Recent Honey Adulteration Practices and Comprehensive Review on Commonly Used Analytical Approaches to Detect Honey Fraud

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balparmak
Dünyaya Faydalı 40 Yıl

Honey Fraud

Legal Basis for Honey Authenticity Judgement

A growing threat to viability of beekeeping industry and for food safety !!!

European Commission

Food, Farming, Fisheries

Food Safety

Home | Food | Animals | Plants

CODEX ALIMENTARIUS
INTERNATIONAL FOOD STANDARDS

Food and Agriculture Organization of the United Nations

World Health Organization

CODEX STANDARD FOR HONEY - CODEX STAN 12-1981

The Codex Alimentarius Standard and the EU Council Directive

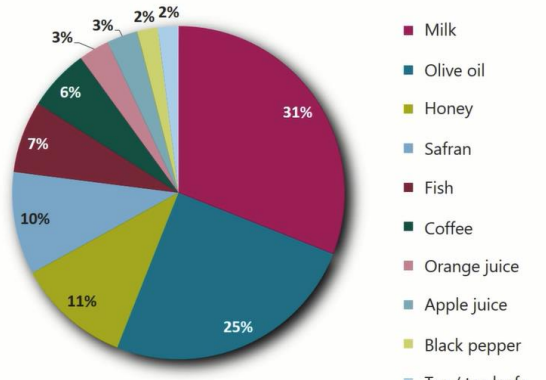
The honey standards of the Codex Alimentarius (CA) (4) and of the European Community (5) have been revised recently. The changes in the standards and the analytical methods used for their determination, following the advice of the International Honey Commission, were recently reviewed (6).

The standards of the Codex Alimentarius and the EU are very similar. The Codex Alimentarius honey standard is more detailed, containing references to quality factors such as heavy metals, pesticides and adulteration.

The definition of honey in both standards is the same:
"Honey is the natural sweet substance, produced by honey bees from the nectar of plants or from secretions of living parts of plants or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own,

According to the CA standard the essential composition and quality factors are:
"3.1 Honey sold as such shall not have added to it any food ingredient, including food additives, nor shall any other additions be made other than honey. Honey shall not have any objectionable matter, flavour, aroma, or taint absorbed from foreign matter during its processing and storage. The honey shall not have begun to ferment or effervesce. No pollen or constituent particular to honey may be removed except where this is unavoidable in the removal of foreign inorganic or organic matter.

Food Fraud list*



*It. USP (United States Pharmacopeial Convention, Rockville, USA, 2013)

Honey is the 3rd most Adulterated Foodstuff !!!

altıparmak

8th International Food Safety Congress
9-10 May 2024 Istanbul-TURKEY
"Safe food for now and future"

Honey Fraud

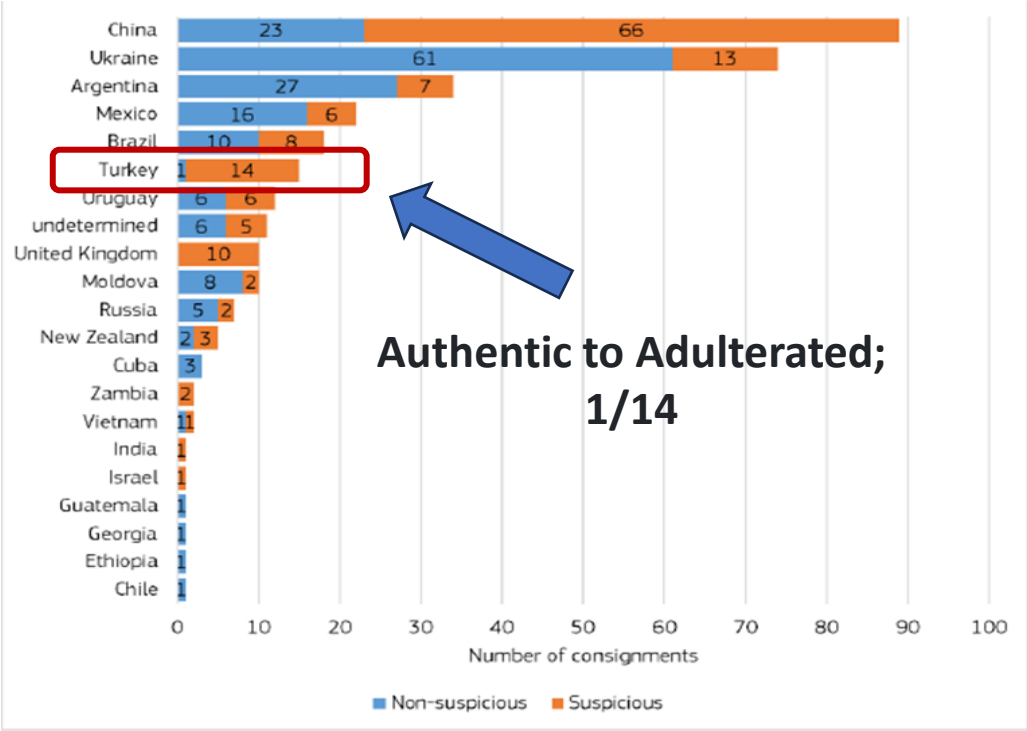
2023, EU JRC Annual Honey Adulteration Technical Report

Why Do We Need to Be Concerned ?

2023; 46% of honeys (*n*=320) imported into the EU are suspicous of not complying with the provision of the 'EU Honey Directive 2001/110/EC'

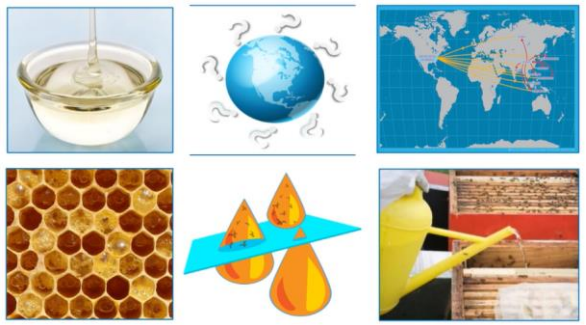
Previous Report; 14%

EUROPEAN COMMISSION JRC



Multiple Modes of Adulteration

- **Honey Adulteration**
  - **Direct Adulteration**
    - **Delibrate Additives**
      - **Exogenous Sugar Syrups** → Liquefied starch based; HFCS (corn/maize), BRS, WRS, Wheat, Agave, Cassava/Tapioca,… Inverted syrups; Beet (thin or thick juice), Cane
      - **Enzymes** → Foreign amylase – heat stable diastase
      - **Dyes** → E150d
      - **Pollens**
    - **Illegal Resin processing & Transhipment** → IEX, Ultrafiltration (depletion or reduction of moisture, HMF, antibiotics, pesticide, syrup markers, ethanol, etc..)
    - **Mixing honeys**
      - Mixing honeydew honeys with blossom honeys
      - Low quality mono or ploufloral with High quality mono or polyfloral honeys
    - **False declaration / Mislabelling**
      - Geographical origin (‘honey laundry’)
      - Botanical origin
      - Organic labelling
  - **Indirect Adulteration**
    - Inaccurate / excessive beefeeding
    - Inconvenient handling or storage
    - Harvesting the unripe honey



