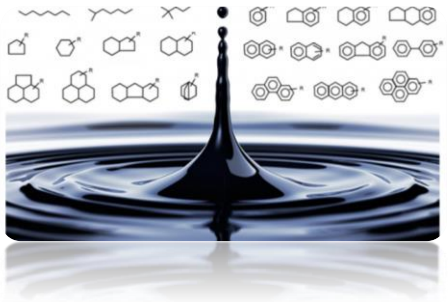
MOSH & MOAH :
remediation strategies and analytical challenges



<u>Giorgia Purcaro</u>, Aleksandra Gorska, Sabine Danthine, Nicolas Jacquet

Gembloux Agro Bio-Tech, University of Liège, Belgium

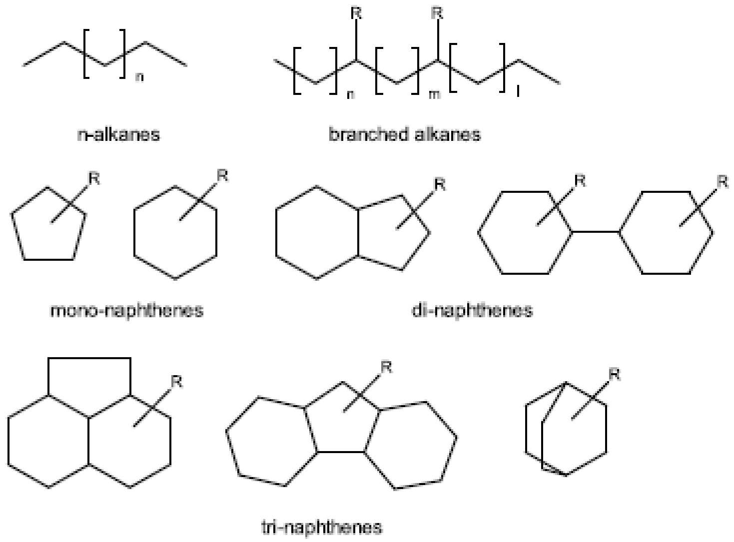
gpurcaro@uliege.be

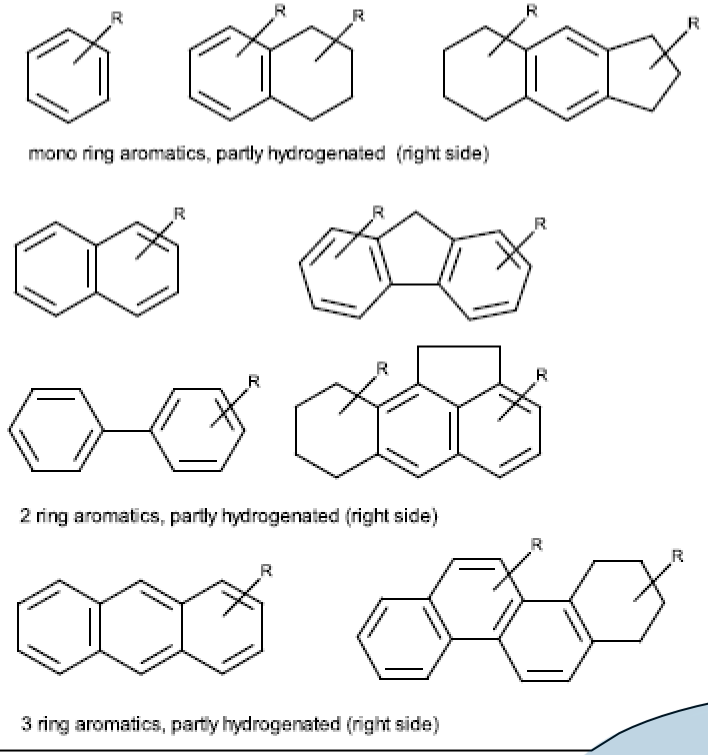
2025 AOCS annual Meeting & Expo
April 27-30, 2025 Oregon Convention Center, Portland, Oregon, USA

MINERAL OIL HYDROCARBONS (MOH): DEFINITION*

a wide range of products deriving from petroleum distillation fractions

MOSH	MOAH
Mineral oil saturated hydrocarbons	Mineral oil aromatic hydrocarbons





-n-alkane
- isoalkane
- cycloalkane

Aromatic hydrocarbons, mainly alkylated

MINERAL OIL HYDROCARBONS (MOH)

- 1989

Original Research Papers

Partially Concurrent Eluent Evaporation with an Early Vapor Exit; Detection of Food Irradiation through Coupled LC-GC Analysis of the Fat

Maurus Biedermann, Konrad Grob*, and Werner Meier

Kantonales Labo

MOH characteristic hump

UCM

As well as detection of pristane and phytane

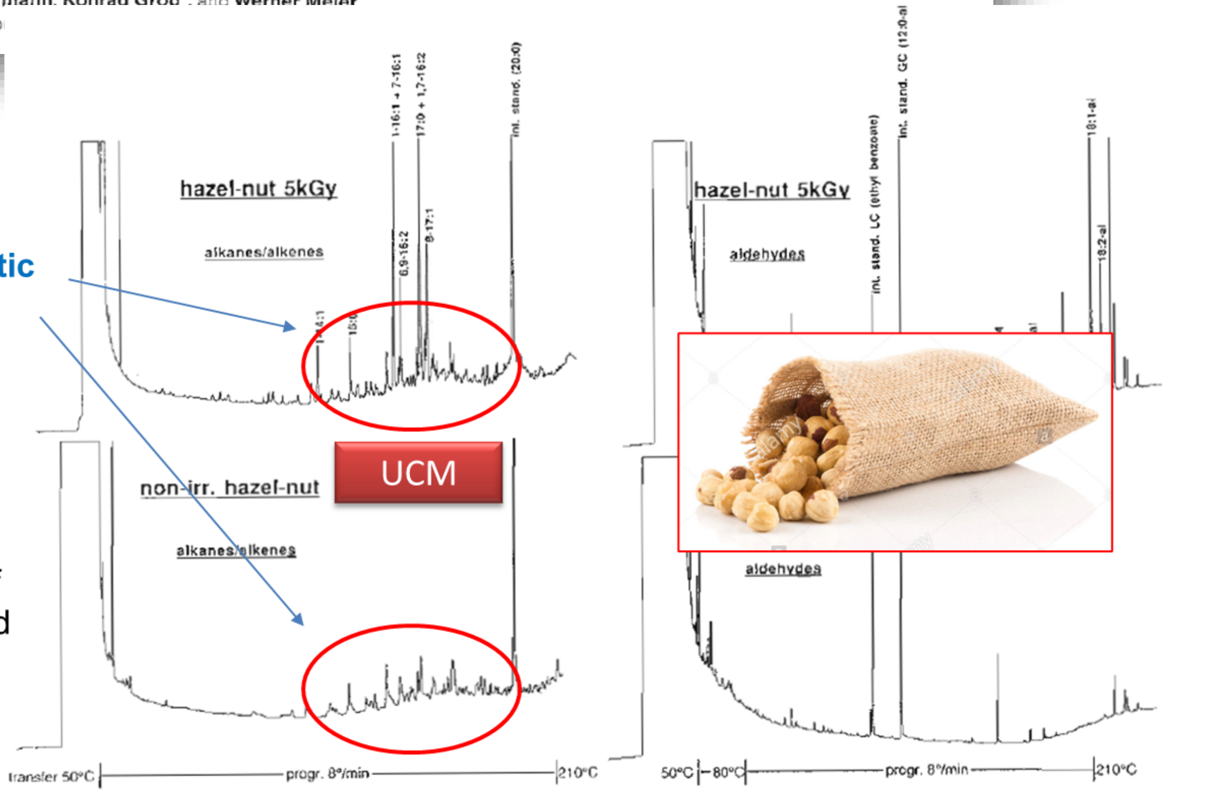


Figure 6

Alkane/alkene and aldehyde fractions of irradiated and non-irradiated hazelnuts. The poorly resolved alkanes in the matrix of the alkane/alkene fraction probably indicate a contamination of the nuts with mineral oil.

MINERAL OIL HYDROCARBONS (MOH)

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- 1989 → Original Research Papers
- 2001 → Mineral Paraffins in Vegetable Oils and ... Feed
- 2008/2009 →

efsa
European Food Safety Authority

English EN

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Home / Newsroom / Sunflower oil: contamination with mineral oil from Ukrain...

Sunflower oil: contamination with mineral oil from Ukraine - Update

Published: 28 April 2008

Eur. J. Lipid Sci. Technol. 2009, *111*, 313–319

Highlight Article

How "white" was the mineral oil in the contaminated Ukrainian sunflower oils?

Maurus Biedermann and Koni Grob

Official Food Control Authority of the Canton of Zurich, Zurich, Switzerland

Up to **1800 mg/kg** of **MOAH**

MINERAL OIL HYDROCARBONS (MOH)

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Feed

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Home / Newsroom / Sunflower oil: contamination with mineral oil from Ukrain...

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JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY ARTICLE

J. Agric. Food Chem. **2009**, *57*, 8711–8721
DOI:10.1021/jf901375e

Aromatic Hydrocarbons of Mineral Oil Origin in Foods: Method for Determining the Total Concentration and First Results

Maurus Biedermann, Katell Fiselier, and Koni Grob*

Kantonales Labor (Official Food Control Authority of the Canton of Zurich), Fehrenstrasse 15, CH-8032 Zurich, Switzerland

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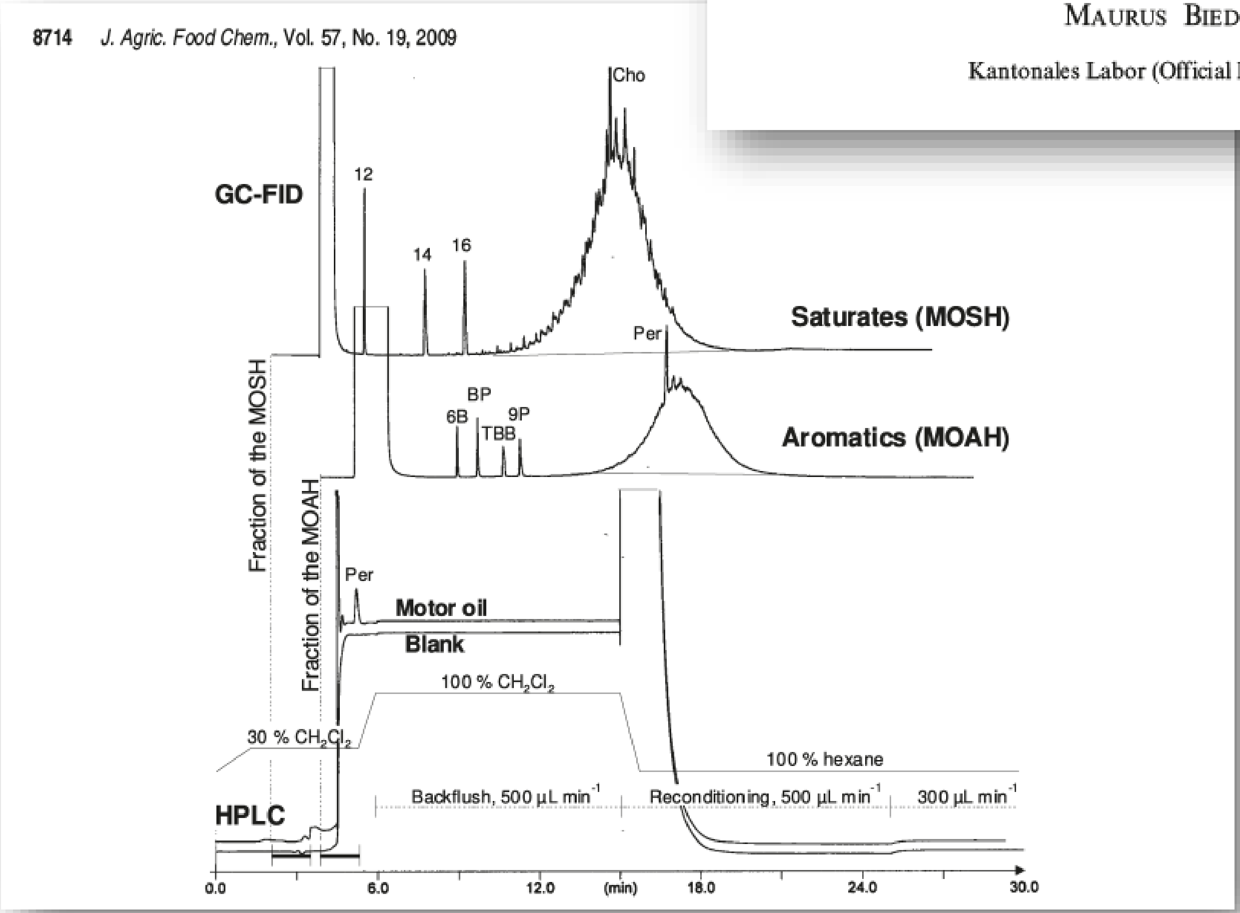

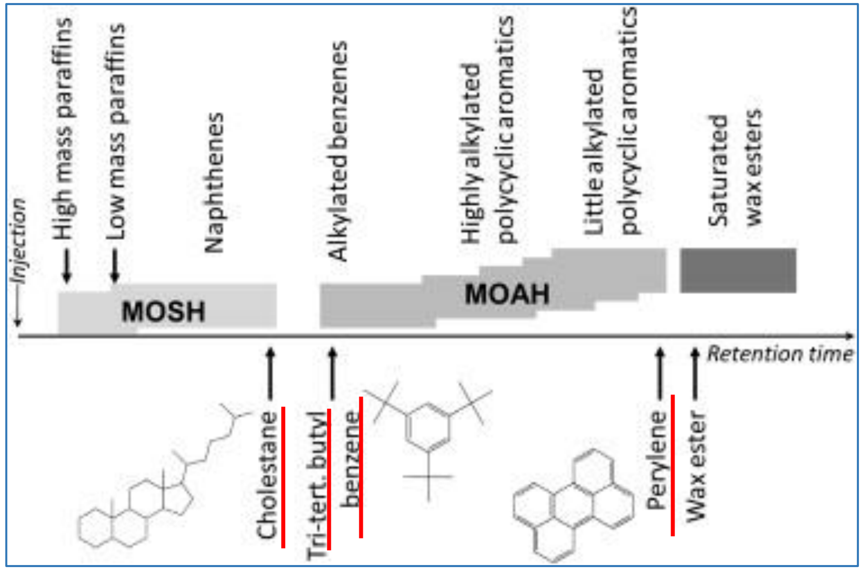

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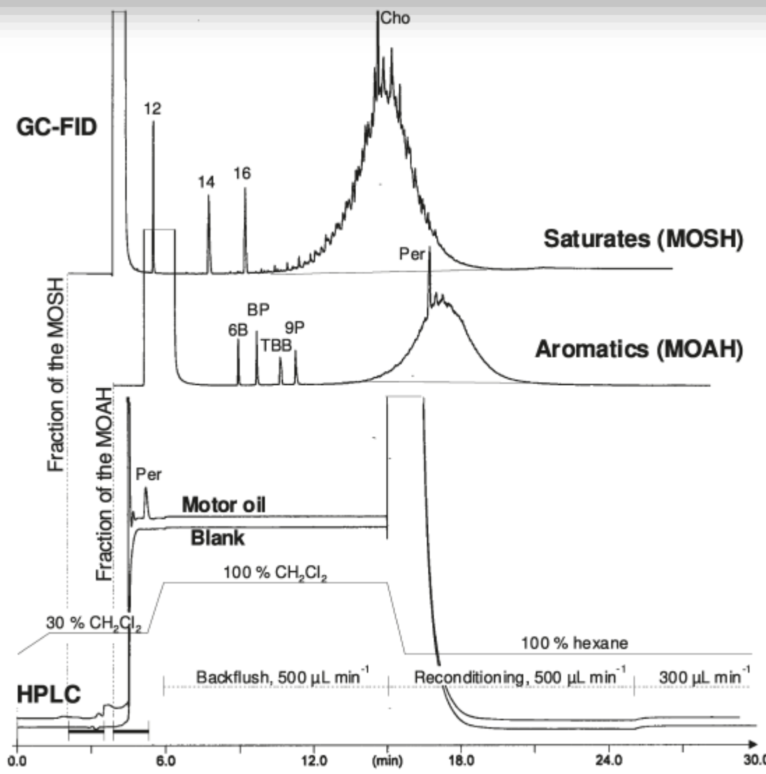

3726 J. Sep.

Maurus Biedermann
Koni Grob

Official Food Control Authority of the Canton of Zurich, Zurich, Switzerland

Received May 23, 2009
Revised August 3, 2009
Accepted August 5, 2009

Research Article

Comprehensive two-dimensional GC after HPLC preseparation for the characterization of aromatic hydrocarbons of mineral oil origin in contaminated sunflower oil

*"For **risk evaluation**, the concentration of the sum of all MOAH might not be satisfactory. The method of Moret et al. used HPLC to group the MOAH by ring number. In the meantime, **comprehensive two-dimensional GC (GC×GC)** was established [12, 13], which is an attractive alternative because of its **simplicity**, **the enhanced sensitivity resulting from focusing by modulation** and **the additional information provided on the extent of alkylation**.*

Mineral oil analysis is the most widely described application of GCGC, though mainly on products like gasoline, heavy naphtha or kerosene with a lower molecular mass than the food contaminants most frequently found."

