



FONDAZIONE  
EDMUND MACH



# DIFFA23

DIRECT INJECTION FOOD FLAVOUR ANALYTICS

---

BOOK OF ABSTRACTS

Fondazione Edmund Mach

San Michele all'Adige (TN), Italy

20 - 22 September 2023

---

1st International Symposium on  
Direct Injection Food Flavour Analytics (DIFFA)

*Edited by*

Research and Innovation Centre

Fondazione Edmund Mach

Via Mach, 1

38010 San Michele All'Adige (TN) Italy

phone +39 0461615427

fax +39 0461650872

[www.fmach.it](http://www.fmach.it)

ISBN 9788878430600



ISBN 9788878430600

**Proceedings of the DIFFA23 - 1<sup>st</sup> International Symposium on Direct Injection  
Food Flavour Analytics**

**Fondazione Edmund Mach – San Michele All’Adige (TN) Italy**

**20-22 September 2023**

This book collects the conference proceedings of the 1<sup>st</sup> International Symposium on Direct Injection Food Flavour Analytics, held at the Fondazione Edmund Mach from 20<sup>th</sup> to 22<sup>nd</sup> September 2023.





## SCIENTIFIC COMMITTEE

<b>Franco Biasioli - Chair</b>	Fondazione Edmund Mach, Italy
<b>Jonathan Beauchamp</b>	Fraunhofer Inst. Process Engineering and Packaging IVV, Germany
<b>Pat Silcock</b>	University of Otago, New Zealand
<b>Giuliana Bianco</b>	University of Basilicata, Italy
<b>Emanuela Gregori</b>	Istituto Superiore di Sanità, Italy
<b>Paola Montoro</b>	University of Salerno, Italy
<b>Donatella Caruso</b>	University of Milano, Italy
<b>Riccardo Flamini</b>	Crea-VE, Conegliano, Italy
<b>Gianluca Giorgi</b>	University of Siena, Italy
<b>Fulvio Magni</b>	University of Milano Bicocca, Italy
<b>Luciano Navarini</b>	Illycaffè, Trieste, Italy

## ORGANIZING COMMITTEE

<b>Emanuela Betta</b>	Fondazione Edmund Mach, Italy
<b>Franco Biasioli</b>	Fondazione Edmund Mach, Italy
<b>Andrea Dell'Olio</b>	Fondazione Edmund Mach, Italy
<b>Iuliia Khomenko</b>	Fondazione Edmund Mach, Italy
<b>Martina Moretton</b>	Fondazione Edmund Mach, Italy
<b>Michele Pedrotti</b>	Fondazione Edmund Mach, Italy
<b>Flaminia Vincenti</b>	Sapienza University of Roma, Italy
<b>Maria Assunta Acquavia - Secretary</b>	University of Basilicata, Italy



## TABLE OF CONTENTS

FOREWORD	1
CONFERENCE PROGRAM	3
LIST OF CONTRIBUTIONS	11
ABSTRACTS	17
LIST OF AUTHORS	187





## FOREWORD

Volatile organic compounds (VOCs), particularly flavour compounds, represent an invaluable noninvasive metric to follow the multi-faceted journey of food, from the farm to the fork and beyond, such as relating to the human microbiome after consumption or in addressing reduction strategies for food waste. VOCs thereby serve as a direct and swift means of measurement and notably act as a main driver of the perceived quality of food.

Mass spectrometry (MS) is an established yet increasingly pivotal tool in food and beverage characterization with a broad range of applications. When coupled with gas chromatography (GC), it stands as the predominant analytical method for exploring many aspects of food, from safety to traceability and nutritional aspects, and equally facilitates control measures in quality and process monitoring.

Recent remarkable advancements in both technology and methodology have paved the way for highly sensitive, specific, rapid, robust, and validated MS-based techniques that have become indispensable in food science and technology research and application. A subgroup of these technologies has been devised over the past two decades in the form of analytical approaches that enable the analysis of VOCs through direct injection. These methods have gained attention for their rapid, highly sensitive and high-throughput analytical capabilities.

A leading technology in this area is proton transfer reaction-mass spectrometry (PTR-MS), which has driven many innovative applications for direct flavour/food analysis. Commencing 2003, the University of Innsbruck, Austria, has organized a biennial event dedicated specifically to PTR-MS and its applications, including a focused session on food science and technology.

The **1<sup>st</sup> International Symposium on Direct Injection Food Flavour Analytics (DIFFA23)** was conceived with the backdrop of the PTR-MS conference but with a different aim, namely to embrace a broader community beyond PTR-MS uses, encompassing similar direct injection mass spectrometry (DIMS) technologies, such as atmospheric pressure chemical ionization-mass spectrometry (APCI-MS) and selected ion flow tube-mass spectrometry (SIFT-MS), with a primary emphasis on flavor compounds. It was also not exclusive to MS-based analytical techniques, but welcomed the inclusion of complementary non-MS approaches, such as solid-state sensors, fast gas chromatographic direct approaches and ion mobility spectrometry (IMS), amongst others, to ensure a wider reach and broader engagement. The meeting was established to foster scientific discussions of common interest and facilitate scientific collaborations. This book of abstract highlights the details of the event and contains the contribution summaries of both the oral and poster presentations.