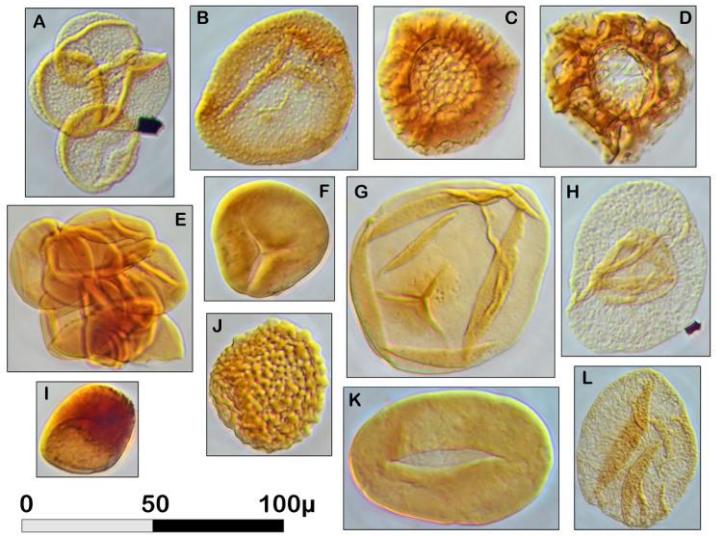
Organoleptic Analysis

It is based on testing of parameters such as **color, transparency, taste, odor, and viscosity** by experienced people.

Highly depends on personal interpretations and biased results are inevitable.

Discriminative laboratory tests are mandatory!!!

Palynologic Investigation



Botanical origins OK but **not satisfying in terms of adulteration identification, pollen composition could be manipulated exogenously !!!**

Physicochemical Assays

Physical - Chemical Parameters

Even if they indicate the abnormalities, different botanical and geographical origins, climate changes, and seasonal variations impact results and false positives may be reported.

Adulteration-focused assays are necessary to provide accurate assessment !!!

description	technology	LOD
citric acid [a)]	enzymatic	20 mg/Kg
colour [a)]	hanna	1-150 mm
conductivity/pH-value [a)]	electrode	---
diastase (activity) [a)]	enzymatic	3 U/Kg
ethanol [a)]	enzymatic	30 mg/Kg
F/G ratio [a)]	enzymatic, calculated	1%
formic acid [a)]	enzymatic	20 mg/Kg
free acids	titration	1 mmol/Kg
glycerine [a)]	enzymatic	30 mg/Kg
HMF [a)]	LC	1 mg/Kg
methylglyoxal (manuka honey) [a)]	LC	30 mg/Kg
methylanthranilate (orange blossom honey) [a)]	LC	0,1 mg/Kg
moisture [a)]	refractometry	13%-24%
saccharase (activity) [a)]	enzymatic	5 U/Kg
pollen analysis [a)] see packages code 200-204	microscopy	---
proline	photometric	10 mg/kg
starch [a)]	microscopy	---
sugar spectrum (5) [a)] fructose, glucose, sucrose, maltose, melezitose	LC	1%
thixotrophy (heather honey) [a)]	Thixotrophy (Louveaux)	pos./neg.
water-insoluble content	gravimetry	0,04 g/100g
yeast [a)]	microscopy	---

Trending Instrumental Analysis Techniques

Targeted vs Untargeted

A Blessing or Curse Vacillation ???

TARGETED ANALYSIS

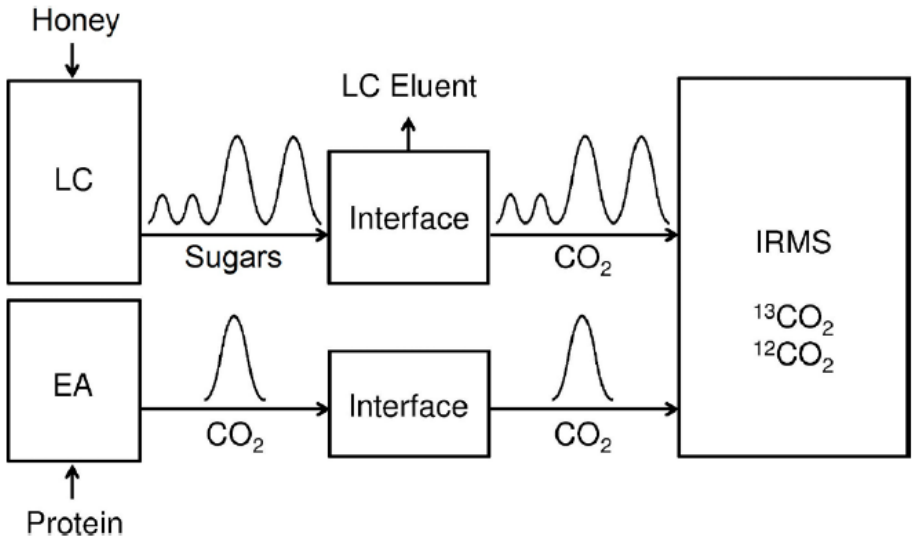
Looks at specific molecular masses and fragments (single substances, e.g. residue analysis, structure elucidation)

Scans an entire mass range (high resolution finger-printing of com-pound mixture)

NON-TARGETED ANALYSIS

Targeted Analyses (Marker Tests) for Identification of Honey Adulteration

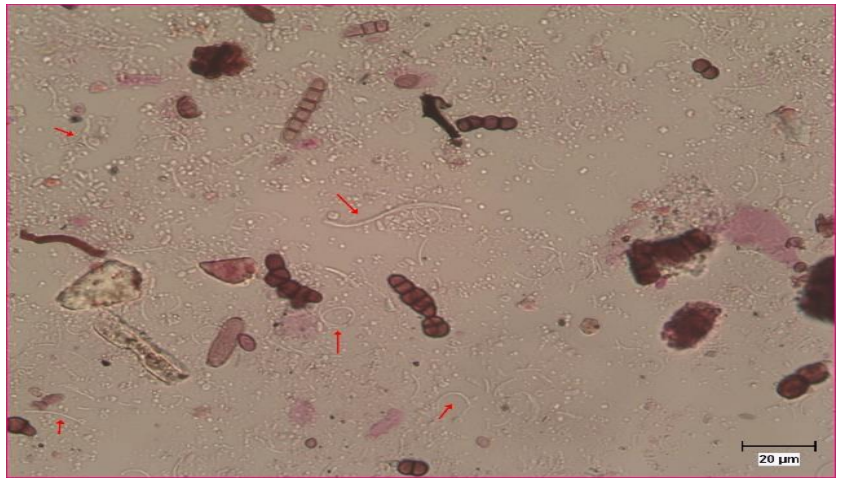
C4 & C3 Sugars by LC-EA-IRMS and EA-IRMS

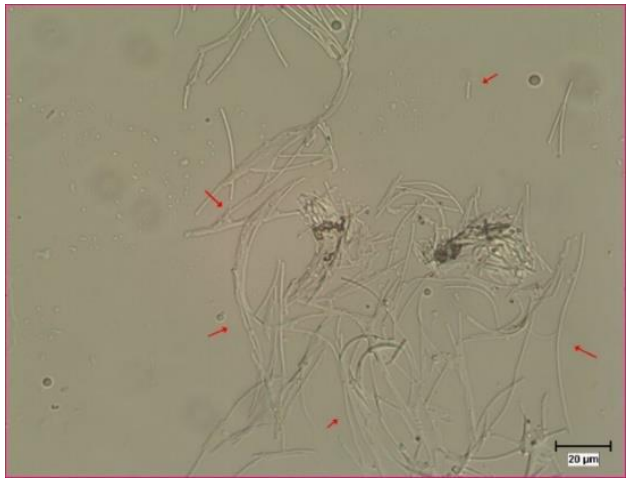


Plant Origin	Examples	Range of $\delta^{13}C$ values	Method
C4-Plants	Corn Sugar Cane	-8 to -13 ‰	EA-IRMS (AOAC 998.12)
C3-Plants	Beet Rice Wheat Cichory	-22 to -30 ‰	**LC-IRMS (new)**

- **If C4 sugars are admixed** to honey, **the carbon isotopic value of the bulk honey will shift to positive value** while the corresponding $\delta^{13}C$ **protein value will remain** same.
- **Inresponsive to well refined (tailored C3 syrups),**
- **Both method produces false positives for some botanical origins, (unique isotopic fingerprints)**
- **LC-EA-IRMS method is not sensitive. Detects roughly 30 %, w/w depending on honey type and adulterant.**
- **Detection of oligosaccharides are deceptive for honeydew honey in LC-EA-IRMS method !!!**

What is the Problem at Pine Honey C4% Measurements ?



