-
Orange Concentrate/Direct	2102/3	OS-K ⁴	0.97	-
Orange Origin	2103/3	Brazil ⁵	0.77	-
Validation Models				
Univariate Analysis (OS-K)	5002/1	Off-Model	-	●
SIMCA (OS-K)	7002/1	Off-Model	-	●
Fruit Content (Orange)	10001/1	-	95%	-
Quantification	Q/1	-	-	●

Results Summary

Type of Analysis	Analysis ID	Result	Values	Status
Classification Models				
Similarity Analysis	1000/2	AS-KS-VRC ¹	-	-
Global Model	1500/3	AS ²	0.93	-
Apple Concentrate/Direct	2201/3	AS-K ³	0.99	-
Apple Origin	2202/4	AS-VRC ⁴	0.84	-
Validation Models				
Univariate Analysis (AS-K-VRC)	5007/1	In-Model	-	●
SIMCA (AS-K-VRC)	7007/1	In-Model	-	●
Fruit Content (Apple)	10000/1	-	100%	-
Quantification	Q/1	-	-	●

Sample not OK

Sample OK

Confirmation by conventional analyses

OK, no further effort needed
(except e.g. pesticides, minerals)

Standard Operation Procedures SOPs



SOPs are one of the most important features for comparable spectra and correct quantification

- Sample collection
- Sample storage
- Sample preparation
- Measurement
 - Temperature equilibration
 - Automatic tuning and matching
 - Lock
 - Shim
 - Lockphase optimization
 - Pulse-calibration, Adjustment of all power levels
 - Generation of shape pulse in case of multiple suppression
 - 1D acquisition
 - fast 2D-J-Resolved acquisition
- Processing
- Post processing

Transferability of statistical models



Need of common standard and protocols in order to secure models and their applicability

Models need to be applicable to data generated :

- By someone else
- At an other spectrometer
- In another lab
- Anywhere in the world
- At any time



Essentiel for the participation to:

- Long-term studies
- Multi-center studies

Bruker-SGF Fruit Juice Screener



The first
NMR push button system
from
order input to final report
providing rapid response



400 MHz system
5mm Probe
Z-Grad, Automatic Tune/Match

Analytical Services for Juice Screening

- **SGF Profiling**

SGF Profiling™ is an NMR based screening method for fruit juices which has been jointly developed by Bruker BioSpin GmbH and SGF International s.r.l. From just a single file we acquired in minutes, a multitude of quality and authenticity parameters is evaluated simultaneously for each fruit juice.

Features

- Automated push-button evaluation and reporting solution based on a 400 MHz NMR spectrometer
- Reliable screening method provides targeted and non-targeted multi-marker analysis
- Distinction analysis is based on an extensive NMR spectroscopic database of more than 16,000 reference juices, obtained from production sites all over the world and is regularly updated.
- Targeted Analysis: Simultaneous absolute quantification of relevant organic compounds with reference to A.U.I. and NMR distribution.
- Non-Targeted Analysis: NMR-Profile is compared with the corresponding group of reference spectra. Deviating concentrations (even of unidentified compounds) are detected automatically.
- Classification Analysis, e.g. the determination of fruit origin (see specification table).
- Determination of fruit content (detection or addition of water, amino acids or sugar)
- Detection of foreign fruit addition

Sample Verification

Verification involves an exact, fast and targeted analysis by comparing the whole NMR profile of a specific sample with the corresponding group of reference spectra. All spectral data points are taken into account irrespective of whether the signals are assigned to previously identified molecules or not.

Sample Classification

Origin of Orange Juice

The aim of the classification analysis is the determination of the origin of the fruit, its variety (e.g. orange, blood-orange, mandarin) and the differentiation between juice made from concentrates and juice not from concentrates.

Compound	Unit	Ref.	Min.	Max.	A.U.I. (Range Test)	SGF Profiling Database
Water	g/L	100	100	100	100	100
Ascorbic acid	mg/L	10	10	10	10	10
Malic acid	g/L	10	10	10	10	10
Quinic acid	g/L	10	10	10	10	10
Glucose	g/L	10	10	10	10	10
Fructose	g/L	10	10	10	10	10
Sucrose	g/L	10	10	10	10	10
Galactose	g/L	10	10	10	10	10
Starch	g/L	10	10	10	10	10

Excerpt from a specification sheet for grapefruit juice

The targeted approach provides the identification and quantification of individual compounds. In comparison with reference standards, specific deviations in the concentration of a particular component or in the profile of a specific combination of compounds may indicate characteristic quality and authenticity problems, such as the addition or sugar.

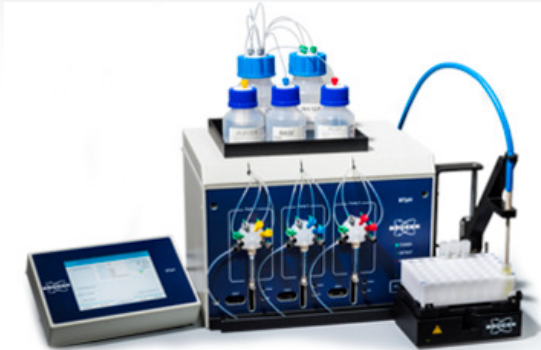
Innovation with Integrity

NMR

^1H -NMR profiling features



- Full Automation (Acquisition → Reporting)
- Only one measurement (~ **20 minutes**)
- Semi automatic preparation
- Targeted Analysis
 - Quantification of tens of compounds
- Non-Targeted Analysis (Statistics)
 - Check of authenticity
 - Check of quality
 - Detection of frauds
- Summary of all results in PDF file



Proof-of-Principle



Same Methodology for other Areas of Mixture Analysis

- Food
 - Wine
 - Honey
 - Edible oil
 - Soft-Drinks
 - Milk, Milk-Powder
- Biofluids (600 MHz)
 - Urine
 - Plasma

BRUKER

Wine Quality & Authenticity

- FoodScreener™ - Wine Profiling module

A new generation of wine analysis has arrived

An innovative solution for the analysis of wine using Nuclear Magnetic Resonance (NMR) spectroscopy has been developed by Bruker with the help of experts in the field.

The principle of the method relies on the acquisition of the spectroscopic fingerprint specific to each individual sample. These profiles are compared to a large database of authentic wine samples using a multivariate statistical approach. Wine Profiling by NMR combines quality control and testing of selected safety issues and authenticity in a unique way.

Features:

- Easy, cost-effective, push-button NMR solution for comprehensive wine screening based on the FoodScreener platform
- Automatic generation of analysis reports
- Reliable screening method providing targeted and non-targeted analyses from a single measurement
- Quantification of 56 parameters
- Comparison of quantification values to official reference values and for all compounds to the concentration distribution of authentic samples, thus supporting interpretation of the results
- Prediction of authenticity parameters such as grape variety, geographical origin and vintage by means of classification analyses
- Non-targeted verification of sample conformity by comparison to authentic reference data by means of verification models

Innovation with Integrity NMR

BRUKER

Authenticity & Quality FoodScreener™

- Application Note: Honey

Analyzing food in a new dimension

The FoodScreener™ is a standardized platform developed by Bruker BioSpin GmbH for food analysis based on 600 MHz Nuclear Magnetic Resonance (NMR) spectroscopy. The principle relies on the acquisition of the spectroscopic fingerprint specific for each individual sample. Sample type-specific and fully automated push-button methods like SGI Profiling™ for fruit juice or Wine Profiling™ already provide reliable targeted and non-targeted multi-marker analyses with reduced cost per sample. Non-NMR experts can easily determine quality and authenticity from measurement to final report.

A new generation of honey analysis has arrived

This proven concept is now under generalization in order to establish an NMR-based screening method for honey samples covering aspects related to authenticity and quality control and quantification. Combining targeted (quantification) and non-targeted (statistics for classification and verification) approaches, it will be possible to address previously unsolved questions:

- Simultaneous identification and absolute quantification of a multitude of relevant parameters (sugars, acids, amino acids, ...) with reference to NMR distribution
- Development of statistical models for the analysis of authenticity according to honey variety such as blossom, honeydew, Linden, lavender, chestnut, pine and according to geographical origin
- Detection of frauds like addition of rice syrup or other types of sugar
- Detection of unspiced and even unknown frauds

Statistical modeling will be based on a reference database containing thousands of authentic samples with worldwide coverage (supported by CGI and ALNuMed).