The conference featured one plenary and four keynote lectures delivered by distinguished guests, as well as numerous invited and contributed talks and 25 poster presentations, with 97 attendees from different EU states, the USA, the UK, Israel and New Zealand. The event provided valuable insights into direct injection food/flavour analytics, with reviews from pioneering scientists who played key roles in developing and advancing DIMS methods in its early days, such as Andy Taylor, Patrik Španěl and Jean-Luc Le-Quéré, showcasing both historical developments and recent advancements in analytical performance and novel applications. Topics discussed included nose-space analysis of composite foods, rapid and high-throughput phenotyping, fermentation monitoring, both as an

innovative technological tool and for investigating the human microbiota, advanced data analysis and data mining tools. These are just a few examples of the themes explored during the conference.

Numerous partners contributed to the success of the event: the sponsors, whose engaging presentations and financial support sustained the quality of the meeting and ensured that the conference fees were kept to a minimum, as well as various supporting institutions and patronages. Special thanks go to the Fondazione Edmund Mach (FEM) for its scientific contributions and for hosting the conference at the Research and Innovation Centre, as well as the Division of Mass Spectrometry of the Italian Chemistry Society (DSM-SCI) for their organizational support and creation and hosting of the conference website. The invaluable support from these companies and institutions are further acknowledged through inclusion of their logos on the back cover of this book.

The conference started a fruitful exchange of results, ideas and issues amongst scientists working with direct tools to monitor VOCs in food science and technology, with broad attendance from sensory and applications scientists from academia and industry.

We would like to thank all those who, through their participation and support, made this event possible, which exceeded our most ambitious expectations.

Thank you all, and we look forward to seeing you at the next edition.

On behalf of the Scientific Committee

*Franco Biasioli, Jonathan Beauchamp, Pat Silcock*

## CONFERENCE PROGRAM

20<sup>th</sup> September 2023

12.30-14.00 Registration and welcome buffet

### Conference opening

14.00-14.10	Welcome addresses Fulvio Magni - <i>Società Chimica Italiana-Divisione Spettrometria di Massa</i> Mario Pezzotti - <i>Fondazione Edmund Mach</i>
14.10-14.20	Why DIFFA23? Franco Biasioli - <i>Fondazione Edmund Mach</i>
14.20-15.05	Plenary lecture: <i>DI-MS – A game changer for flavour research?</i> Andy Taylor - <i>University of Nottingham</i>

### Session 1 | Unlocking Flavour with DIMS

Chairs: Pat Silcock & Nina Cleve

15.05-15.35	Jonathan Beauchamp - Fraunhofer Institute for Process Engineering and Packaging IVV <i>The long and winding road: a flavoursome tale of PTR-MS</i>
15.35-15.55	Graham Eyres - <i>University of Otago</i> <i>What is Flavour and how can DIMS help untangle the puzzle?</i>
15.55-16.15	Andreas Mauracher - <i>IONICON</i> <i>Advantages of Next-Gen PTR-ToF instruments for food and flavour sciences</i>

16.15-17.00 Tea break and poster session

## Session 2 | DIMS in Health and Wellbeing

Chairs: Donatella Caruso & Eirini Pegiou

17.00-17.20	Josep Rupert - <i>Wageningen University &amp; Research</i> <i>Signalling volatile compounds in the human gut microbiota: new avenues offered by direct analytical methods.</i>
17.20-17.40	Chris Mayhew - <i>University of Innsbruck</i> <i>Real-Time Trace Analysis of Breath Volatiles using Proton Transfer Reaction Mass Spectrometry: implications for in-vivo flavour release measurements</i>
17.40-18.00	Enrico Davoli - <i>Istituto Mario Negri</i> <i>Direct analysis of sex-wellness products using a field deployable MS equipped with a Direct Sampling Atmospheric Pressure (DSAP) source</i>
18.00-18.20	Corrado Di Natale - <i>University of Rome Tor Vergata</i> <i>Direct injection mass spectrometry and gas sensors: a teacher-pupil relationship</i>
18.20-18.40	Luca Cappellin - <i>University of Padua</i> <i>Improved compound identification in direct VOC analysis using an EI&amp;CI-TOFMS</i>
19.00	Welcome cocktail - cloister of the monastery and historical cellar

**21<sup>st</sup> September 2023**

**Session 3 | Linking DIMS Data to Sensory Perception**

Chairs: Graham Eyres & Iuliia Khomenko

9.00-9.30	Jean-Luc Le-Quéré - <i>INRAE-CSGA Dijon</i> <i>Twenty years of Direct Injection Mass Spectrometry for aroma research in Dijon</i>
9.30-9.50	Catrienus De Jong - <i>Wageningen University &amp; Research</i> <i>Exploring new in vivo and in vitro methods to integrate sensory and instrumental analysis to get insight and improve the flavour of plant-based food products during oral processing and drinking</i>
9.50-10.10	Markus Stieger - <i>Wageningen University &amp; Research</i> <i>In vivo aroma release and sensory perception of composite foods</i>
10.10-10.20	Michele Pedrotti - <i>Wageningen University &amp; Research</i> <i>Characterization of plant-based milks by combining sensory analysis with headspace and nose-space direct injection mass spectrometry</i>
10.20-10.30	Karina Gonzalez-Estanol - <i>Wageningen University &amp; Research</i> <i>In vivo analysis of nose-space concentration by direct injection mass spectrometry to study the effect of chewing rate on aroma release during food consumption</i>
10.30-10.40	Laura Hill - <i>University of Nottingham</i> <i>Understanding the relationship between lipids, capsaicin and aroma release in confectionery</i>