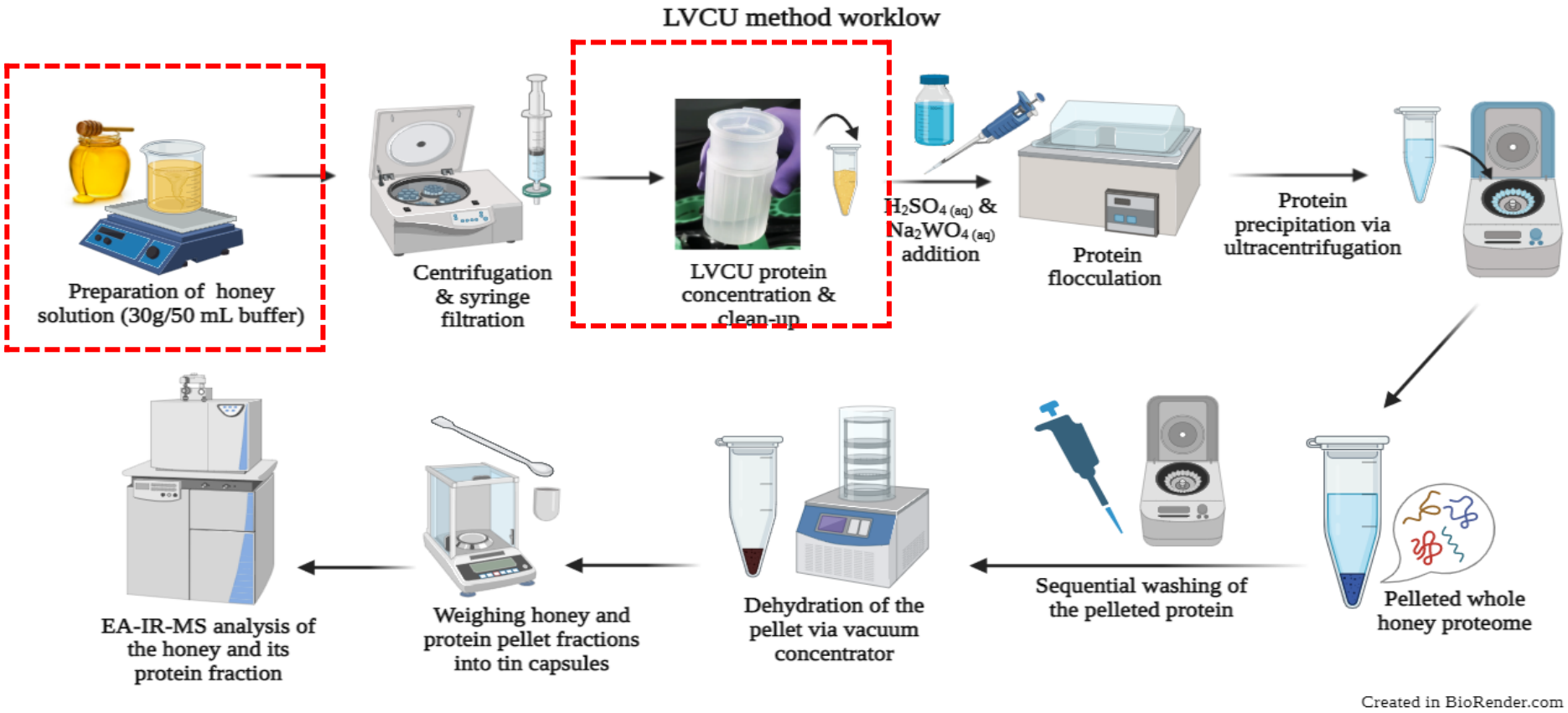


Pine honey is generally characterized by small-sized insoluble wax wools and honeydew elements (**fungal spores, hyphae, pine spores, pollen grains**).

These substances can form an appreciable amount of precipitate during acid/ heat induced protein flocculation at C4 assay.

Hence, these may shift the protein-centric δ13C values to more negative resulting higher C-4% levels at pine honeys

Developed Sample Pretreatment Protocol



LVCU = Large Volume Centrifugal Ultrafiltration Method

Feedback on Global Acceptance for New Protocol

Journal of Food Composition and Analysis 114 (2022) 104787

Contents lists available at ScienceDirect

Journal of Food Composition and Analysis

journal homepage: www.elsevier.com/locate/jfca

Elucidating the false positive tendency at AOAC 998.12 C-4 sugar test for pine honey samples: Modified sample preparation method for accurate $\delta^{13}C$ measurement of honey proteome

İsmail Emir Akyıldız [a,b,*,**,1], Özge Erdem [b,2], Sinem Raday [b,3], Tuğçe Daştan [b,4], Sezer Acar [b,5], Dilek Uzunöner [b,6], Gamze Düz [b,7], Emel Damarlı [b,8]

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Assessment of pine honey

Yanıtla | Tümünü yanıtla | İlet

From: Ulrike Burmester
Sent: Wednesday, September 28, 2022 12:31 PM
To: Emel Damarlı <Emel.Damarli@balparmak.com.tr>
Subject: Assessment of pine honey

Dear Emel,

I hope, this finds you well. Thank you for publishing your research on pine honey. Based on your publication, we will now change our assessment of pine honey. In case the 13C/12C isotope ratio of the protein is more negative than the value of honey, we have now the possibility to exclude the protein from assessment and can refer to your investigations. Unfortunately, we did not have the technical possibilities and capacities to carry out these investigations ourselves in the depth described.

Best wishes from Bremen

Ulrike

Ulrike Burmester
Senior Lab Supervisor for Authenticity
Food Services

Rice Syrup (White Rice Syrups & Brown Rice Syrups) Detection

SM-R Method (AFGP)

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Article

pubs.acs.org/JAFC

2-Acetylfuran-3-Glucopyranoside as a Novel Marker for the Detection of Honey Adulterated with Rice Syrup

Xiaofeng Xue,[†,‡,⊥] Qiang Wang,[†,∥] Yi Li,[‡,∥] Liming Wu,[‡] Lanzhen Chen,[§] Jing Zhao,[§] and Fengmao Liu[⊥,*]

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[‡]Risk Assessment Laboratory for Bee Products Quality and Safety of Ministry of Agriculture, Beijing 100093, China

[§]Bee Product Quality Supervision and Testing Center, Ministry of Agriculture, Beijing 102202, China

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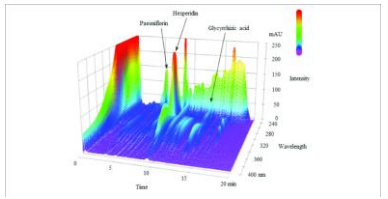
ABSTRACT: The determination of honey authenticity is of importance to ensure its quality and safety. There is an urgent need of effective methods to detect adulterated honey. A simple, rapid, and effective HPLC−DAD method was developed to detect honey adulteration by rice syrup, using a characteristic compound from rice syrup, which is presently difficult to detect by current analytical methods. The characteristic compound was identified as 2-acetylfuran-3-glucopyranoside (AFGP) by MS and NMR. Based on HPLC analyses, the average concentration of AFGP was 92 ± 60 mg/kg in rice syrup. However, AFGP was not detected in any of the natural honey samples, so it could be used as a marker for the detection of honey adulteration by rice syrup. The developed method enabled a rapid detection of honey samples adulterated with 10% rice syrup. Using the developed method, 16 out of 186 honey samples from some markets were found to be adulterated with rice syrup.