Innovation with Integrity NMR

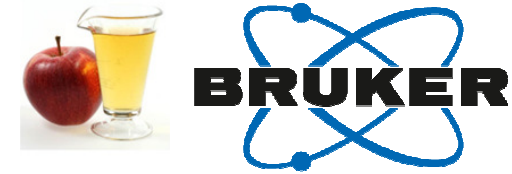
Illustration: Sample Classification

The origin plays an important role in the analysis of authenticity of honey samples. The figure shows a classification model which is able to distinguish between several European polyfloral honeys.

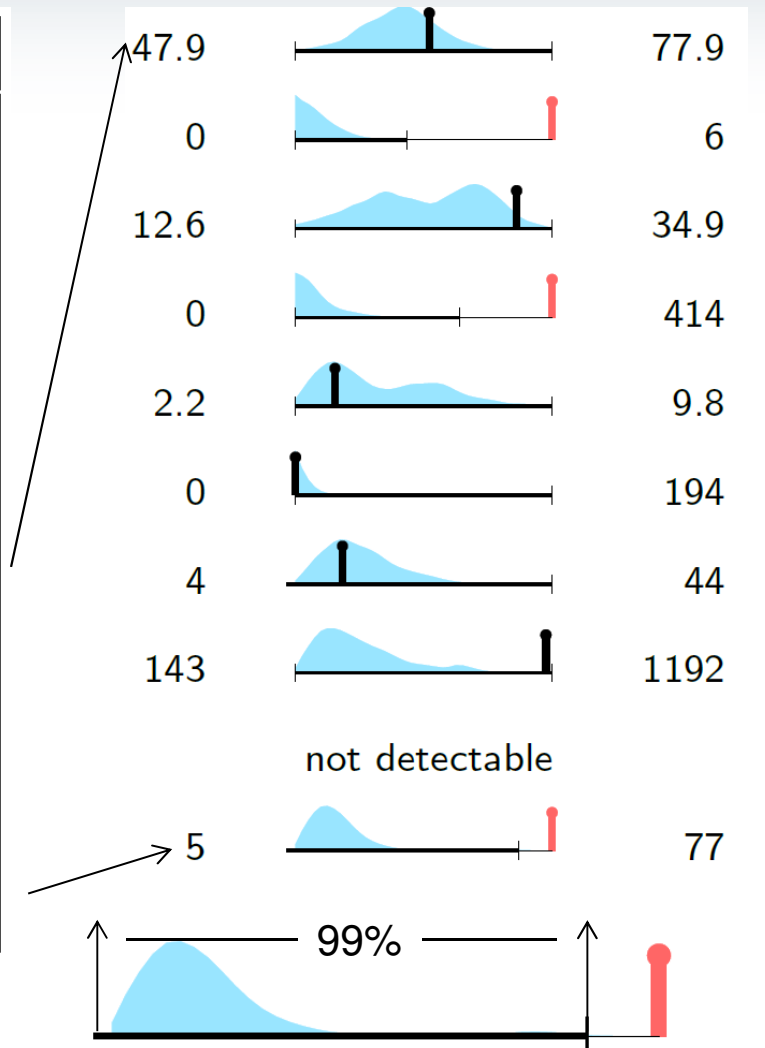
Illustration: Sample Verification

Verification models are used for the non-targeted analysis by comparing the wine NMR profile of a specific sample with the corresponding group of reference spectra (database). As specific size peaks are taken into account irrespective of whether the signal is caused by previously identified molecules or not.

Automatic Report Fruit juice-Screener



Compound	Result	Unit	Flag	A.I.J.N.		SGF-Profiling	
				min	max	n = 2733	
5-hydroxymethylfurfural	N/Q	mg/l	●	-	20	0	16
D-galacturonic acid	410	mg/l	○	-	-	0	1950
acetaldehyde	<5	mg/l	○	-	-	not detectable	
acetoine	N/Q	mg/l	○	-	-	not detectable	
alanine	43	mg/l	●	1	50	10	53
arbutin	N/Q	mg/l	○	-	-	not detectable	
benzaldehyde	N/Q	mg/l	○	-	-	not detectable	
benzoic acid	N/Q	mg/l	○	-	-	not detectable	
chlorogenic acid	69	mg/l	○	-	-	0	227
citramalic acid	34	mg/l	○	-	-	3	114
citric acid	N/Q	g/l	●	-	0.15	not detectable	
ethanol	14	mg/l	●	-	3000	0	619
formic acid	<5	mg/l	○	-	-	0	17
fructose	63.6	g/l	●	45.0	85.0	47.9	77.9
fumaric acid	13	mg/l	●↑	-	5	0	6
glucose	31.8	g/l	●	15.0	35.0	12.6	34.9
lactic acid	650	mg/l	●↑	-	500	0	414
malic acid	3.4	g/l	●	3.0	-	2.2	9.8
methanol	N/Q	mg/l	○	-	-	0	194
pyruvic acid	11	mg/l	○	-	-	4	44
quinic acid	1166	mg/l	○	-	-	143	1192
sorbic acid	N/Q	mg/l	○	-	-	not detectable	
succinic acid	88	mg/l	○	-	-	5	77
sucrose	8.7	g/l	●	5.0	30.0	6.5	39.6



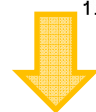
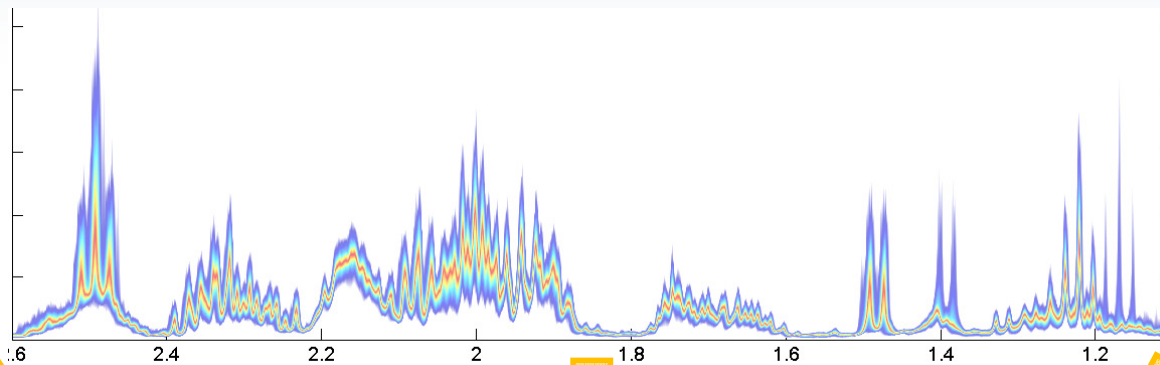
Report of a non-conformous apple juice

Conclusions made by Quantification

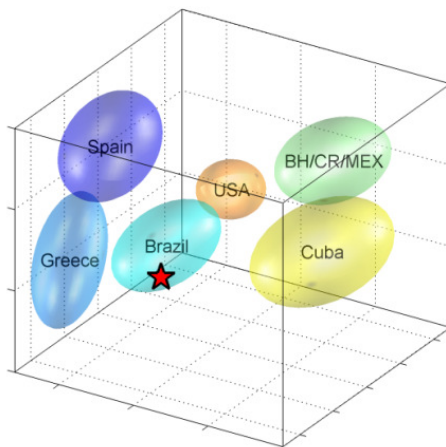


- **Sugar profile** ⇒ Addition of sugar
- **Acids profile** ⇒ Addition of acids
 - e.g.: Citric acid, malic acid in apple Juice
- **Ratio Malic acid / Quinic acid**
 - Ripeness of the fruit
- **Ratio Citric acid / Iso-citric acid** in lemon juice
 - Addition of citric acid
- **Concentration of galacturonic acid**
 - Enzymatic treatment of the fruits (e.g. in apple juice)
- **Concentration of Phlorin in citrus fruit**
 - Usage of peels in the juice
- **Concentration of lactic acid, fumaric acid, formic acid, ethanol, HMF**
 - Quality parameters
- **Addition of another fruit**
 - e.g. pear in apple juice (marker: arbutin)