MINERAL OIL HYDROCARBONS (MOH)

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY
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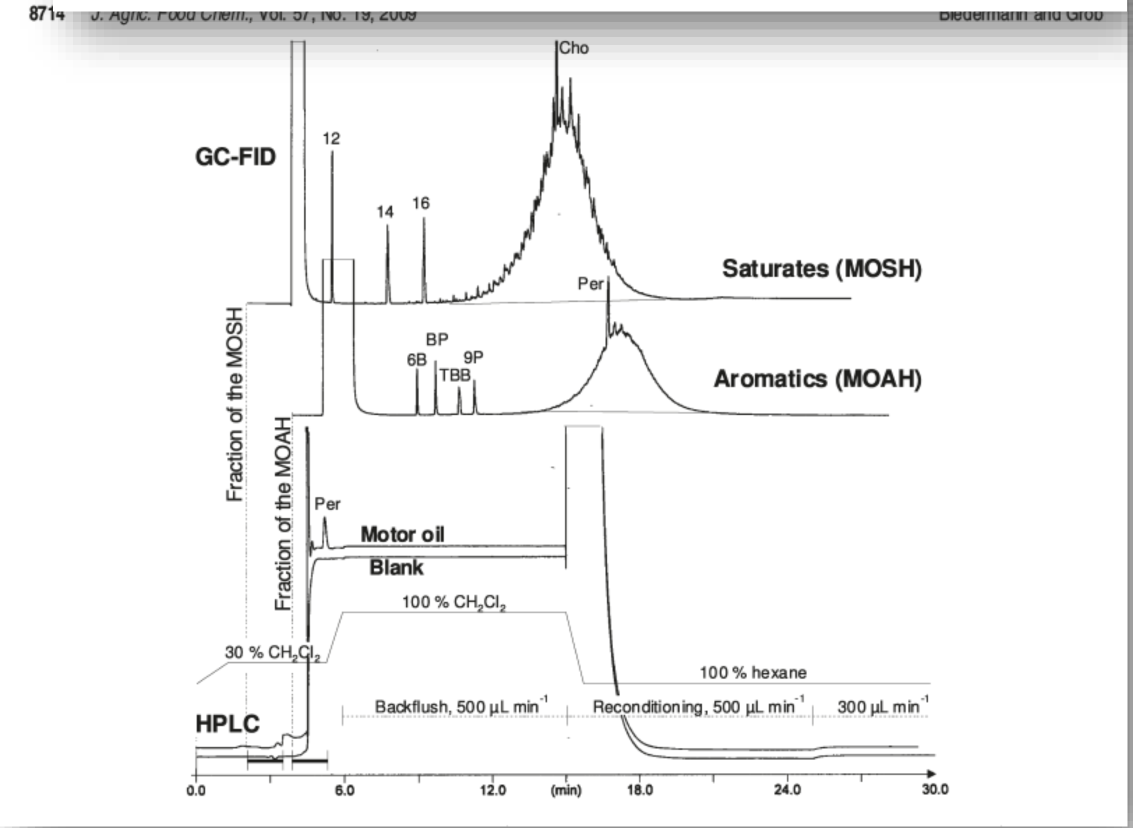

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Up to **1800 mg/kg** of **MOAH**

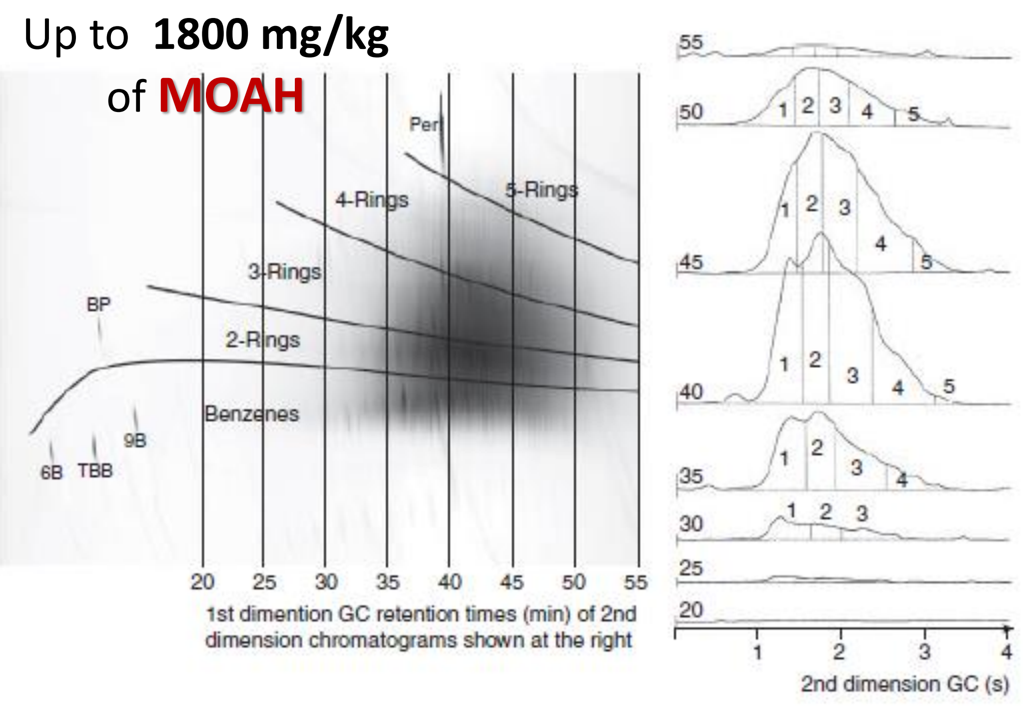
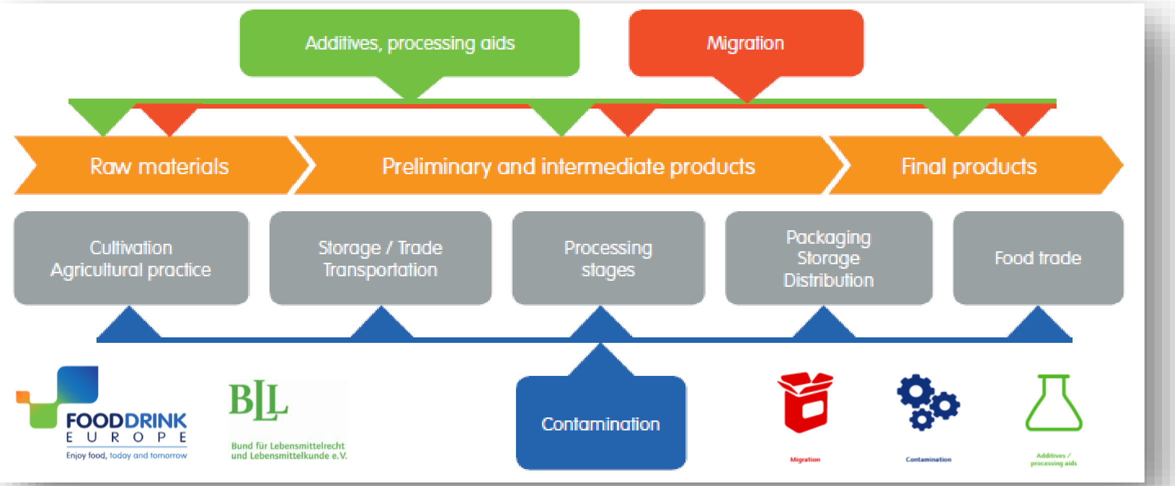
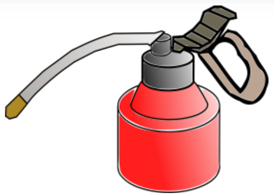
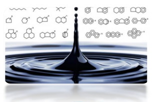


Figure 7. MOAH in the crude mineral oil fraction by GC×GC

MINERAL OIL HYDROCARBONS (MOH)







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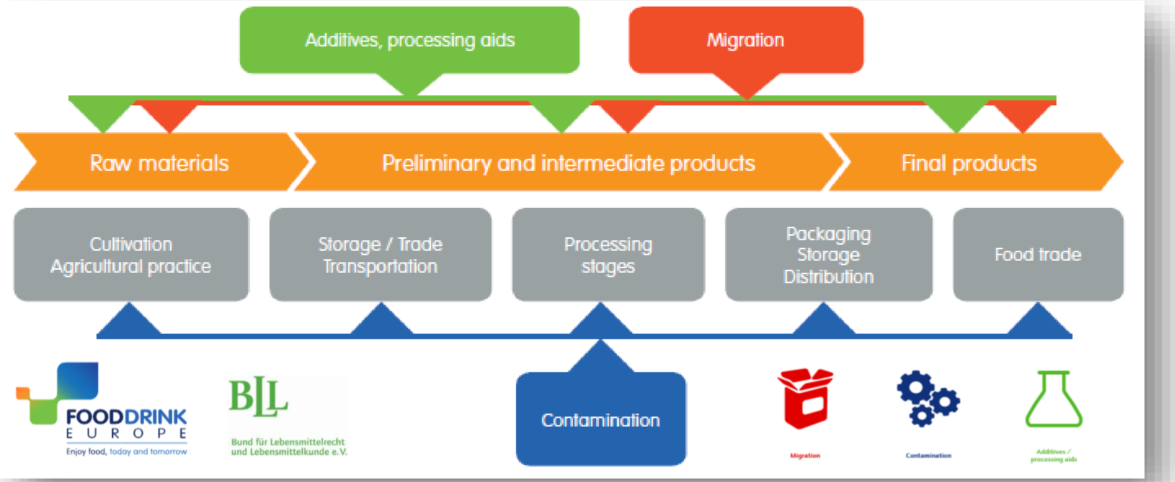

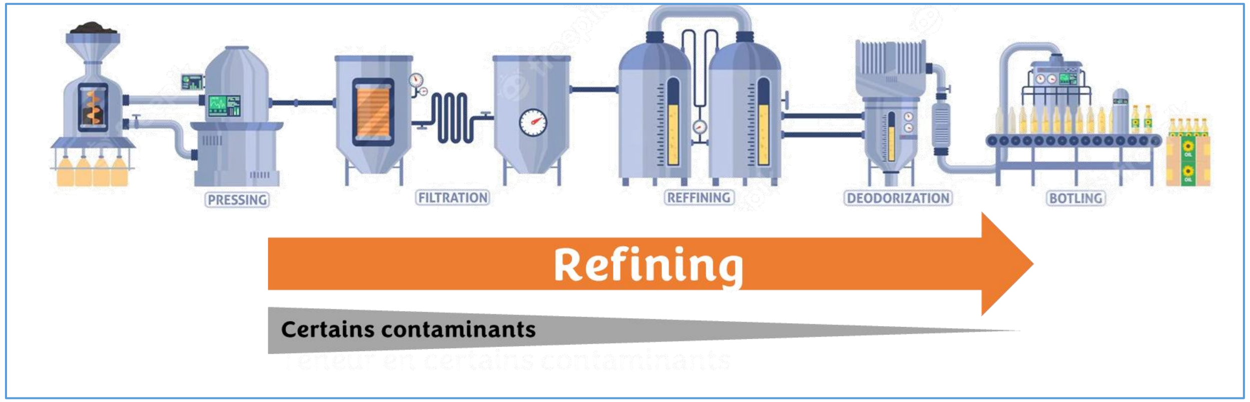

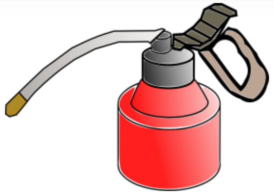

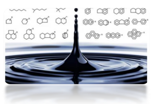

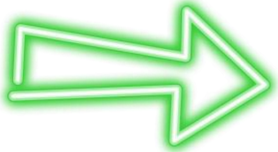

remediation

Copilot

MOH – Remediation

Steps of edible oil refining (simplified)

Degumming → (Neutralization) → Bleaching → (Dewaxing) → Deodorization

Refining:

- Industrial process applied to edible oils to remove undesirable compounds that are either **naturally present** (e.g., free fatty acids, waxes, phospholipids) or **introduced during cultivation or processing** (e.g., pesticides, metals, MOH, PAH).
- The objective is to obtain a standardized product with low odour, neutral taste, and clear appearance, which is stable over time, and safe for consumption.

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Effect of refining on MOH content

- Limited litterature, mostly published between 2017 and 2025

MOH Remediation

1989

2001

Original Papers — Mitt. Lebensm. Hyg. 92, 499–514 (2001)

Mineral Paraffins in Vegetable Oils and Refinery By-Products for Animal Feeds

Christoph Wagner, Hans-Peter Neukom and Koni Grob, Official Food Control Authority of the Canton of Zurich (Kantonales Labor), Zurich, Switzerland

Sabrina Moret, Tiziana Populin and Lanfranco S. Conte, Department of Food Science, University of Udine, Udine, Italy

Received 2 August 2001, accepted 23 August 2001

Acids for animal feed

The by-products of edible oil refining, consisting of the free fatty acids and the condensate from the deodorization process, contained between 120 and 6800 mg/kg of mineral paraffins. This by far exceeds the Swiss limit of 30 mg/kg for fats used in animal feeds (22).

Edible oils

Probably more than half of all raw vegetable oils and fats produced worldwide contain more than 10 mg/kg mineral paraffins and still a substantial proportion exceeds 50 mg/kg. Deodorization removes the hydrocarbons up to C25–C30, depending on the conditions. Usually this corresponds to about two thirds of the contamination (depending on the composition of the paraffins and the conditions of deodorization). However, many refined oils on the market still contained 20–80 mg/kg mineral paraffins. Some exceptional samples reached concentrations up to 3000 mg/kg.

Total MOH
(no MOSH+MOAH distinction)

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Summary of litterature (2017-2025)

ACESSS Academic Center of Excellence in Separation Science and Sensing

Authors	Key Process	Main Findings
Stauff et al. **2020**	**Deodorization** (140-240°C, 18-27 mbar, 2% water)	• Min. temperature for noteworthy MOH reduction: 210 °C • 10-75% of removal of MOH ≤ C24
Gelmez et al. **2017** Zhang et al. **2022**	**Molecular distillation** (220°C, 10^{-3} mbar, 1 kg/h feedstock)	• ~85% MOH ≤ C40 removed
Bauwens et al. **2023**	**Bleaching** **+** **Deodorization** (230°C, 3h, 1 mbar)	• 66% C16-C25 MOH removed • No modifications in C25-C50 MOH • >98.9% spiked alkylated PAHs ≥ 3 rings removed
Gorska et al. **2024**	**Deodorization** (150–240°C, 3 mbar, 1% water)	• At 200 °C, < LOQ MOAH < C24 (incl. weakly alkylated triaromatics) • At 230 °C, >60% reduction of C24–C35 MOAH (incl. low-alkylated pentaromatics)
Ursol et al. **2025**	**Bleaching** **+** **Deodorization** (180-227 °C, 2.5-5h, 0.8-1 mbar)	• ~10–30% total MOH reduction, ~90% C10-25 MOH reduction, ~40% C10–35 MOH reduction • Deodorization was the only effective MOH-reducing step • Bleaching reduced weakly alkylated/non-alkylated 2–4 ring PAHs

MOH - Remediation

LIÈGE université Gembloux Agro-Bio Tech

ACESSS Academic Center of Excellence in Separation Science and Sensing

2020

RESEARCH ARTICLE

European Journal of Lipid Science and Technology www.ejlst.com

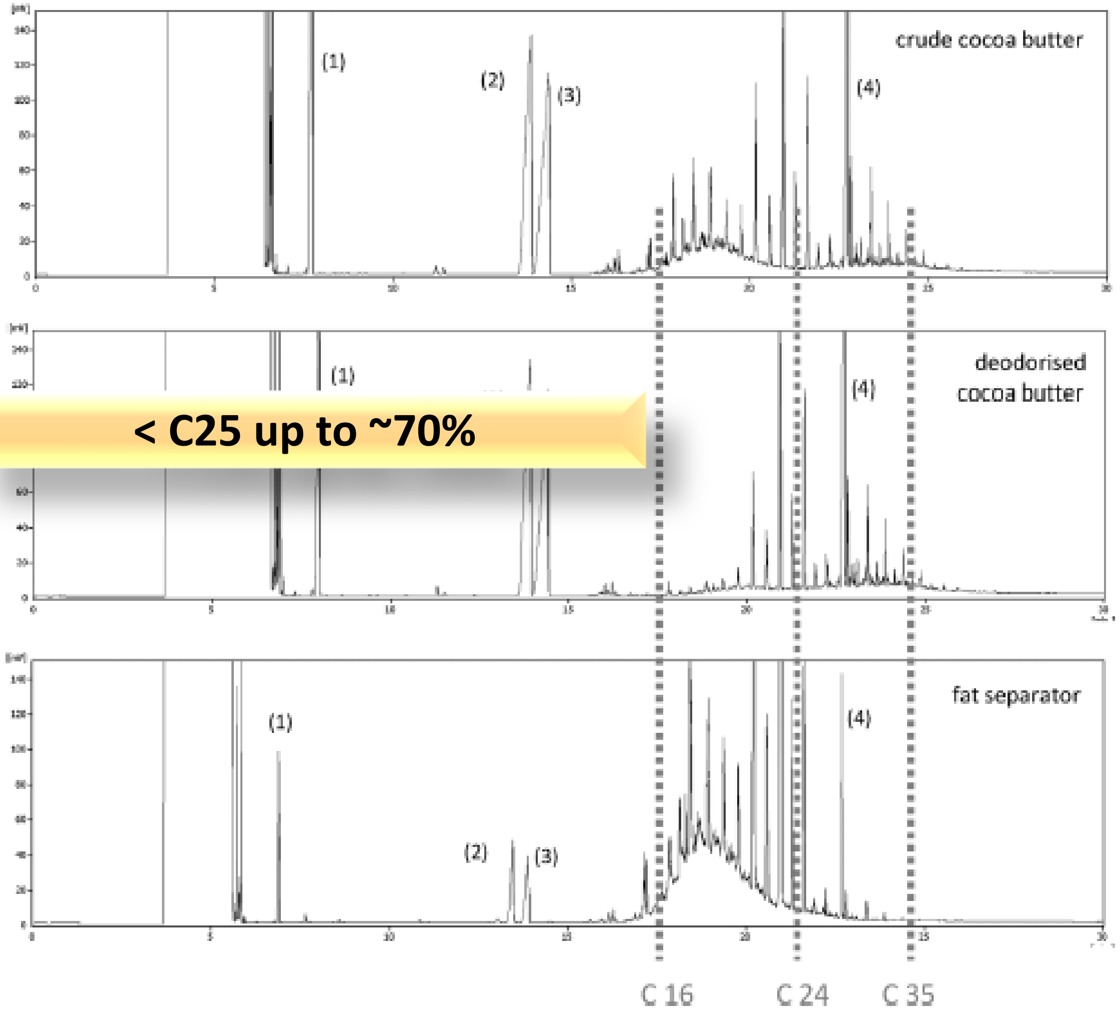
Mineral Oil Hydrocarbons (MOSH/MOAH) in Edible Oils and Possible Minimization by Deodorization Through the Example of Cocoa Butter

Eur. J. Lipid Sci. Technol. 2020, 122, 1900383

Anna Stauff, Julia Schnapka, Frank Heckel, and Reinhard Matissek*

Table 2. Reduction of MOSH/MOAH subfractions ≤C24 by industrial deodorization of cocoa butter (LOD: 1.5 mg kg^{-1}, LOQ: 2.5 mg kg^{-1}; n = 9).