10.40-11.10 Coffee break and poster session

## Session 4 | Flavour Complexity and Cooking

Chairs: Fulvio Magni & Caroline Perltier

11.10-11.30	Samo Smrke - <i>ZHAW School of Life Sciences and Facility Management</i> <i>Development of fast-GC PTR-MS method for coffee VOCs analysis</i>
11.30-11.45	Nina Cleve - <i>Fraunhofer Institute for Process Engineering and Packaging IVV</i> <i>Milk matters: Unraveling retronasal aroma release and perception of coffee by combining in vivo nosespace analytics with dynamic sensory methods</i>
11.45-12.05	Tomasz Majchrzak - <i>Gdansk University of Technology</i> <i>What happens when food goes into oil during deep frying? Monitoring the first minutes of frying using PTR-MS</i>
12.05-12.20	Gregory Schmauch - <i>Rational F&amp;E GmbH</i> <i>Influence of product quantity, cooking parameter and flow tube pressure on the measurement with Sift-MS in a cooking oven</i>
12.20-12.40	Vaughan Langford - <i>Syft Technologies</i> <i>Application of SIFT-MS to chemical and sensory screening of packaging materials</i>
12.40-14.00	Conference group photo and lunch

## Session 5 | Latest DIMS Showcasing

Chairs: Jonathan Beauchamp & Karina Estanol-Gonzalez

- |             |  |
|-------------|--|
| 14.00-14.15 | Terry Bates - <i>Cornell University</i><br><i>Rapid headspace solid-phase microextraction with sheets with direct analysis in real time mass spectrometry (SPMESH-DART-MS) of derivatized volatile phenols in grape juices and wines</i> |
| 14.15-14.30 | Matteo Tonezzer - <i>University of Cagliari</i><br><i>PTR-MS as a tool to understand and improve the performance of electronic noses</i>   |
| 14.30-14.45 | Andrea Warburton - <i>University of Otago</i><br><i>Application of PTR-ToF-MS to monitor development of flavour in sourdough</i>   |
| 14.45-15.05 | Paolo Redegalli - <i>Shimadzu Italia S.r.l.</i><br><i>Characterization of isoflavones and its metabolites in foods by direct probe ionization mass spectrometer (DPiMS) with high resolution detection</i>                               |
| 15.05-15.25 | Hansruedi Gygax - <i>GAS Dortmund</i><br><i>GC-IMS instruments and their use in food and flavour analysis</i>  |

15.25-16.15 Tea break and poster session

## Session 6 | Microbial, Fermentation and Modelling

Chairs: Riccardo Flamini & Michele Pedrotti

16.15-16.45	Pat Silcock - <i>University of Otago</i> <i>The use of DIMS to understand microbially induced flavour changes</i>
16.45-17.05	Vittorio Capozzi - <i>Institute of Sciences of Food Production - National Research Council of Italy (CNR)</i> <i>DIMS techniques and the study on microbial VOCs in food: flavour attributes, fermentation monitoring and emerging trends</i>
17.05-17.20	Eirini Pegiou - <i>Wageningen University &amp; Research</i> <i>Easy and fast detection of abnormal olive brine fermentation – A showcase of SPOTDETECT.</i>
17.20-17.40	Caroline Peltier - <i>INRAE</i> <i>Automatic pretreatment and multiblock analysis of flavor release and sensory temporal data simultaneously collected in vivo</i>
17.40-18.00	Ana Rita Monforte - <i>AFB INTERNATIONAL</i> <i>Modelling the kinetics of flavour formation &amp; release as a function of ingredients addition in real food systems</i>
18.00-18.20	Pietro Franceschi - <i>Fondazione Edmund Mach</i> <i>Mining datasets from untargeted direct analytical methods: a data analyst point of view</i>
18.20-18.35	Mickael Le Behec - <i>Institute of Analytical Sciences and Physico-Chemistry for Environment and Materials (IPREM)</i> <i>Volatile fingerprints of food thanks to the untargeted use of SIFT-MS raw data</i>

20.00 Social dinner - cloister of the Museo Etnografico Trentino



22<sup>nd</sup> September 2023

Session 7 | Food Spoilage and Off-Flavour

Chairs: Catreinus de Jong & Brian Farneti

9.30-10.00	Patrik Španěl - <i>J. Heyrovský Institute of Physical Chemistry</i> <i>Progress in Selected Ion Flow Tube Mass Spectrometry, SIFT-MS, analyses of food flavour, freshness and spoilage</i>
10.00-10.15	Antonella Grosso - <i>University of Bolzano</i> <i>Monitoring autoxidation of vegetable oils by proton transfer reaction mass spectrometry</i>
10.15-10.30	Pedro Martinez Noguera - <i>University of Copenhagen</i> <i>Using PTR-ToF-MS to quantify microbial off-flavors geosmin and 2-methylisoborneol in water. Method development, performance assessment and comparison with established GC-MS methods</i>
10.30-10.45	Davide Papurello - <i>Turin Polytechnic</i> <i>Supporting sustainable energy production by PTR-MS: a review on the work accomplished on biofuel production from food waste to SOFC systems</i>
10.45-11.05	Rupert Holzinger - <i>Utrecht University</i> <i>Using SI traceable gas standards to improve the accuracy of untargeted PTR-MS measurements</i>