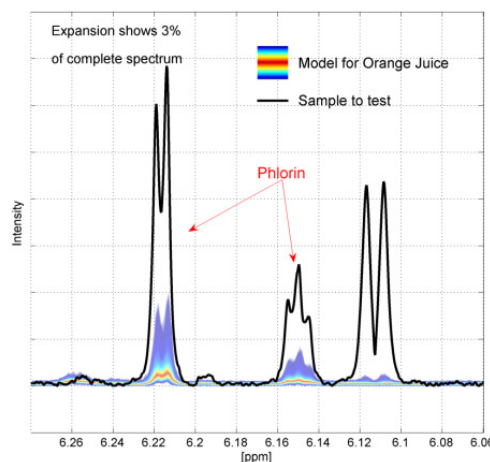
Applications of statistical analysis



Classification



Verification



Indirect Quantification of components by Regression

Parameter	Result	Unit
Total Acid pH 7	112	meq/l
Total Acid pH 8.1	118	meq/l
Total Acid (pH 7, tartaric acid)	8.4	g/l
Total Acid (pH 7, malic acid)	7.5	g/l
Total Acid (pH 8.1, citric acid)	7.6	g/l
Potassium	1808	mg/l
Magnesium	103	mg/l

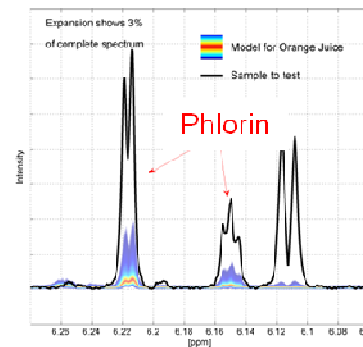
Verification of samples



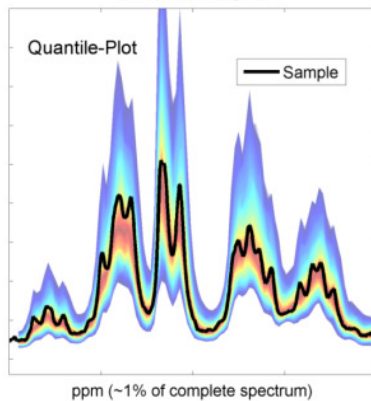
NMR profile is compared with the corresponding group of reference spectra

Reference Spectral database > 20.000 samples

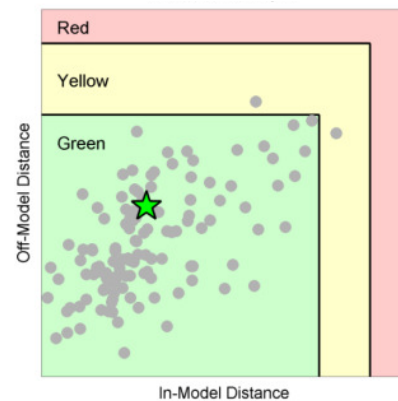
Verification models include uni-variate and multivariate models



Univariate analysis

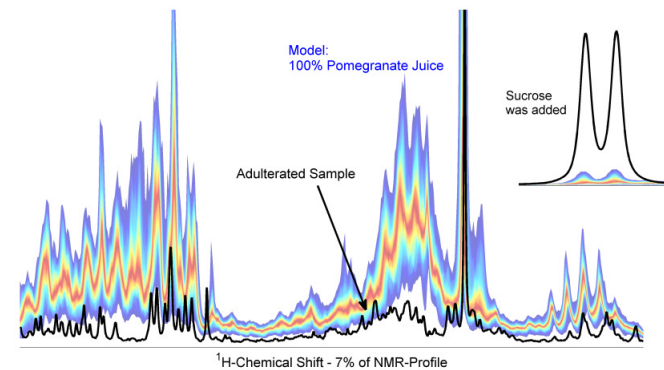


Multivariate analysis

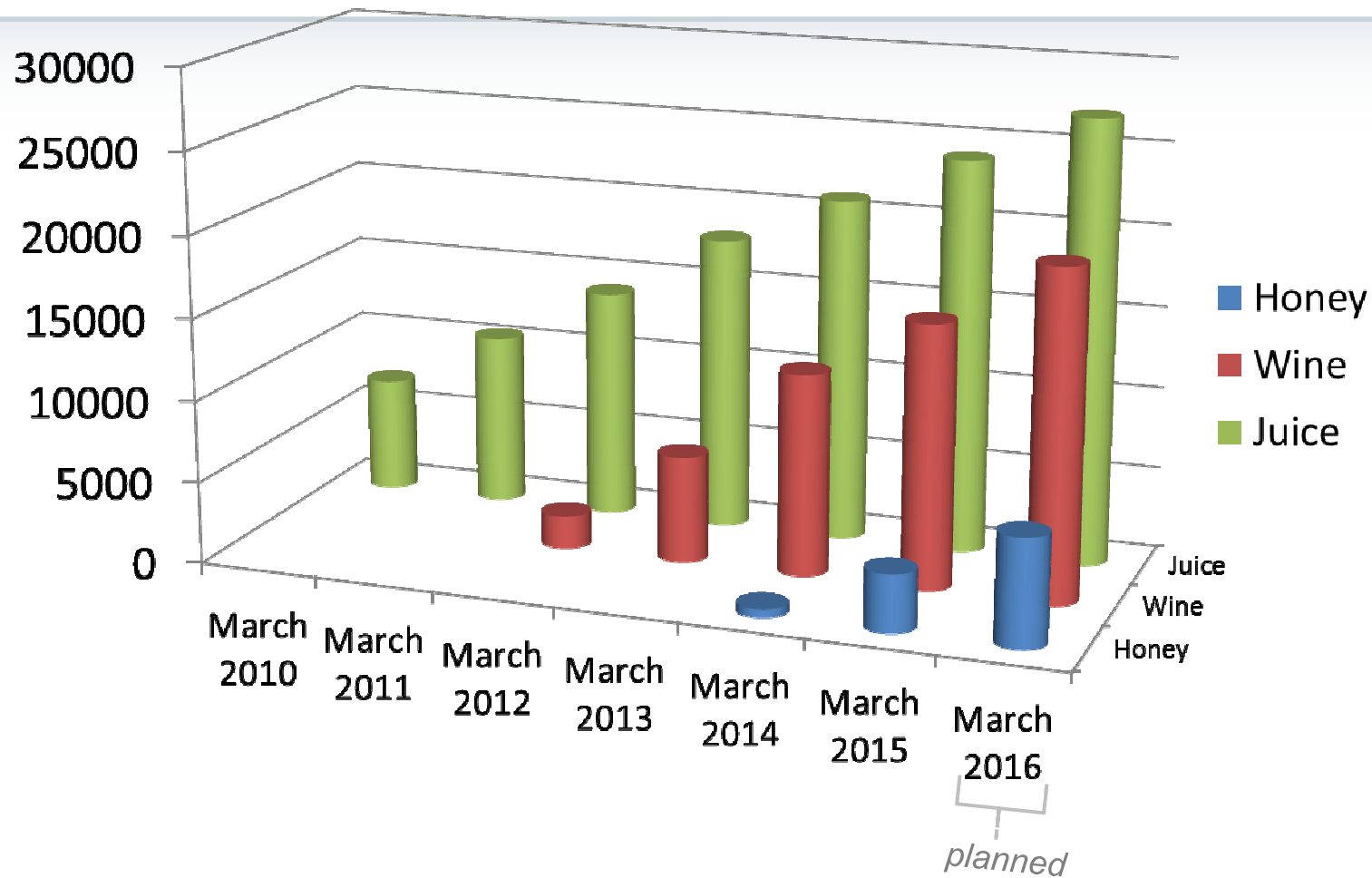


Possibility to detect atypical deviations, unexpected frauds

Examples in juices : falsifications, adulteration, illegal production process, fruit blending, lower fruit content..