	MOSH MOSH ≤ C24 [mg kg^{-1}]			**MOAH** MOAH ≤ C24 [mg kg^{-1}]		
	Crude	Deodorized (reduction)		Crude	Deodorized (reduction)	
Set 1	12	5.8	(53%)	<LOQ	<LOD	(40%)
Set 2	4.9	2.5	(49%)	3.4	<LOD	(56%)
Set 3	8.9	5.0	(44%)	<LOD	<LOD	—
Set 4	27	12	(54%)	8.8	3.3	(62%)
Set 5	21	6.3	(70%)	16	4.0	(75%)
Set 6	17	13	(25%)	9.0	7.1	(21%)
Set 7	5.8	5.2	(10%)	2.8	<LOQ	(21%)
Set 8	5.3	4.2	(21%)	<LOD	<LOD	—
Set 9	4.3	3.3	(23%)	<LOQ	<LOD	—



< C25 up to ~70%

Min 210°C for removal

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MOH – Remediation
Molecular distillation

2017

Eur. J. Lipid Sci. Technol. 2017, *119*, 1600001

Research Article

Removal of di-2-ethylhexyl phthalate (DEHP) and mineral oil from crude hazelnut skin oil using molecular distillation–multiobjective optimization for DEHP and tocopherol

Beyza Gelmez[1], Onur Ketenoglu[2], Huseyin Yavuz[3] and Aziz Tekin[2]

Only MOSH

Table 1. Chain length distribution of MOSH in the samples

		MOSH fractions, mg/kg			
		C(0)–C(15)	C(16)–C(24)	>C(25)	Total
Crude hazelnut skin oil		4.1	13.95	45.95	64
Temp. (°C)	Pressure (mbar)				
200	1	0.86	3.09	7.24	11.19
	2	1.53	3.83	3.49	8.85
	3	0.66	3.11	3.16	6.93
210	1	0.72	4.15	7.41	12.28
	2	1.35	5.36	6.67	13.38
	3	1.16	3.93	3.18	8.27
220	1	0.34	1.45	3.79	5.58
	2	0.97	5.83	5.81	12.61
	3	0.41	3.65	2.24	6.30
230	1	0.20	4.28	4.95	9.43
	2	0.72	4.80	5.60	11.12
	3	1.10	2.96	3.61	7.67

2022

ORIGINAL ARTICLE

AOCS WILEY

Mineral saturated hydrocarbons and mineral aromatic hydrocarbons in tropical plant oils and their removal by molecular distillation

Mingming Zhang | Hai Zhang | Tosin Michael Olajide | Wenming Cao | Yan Wang | Hong Zhang | Yuanrong Jiang

MOSH+MOAH

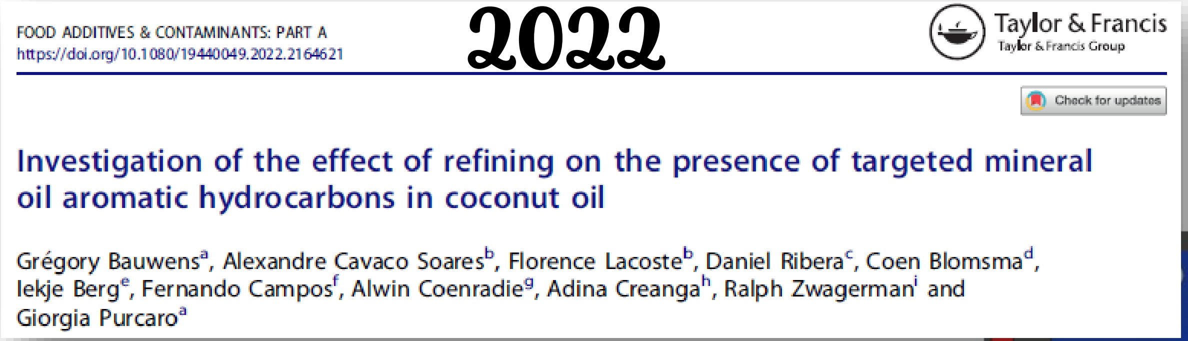
TABLE 3 Reduction of MOSH/MOAH sub-factions (C10–C50) by molecular distillation

Palm olein		MOSH sub-fractions (mg kg^{-1})							MOAH sub-fractions (mg kg^{-1})				
Temp. (°C)	Feed rate (kg h^{-1})	C10–C16	C16–C20	C20–C25	C25–C35	C35–C40	C40–C50	Sum (C10–C50)	C10–C16	C16–C25	C25–C35	C35–C50	Sum (C10–C50)
-	-	<LOQ	<LOQ	4.5	36.8	8.1	8.7	58.1	<LOQ	3.0	6.1	1.2	10.3
200	1	<LOQ	<LOQ	<LOQ	6.7 (82)[a]	4.8 (40)	8.5 (2)	20.0 (65)	<LOQ	<LOQ	1.9 (69)	1.2 (–)	3.1 (70)
	2	<LOQ	<LOQ	<LOQ	17.1 (54)	6.1 (24)	8.5 (2)	31.7 (45)	<LOQ	<LOQ	3.0 (51)	1.2 (–)	4.2 (59)
	3	<LOQ	<LOQ	<LOQ	21.1 (43)	6.9 (14)	8.6 (1)	36.6 (37)	<LOQ	<LOQ	4.1 (33)	1.2 (–)	5.3 (49)
210	1	<LOQ	<LOQ	<LOQ	1.7 (95)	3.1 (61)	8.4 (3)	13.2 (77)	<LOQ	<LOQ	<LOQ	1.2 (–)	1.2 (88)
	2	<LOQ	<LOQ	<LOQ	9.8 (73)	5.1 (36)	8.5 (2)	23.4 (60)	<LOQ	<LOQ	1.8 (71)	1.2 (–)	3.0 (71)
	3	<LOQ	<LOQ	<LOQ	10.3 (72)	5.8 (28)	8.5 (2)	24.6 (58)	<LOQ	<LOQ	2.2 (64)	1.3	3.5 (67)
220	1	<LOQ	<LOQ	<LOQ	<LOQ	1.6 (80)	8.2 (5)	9.8 (83)	<LOQ	<LOQ	<LOQ	1.2 (–)	1.2 (89)
	2	<LOQ	<LOQ	<LOQ	2.1 (94)	3.4 (58)	8.4 (3)	13.9 (76)	<LOQ	<LOQ	<LOQ	1.2 (–)	1.2 (89)
	3	<LOQ	<LOQ	<LOQ	7.0 (81)	4.0 (50)	8.5 (2)	19.5 (66)	<LOQ	<LOQ	1.5 (75)	1.2 (–)	2.7 (74)

Abbreviations: LOQ, limit of quantification; MOAH, mineral aromatic hydrocarbons; MOSH, mineral saturated hydrocarbons.
[a]Removal rate (%) is given in brackets.

< C40 up to ~80%

MOH – Remediation
Analytical strategy


FOOD ADDITIVES & CONTAMINANTS: PART A
https://doi.org/10.1080/19440049.2022.2164621

2022

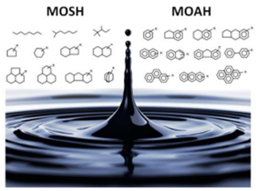
Taylor & Francis
Taylor & Francis Group

Check for updates

Investigation of the effect of refining on the presence of targeted mineral oil aromatic hydrocarbons in coconut oil

Grégory Bauwens[a], Alexandre Cavaco Soares[b], Florence Lacoste[b], Daniel Ribera[c], Coen Blomsma[d], Iekje Berg[e], Fernando Campos[f], Alwin Coenradie[g], Adina Creanga[h], Ralph Zwagerman[i] and Giorgia Purcaro[a]

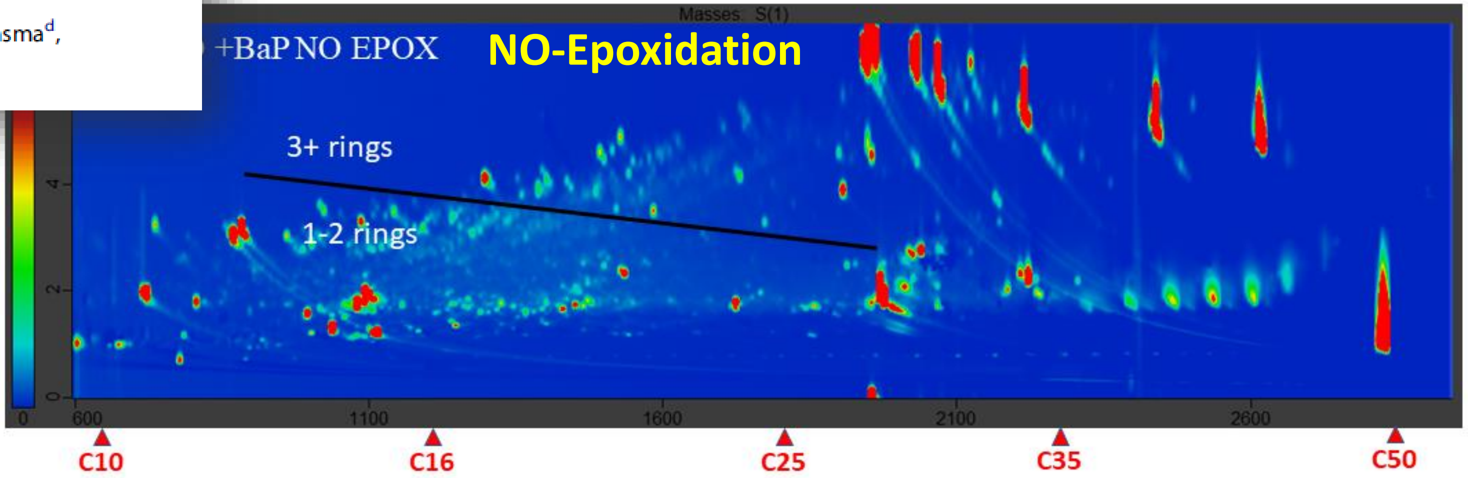
Crude coconut oil

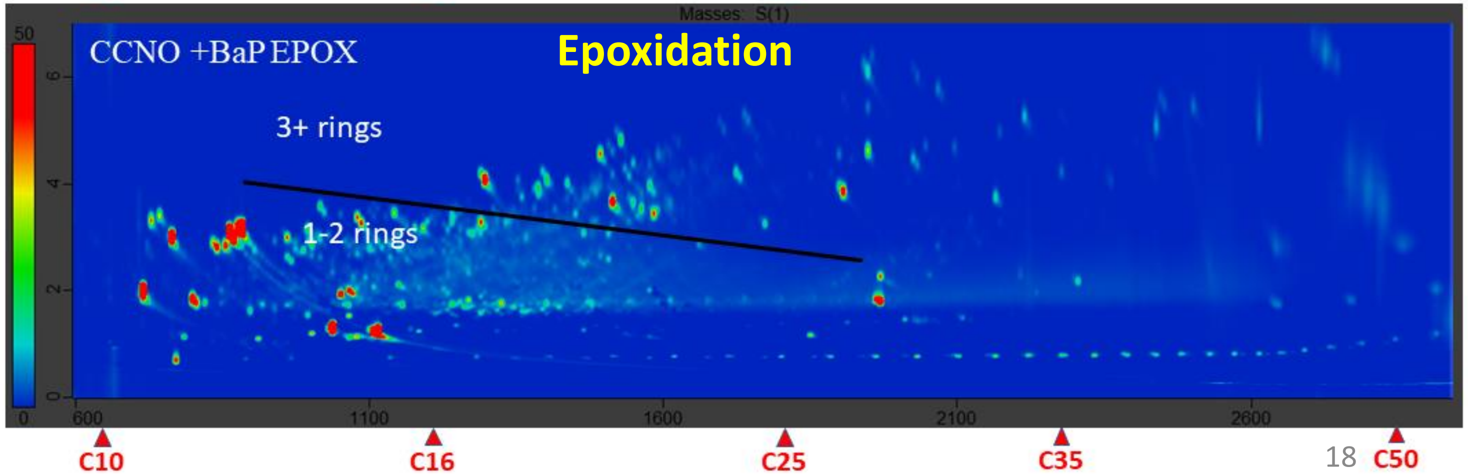


Deodorization + bleaching

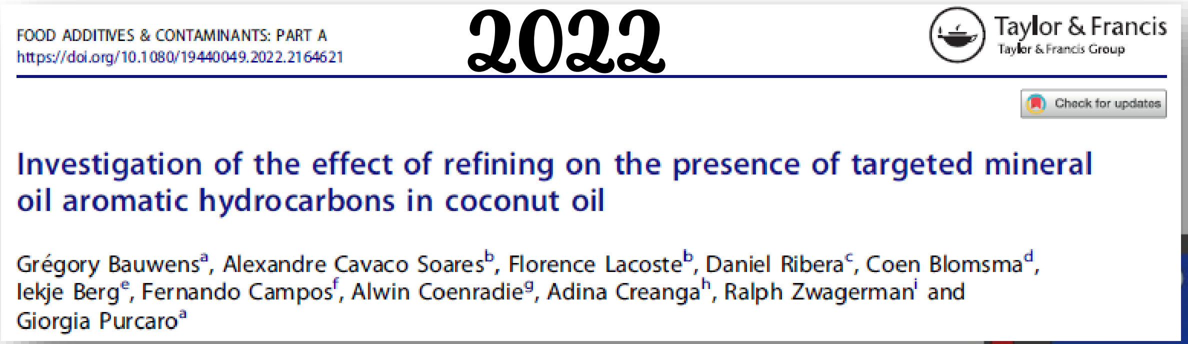
(230°C, 3h, 1 mbar + 1.7% mass of bleaching earth (Pureflow B80) 95°C x 30 min)

Epoxidation cannot be applied for this kind of studies!





MOH – Remediation
Analytical strategy


2022

FOOD ADDITIVES & CONTAMINANTS: PART A
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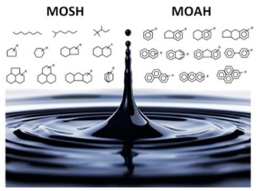
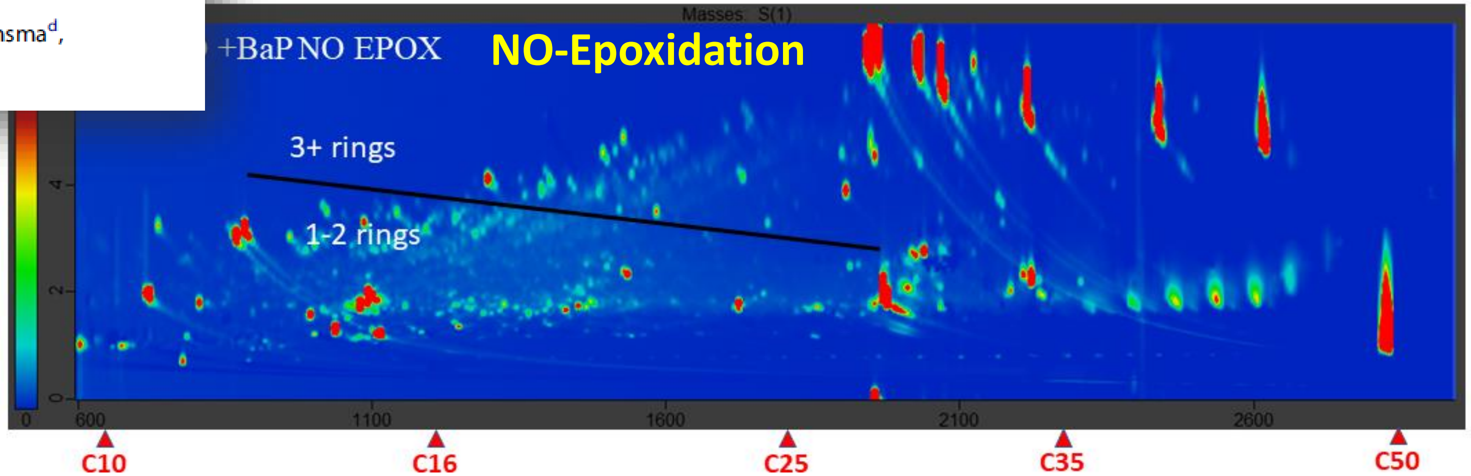


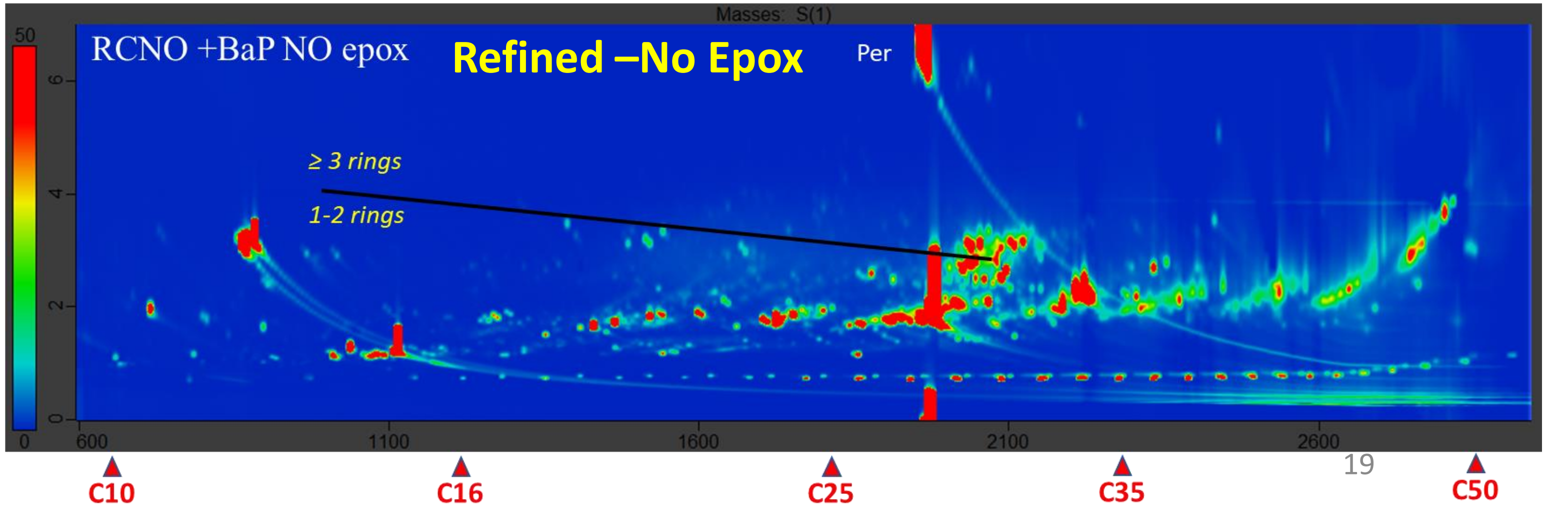
Crude coconut oil

Deodorization + bleaching

Epoxidation cannot be applied for this kind of studies!