KEYWORDS: *2-acetylfuran-3-glucopyranoside, rice syrup, HPLC-DAD, adulterated honey*

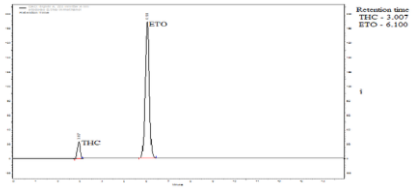
Marker Determination & Identification Workflow

UHPLC-DAD molecular screening (untargeted approach)

Syrup samples / Authentic Honeys from different origins / Adultered Honeys



Fractionation & Isolation the compound of interest – Analytical Scale



Sample enrcihment- extraction solvent/ratio optimization (MSweEt)

SALLE - Swedish Ext.
Sample prep. development

Scale up – semi preparative fractionation

LC-MS & GC-MS mass identification and database research

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Targeted Analysis of identified molecule along with AFGP

Publication

Contents lists available at ScienceDirect

LWT

journal homepage: www.elsevier.com/locate/lwt

Identification of the rice syrup adulterated honey by introducing a candidate marker compound for Brown rice syrups

İsmail Emir Akyıldız [a,b,*], Dilek Uzunöner [b], Sinem Raday [b], Sezer Acar [b], Özge Erdem [b], Emel Damarlı [b]

[a] Chemistry Department, Marmara University, Istanbul, Turkey
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ARTICLE INFO

Keywords:
Authenticity
Honey
Rice syrup
Sorbic acid

ABSTRACT

Identification of honey adulteration is an important area to ensure product safety and quality. White rice syrups (WRS) or brown rice syrups (BRS) can be used for honey adulteration. Up to date, qualitative analysis of 2-acetylfuran-3-glucopyranoside (AFGP) and the quantification of the arsenic residue are the commonly preferred methods to detect rice syrups (RS). We have figured out the BRS may have very low amount of AFGP. Therefore, it was estimated that AFGP alone may not be a very reliable marker for BRS identification. We aimed at identifying a new marker compound for BRS and to develop a novel analytical method that allows simultaneous monitoring of this compound and AFGP to highlight the addition of RS from different origins. The characteristic molecule in BRS was identified as sorbic acid. A UHPLC-MS/MS method was developed by combining dilute & shoot sample pretreatment and 107 samples were analyzed. While 21 of the samples were found adulterated with BRS, 3 samples were found to contain WRS. We suggest using sorbic acid as a marker of BRS addition to honey. Within this research, it was hypothesized that fraudulent was mostly made with BRS and adulteration may be overlooked applying the existing methodology.

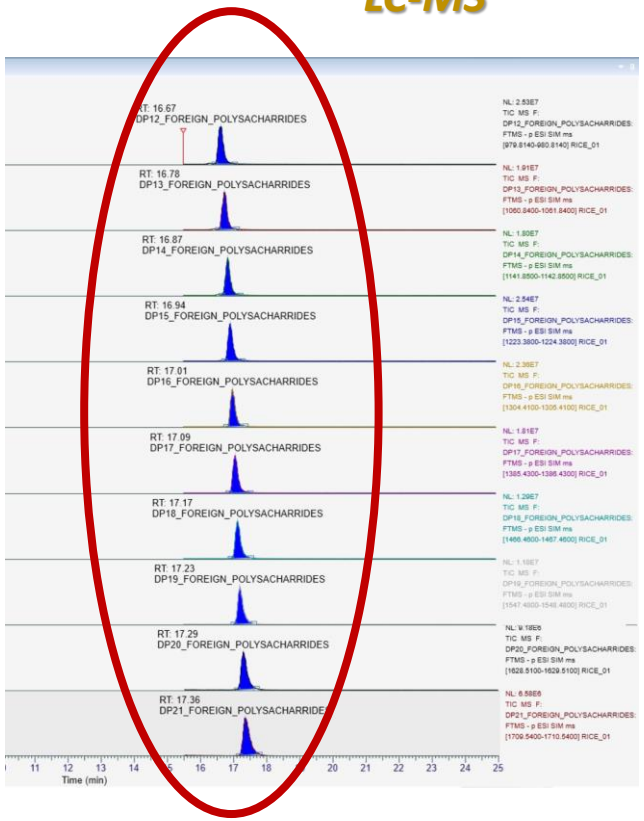
Foreign Oligosaccharides Monitoring

False Positives for Honeydew Honeys such as Pine, Oak, Metcalfa, Quillay !!!

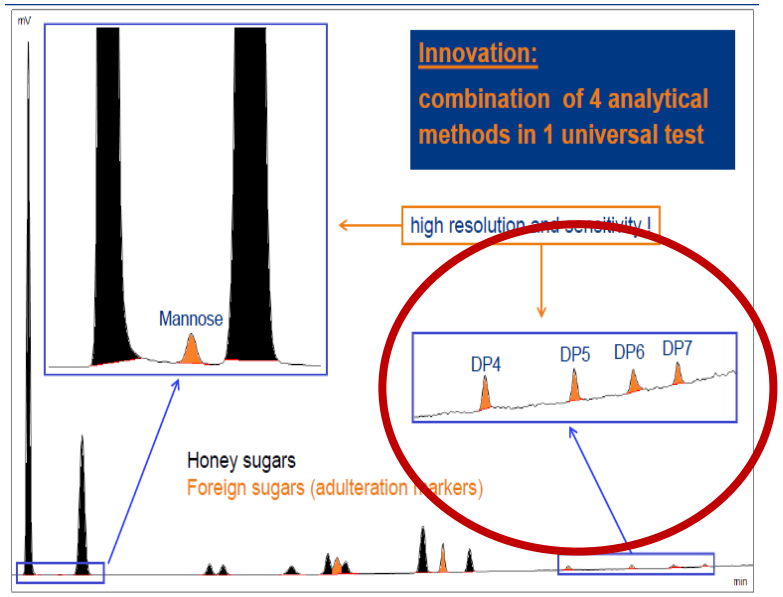
LC-ELSD/CAD

Fig. 3: LC-ELSD chromatogram of authentic and adulterated honey. The adulterated sample shows honey-foreign oligosaccharides (DP 5 to DP 10) which serve as marker substances to detect adulteration.