Authentic samples databases



For every matrix: 3000 – 4000 samples per year

PDF report : classification models



Fruit-Type Model

Class "Orange/Mand

Following classes are available:

OS/MN/BOS = Orange/Mandarin/Bh
ER = Strawberry, JS = Black Currant
Guava



OS/MN/BOS
AS
TR/TW
GS/GR
AN
ZS
PF
HI
ER
JS
SK
BS
GT
PS
BA
AP
MA
GU

Orange: Variety

Class "Orange" w

Following classes are available:

OS = Orange, MN = Mandarin,



C

M

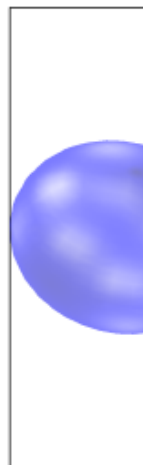
BC

Orange: Product-Type

Class "Orange, Direct J

Following classes are available:

OS-K = Orange, Concentrate, OS-S = Ora



OS-K < 0.0

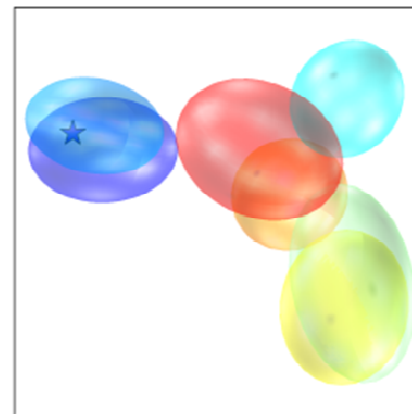
OS-S

Orange: Origin

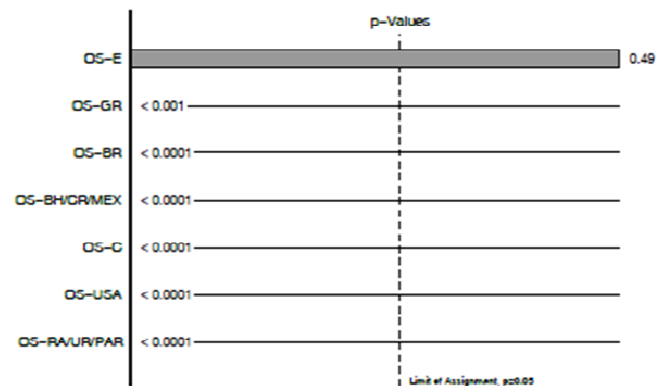
Class "Orange Juice from Spain" was assigned.

Following classes are available:

OS-E = Orange Juice from Spain, OS-GR = Orange Juice from Greece, OS-BR = Orange Juice from Brazil, OS-BH/CR/MEX = Orange Juice from Belize/Costa Rica/Mexico, OS-C = Orange Juice from Cuba, OS-USA = Orange Juice from USA, OS-RA/UR/PAR = Orange Juice from Argentina/Uruguay/Paraguay



OS-E
OS-GR
OS-BR
OS-BH/CR/MEX
OS-C
OS-USA
OS-RA/UR/PAR



(Classification, Analysts ID: 1003/0600)

PDF report : verification results



Verification Models

Applied Model: Orange from Europe

Univariate Verification

(Verification, A)

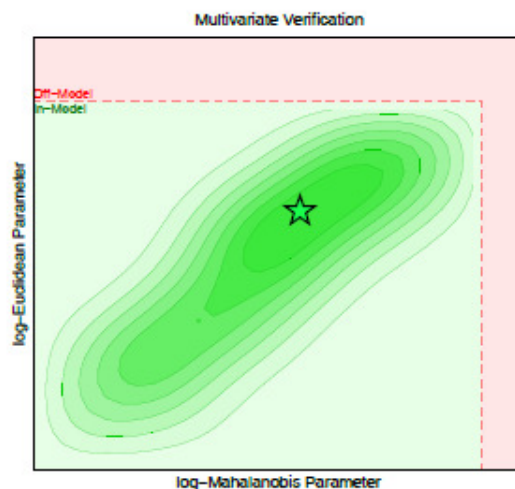
Result: Deviating signals were found at following chemical shifts:

1.387^{up} 1.404^{up}

Multivariate Verification

(Verification, A)

Result: No deviation was detected in multivariate verification (In-Model).



Fruit Content

Applied Model: Orange, Spain

Fruit Content is consistent compared to 100%: Yes

Blend Citrus Sinensis/Reticulata

Model: Model could not be applied.

Due to detected deviations in verification analysis, fruit blending models have not been applied.

Wine Analysis and Requests

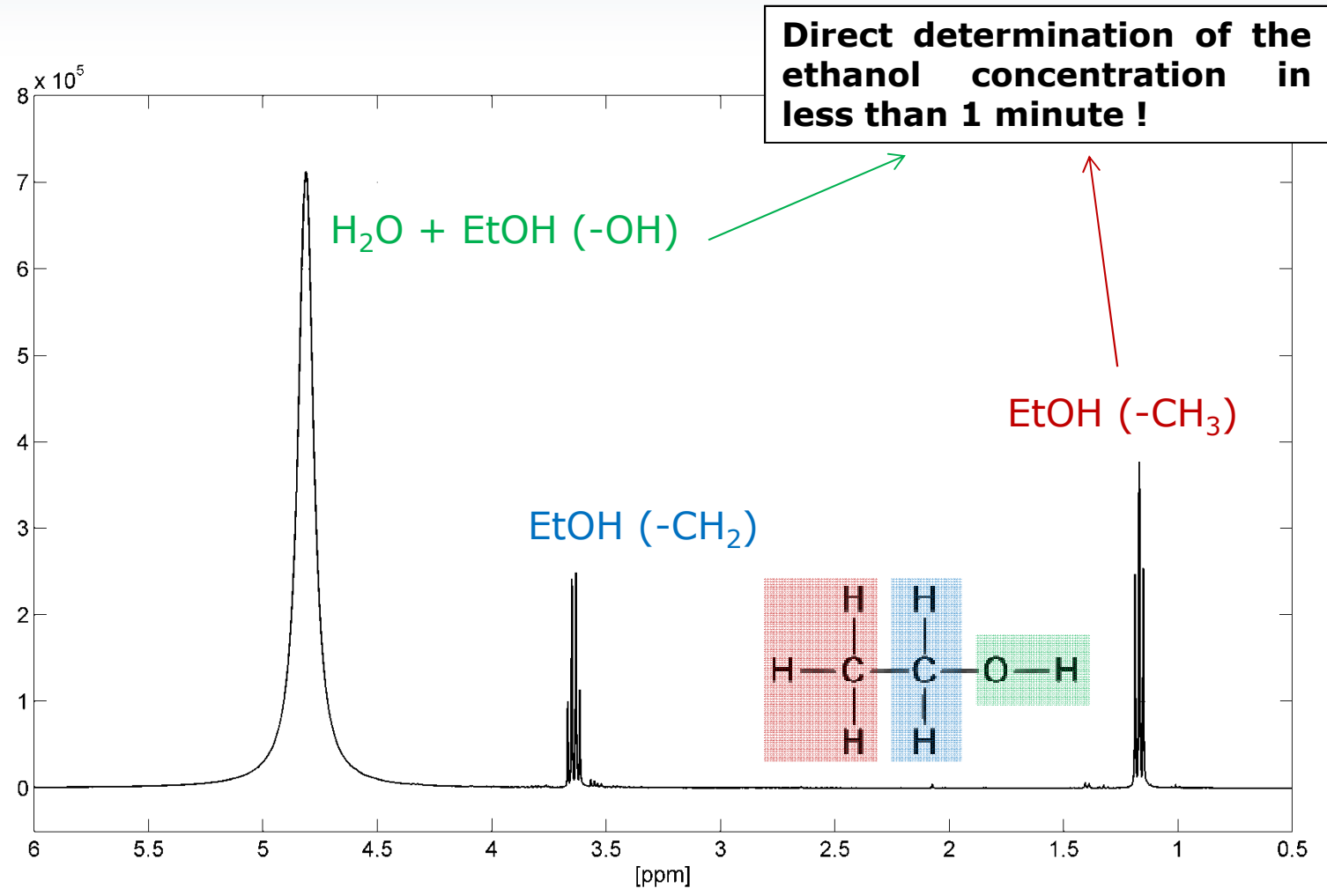
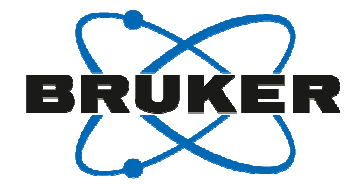