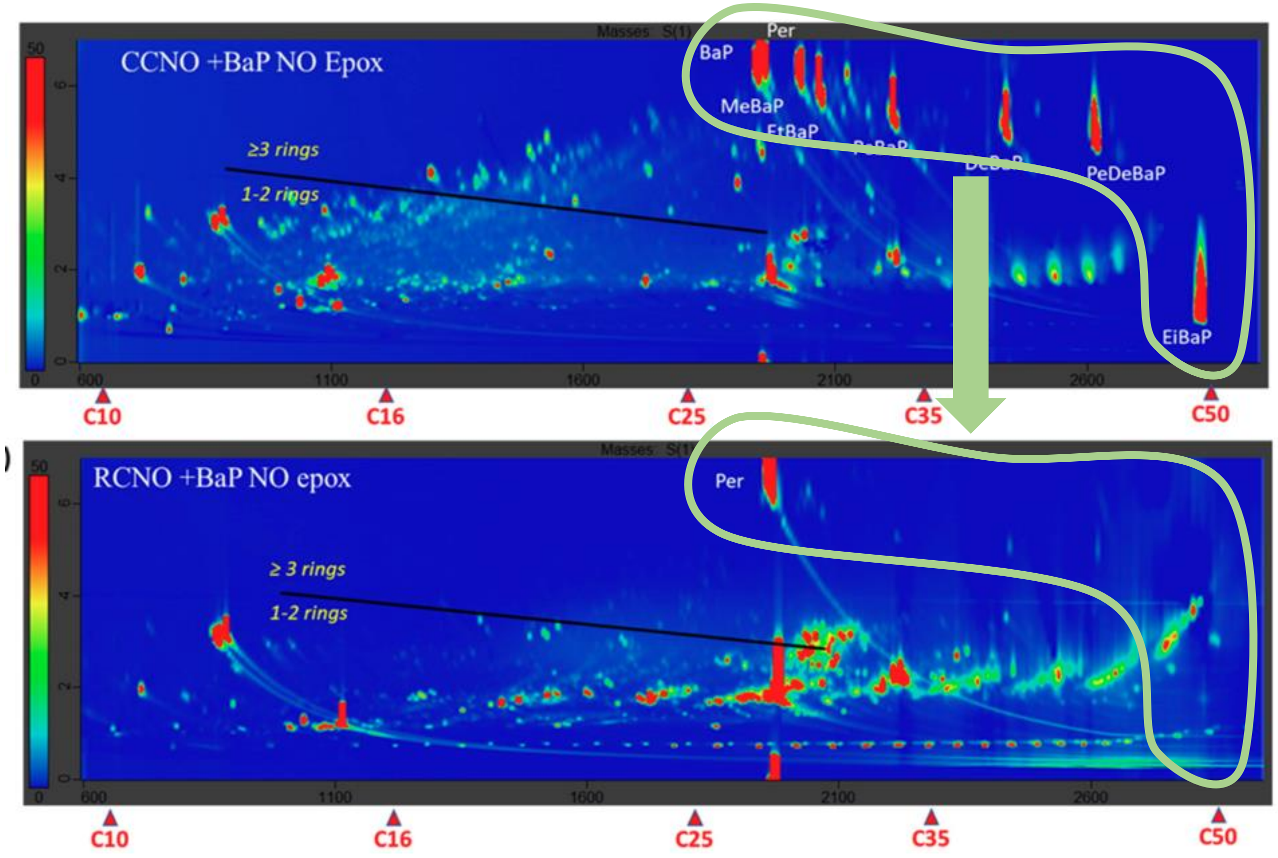
- 66% C16-C25 MOH removed
- No modifications in C25-C50 MOH (but **not clear contamination** there)
- **>98.9% spiked alkylated PAHs** ≥ 3 rings removed





Removal of alkylated PAHs by bleaching

Bauwens et al. (2023) – bleaching + deodorization



Which is the contribution of deodorization and bleaching separately?

>98.9% removal of the spiked alkylated PAHs

FOOD ADDITIVES & CONTAMINANTS: PART A 2023, VOL. 40, NO. 3, 392–403
https://doi.org/10.1080/19440049.2022.2164621

MOH – Remediation Deodorization

FOOD ADDITIVES & CONTAMINANTS: PART A
https://doi.org/10.1080/19440049.2024.2371925
Taylor & Francis
Taylor & Francis Group
Check for updates

Impact of deodorisation time and temperature on the removal of different MOAH structures: a lab-scale study on spiked coconut oil

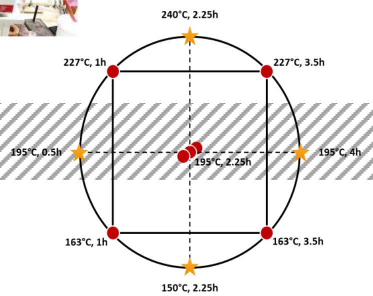
Aleksandra Gorska[a], Sabine Danthine[b], Nicolas Jacquet[b] and Giorgia Purcaro[a]

[a]Analytical Chemistry, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium; [b]Food Technology, Gembloux Agro-Bio Tech, University of Liège, Gembloux, Belgium

DEODORIZATION

The most delicate step of this project was the MOAH analysis → required an adapted **strategy**

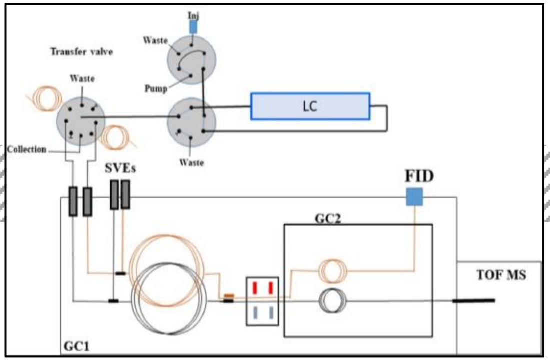

Coconut oil spiked with MOAH
(9 mg/kg)



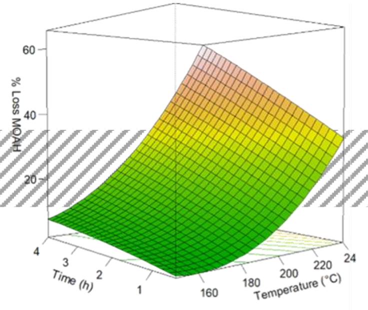
Deodorization at lab-scale
(11 experiments - CCD)

Variables:
time (0.5-4h), T° (150-240°C)

Constants:
pressure (3mbar), steam flow (1%$_w$/h)



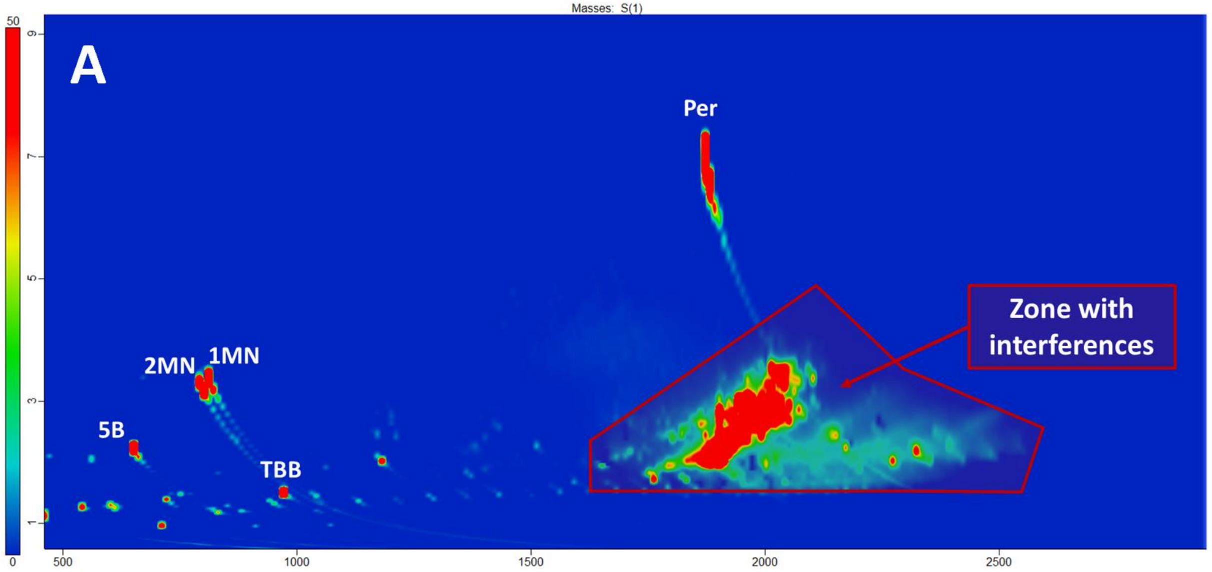
MOAH analysis before/after deodorization (by LC-GC×GC-FID)



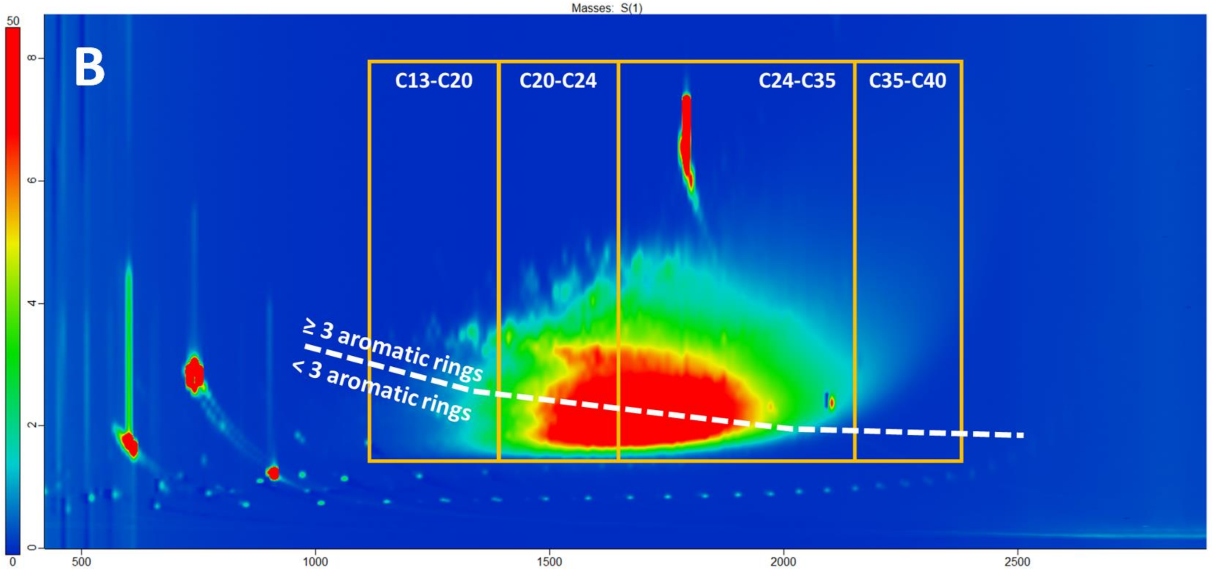
Response surfaces
MOAH loss according to time and temperature

MOH – Remediation
Deodorization time-temperature

Coconut oil

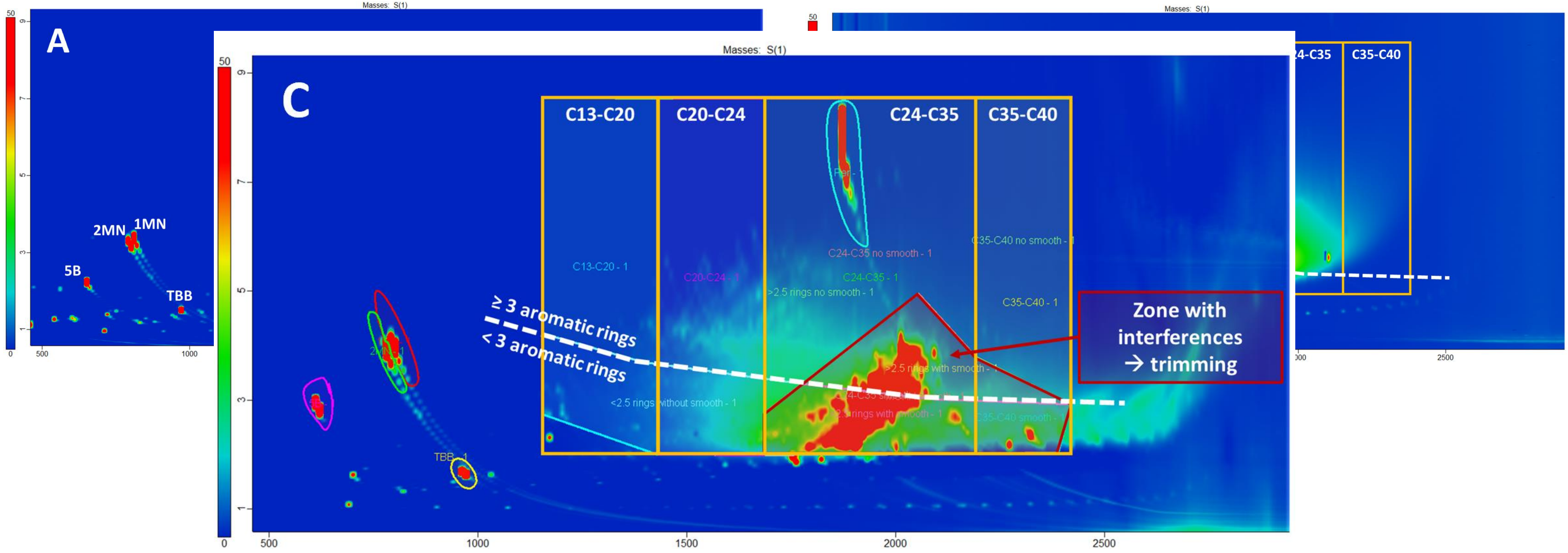


Motor oil



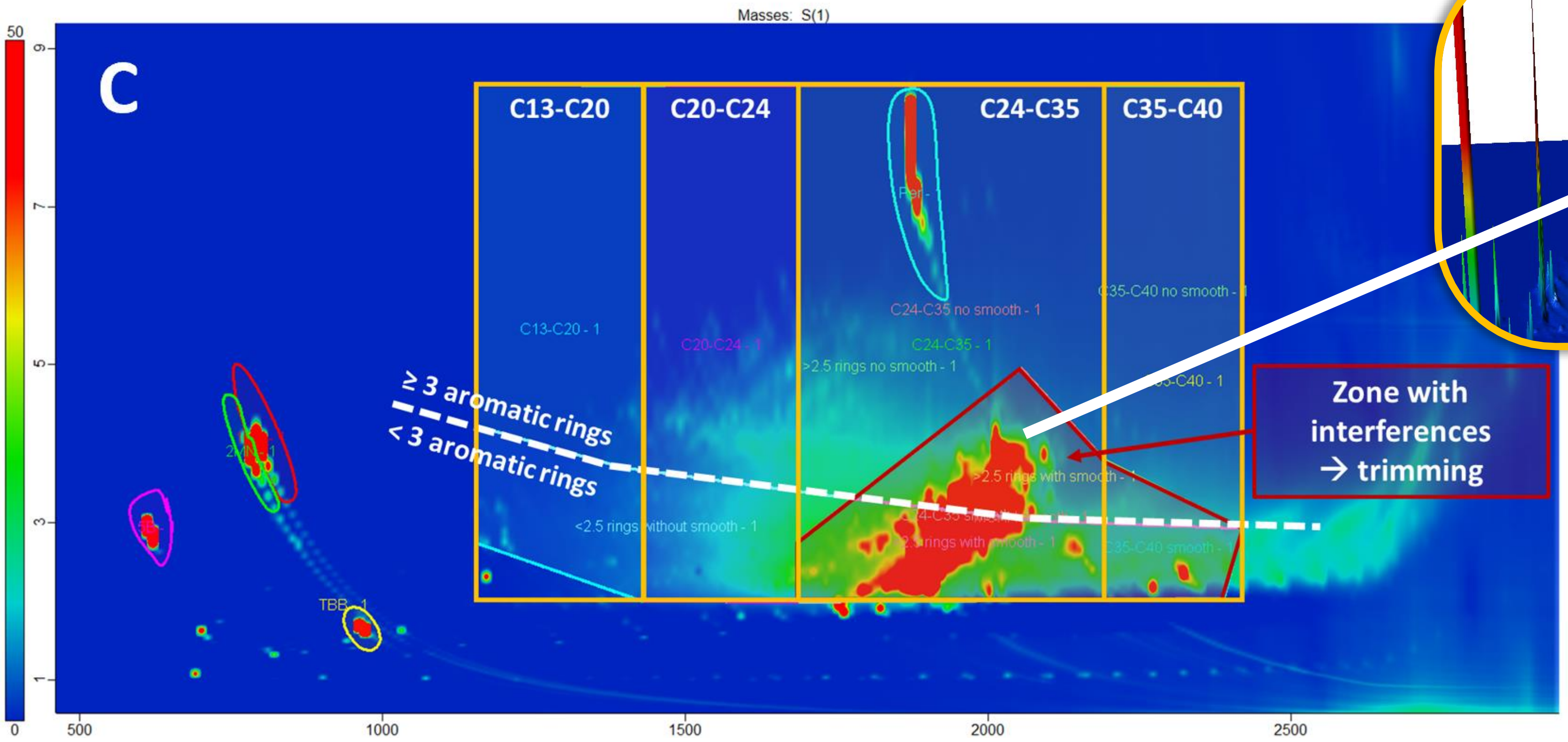
MOH – Remediation
Deodorization time-temperature

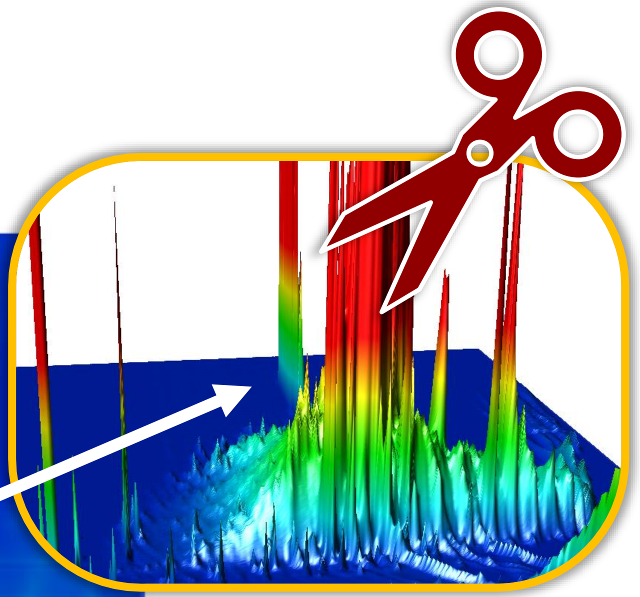
Coconut oil **Spiked Coconut oil** **Motor oil**



MOH – Remediation
Deodorization time-temperature

Spiked Coconut oil





Interferences hinder accurate determination of MOAH → **purification method needed!**

MOH – Remediation
Analytical strategy


Journal of Chromatography A 1743 (2025) 465684

Contents lists available at ScienceDirect

Journal of Chromatography A

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

Purification of mineral oil aromatic hydrocarbons and separation based on the number of aromatic rings using a liquid chromatography silica column. An alternative to epoxidation