LC-MS



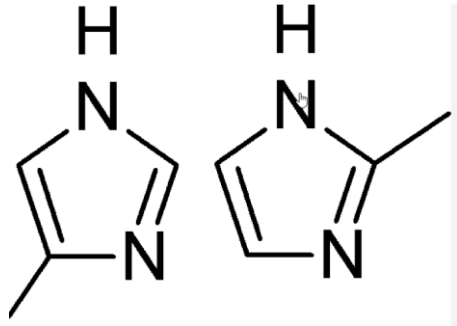
HPAE-PAD



Specific Markers for E150d Adulterants

E150d Food Dyes (Caramel Sulfide Coloring)

Methyl-imidazole derivates does not seem Reliable. Residues may also be observed due to the different botanical origins of honey !!!



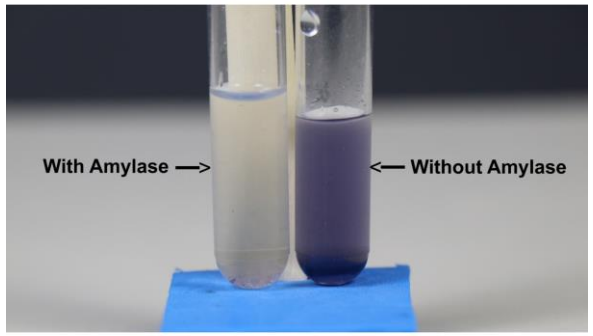
2-Methylimidazole / 4-Methylimidazole

X

Foreign Diastase

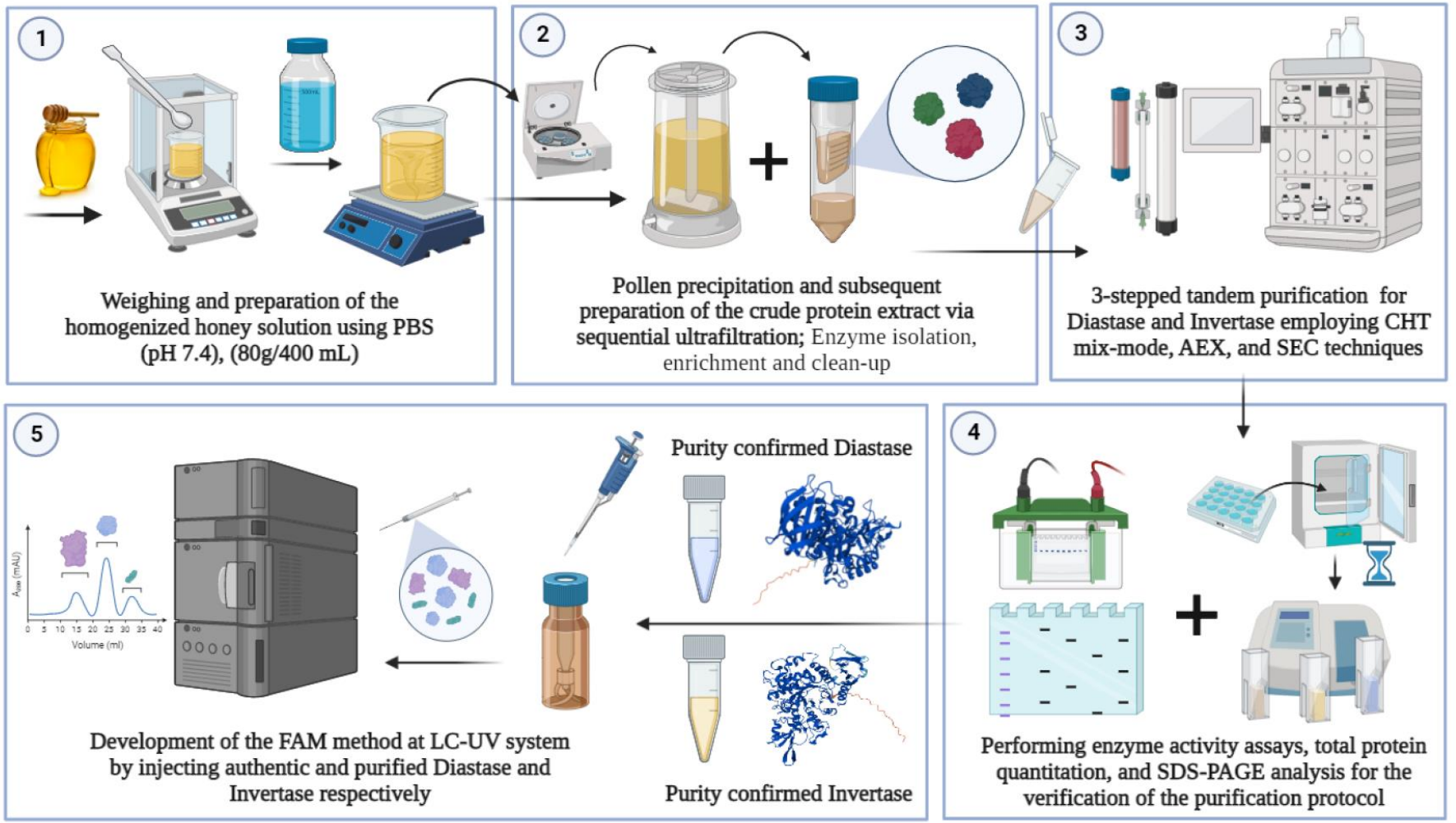
Typically, total diastase assays use pure or dye-conjugated starch as substrate and measurements are made colorimetrically after enzymatic hydrolysis.

These assays are not specific in terms of *Apis Mellifera* L. (honey bee) amylase and can produce false positives if amylases from other organisms are added to honey.



FAM (Foreign Amylase Monitoring)

(Enzyme extraction / Enrichment and Clean-up / Purification / LC-UV Analysis)



Publications

Microchemical Journal 193 (2023) 109039

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Straightforward monitoring of honey with foreign diastase by leveraging the differentiation in LC-UV proteome profiles of authentic and fraudulent samples

İsmail Emir Akyıldız [a,b,*,1], Özge Erdem [b,2], Sinem Raday [b,3], Sezer Acar [a,b,4], Dilek Uzunöner [b,5], Emel Damarlı [b,6], Ece Kök Yetimoğlu [a,7]

[a] Chemistry Department, Marmara University, Istanbul, Türkiye
[b] Balparmak R&D Center, Altıparmak Food Industry and Trade Inc., Istanbul, Türkiye

Journal of Food Measurement and Characterization
https://doi.org/10.1007/s11694-022-01380-8

ORIGINAL PAPER

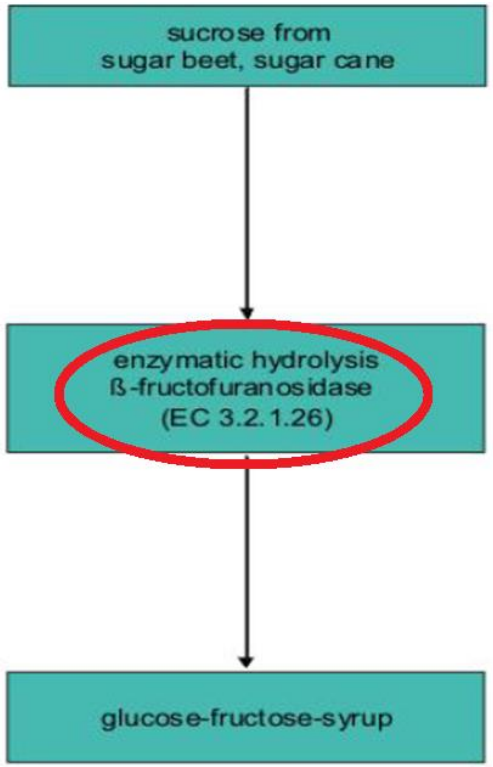
Development of a novel pretreatment protocol for the efficient isolation and enrichment of honey proteome using pine honey and the hypopharyngeal glands of *Apis mellifera* L.