11.05-11.45 Coffee break and Poster Session

## Session 8 | Floral, Biogenics and Phenotyping

Chairs: Rupert Holzinger & Vittorio Capozzi

11.45-12.05	Štefan Matejčík - <i>Comenius University</i> <i>Ion mobility spectrometry detection of plant hormones</i>
12.05-12.25	Brian Farneti - <i>Fondazione Edmund Mach</i> <i>DI-MS as high performing VOC phenotyping tool to support the horticultural production chain management</i>
12.25-12.40	Alberto Roncone - <i>Fondazione Edmund Mach</i> <i>Validation of gas chromatographic methods for the botanical characterization and authentication of lavender essential oil by stable isotope analysis of its organic volatile compounds</i>
12.40-12.55	Eugenio Aprea - <i>University of Trento</i> <i>Contribution of volatile organic compounds to multifloral honey flavor</i>
12.55-13.15	Daniele Zatta - <i>University of Padua</i> <i>Comparative analysis of VOC purification techniques in complex cooking emission: adsorption, photocatalysis and combined systems.</i>
13.15-13.30	Closing remarks Fulvio Magni - <i>Società Chimica Italiana-Divisione Spettrometria di Massa</i> Franco Biasioli - <i>Fondazione Edmund Mach</i>

13.30 Farewell buffet

## LIST OF CONTRIBUTIONS

<b>Plenary Lecture</b>		<b>Pag</b>
PL.01	DI-MS – A game changer for flavour research? <i>Andy Taylor</i>	17
<b>Keynote Speakers</b>		
K.01	The long and winding road: a flavoursome tale of PTR-MS <i>Jonathan Beauchamp</i>	20
K.02	Twenty years of Direct Injection Mass Spectrometry (DIMS) for aroma research in Dijon <i>Jean-Luc Le Quéré</i>	22
K.03	The use of DIMS to understand microbially induced flavour changes <i>Patrick Silcock</i>	24
K.04	Progress in Selected Ion Flow Tube Mass Spectrometry, SIFT-MS, analyses of food flavour, freshness and spoilage <i>Patrik Španěl</i>	25
<b>Invited Speakers</b>		
I.01	What is Flavour and how can DIMS help untangle the puzzle? <i>Graham T. Eyres</i>	27
I.02	Signaling volatile compounds in the human gut microbiota: new avenues offered by direct analytical methods <i>Rubert Josep, Dell'Olio Andrea, Fogliano Vincenzo, Khomenko Iuliia, Betta Emanuela, Capozzi Vittorio, Biasioli Franco</i>	28
I.03	Real-Time Trace Analysis of Breath Volatiles using Proton Transfer Reaction Mass Spectrometry: implications for <i>in-vivo</i> flavour release measurements <i>Chris A. Mayhew</i>	30
I.04	Direct injection mass spectrometry and gas sensors: a teacher-pupil relationship <i>Rosamaria Capuano, Alexandro Catini, Corrado Di Natale</i>	32
I.05	Exploring new <i>in vivo</i> and <i>in vitro</i> methods to get insight and improve the flavour release of plant-based food products during oral processing <i>Catrienus de Jong, Rene de Wijk, Valentina Acierno, Rita Boerrigter-Eenling</i>	34
I.06	<i>In vivo</i> aroma release and perception of composite foods using nose space PTR–ToF–MS analysis with Temporal-Check-All-That-Apply <i>Karina Gonzalez-Estanol, Iuliia Khomenko, Danny Clicer, Franco Biasioli, Markus Stieger</i>	35
I.07	Development of Fast-GC PTR-MS Method for Coffee VOCs Analysis <i>Samo Smrke, Oliver Lipp, Nicolas Wernli, Chahan Yeretizian</i>	36
I.08	What happens when food goes into oil during deep frying? Monitoring the first minutes of frying using PTR-MS.	38

	<i>Rohmah Nur Fathimah, Muhammad Saad Arshad, Tomasz Majchrzak</i>	
I.09	DIMS techniques and the study on microbial VOCs in food: flavour attributes, fermentation monitoring and emerging trends <i>Mariagiovanna Fragasso, Antonia Corvino, Martina Moretton, Iuliia Khomenko, Vittorio Capozzi</i>	41
I.10	Automatic pre-treatment and multiblock analysis of flavor release and sensory temporal data simultaneously collected <i>in vivo</i> <i>Caroline Peltier, Michel Visalli, H��l��ne Labour��, Cantin H��lard, Isabelle Andriot, Sylvie Cordelle, Jean-Luc Le Qu��r��, Pascal Schlich</i>	44
I.11	Modelling the kinetics of flavour formation & release as a function of ingredients addition in real food systems <i>Ana Rita Monforte, Sara Martins</i>	46
I.12	Volatile fingerprints of food thanks to the untargeted use of SIFT-MS raw data <i>Mickael Le Behec, Marine Reyrolle, Val��rie Desauziers, Thierry Pigot, Gilles Bareille, Sylvain Berail, Ekaterina Epova, Julien Barre, Lydia Gautier, Val��rie Chesneau</i>	47
I.13	Using SI traceable gas standards to improve the accuracy of untargeted PTR-MS measurements <i>Rupert Holzinger, Dusan Materic, Sebastien Dusanter, Sergi Moreno, David Worton</i>	50
I.14	Ion mobility spectrometry detection of plant hormones <i>Vahideh Ilbeigi, Younes Valdbeigi, Ladislav Moravsk��y, ��tefan Matej��k</i>	53
I.15	DI-MS as high performing VOC phenotyping tool to support the horticultural production chain management <i>Brian Farneti</i>	56