Aleksandra Gorska [a], Grégory Bauwens [a], Marco Beccaria [b], Giorgia Purcaro [a,*]

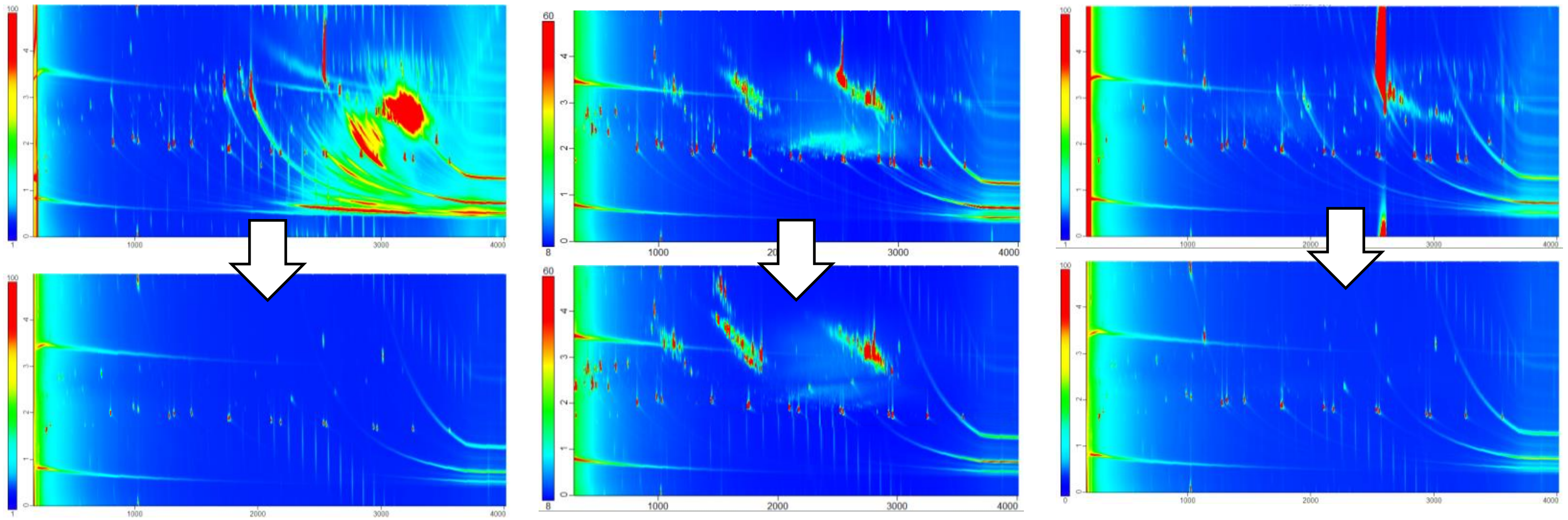
Very good removal of carotenoids and squalene

Other terpenoids are less well removed


✓


~


✓



MOH – Remediation
Analytical strategy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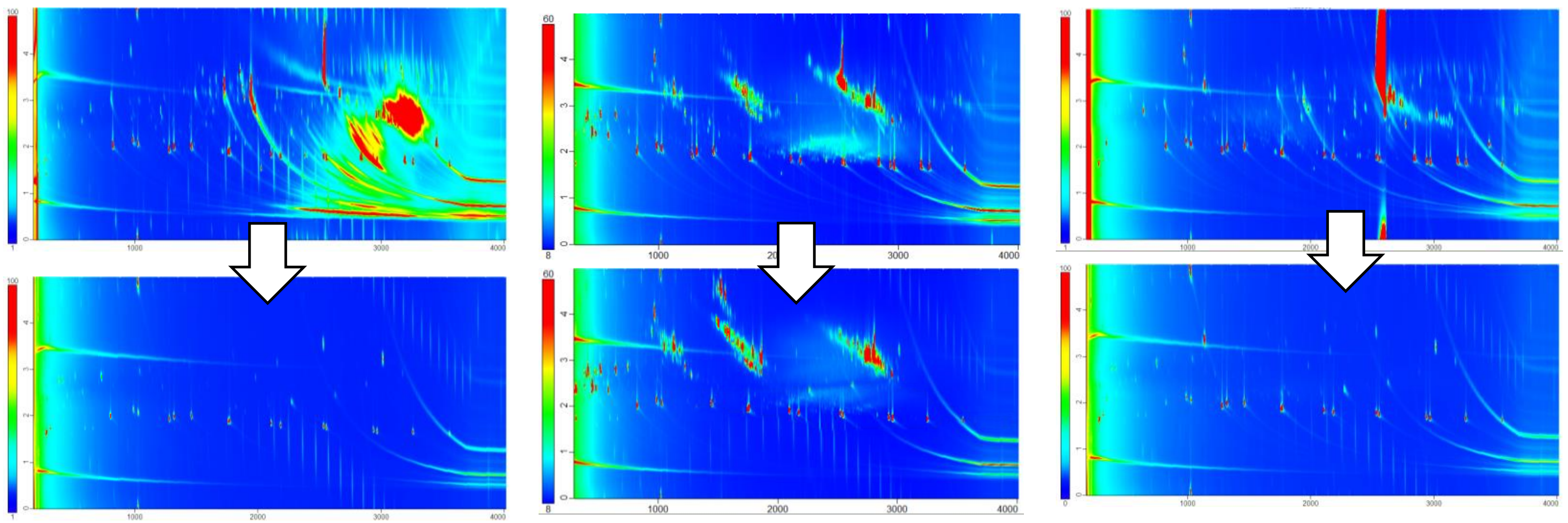


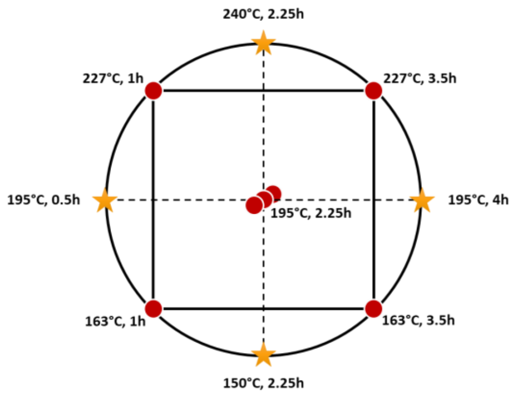
MOAH Recovery LC Purification:

94% ± 2%

Epoxidation

mCPBA	performic acid
82%± 10%	71 ± 16%

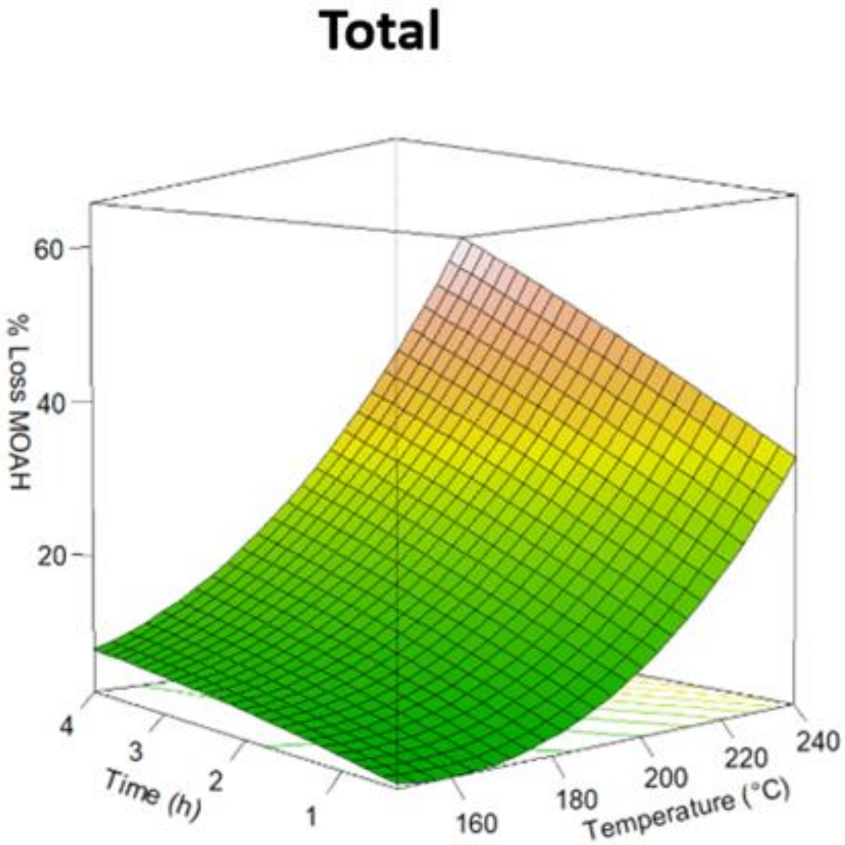
MOH – Remediation
Analytical strategy



Deodorization at lab-scale

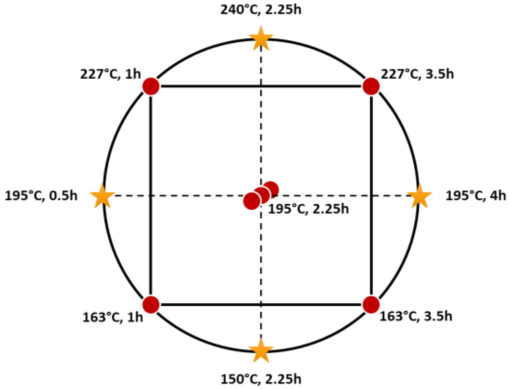
Variables:
time (0.5-4h), T° (150-240°C)

<u>Constants</u>:
pressure (3mbar),
steam flow (1%$_w$/h)



Max removal: 60%

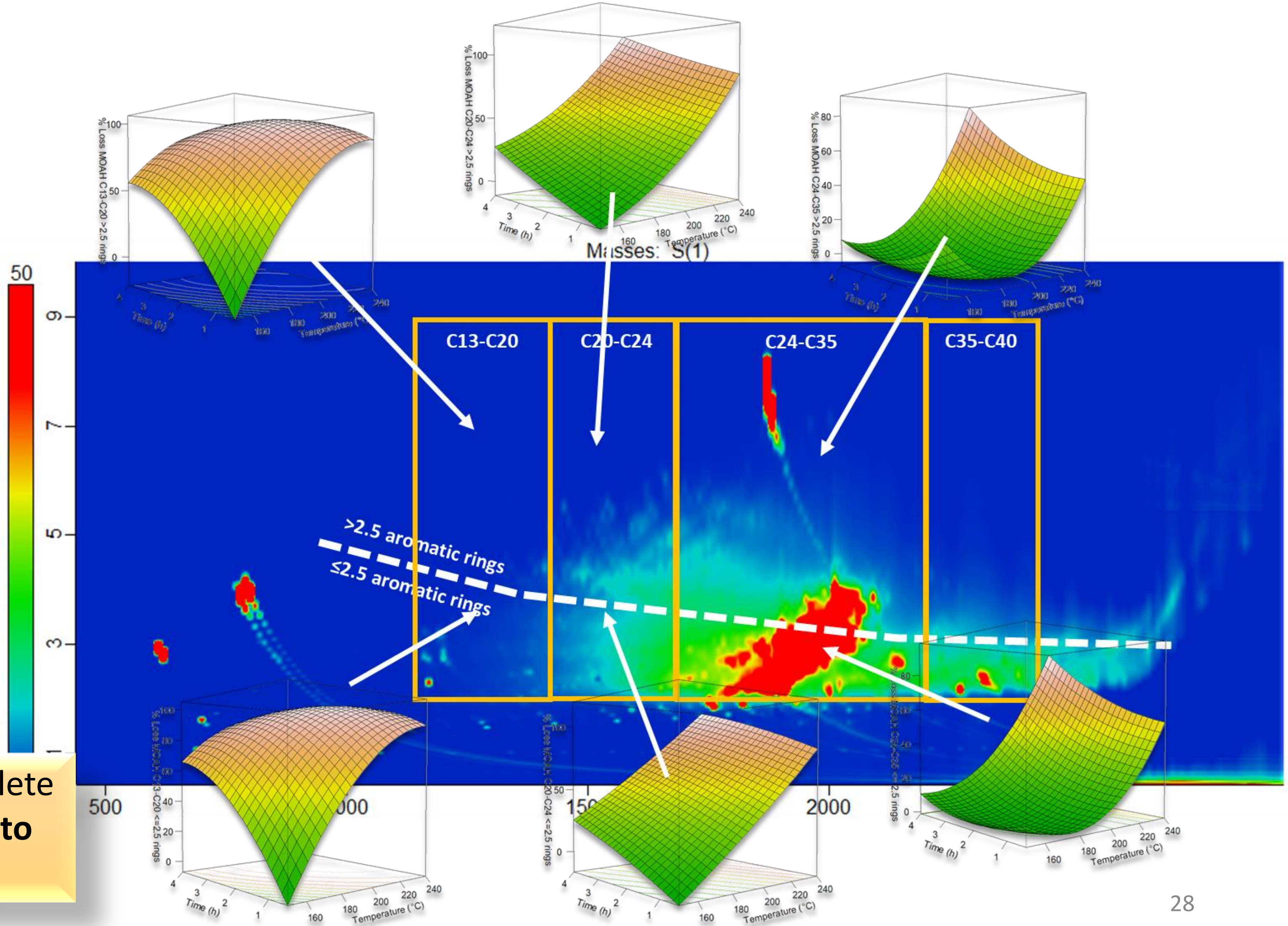
MOH – Remediation
Analytical strategy



Deodorization at lab-scale

Variables:
time (0.5-4h), T° (150-240°C)

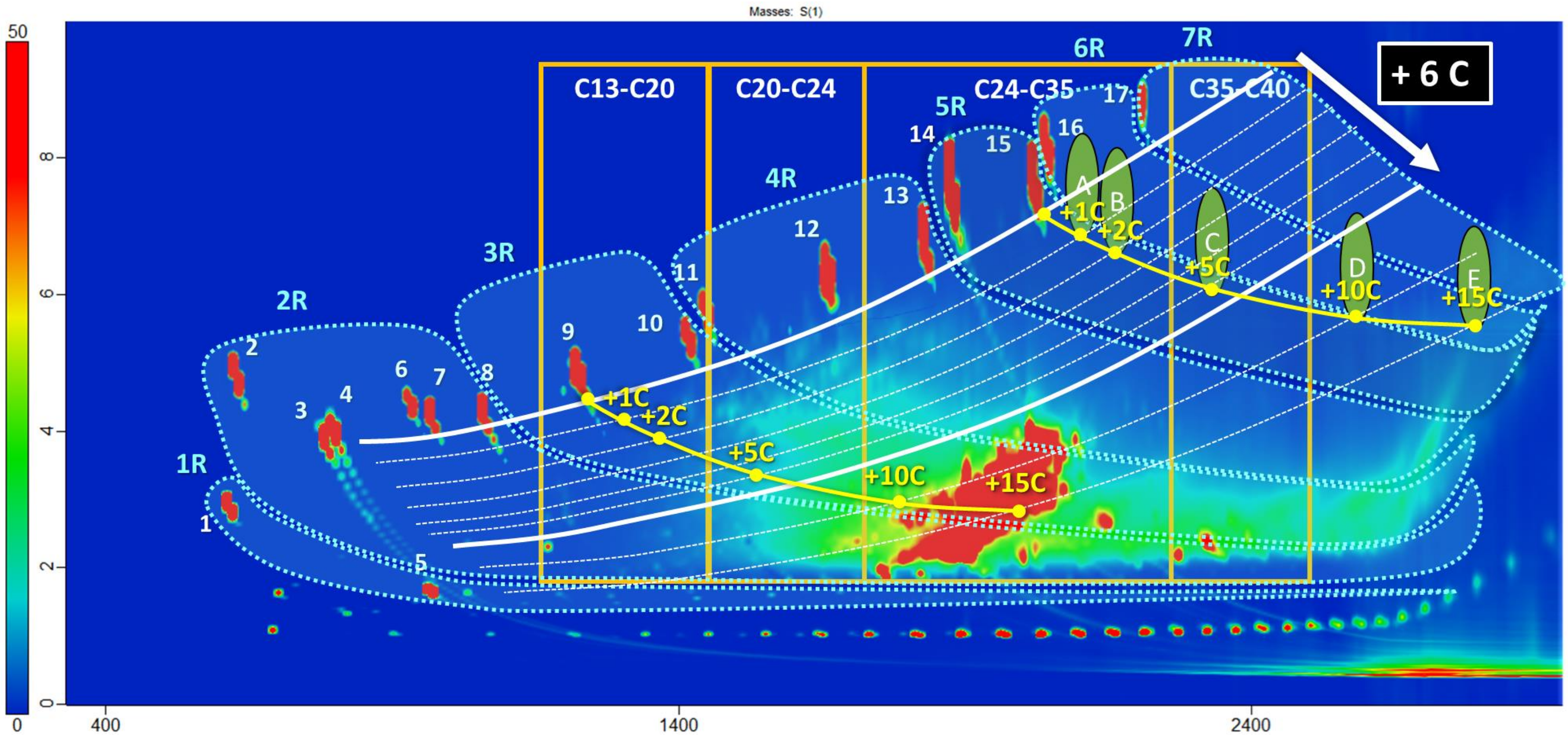
Constants:
pressure (3mbar),
steam flow (1%$_w$/h)



Almost complete removal **up to C30**!

What chemical structures are removed?