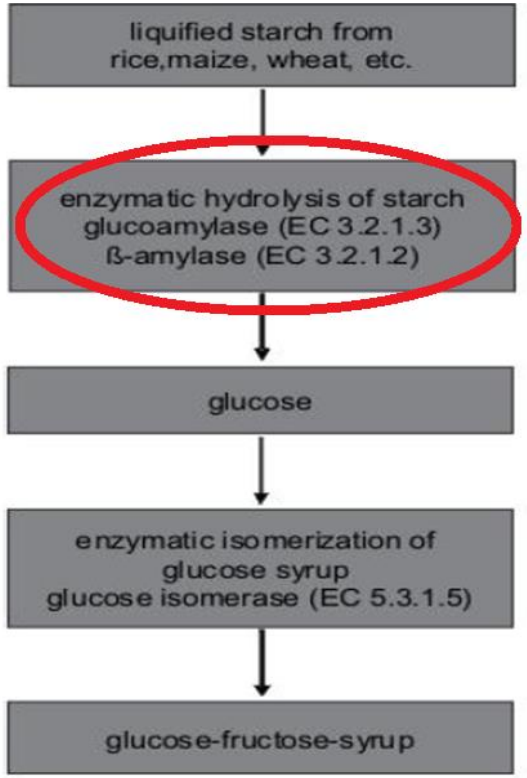
İsmail Emir Akyıldız[1,2] · Ece Kök Yetimoğlu[1] · Sinem Raday[2] · Özge Erdem[2] · Sezer Acar[1,2] · Özlem Yilmaz[2] · Dilek Uzunöner[2] · Gamze Düz[2] · Emel Damarli[2]

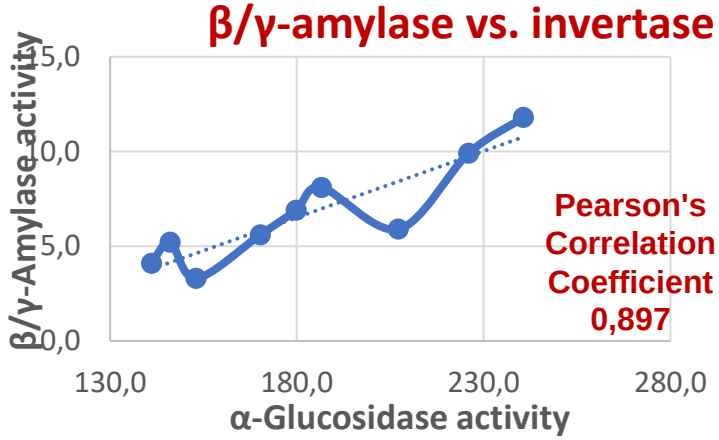
Received: 9 January 2022 / Accepted: 16 March 2022

ß-Fructofuranosidase and ß/γ Amylase Assays

Beet and Cane sucrose are inverted mostly using other techniques and/or BFF residue is removed !!!







Equal to or greater than 5 U/kg is considered as an indicator of the use of sugar syrup.

Pine honey has high invertase values and this creates false positives !!!

Trending Techniques

Non-Targeted Metabolomic (Foodomic) Based Adulteration Identification Methods

Conventional Single marker methods (targeted only)

Advanced Analytical Technologies

(Targeted and Untargeted Approaches)

As frauds become more sophisticated and deceive conventional techniques, there is a need for advanced multi-marker methods employing modern instrumentation !!!

Snippets From Our Novel Targeted & Un-Targeted Metabolomic Based HR-MS Method

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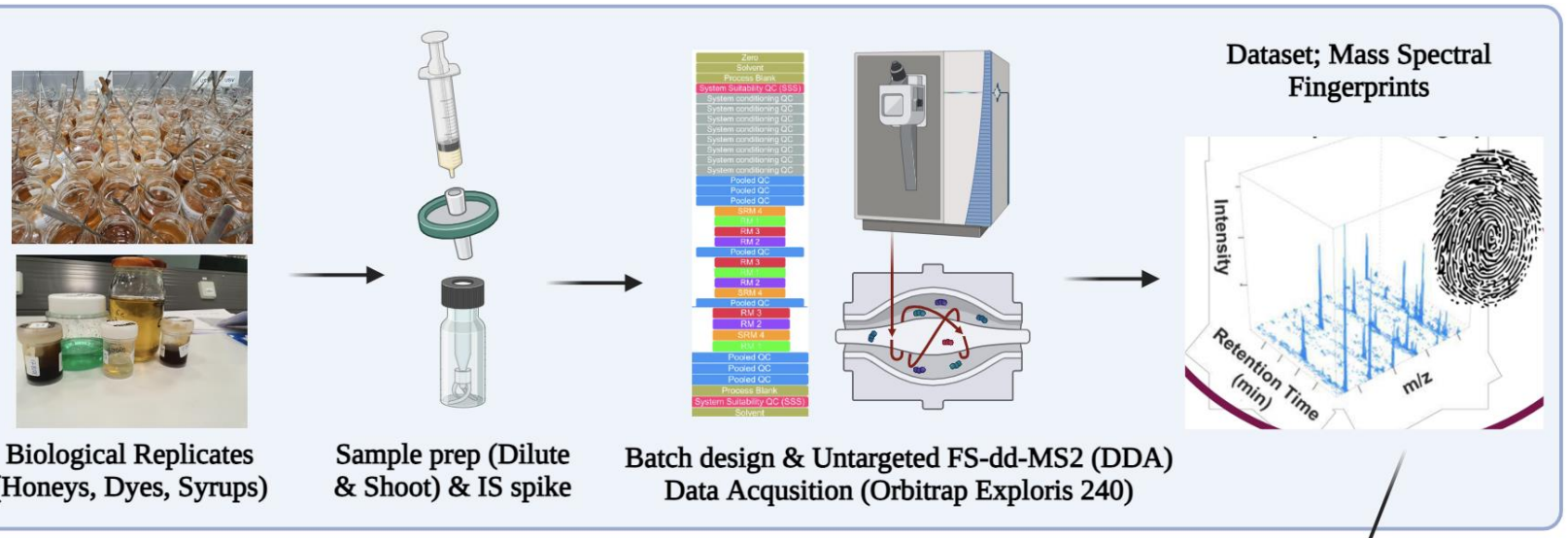
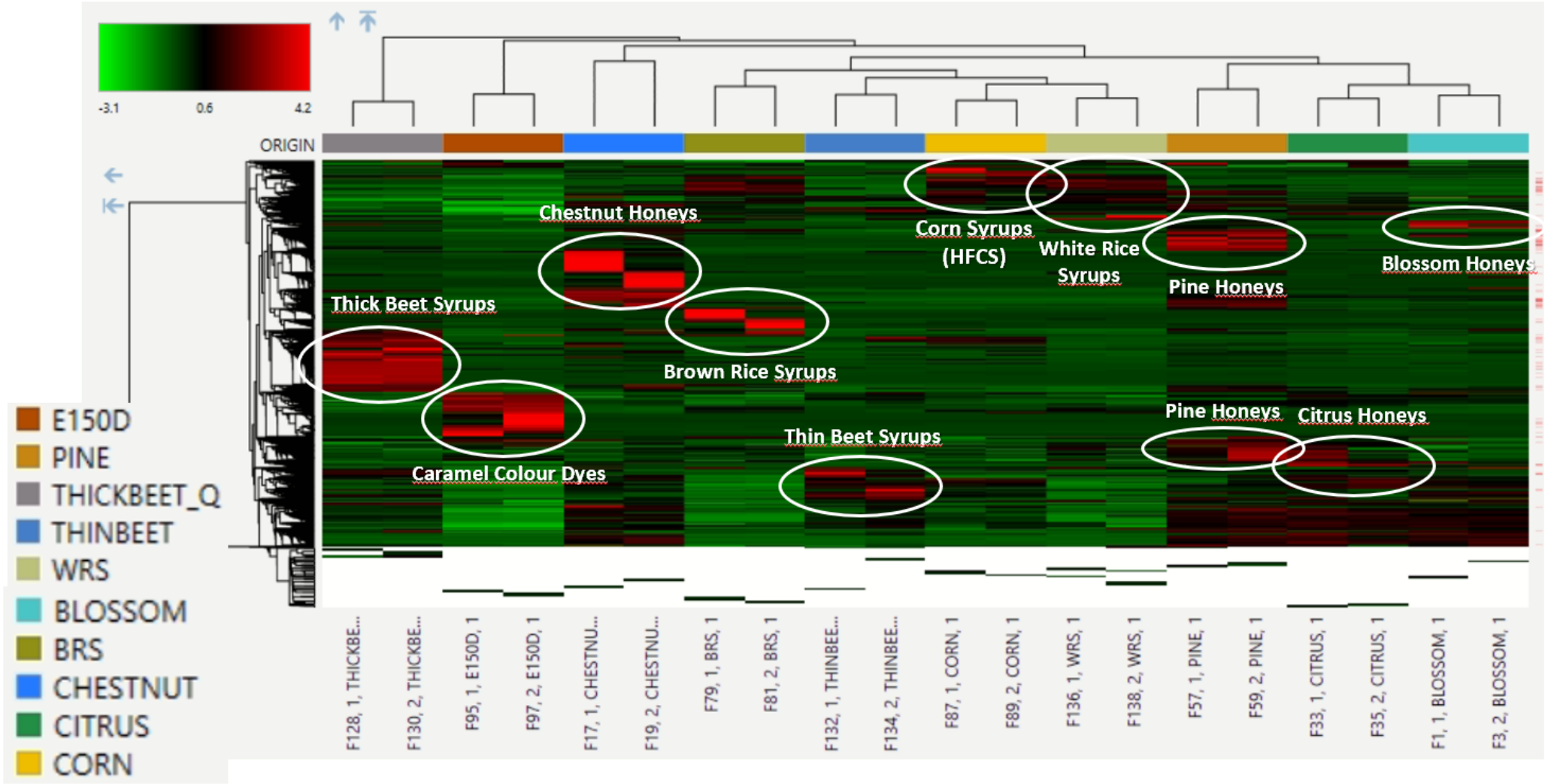
8th International Food Safety Congress
9-10 May 2024 Istanbul-TURKEY
Grand Cevahir Hotel & Convention Center
"Safe food for now and future"