Wine by NMR:

- Replaces conventional, targeted wine analysis
(currently ~ 60 compounds quantified)
- Determination of grape variety
- Geographical origin for selected regions
- Company product profile NMR
- Detection of irregularities of any kind



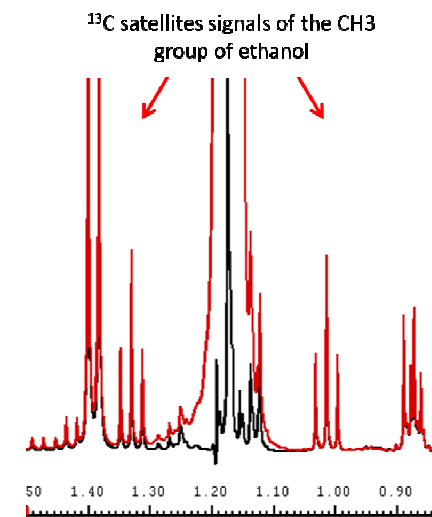
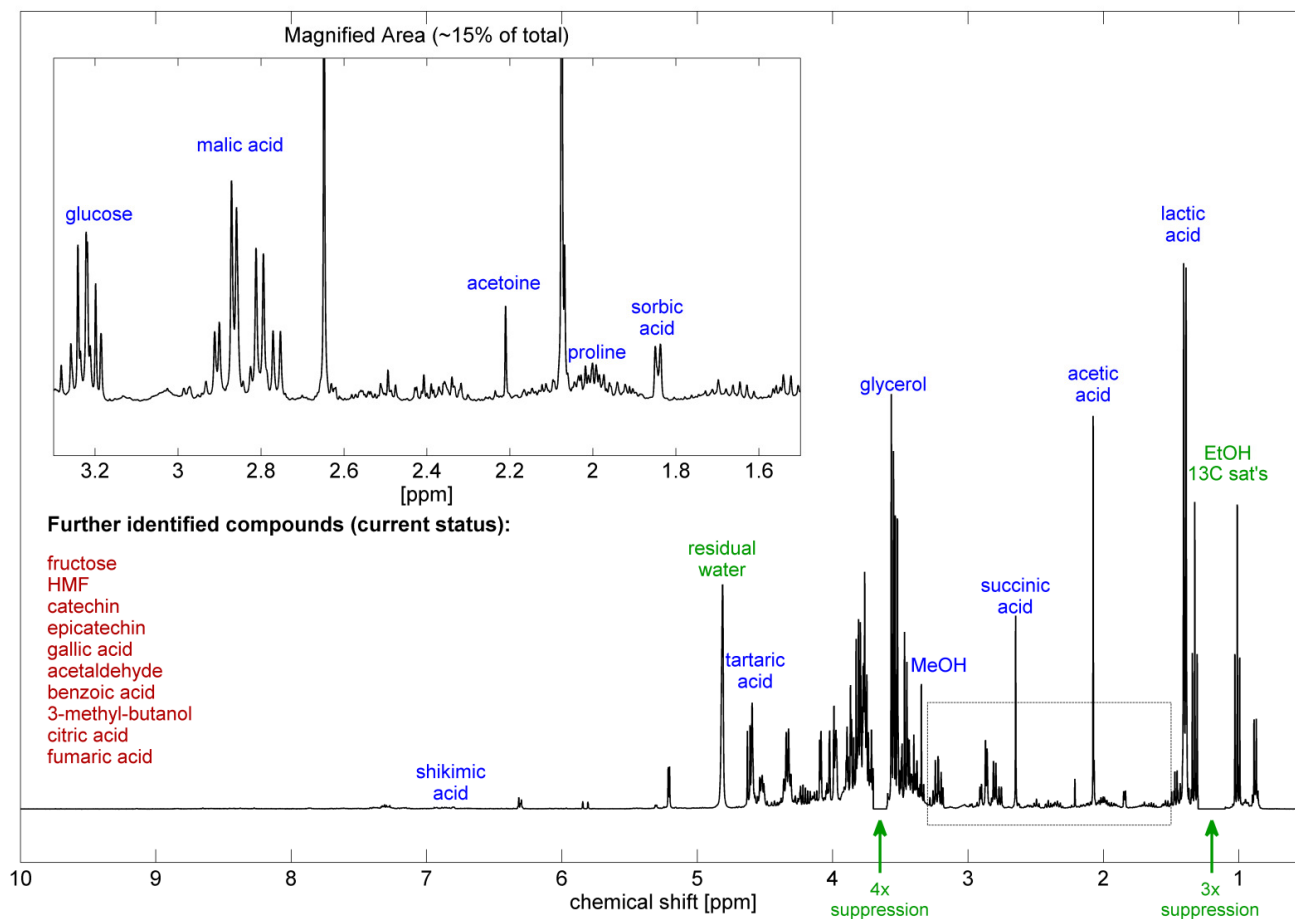
Proton spectrum of wine: Direct measurement



Multi-suppression on ethanol and water



Multiple Suppression with 8 irradiation bands



Automated quantification and reporting



Targeted Analysis

In the following tables the results of the quantitative analysis are given. Parameters labelled with * are calculated parameters. Please refer to the additional remarks for quantified parameters, flags and reference values on page 8. The displayed distributions of the Wine-Profiling™ NMR reference database refer to group *Tempranillo*.

Standard Parameters:

Compound	Value	Unit	LOQ	Flag	Official Ref.		Wine-Profiling™	
					min	max	NMR reference database	
total alcohol*	116.5	g/L	-	○	-	-	98.3	127.6
total alcohol-v*	14.8	%vol	-	○	-	-	12.5	16.2
ethanol	116.1	g/L	5.0	○	-	-	98.0	127.0
ethanol-v*	14.7	%vol	-	○	-	-	12.4	16.1
glycerol	9.7	g/L	0.5	○	-	-	4.4	10.6
glucose	<0.5	g/L	0.5	○	-	-	<0.5	4.4
fructose	<0.5	g/L	0.5	○	-	-	<0.5	4.8
glucose/fructose*	-	-	-	○	-	-	not available	
sucrose	<0.2	g/L	0.2	●	-	-	<200 mg/L in reference set	
arabinose	448	mg/L	100	○	-	-	<100	510
total sugar (bef. inv.)*	<1.0	g/L	1.0	○	-	-	<1.0	9.2
total fermentable sugar*	<1.0	g/L	1.0	○	-	-	<1.0	9.2
tartaric acid	2.1	g/L	0.5	●	-	-	1.3	2.8
malic acid	<0.2	g/L	0.2	○	-	-	<0.2	0.3
lactic acid	1.5	g/L	0.2	○	-	-	0.9	3.4
citric acid	<200	mg/L	200	●	-	1000	<200	218
energy value*	3650	kJ/L	-	○	-	-	3080	3970
bread units*	<0.2	1/L	0.2	○	-	-	<0.2	0.8
carbohydrate units*	<0.2	1/L	0.2	○	-	-	<0.2	0.9

Degradation Parameters:

Compound	Value	Unit	LOQ	Flag	Official Ref.		Wine-Profiling™	
					min	max	NMR reference database	
acetic acid	733	mg/L	100	○	-	-	355	970
acetoine	12	mg/L	10	○	-	-	<10	64
ethylacetate	169	mg/L	50	○	-	-	<50	212
ethylacetate	325	mg/L	150	○	-	-	<150	450
formic acid	9	mg/L	5	○	-	-	<5	13
fumaric acid	<5	mg/L	5	○	-	-	<5 mg/L in reference set	
gluconic acid	<400	mg/L	400	●	-	-	<400 mg/L in reference set	
putrescine	<50	mg/L	50	○	-	-	<50	75
cadaverine	<50	mg/L	50	○	-	-	<50 mg/L in reference set	
HMF	<5	mg/L	5	●	-	-	<5 mg/L in reference set	
furfural	<2	mg/L	2	○	-	-	<2 mg/L in reference set	