Possible to study the **MOAH chemical structures** that are removed thanks to an **LC-GC×GC-FID/TOFMS** analysis



Possible estimation of the number of aromatic rings an alkylation degree of present compounds

Food Additives & Contaminants: Part A 2024, vol. 41, no. 9, 1118–1131 https://doi.org/10.1080/19440049.2024.2371925

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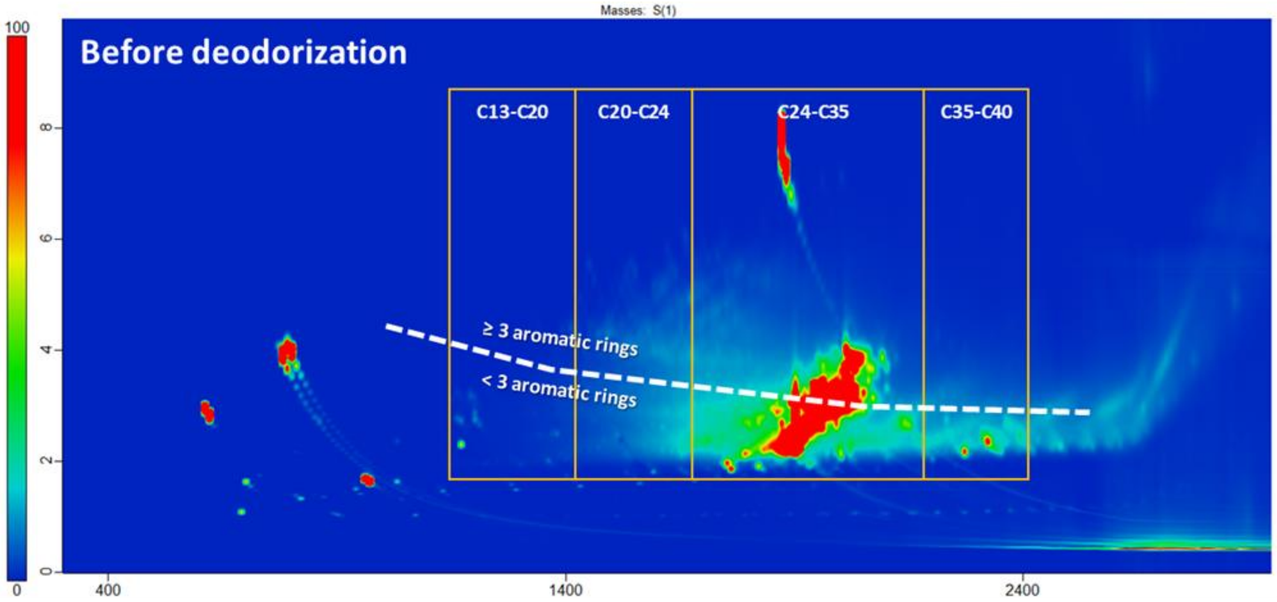
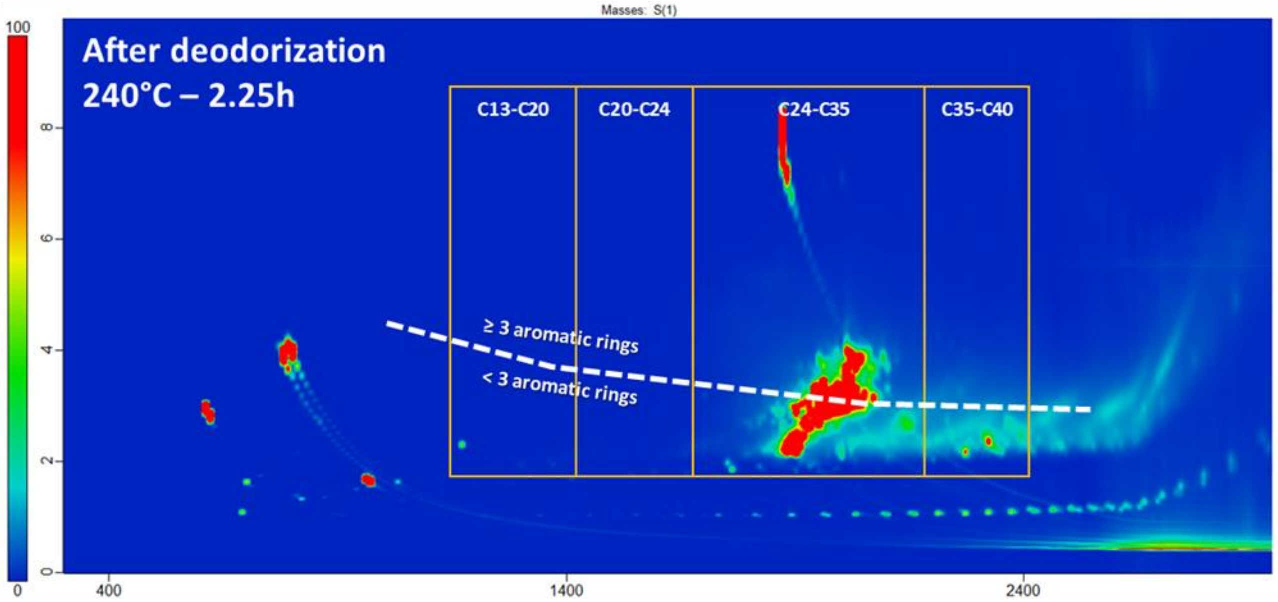
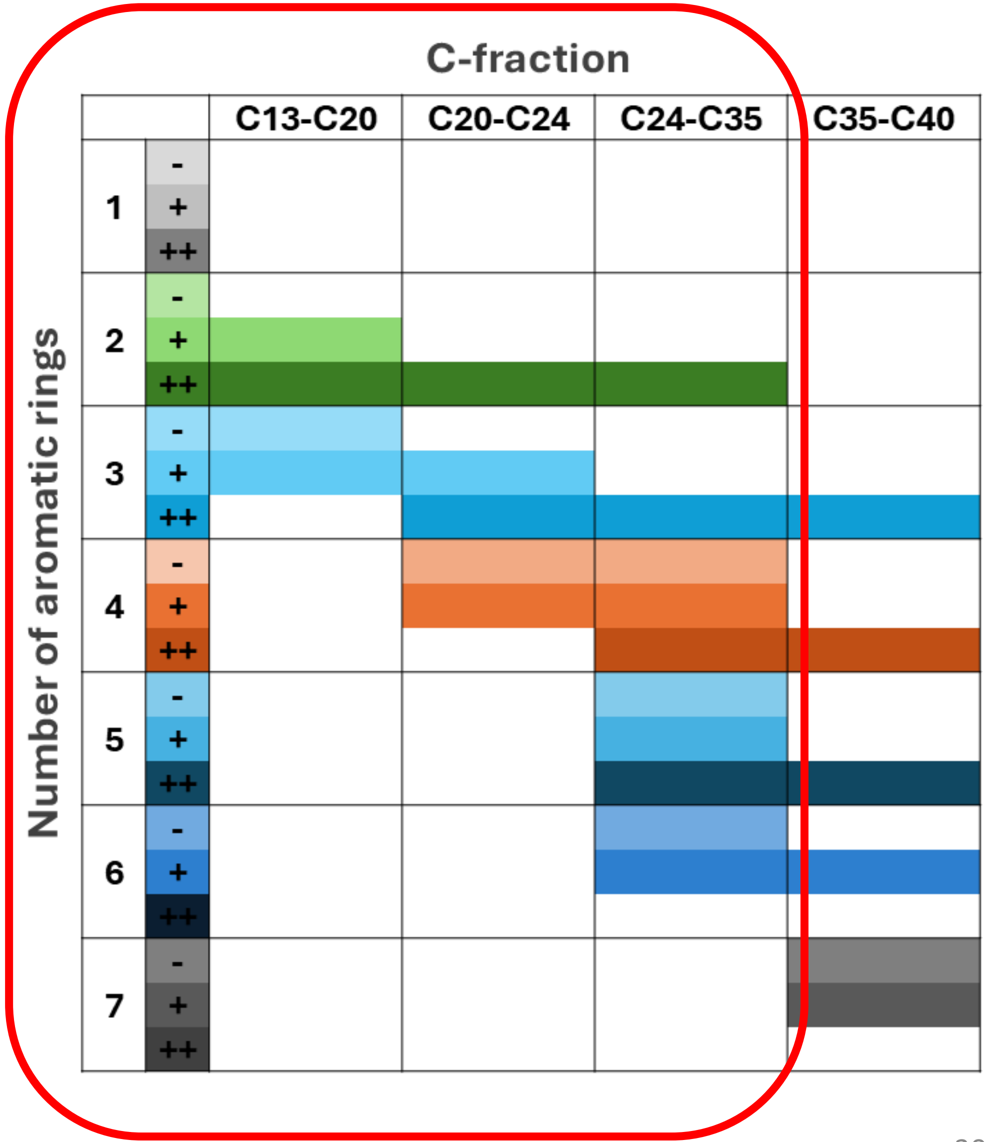
MOH – Remediation
Analytical strategy







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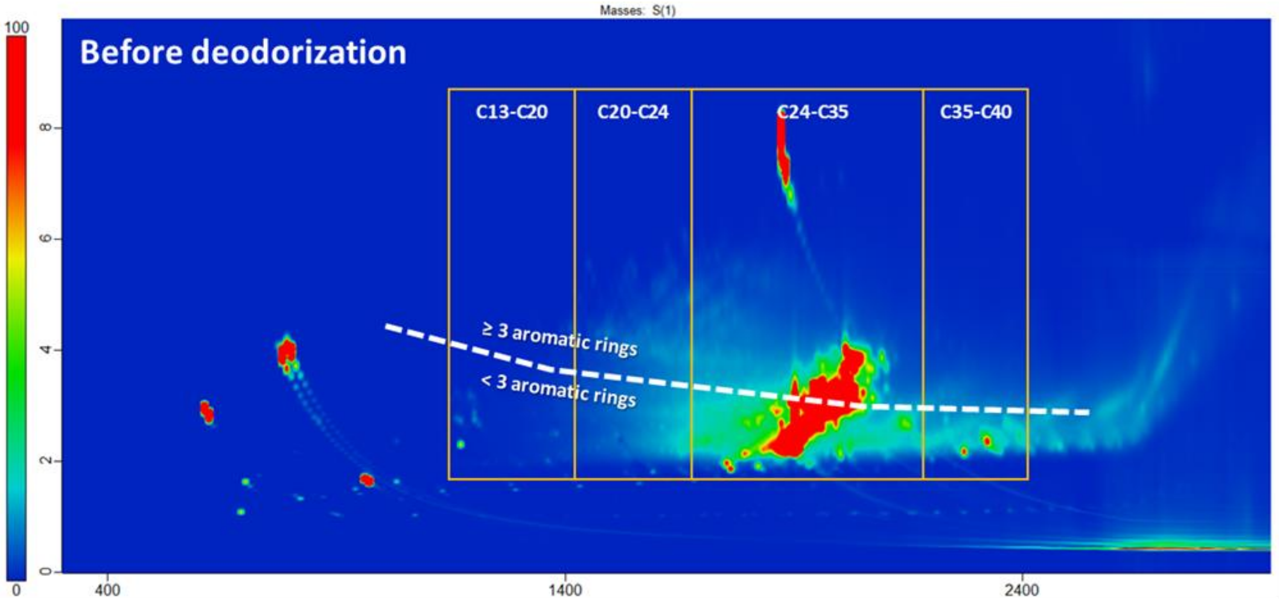
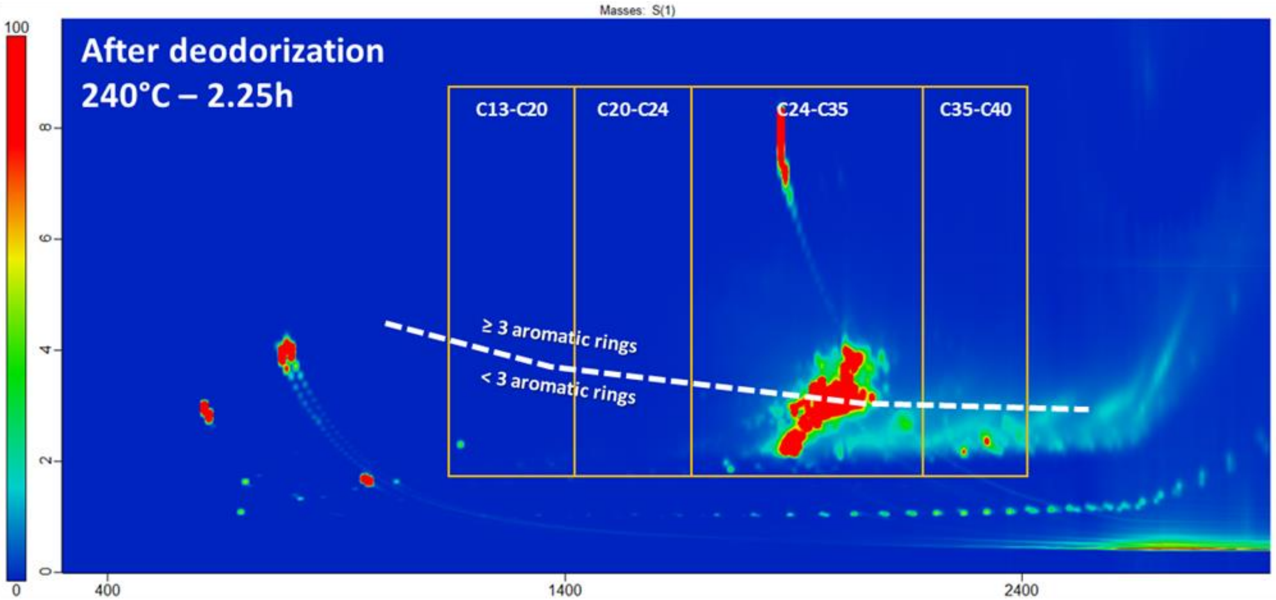




After deodorization (T°/time variable, 3 mbar, 1% steam)

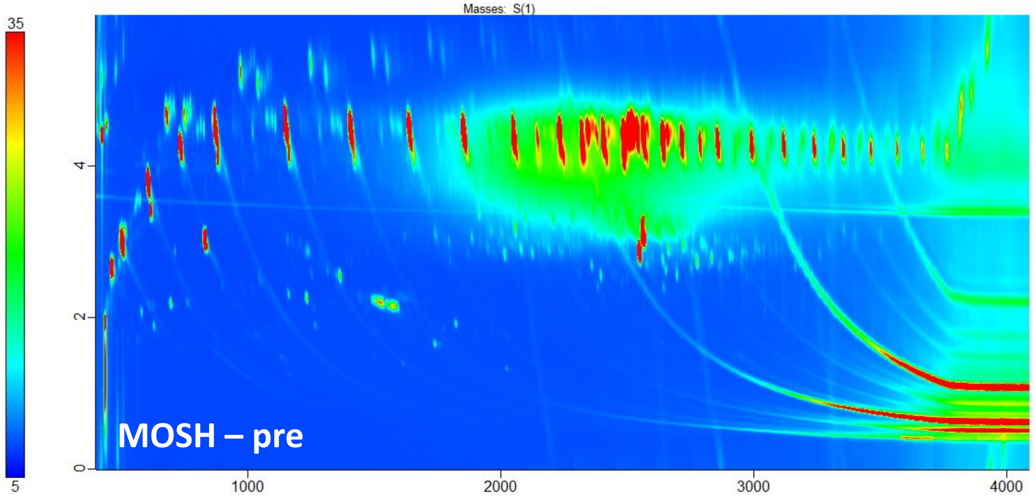
- **C13-C20**: reduction <LOQ at ~200°C ✓
- **C20-C24**: reduction <LOQ ~220°C ✓
- **C24-C35**: reduction of ~60% at >230°C ~
- **C35-C40**: no visible reduction at 240°C ⊗

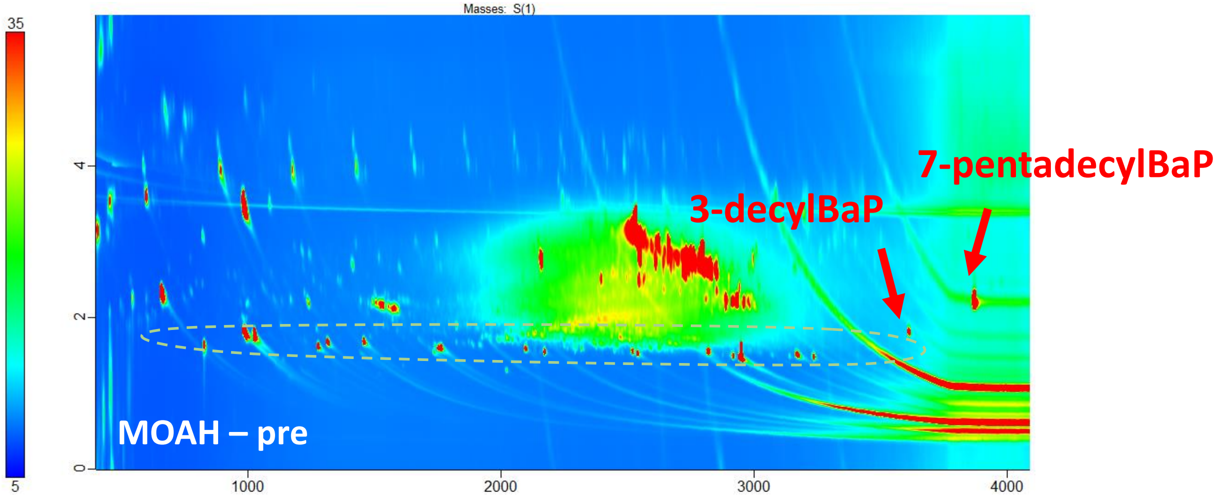
Open question at the end of the study

*Is it possible to reduce **C35-C40 MOH** applying lower (but technically feasible) pressures?*

New deodorization trials with lower pressure

Coconut oil spiked with lubricant oil and PAHs (included two alkylated PAHs)