Workflow – Untargeted Metabolomic Survey - Overview

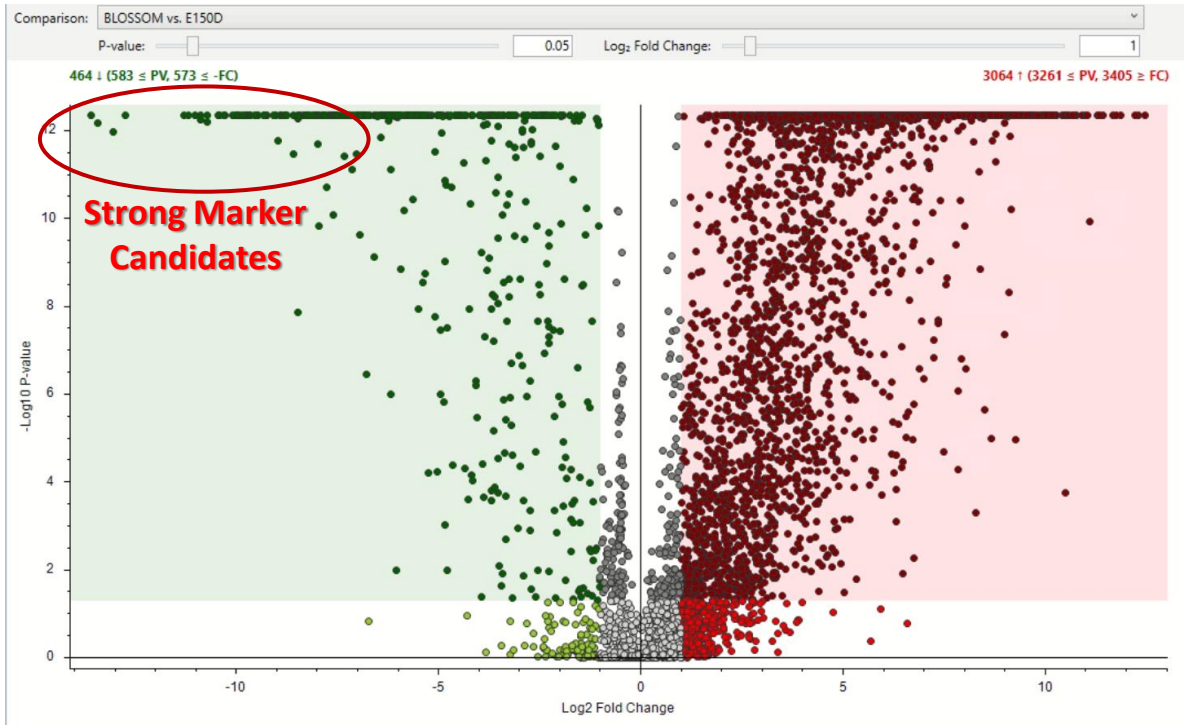


PCA Plots & Hierarchical Cluster Heatmaps (Shotgun Metabolomic – Adulterants & Honeys)



Volcano Plots
(Shotgun Metabolomic – Adulterants & Honeys)

Blossom Honey
vs
E150d Dyes



Blossom Honey
vs
Corn Syrups (HFCS)

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Targeted LC-SIM-MS Metabolomic

Multiplexed LC-SIM Assay; (E150d=10, BRS+WRS=5, CORN=9, BEET=11, Polysaccharides=10, Botanical Markers=4, Natural Honey Markers=2)