### Sponsored talk

S.01	Advantages of Next-Gen PTR-TOF instruments for food and flavour sciences <i>A. Mauracher, R.Gutmann, S. Feill, A. Jordan, J. Herbig, M. M��ller, T. Reinecke, P. Sulzer</i>	58
S.02	Improved compound identification in direct VOC analysis using an EI&CI-TOFMS <i>Luca Cappellin, Marleen Vetter, Christina Hinterleitner, Steffen Br��kling, Sonja Klee</i>	60
S.03	Application of SIFT-MS to Chemical and Sensory Screening of Packaging Materials <i>Vaughan Langford, Mark Perkins</i>	63
S.04	Characterization of Isoflavones and Its Metabolites in Foods by Direct Probe Ionization Mass Spectrometer (DPiMS) with High Resolution Detection <i>Paolo Redegalli</i>	64
S.05	GC-IMS instruments and their use in Food and Flavour Analysis <i>Hansruedi Gygax, Thomas Wortelmann</i>	67

S.06	Comparative analysis of VOC purification techniques in complex cooking Emission: adsorption, photocatalysis and combined systems. <i>Daniele Zatta, Mattia Segata, Franco Biasioli, Ottaviano Allegretti, Roberto Verucchi, Francesco Chiavarini, Luca Cappellin</i>	69
------	---	----

## Orals

O.01	Direct analysis of sex-wellness products using a field deployable MS equipped with a Direct Sampling Atmospheric Pressure (DSAP) source <i>Enrico Davoli, Alice Passoni, Claudio Medana, Enrica Mecarelli, Victor Laiko, Vladimir M. Doroshenko</i>	72
O.02	Characterization of plant-based milks by combining sensory analysis with headspace and nose-space direct injection mass spectrometry <i>Michele Pedrotti, Puneet Mishra, Christian Wintermeyer, Lars Grohmann, Annika Volle, Sylvia Barnekow, Theo Verkleij</i>	74
O.03	<i>In vivo</i> analysis of nose-space concentration by direct injection mass spectrometry to study the effect of chewing rate on aroma release during food consumption <i>Karina Gonzalez-Estanol, Michele Pedrotti, Monica Fontova-Cerda, Iuliia Khomenko, Franco Biasioli, Markus Stieger</i>	76
O.04	Understanding the relationship between lipids, capsaicin and aroma release in confectionery <i>Laura Hill, Lewis Jones, Katrin Pechinger, Ni Yang</i>	78
O.05	Milk matters: Unraveling retronasal aroma release and perception of coffee by combining <i>in vivo</i> nosespace analytics with dynamic sensory methods <i>Nina Cleve, Karina Gonzalez-Estanol, Iuliia Khomenko, Luca Cappellin, Jonathan Beauchamp, Franco Biasioli</i>	81
O.06	Influence of product quantity, cooking parameter and flow tube pressure on the measurement with Sift-MS in a cooking oven <i>Grégory Schmauch, Eugen Engelmann</i>	85
O.07	Rapid headspace solid-phase microextraction with sheets with direct analysis in real time mass spectrometry (SPMESH-DART-MS) of derivatized volatile phenols in grape juices and wines <i>Terry L. Bates, Gavin Sacks</i>	87
O.08	PTR-MS as a tool to understand and improve the performance of electronic noses <i>Matteo Tonezzer</i>	89
O.09	Application of PTR-ToF-MS to monitor development of flavour in sourdough. <i>Andrea Warburton, Graham Eyres, Pat Silcock</i>	90
O.10	Easy and fast detection of abnormal olive brine fermentation – A showcase of SPOTDETECT <i>Eirini Pegiou, Maxence Paillart, Yannick Weesepeol</i>	93
O.11	Mining datasets from untargeted direct analytical methods: a data analyst point of view <i>Pietro Franceschi</i>	96