Higher Alcohols / Fermentation Products:

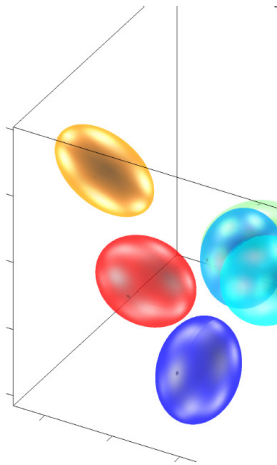
Compound	Value	Unit	LOQ	Flag	Official Ref.		Wine-Profiling™	
					min	max	NMR reference database	
methanol	190	mg/L	30	●	-	400	<30	191
1,3-propanediol	<40	mg/L	40	○	-	-	<40	359
2,3-butanediol	727	mg/L	100	○	-	-	265	1100
2-methyl-propanol	<70	mg/L	70	○	-	-	<70	80
2-phenylethanol	61	mg/L	25	○	-	-	<25	73
3-methyl-butanol	237	mg/L	100	○	-	-	143	282
acetaldehyde	<10	mg/L	10	○	-	-	<10	39
pyruvic acid	<20	mg/L	20	●	-	-	<20 mg/L in reference set	
galacturonic acid	1.3	g/L	0.2	○	-	-	0.2	1.3
succinic acid	965	mg/L	50	○	-	-	490	1100
glycerol/ethanol*	8.3	%	-	●	-	-	4.3	9.4

Non targeted analysis



Model: Italian Variety

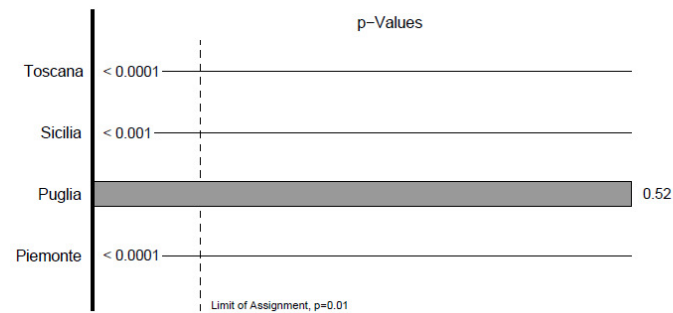
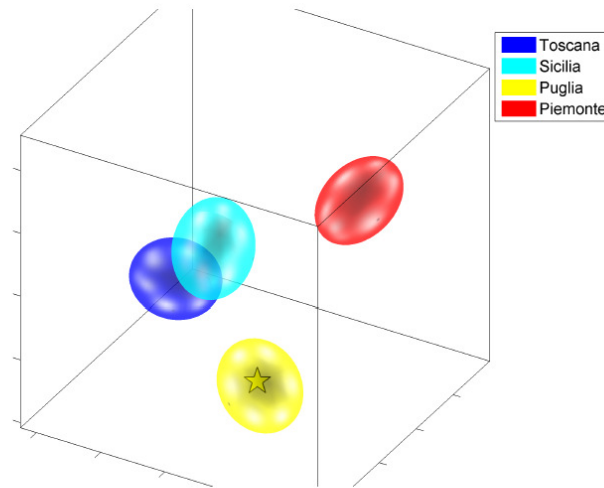
Result: Declared variety *Nebbiolo* is consistent with classification result.



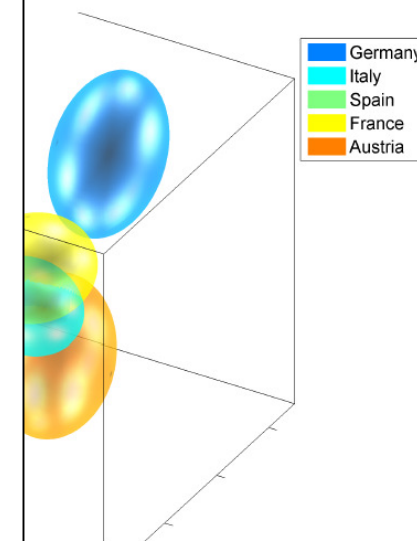
Model: Italian Region

(Analysis-ID: WI-1102-01/0681)

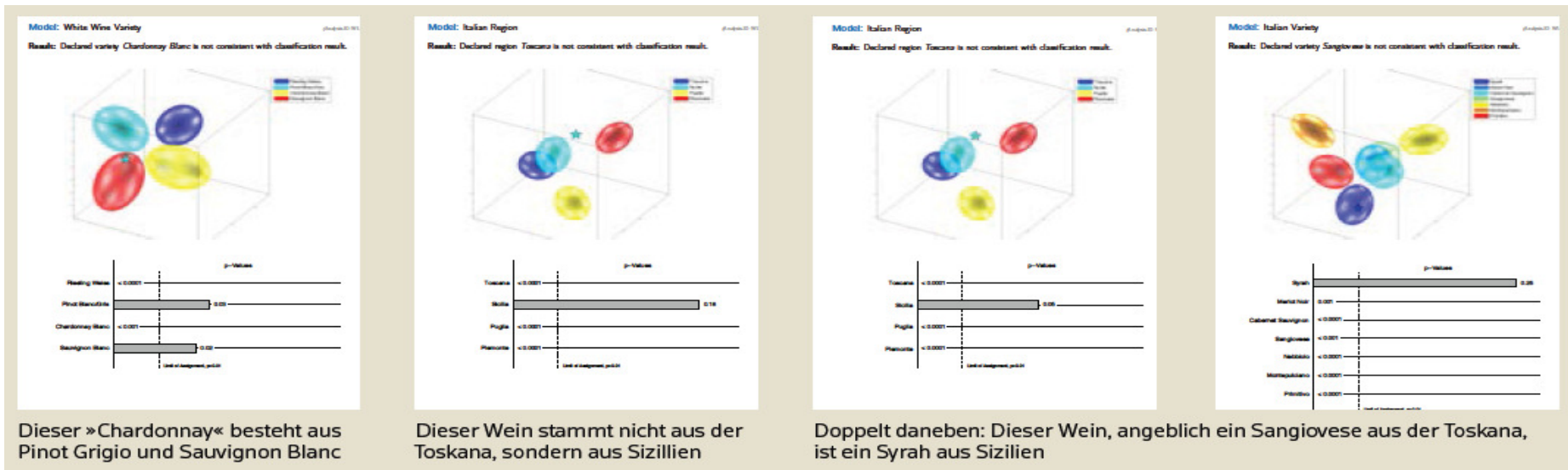
Result: Declared region *Puglia* is consistent with classification result.



istent with classification result.



QC in German Supermarkets using Wine-Profiling



Dieser »Chardonnay« besteht aus Pinot Grigio und Sauvignon Blanc

Dieser Wein stammt nicht aus der Toskana, sondern aus Sizilien

Doppelt daneben: Dieser Wein, angeblich ein Sangiovese aus der Toskana, ist ein Syrah aus Sizilien

Chardonnay really is mix of Pinot Grigio + Sauvignon blanc

Wine not from Tuscany as labeled, but from Sicily

Double fraud, labeled as Sangiovese from Tuscany really is a Syrah from Sicily

Honey frauds



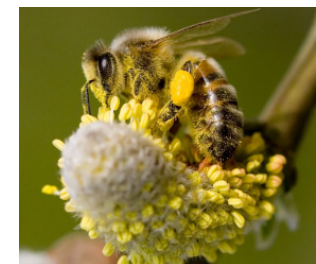
If pollen are removed, conventional analysis can not detect origin or type of honey, while NMR still can.

The following syrups show a marker to identify addition to honey:

- Some Fructose/Glucose syrups available large scale on the market derived from corn
- Agave Sirups and products thereof (in Germany Schneekoppe, ...)