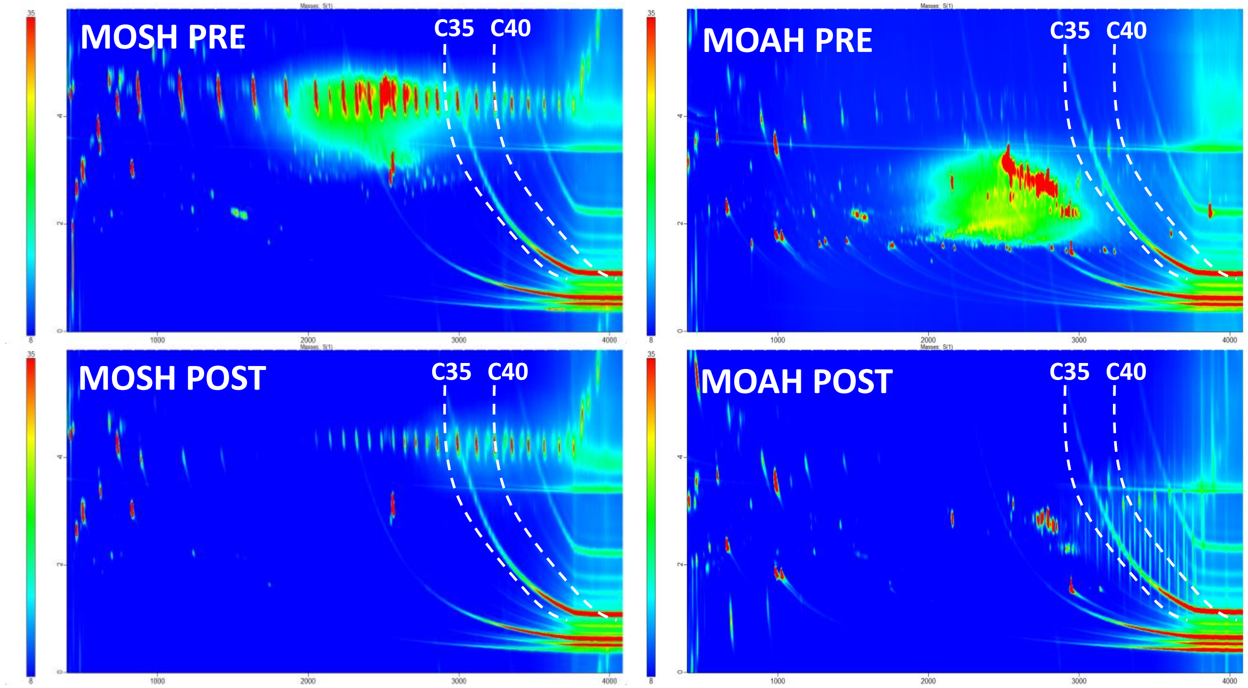


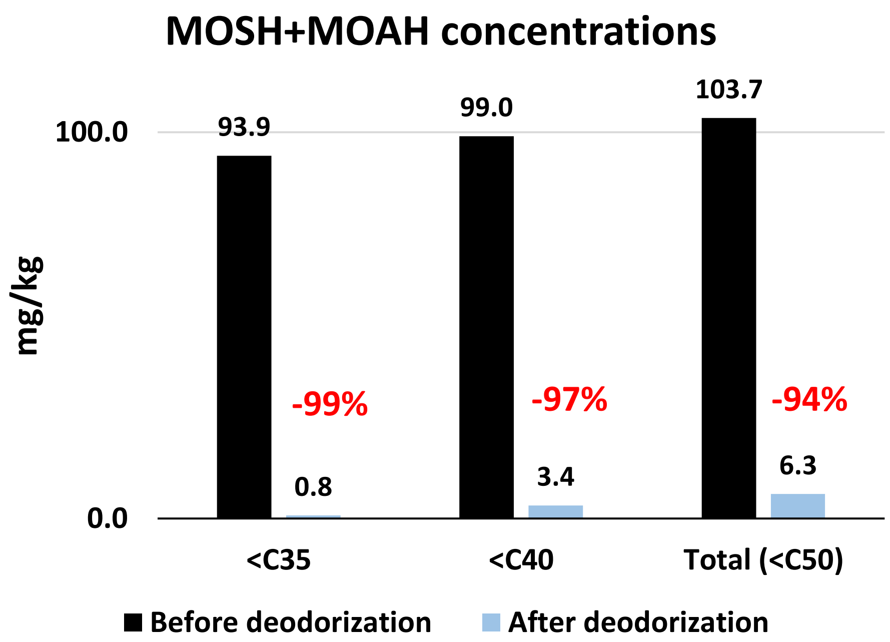


New deodorization trials with lower pressure

Deodorization conditions: 240°C, 4h, **1 mbar** (instead of 3 mbar as in *Gorska et al.*) , 1%/h steam

Matrix: spiked coconut oil





Reduction of 99% (from 66.9 to <1 mg/kg) **of the C25-C35 fraction** (compared to ~60% in Gorska et al. (2024))

Weak reduction of ~50% of the C35-C40 (5.5 to 2.7 mg/kg MOH) and C40-C50 (4.8 to 2.9 mg/kg MOH)

What about bleaching?

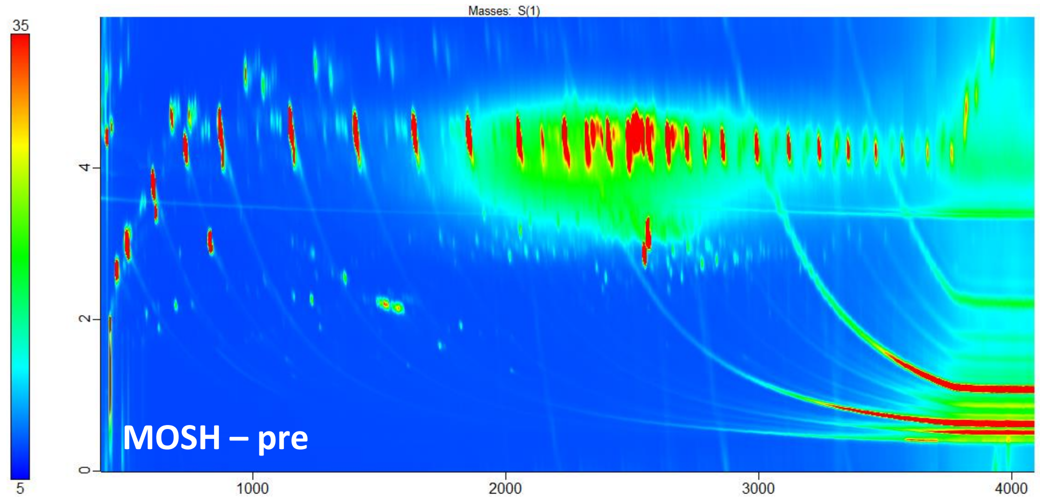
Bleaching: Adsorptive treatment (e.g. bleaching earth) under vacuum and heat to remove pigments (carotenoids, chlorophyll), peroxides, soaps, and residual salts.

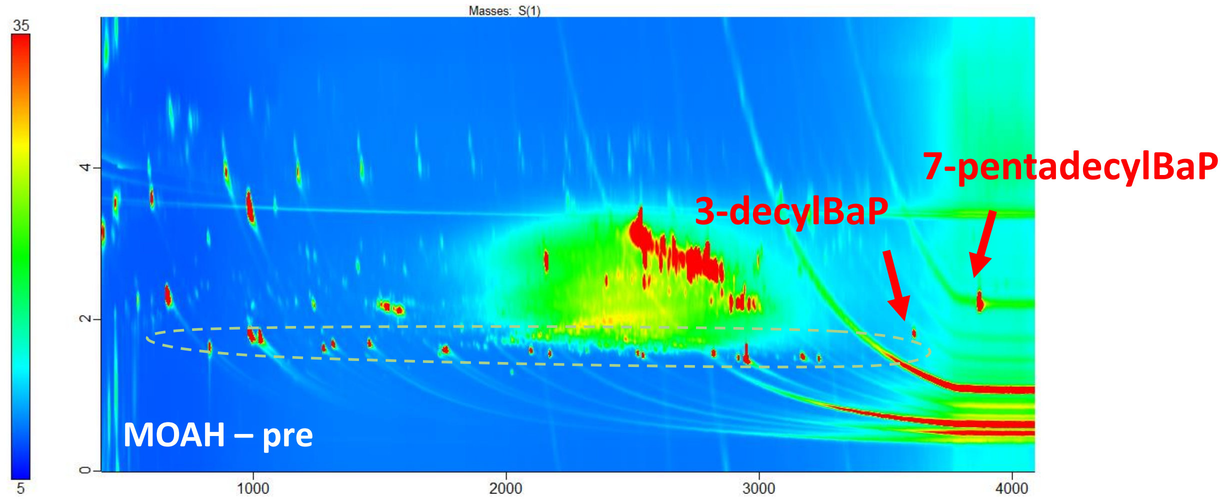
Limited available litterature for MOH

- **Heavy PAHs** are known to be able to adsorb on **activated carbon**
- Little information on the **effect of alkylation** of the parent PAH
- Significant (> 98.5%) reduction of **alkylated BaP** was observed by Bauwens et al. (2023) after **combined bleaching and deodorization**, but the effect of each individual step was not investigated
- Ursol et al. (2025) observed a **reduction of low alkylated PAHs** in bleached samples, but **epoxidation** was applied

What about bleaching?

Coconut oil spiked with lubricant oil and PAHs (included two alkylated PAHs)

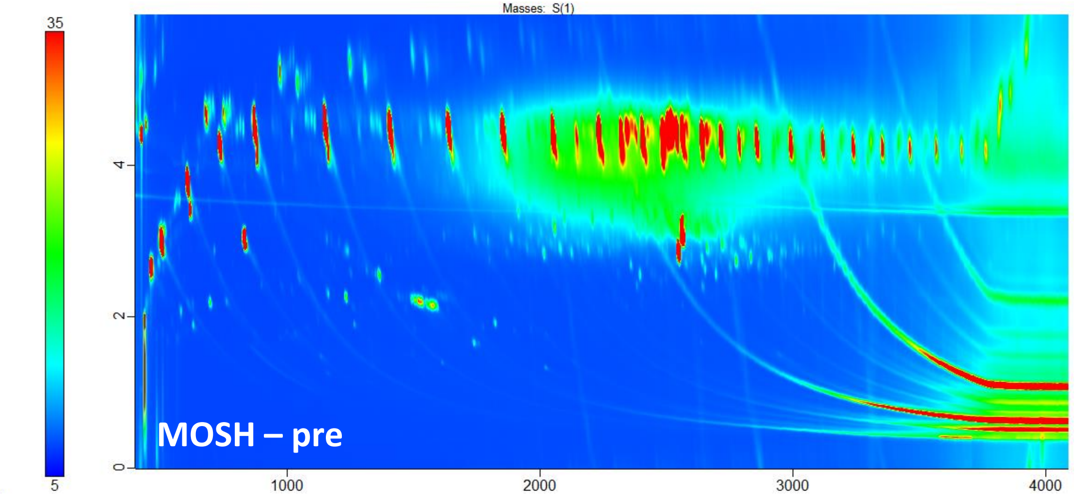


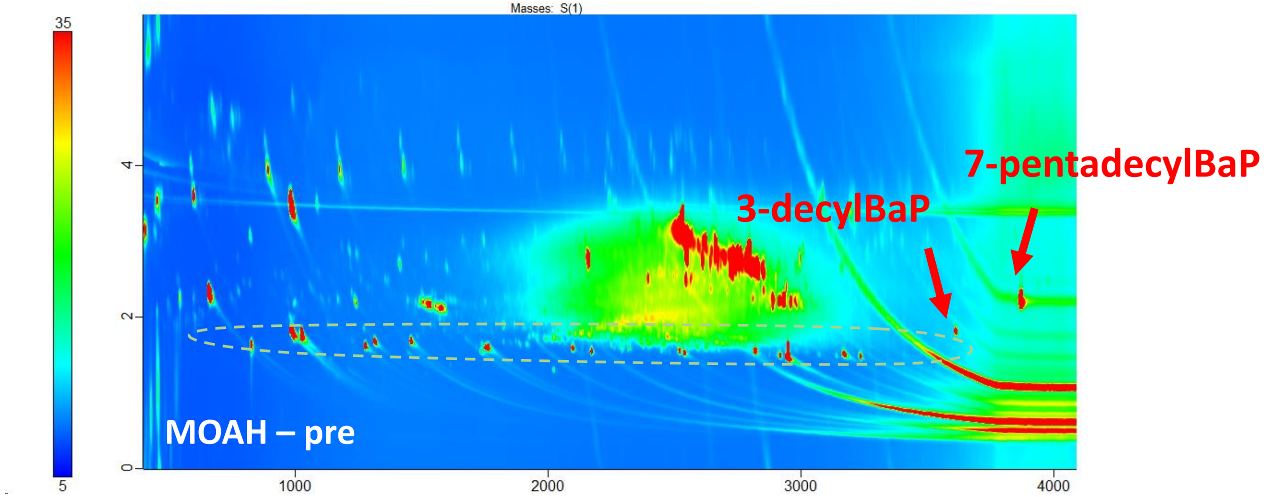


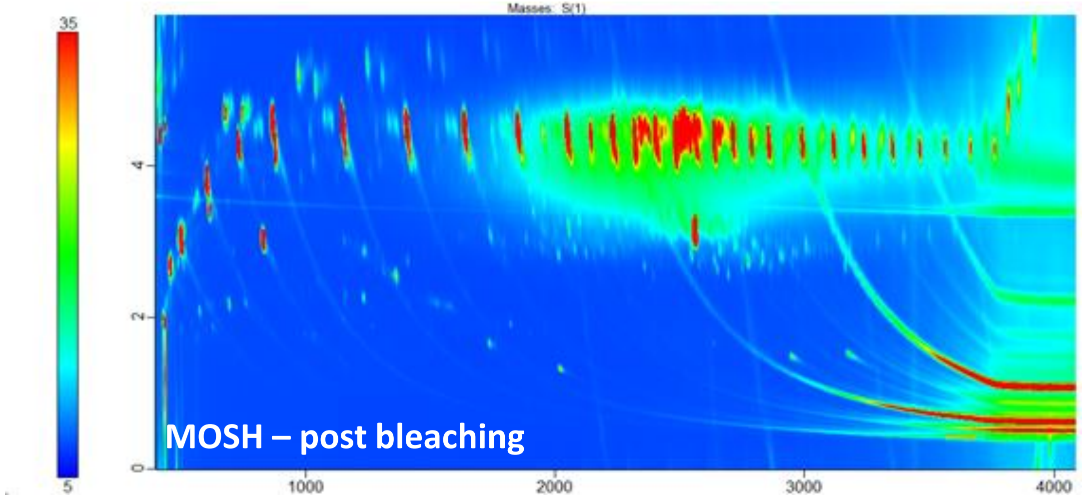
Bleaching conditions: activated carbon (Jacobi ColorSorb™ XFP21), 240°C, 1 mbar, 4 h

What about bleaching?

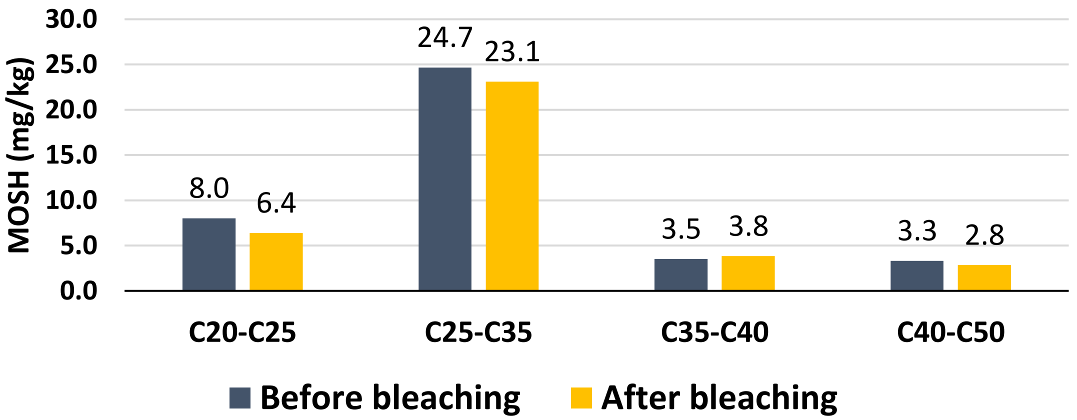
Coconut oil spiked with lubricant oil and PAHs (included two alkylated PAHs)







MOSH concentrations before and after bleaching



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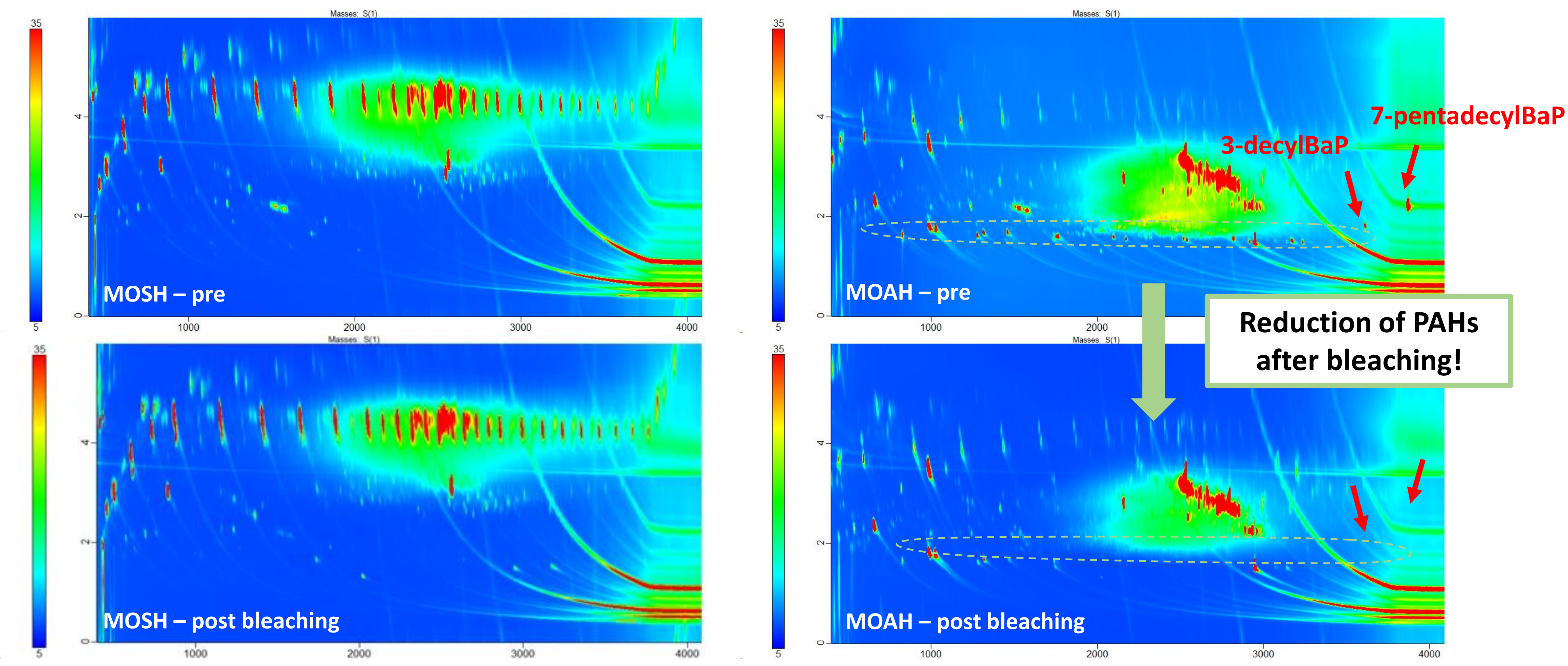

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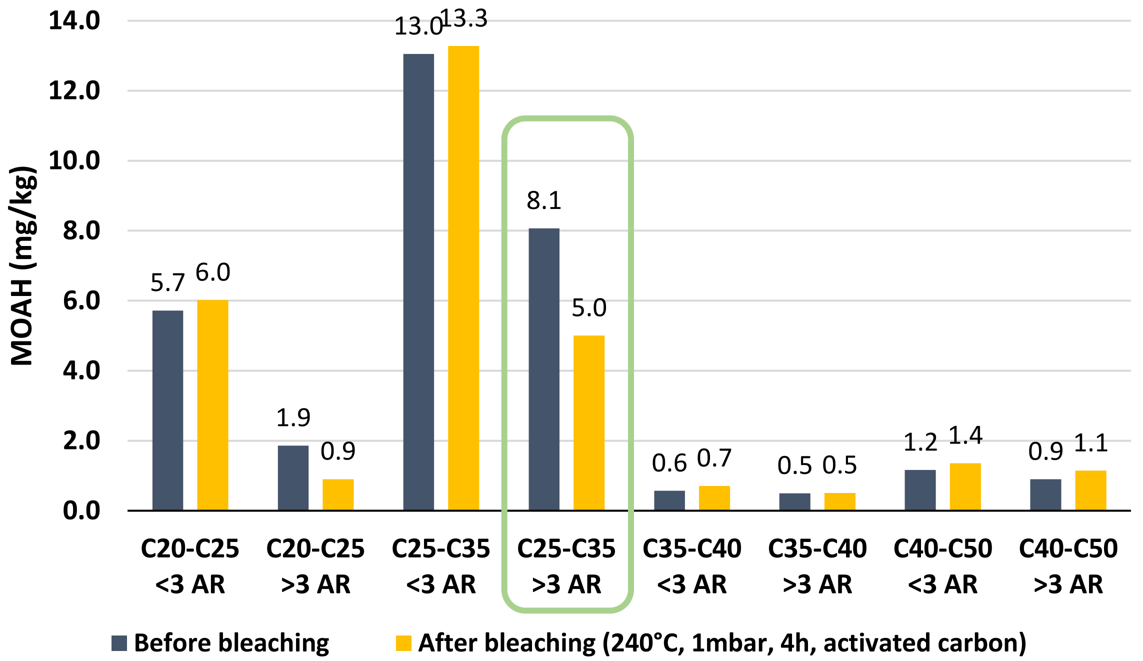
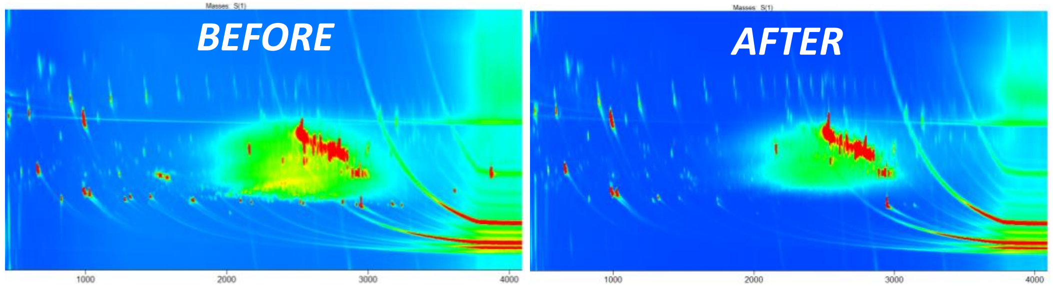
What about bleaching?