O.12	Monitoring autoxidation of vegetable oils by Proton Transfer Reaction Mass Spectrometry <i>Antonella L. Grosso, Ksenia Morozova, Giovanna Ferrentino, Matteo Scampicchio</i>	97
O.13	Using PTR-ToF-MS to quantify microbial off-flavors geosmin and 2-methylisoborneol in water. Method development, performance assessment and comparison with established GC-MS methods. <i>Pedro Martínez Noguera, Sylvester Holt, Raju Podduturi, Wender L.P. Bredie, Jonathan Beauchamp, Mikael A. Petersen</i>	100
O.14	Supporting sustainable energy production by PTR-MS: a review on the work accomplished on biofuel production from food waste to SOFC systems <i>Davide Papurello, Silvia Silvestri</i>	103
O.15	Validation of gas chromatographic methods for the botanical characterization and authentication of lavender essential oil by stable isotope analysis of its organic volatile compounds <i>Alberto Roncone, Purna K. Khatri, Mauro Paolini, Roberto Larcher, Luca Ziller, Dana Alina Magdas, Olivian Marincas, Luana Bontempo</i>	111
O.16	Contribution of volatile organic compounds to multifloral honey flavor <i>Eugenio Aprea, Danny Clicer, Emanuela Betta, Flavia Gasperi</i>	113

## Posters

P.01	Effect of different carbon sources on fermentation volatile organic compounds (VOCs) profile by <i>Levilactobacillus brevis</i> WLP672 using proton transfer reaction-time of flight-mass spectrometry (PTR-ToF-MS) <i>Sarathadevi Rajendran, Iuliia Khomenko, Patrick Silcock, Emanuela Betta, Franco Biasioli, Phil Bremer</i>	116
P.02	“Mild” Extra Virgin Olive Oil: evolution of the volatile profile during storage <i>Benedetta Fanesi, Deborah Pacetti, Erica Moret, Paolo Lucci, Lanfranco Conte, Mauro Amelio</i>	119
P.03	PTR-ToF-MS as a high sensitivity sensor for online monitoring of lacto-fermentation in plant-based beverages <i>Antonia Corvino, Maria Mazzucotelli, Iuliia Khomenko, Vittorio Capozzi</i>	122
P.04	Sensor Array for alcoholic beverages discrimination <i>Lai Van Duy, Rosamaria Capuano, Alexandro Catini, Nguyen Van Duy, Nguyen Duc Hoa, Matteo Tonezzer, Corrado Di Natale</i>	126
P.05	Human Volatilomics with GC/IMS <i>Rosamaria Capuano, Alexandro Catini, Corrado Di Natale</i>	129
P.06	Volatile compounds of natural vanilla-extract and stable isotope ratio analysis of carbon and hydrogen of vanillin and ethyl vanillin: Validation of a GC-IRMS analytical method <i>Long Chen, Purna K. Khatri, Mauro Paolini, Roberto Larcher, Luca Ziller, Luana Bontempo</i>	131

P.07	Characterization of fresh and oxidized coriander seed oil volatilome by using PTR-MS <i>Antonella L. Grosso, Katerina Sasinova, Giovanna Ferrentino, Matteo Scampicchio</i>	134
P.08	Automated untargeted peak detection for GC-IMS data <i>Maria Mazzucotelli, Pietro Franceschi</i>	137
P.09	Application of conventional and rapid analytical strategies for hazelnut volatilome characterization <i>Maria Mazzucotelli, Pietro Franceschi, Iuliia Khomenko, Brian Farneti, Emanuela Betta, Elena Gabetti, Luca Falchero, Andrea Cavallero, Eugenio Aprea</i>	139
P.10	Preliminary screening of elderly gut microbiota metabolites of pea protein enrich-bread <i>Martina Moretton, Monica Anese, Edoardo Capuano, Nicoletta Pellegrini</i>	142
P.11	Tailoring dietary intervention based on PTR-ToF-MS rapid pre-clinical screening <i>Andrea Dell'Olio, Josep Rubert, Vincenzo Fogliano, Vittorio Capozzi, Iuliia Khomenko, Martina Moretton, Franco Biasioli</i>	145
P.12	Characterization of key aroma compounds during black garlic production: GC-MS analyses and SIFT-MS quantification <i>Kseniya Dryahina, Emre Turan, Nikola Sixtova, Gülşah Özcan Sinir, Atilla Şimşek, Patrik Španěl</i>	147
P.13	PTR-ToF-MS VOC's profiling and monitoring of Red Delicious and Granny Smith apples <i>Alessia Panarese, Iulia Khomenko, Brian Farneti, Franco Biasioli, Angelo Zanella</i>	150
P.14	PTR-MS applications inside the SISTERS project – Preventing food loss and waste of fresh vegetables by monitoring quality decay through VOCs emissions <i>Pedrotti Michele, Emanuela Betta, Khomenko Iuliia</i>	153
P.15	PTR-Tof-MS analyses as a high-throughput volatilome phenotyping technique in a Genome Wide Association study of an almond germplasm collection <i>Leonardo Luca*, Brian Farneti, Iulia Khomenko, Mario Di Guardo, Stefano La Malfa, Alessandra Gentile, Franco Biasioli, Gaetano Distefano</i>	156
P.16	Volatile organic compounds: a potential marker for early detection of kiwifruit Storage Breakdown Disorder (SBD) <i>Andrea Strano, Brian Farneti, Iulia Khomenko, Emanuela Betta, Franco Biasioli, Francesco Spinelli</i>	157
P.17	Evaluation of flavour release and perception from sugar-free chewing gum using APCI-MS and temporal sensory profiling <i>Jing Feng, Gary Gray, Rebecca Ford, Ni Yang</i>	161
P.18	Emission of volatile organic compounds from wild mushrooms and coffee using proton transfer reaction mass spectrometry <i>T. Wróblewski, A. Kamińska, A. Włodarkiewicz, D. Ushakou, G. Karwasz</i>	164
P.19	Direct-Mass Spectrometry in wine analysis <i>Annarita Panighel, Mirko De Rosso</i>	167