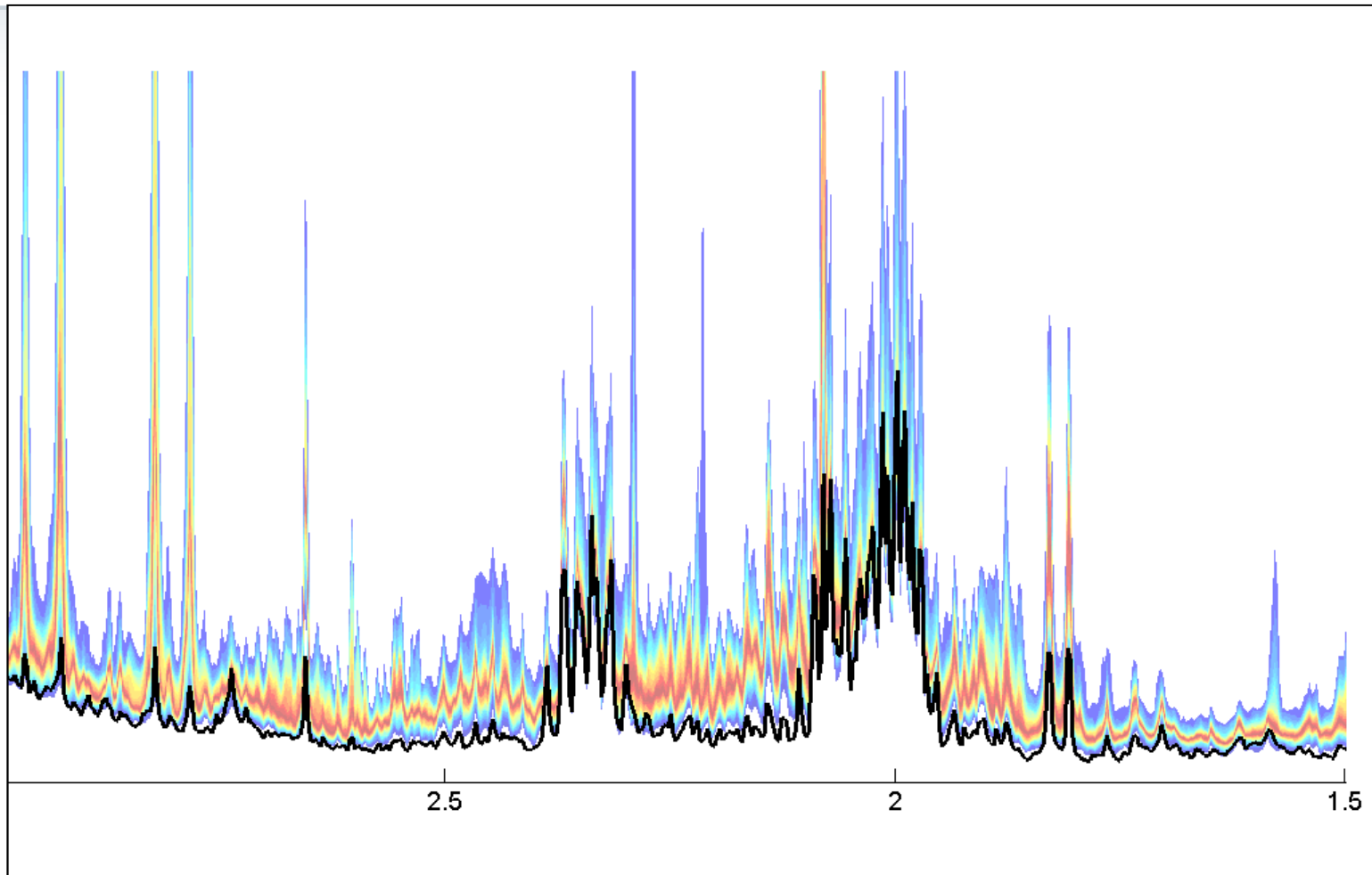
The marker is not found in the following syrups tested so far:

- Rice
- Sugar-cane
- Sugar-beet
- Bee-feed (sirup or dough)



Without marker only dilution detection can be used:
needs NMR and well populated authentic honey database

Honey frauds



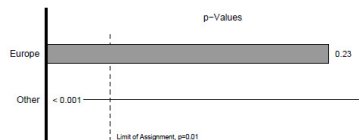
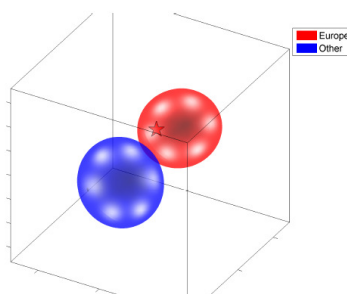
Normal Model Blossom Honey + new sample with sugar syrup addition

Honey profiling



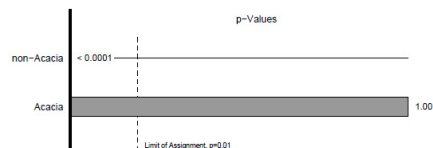
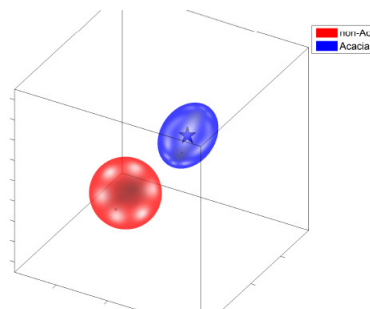
Model: Origin Europe (Analysis-ID: 140-1021-01/242)

Result: Declared geographical origin *Europe - Eastern* is consistent with classification result.



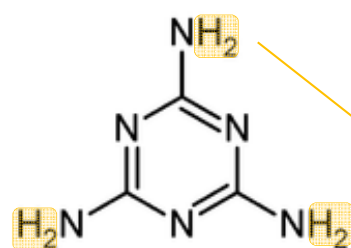
Model: Variety Acacia

Result: Declared botanical variety *Acacia/Robinia* is consistent with classification result.

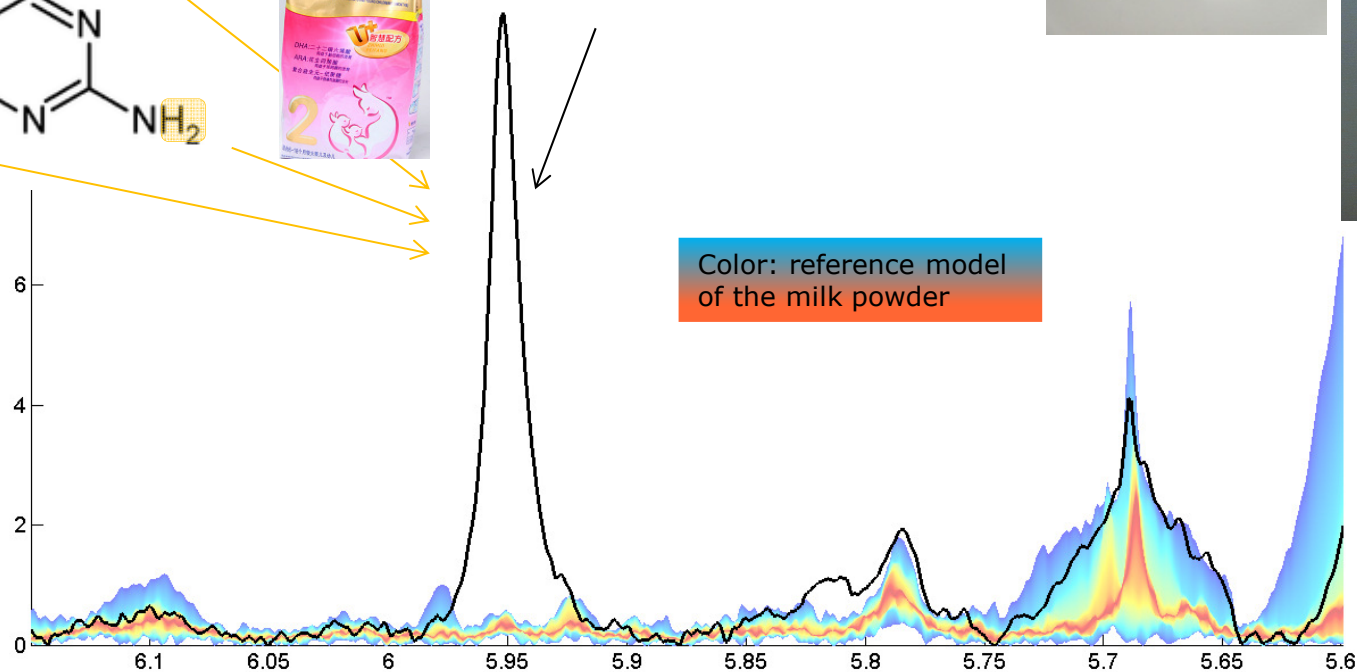
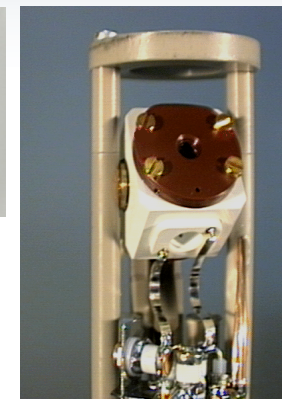