	Compound	Form	Adduct	Precursor (m/z)	Precursor Charge (z)	t start (min)	t stop (min)	Scan Width (m/z)	RF Lens (%)	Polarity
1	BRS_M1		(no adduct)	483.2729	1	2.9	6	1	70	Negative
2	BRS_M2		(no adduct)	520.3394	1	5.4	8	1	70	Positive
3	BRS_M3		(no adduct)	468.3082	1	5.3	8.5	1	70	Positive
4	E150D_M1		(no adduct)	188.9864	1	1.5	4.5	1	70	Negative
5	BEET+CORN_M1 (Inversion and/or isomerization marker)		(no adduct)	524.1495	1	8.5	13	1	70	Positive
6	BEET+CORN_M2 (Inversion and/or isomerization marker)		(no adduct)	344.1163	1	8.5	13	1	70	Positive
7	BEET_M1		(no adduct)	683.2248	1	11.5	13.5	1	70	Negative
8	BEET_M2		(no adduct)	127.0391	1	12.2	13.7	1	70	Positive
9	BEET_M3		(no adduct)	408.1113	1	11.1	13.2	1	70	Positive
10	BRS_M4		(no adduct)	554.3463	1	5.5	8.6	1	70	Negative
11	WRS_M1		(no adduct)	305.0878	1	5	10	1	70	Negative
12	BEET_M4		(no adduct)	504.1923	1	10	15.5	1	70	Positive
13	CORN_M1		(no adduct)	239.0229	1	4	6	1	70	Negative
14	CORN_M2		(no adduct)	299.9931	1	4	6	1	70	Negative
15	CORN_M3		(no adduct)	376.9669	1	4	6	1	70	Negative
16	BEET+CORN_M3		(no adduct)	298.989	1	4	6	1	70	Negative
17	CORN_M4		(no adduct)	221.0667	1	4	6	1	70	Negative
18	CORN_M5		(no adduct)	728.2101	1	14	15.5	1	70	Negative
19	CORN_M6		(no adduct)	695.4301	1	1.5	4	1	70	Negative
20	BEET_M5		(no adduct)	307.1023	1	10	14	1	70	Positive

	Compound	Formula	Adduct	Precursor (m/z)	Precursor Charge (z)	t start (min)	t stop (min)
1	DP12_FOREIGN_POLYSACHARRIDES		(no adduct)	980.314	2	15.5	25
2	DP13_FOREIGN_POLYSACHARRIDES		(no adduct)	1061.34	2	15.5	25
3	DP14_FOREIGN_POLYSACHARRIDES		(no adduct)	1142.35	2	15.5	25
4	DP15_FOREIGN_POLYSACHARRIDES		(no adduct)	1223.88	2	15.5	25
5	DP16_FOREIGN_POLYSACHARRIDES		(no adduct)	1304.91	2	15.5	25
6	DP17_FOREIGN_POLYSACHARRIDES		(no adduct)	1385.93	2	15.5	25
7	DP18_FOREIGN_POLYSACHARRIDES		(no adduct)	1466.96	2	15.5	25
8	DP19_FOREIGN_POLYSACHARRIDES		(no adduct)	1547.98	2	15.5	25
9	DP20_FOREIGN_POLYSACHARRIDES		(no adduct)	1629.01	2	15.5	25
10	DP21_FOREIGN_POLYSACHARRIDES		(no adduct)	1710.04	2	15.5	25

21	E150D_M2	(no adduct)	188.0023	1	1	4	1	70	Negative
22	E150D_M3	(no adduct)	194.9969	1	2	5	1	70	Negative
23	E150D_M4	(no adduct)	164.9863	1	2	5	1	70	Negative
24	E150D_M5	(no adduct)	203.9973	1	2	5	1	70	Negative
25	E150D_M6	(no adduct)	225.0075	1	5	8	1	70	Negative
26	E150D_M7	(no adduct)	247.0395	1	7	10	1	70	Negative
27	E150D_M8	(no adduct)	213.0075	1	11	14	1	70	Negative
28	E150D_M9	(no adduct)	182.9968	1	11	14	1	70	Negative
29	E150D_M10	(no adduct)	115.0411	1	7	10	1	70	Negative
30	Pine Marker_AcetylMaltose	(no adduct)	383.1194	1	11.5	13.5	1	50	Negative
31	(IS)_Glutaric Acid_neg	(no adduct)	131.0005	1	12	14	1	50	Negative
32	Citrus Marker_1_AnthranosideA	(no adduct)	314.1233	1	1	5	1	70	Positive
33	Citrus Marker_2_Caffeine	(no adduct)	195.0876	1	1	5	1	70	Positive
34	Chestnut Marker_KynurenicAcid	(no adduct)	188.0353	1	1	5	1	70	Negative
35	Manuka Marker_Rhamnopyranoside	(no adduct)	346.1497	1	1	7	1	70	Positive
36	Dilution Indicator_Gluconic Acid	(no adduct)	195.0516	1	12	15	1	70	Negative
37	Prolin	(no adduct)	116.1311	1	11	14	1	70	Positive

	Compound	Formula	Adduct	Precursor (m/z)	Precursor Charge (z)	t start (min)	t stop (min)
1	Psicose_Mannose_X_(MAJORITY BEET MARKERS)		(no adduct)	179.056	1	7.75	15

DEVELOPED SIM ACQUSITIONs for 50 Markers !!!

altıparmak

8th International Food Safety Congress
9-10 May 2024 Istanbul-TURKEY
"Safe food for now and future"

NMR & HR-MS Analysis Reports

Thin Beet (Refined-designer syrup) Inverted Sugar Syrup Detection

40% Thin Beet w/w

Assessment
The NMR profiling test did not reveal any sugar addition.

The NMR profiling test revealed the following anomalies:
- the sucrose level is higher than usual in polyfloral honeys and exceeds the maximum defined by the EC directive 2001/110 for honey in general

However without knowledge of the floral composition we have passed the sample in the benefit of the doubt.

NMR Failed !!!

Sample name	ST40
Packaging	Plastic cup
Sampler	Client
Number sample tubes	2
Type of seal	Without seal
Amount	approx.50 g (each)
Reception temperature	room temperature
Reception date time	26.09.2023
Start / End of analysis	26.09.2023 / 30.09.2023

Test results

Authenticity

THP01 Honey Authenticity by LC-HRMS (#)
Method ICS SOP 520-17 (2021-04), LC-Orbitrap-HRMS

	Result
Exogenous sugar	Not detected

HR-MS Failed

Methods Should be Advanced !!!

Proficiency / Verification

BIPEA PT Result

INTERLABORATORY COMPARISONS FINAL REPORT

PT: 46A-ADULTERATED HONEYS

(**Test No.** 9)

Matrix: Adulterated honey - 9-9

Month of the test: NOVEMBER 2023

Only 2 labs among 17 participants were able to report the beet syrup adulteration (13.2%, w/w) using novel HR-MS method (E9491 – Balparmak) !!!

CRITERION	INT46
UNIT	
LAB.	x
E1027	
E2560	
E2637	
E3028	
E3844	
E4698	
E5910	
E6009	
E6365	
E6414	
E7981	L'analyse par analyseur élémentaire couplé à un spectromètre de masse des rapports isotopiques a permis de mesurer la déviation isotopique du 13C du miel à et des protéines du miel. La différence arrondie (protéines-miel) est égale à -0.9 ce qui est supérieur à -1.2. Par conséquent ce miel ne semble pas être adultéré par un sucre exogène en C4.
E8152	The measured sample is likely not adulterated with any C4 derived sugar
E9043	LC_HRMS Marker: detected of beet sugar syrup; NMR Detection of foreign sugars = yes; beet sugar syrup (SM-B) positiv detected
E9151	Non conforme
E9411	
E9491	Adulterated with beet sugar syrup
E9843	

Steps	Detail of activities
Matrix	Polyfloral honey spiked with beet syrup.
Spiking	Yes (13.2%)

Real Sample Analysis

By utilizing novel targeted LC-SIM-MS metabolomic;

In 2023; 146 of 173 (72.3%) honeys from market were found as adulterated in alignment with the JRC report.

Predominant types of adulterations were found as beet syrup (inverted sugar syrup) (80%) and Foreign Diastase (89.2%).

This indicates inverted beet syrup usage and dilution effect masked with artificially increased diastase is the main fraudulent approach recently..

altıparmak

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