P.20	High-throughput automatic cooking, analysis, and data mining of food matrices by PTR-ToF-MS <i>Iuliia Khomenko</i>	169
P.21	Influence of the model cheese composition on the aroma content, release and perception <i>I. Andriot, C. Septier, C. Peltier, P. Barbet, R. Palme, C. Arnould, S. Buchin, C. Salles</i>	171
P.22	Dynamic production of standards gases with liquid & online monitoring with VOCUS CI TOF at ppb level <i>L. Damont, L. Cossard, T. Bruderer</i>	173
P.23	Relevance of VOCs in microbial cross-over: the potential of DIMS in assisting new product development <i>Mariagiovanna Fragasso, Hülya Cunedioğlu, Antonia Corvino, Ester Presutto, Andrea Dell'Olio, Giuseppe Spano, Vittorio Capozzi</i>	176
P.24	Real time MS nose space monitoring allows to get insights into biological and behavioral factors affecting the inter-individual variability on flavor release <i>Leonardo Menghi, Iuliia Khomenko, Michele Pedrotti, Danny Clicerì, Eugenio Aprea, Isabella Endrizzi, Franco Biasioli, Flavia Gasperi</i>	178
P.25	Stable isotope ratio analysis for the authentication of organic wheat, pasta and bakery products <i>Zoe Giannioti, Alberto Roncone, Michele Suman, Luana Bontempo</i>	181
P.26	Venezuelan stingless bee <i>Tetragonisca angustula</i> (Latreille, 1811) pot-pollen and cerumen pollen pot Volatile Organic Compound VOC profiles by HS-SPME/GC-MS <i>Emanuela Betta, Ricardo R Contreras, Enrique Moreno, Silvia RM Pedro, Iuliia Khomenko, Patricia Vit</i>	183



## O.16 Contribution of volatile organic compounds to multifloral honey flavor

Eugenio Aprea<sup>1\*</sup>, Danny Cliceri<sup>1</sup>, Emanuela Betta<sup>2</sup>, Flavia Gasperi<sup>1</sup>

<sup>1</sup>Center Agriculture Food Environment (C3A), University of Trento, Trento, Italy

<sup>2</sup>Research and Innovation Centre, Fondazione Edmund Mach, San Michele All'Adige, Italy

\*eugenio.aprea@unitn.it

*Summary:* With the scope of exploring flavor determinants of multifloral honeys, the VOC profile of multifloral honeys from Trentino area were acquired by SPME/GC-MS and associated with the sensory descriptive profiles obtained by Check-all-that-apply (CATA) method generated by a trained panel of honey experts.

*Keywords:* SPME/GC-MS, CATA, Multifloral honey

### 1 Introduction

Multifloral honey is derived from the nectar of multiple natural sources, collected by honeybees from various flowers and plants, resulting in a blend of different floral flavors. From a chemical-physical standpoint, multifloral honey includes honeys that don't fit within limits set for "monofloral" honeys, forming a continuum that makes it hard to distinguish characteristic groups. The high variability of botanical species in multifloral honey causes its "downgrading," but also grants it complexity and unique sensory quality. The variety and quantity of nectar sources in multifloral honey are closely linked to the territory and seasons. For instance, multifloral honey from Trentino blends temperate, sub-Mediterranean, Mediterranean, and Alpine climates, creating a diverse botanical variety. Understanding whether this combination generates distinctive characteristics for a specific area is relevant for local product promotion.

From the flavor point of view, multifloral honey can be considered the maximum expression of the flora of a territory, often resulting in unique and often unrepeatable combination of sensory characteristics. These peculiarities can be objectified with sensory science approaches that make it possible to obtain the descriptive profile of a food. In a broader sense, the enhancement of multifloral honey can find a more complete vision by studying the volatile organic compounds (VOC) responsible for the differ flavor components. The aim of the study was to identify the VOCs mainly involved in the odor and flavor perception of multifloral honey. In this first attempt we focused on honey flavor macro categories.

### 2 Experimental

Samples: Thirty-six multifloral honeys produced in 2021 collected from the Trentino (Italy) representative of the different mountain areas with different botanical characteristics.

VOCs profile: VOCs were measured by SPME/GC-MS. 1 g of honey was mixed with 1 mL of distilled water and 0.5 g of NaCl within a 20 mL GC vial and spiked with 2-octanol. SPME and GC-MS details can be found in [1]. Data were reported as the relative amount of 2-octanol used ad IS.

Sensory profile: After proper training, 47 judges described the odors by smelling and the flavors by tasting the samples (14 g of honey in a 40 ml glass jar) using CATA method [2] with sensory attributes from the honey sensory wheel [3] and evaluated their category representativeness. The evaluations were carried out remotely and samples were provided anonymously and in randomized order.