Compound	Value	Unit	NMR Distribution
5-hydroxymethylfurfural	44	mg/kg	<5 71
L-pyrroglutamic acid	<30	mg/kg	<30 380
acetic acid	17	mg/kg	7 140
acetoin	<5	mg/kg	<5 10
alanine	<5	mg/kg	<5 120
citric acid	<100	mg/kg	<100 834
ethanol	28	mg/kg	<10 1025
formic acid	12	mg/kg	<5 226
fructose	40.2	g/100g	28.5 40.8
fructose / glucose	1.58	-	0.93 1.59
glucose	25.4	g/100g	21.9 35.2
glucose + fructose	65.6	g/100g	51.1 72.5
isoleucine	<50	mg/kg	<50 83
leucine	<50	mg/kg	<50 113
malic acid	<100	mg/kg	<100 839
maltose	0.8	g/100g	<0.5 0.9
melezitose	1.0	g/100g	<0.2 1.6
phenylalanine	11	mg/kg	<10 813
proline	217	mg/kg	<100 877
shikimic acid	<50	mg/kg	<50 192
succinic acid	8	mg/kg	5 209
sucrose	1.5	g/100g	<0.5 2.1
trigonelline	<10	mg/kg	<10 33
tyrosine	<50	mg/kg	<50 250
valine	<10	mg/kg	<10 51

Study of milk powder in semi-solid state



San-Lu milk powder:
Melamine (460 mg/kg)



Color: reference model
of the milk powder

Solvent : DMSO ; CPMG experiment

Melamine can be quantified directly
(Integral corresponds to 6 Protons, M = 126 g/mol)

Conclusions



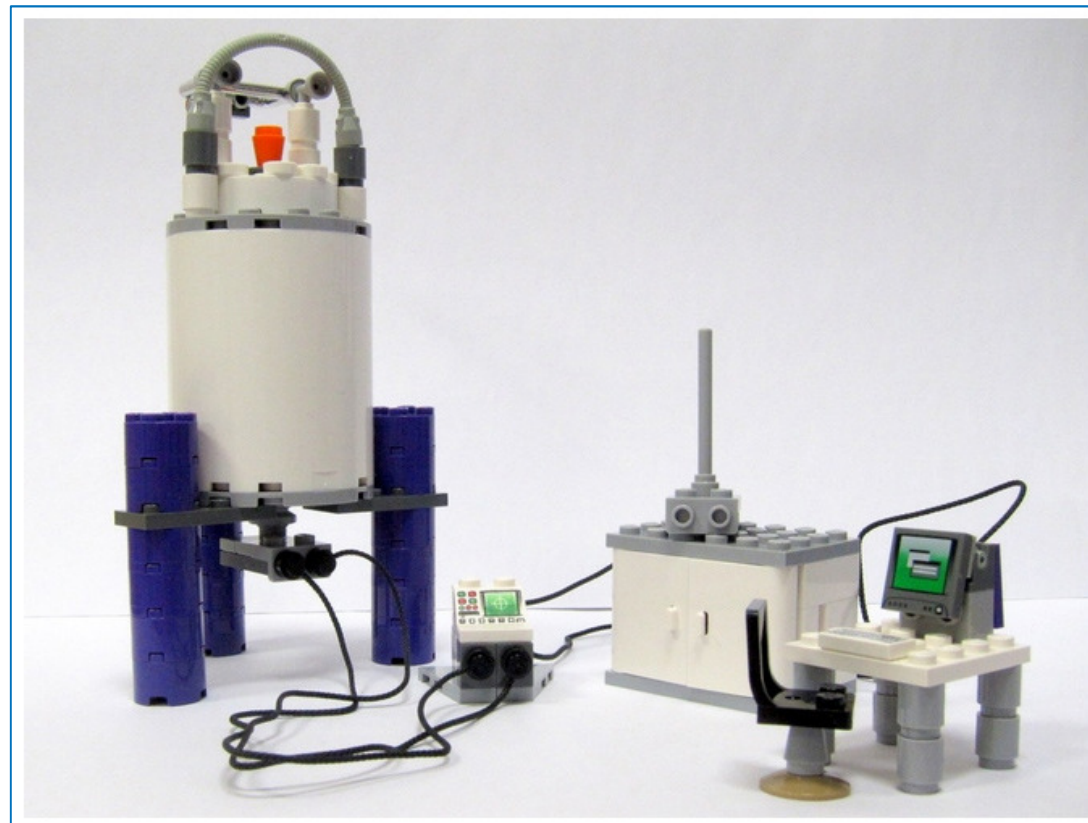
NMR in high throughput mode can generate a multitude of targeted and untargeted results in one measurement, such offering best analytical value at low price per sample.

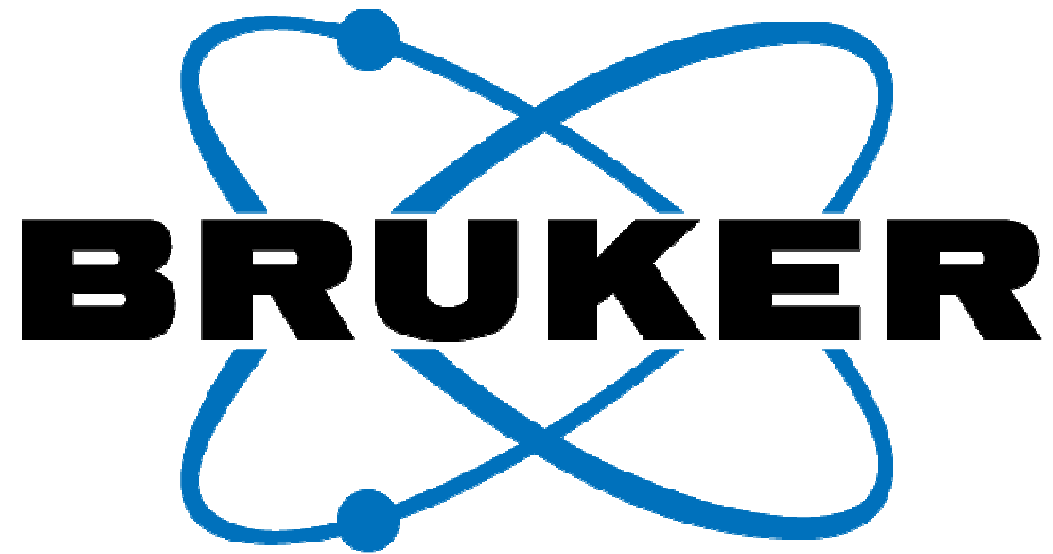
SGF-Profiling for the screening of fruit juices can be seen as **proof-of-principle** for other upcoming applications. The same workflow and underlying mathematical methods can be easily transferred to other quality control application as well as to a wide range of clinical/medical applications.

Multiple suppression helps in the detection of small signals in the presence of very large signals.

Easy sample preparation in all applications.

Thank you for your
kind attention!





Innovation with Integrity