Data analysis: Attributes from CATA were submitted to Cochran Q test to identify significant discriminating descriptors. Spearman correlation coefficient was applied to study associations between category representativeness and attributes. Multivariate visualization was obtained through Multi Factor Analysis applied on discriminating descriptors. Data from SPME/GC-MS were pre-processed by a Log transformation, mean-centered and scaled to pareto scaling. CV-ANOVA was performed to assess the reliability of PLS predictive models cross-validated [4]. The coefficients were used to assess the contribution of the single volatile compounds to the model of each sensory descriptor. Multivariate analyses were performed by SIMCA 17.2 software and R software v 3.1.1.

### 3 Results

Sensory data: 49 sensory attributes out of 55 were found to be significantly discriminative. The descriptors with a positive contribution on category representativeness ( $Rho > 0.7$ ) were related to the odor and flavor of the Fruity family, the Vegetable, the Animal, the Acid taste, the Astringent sensation, the light Amber color, and a Fluid consistency.

VOCs data: From Honey chromatograms 118 peaks have been extracted of which 108 have been identified while 10, present clearly in some of the honeys, are reported as unknown. Forty-four compounds were present in all the analyzed honeys and 18 compounds were present in at least half of the samples. The chemical class mainly represented is that of the terpenes with at least 47 compounds (at least 2 of the unknown present typical fragments of terpenes). The other compounds, reported in decreasing order, belong to the following chemical classes: alcohols (16), aldehydes (10), esters (8), acids (7), ketones (6), furans (4), norisoprenoids (3), N-compounds (3), hydrocarbons (2) and a S-compound and the cyclohexyl isothiocyanate.

Association models. To identify the association between VOCs and the sensory descriptors (odor and flavor attributes), OPLS regression models were built and tested by CV-ANOVA ( $\alpha < 0.001$ ) and the coefficients of these models were used to identify the contribution of the VOCs to the different sensory descriptors in honeys (Table1).

**Table 1.** Main associations between sensory macro categories and VOCs. *o*- odor, *f*- flavor

Attribute	Main associated VOCs			
<i>o</i> -Floral	4,5-Dimethylfurfural	Heptanal	Nonanal	Lilac Aldehydes (A,B,C,D)
<i>o</i> -Warm	Ethyl hexadecanoate	Ethyl tetradecanoate	3-Methyl-3-buten-1-ol	Lavender lactone
<i>o</i> -Aromatic	Ethyl tetradecanoate	Ethyl hexadecanoate	Isoamyl acetamide	Thymol
<i>o</i> -Chemical	Ethyl tetradecanoate	Ethyl hexadecanoate	8-p-Menthen-1,2-diol	Isoamyl acetamide
<i>f</i> -Floral	4,5-Dimethylfurfural	<i>p</i> -Cymen-8-ol	Lilac Aldehydes (A,B,C,D)	( <i>Z</i> )-Linalool oxide (furan)
<i>f</i> -Fruit	Terpenediol I	UnknownH	UnknwonF	Ipomeanol
<i>f</i> -Warm	Ethyl hexadecanoate	Ethyl tetradecanoate	3-Methyl-3-buten-1-ol	Borneol
<i>f</i> -Aromatic	Isoamyl acetamide	Benzyl Alcohol	Ethyl tetradecanoate	8-p-Menthen-1,2-diol
<i>f</i> -Chemical	Ethyl tetradecanoate	8-p-Menthen-1,2-diol	Thymol	Ethyl hexadecanoate

For example, among the main contributors to the *o*-Floral, we found heptanal, described as fresh, green, citrus-like [5], nonanal, described as waxy, aldehydic, citrus, green lemon peel like and

cucumber fattiness [5] and the 4 stereoisomers of lilac aldehyde that are characterized by flowery odors [6]. The sensory categories of o-Warm, o-Aromatic and o-Chemical partial overlap and encompass a broad range of more specific attributes. Their common characteristics are supported by the presence of the two esters ethyl tetradecanoate and ethyl hexadecanoate which contribute sweet, waxy, fruity, creamy, and balsamic notes [5]. However, the differentiation among the three categories is defined by the combinations of specific compounds, mainly belonging to the terpene class.

#### 4 Conclusions

In this study, we assessed the qualitative impact of volatile organic compounds on odor and flavor macro attributes in multifloral honey. The identified associations align with the sensory influence of individual compounds, whose combination give rise to the rich flavor profile of the honeys. We believe that this approach can be expanded to sensory subcategories to encompass more precise sensory attributes, thereby enhancing the correlation between odor/flavor descriptors and chemical compounds.

#### References

- [1] A.C. Mosca, L. Menghi, E. Aprea, M. Mazzucotelli, J. Benedito, A. Zambon, S. Spilimbergo, F. Gasperi; *Molecules*, 25 (2020), p. 5598.
- [2] J. Adams, A. Williams, B. Lancaster, M. Foley; *7<sup>th</sup> Pangborn Sensory Science Symposium (2021)* Minneapolis, USA, 12–16.
- [3] G.L. Marcazzan, C. Mucignat-Caretta, C.M. Marchese, M.L. Piana; *Journal of Apicultural Research*, 57 (2018), p. 75-87.
- [4] L. Eriksson, J. Trygg, S. Wold; *Journal of Chemometrics*, 22 (2008), p. 594–600.
- [5] The Good Scents Company (<http://www.thegoodscentscompany.com/index.html>)
- [6] M. Kreck, A. Mosandl; *Journal of Agricultural and Food Chemistry*, 51 (2003), p. 2722-2726.