Effect of bleaching on MOAH

MOAH concentrations before and after bleaching

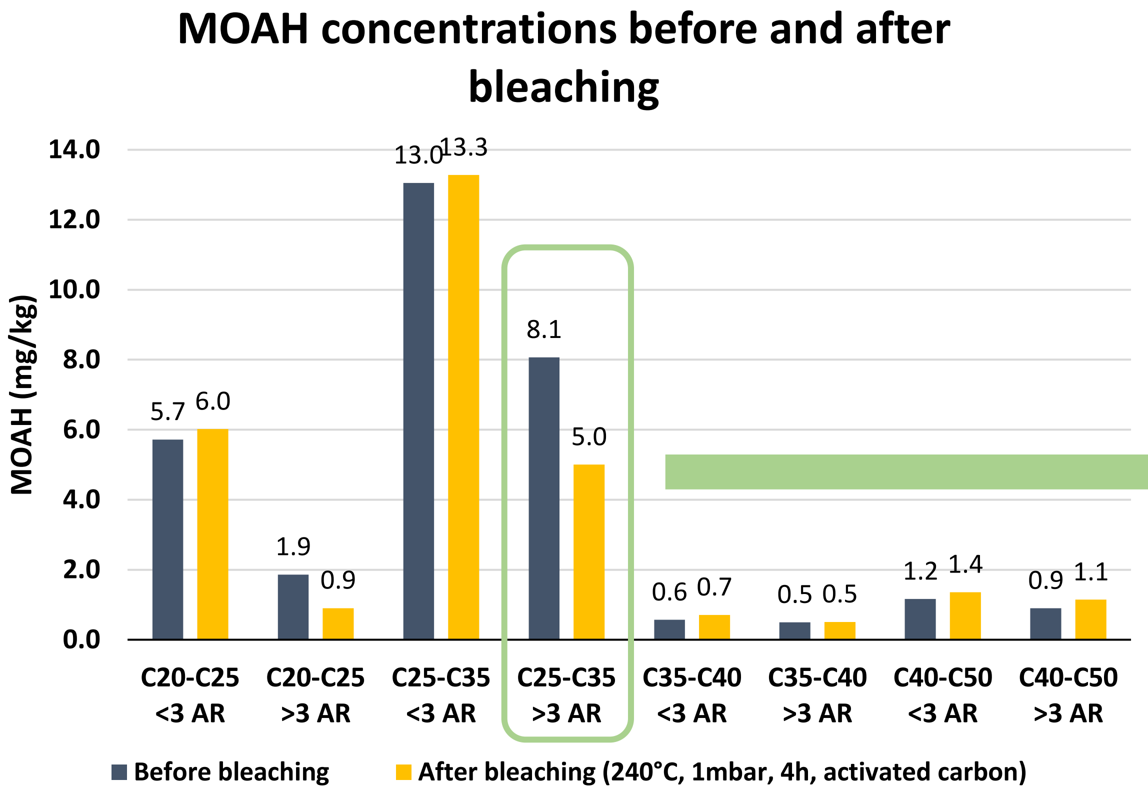


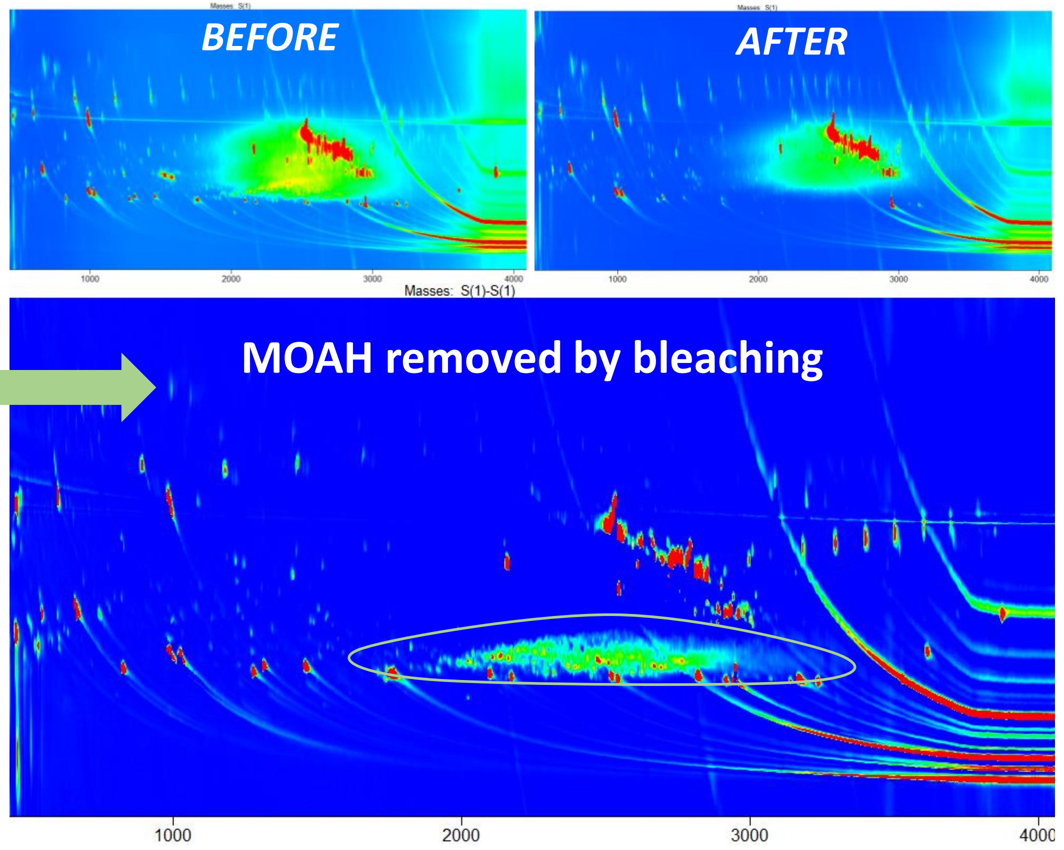


Noticeable reduction of MOAH >3 aromatic rings between C25 and C35

What about bleaching?

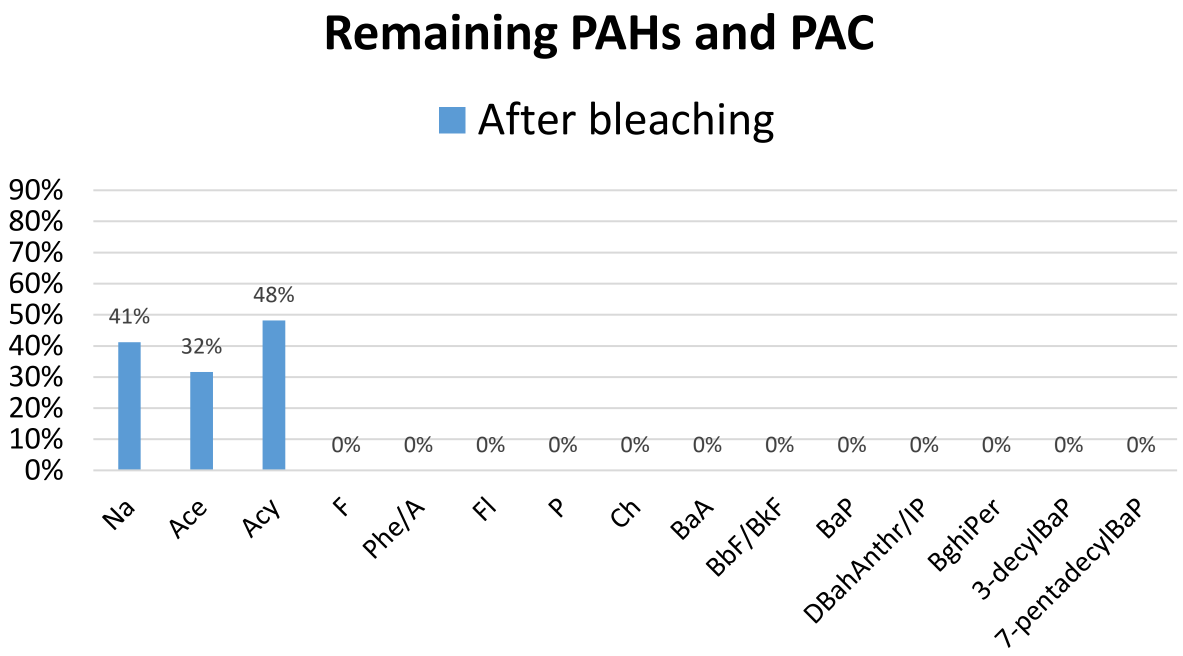
Effect of bleaching on MOAH

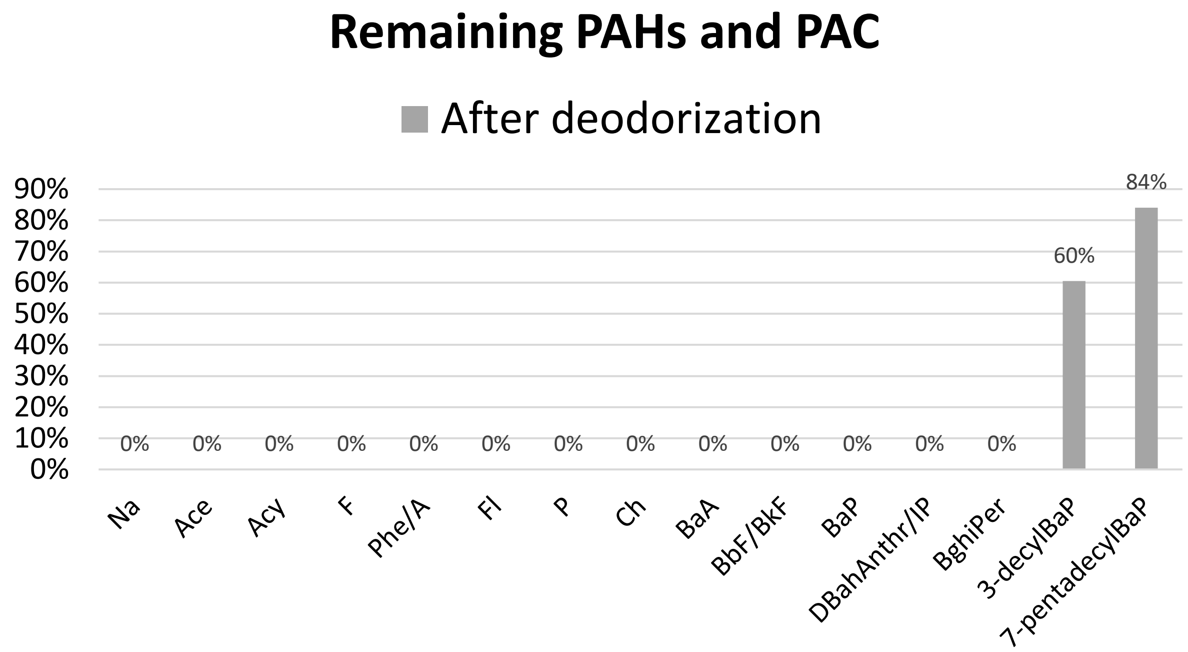


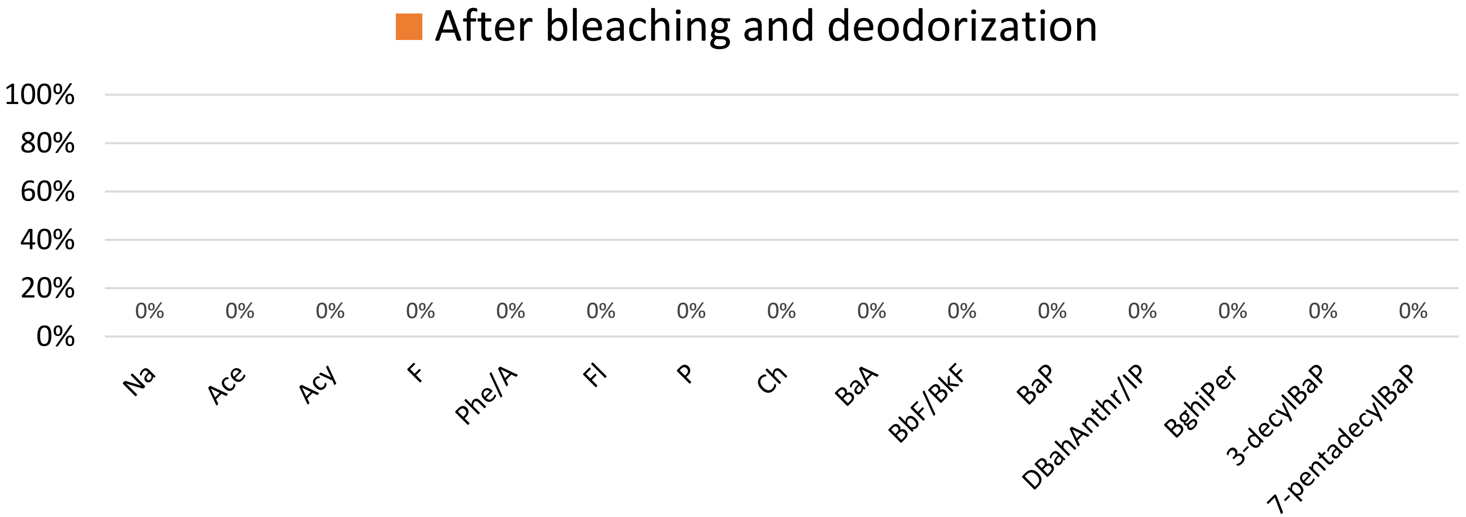


Noticeable reduction of MOAH >3 aromatic rings between C25 and C35

Effect on PAHs and PACs





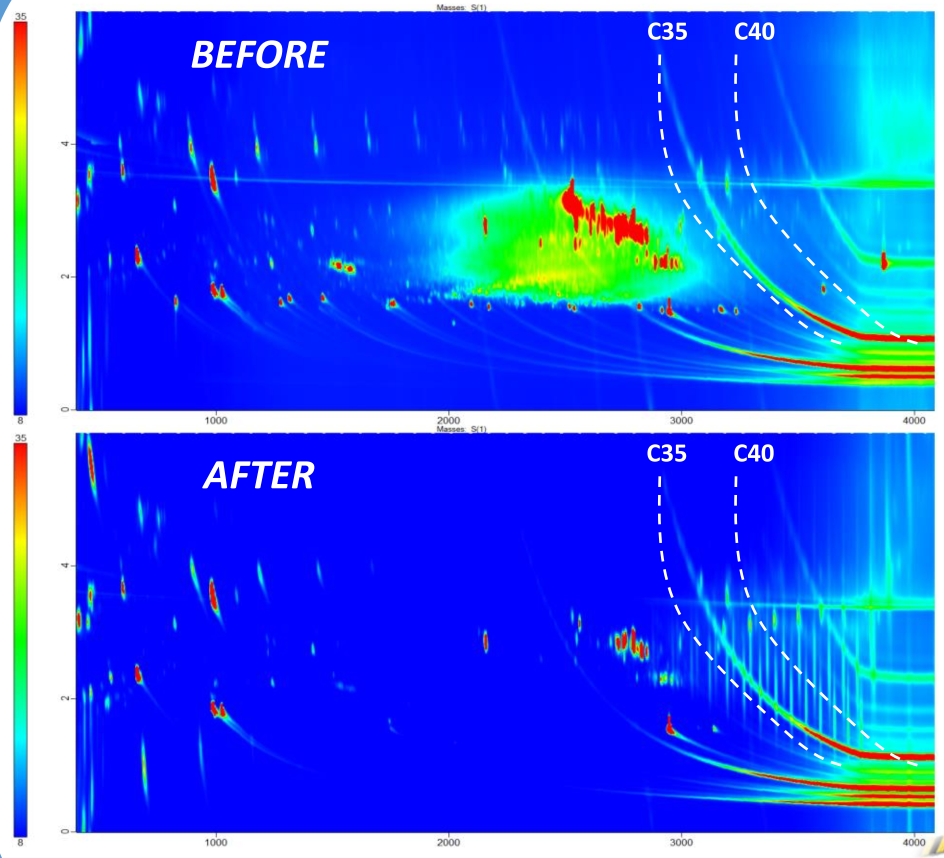


Bleaching removed all PAHs apart from Na, Ac, Ap, which could then anyway be removed during the deodorization step

Work in progress

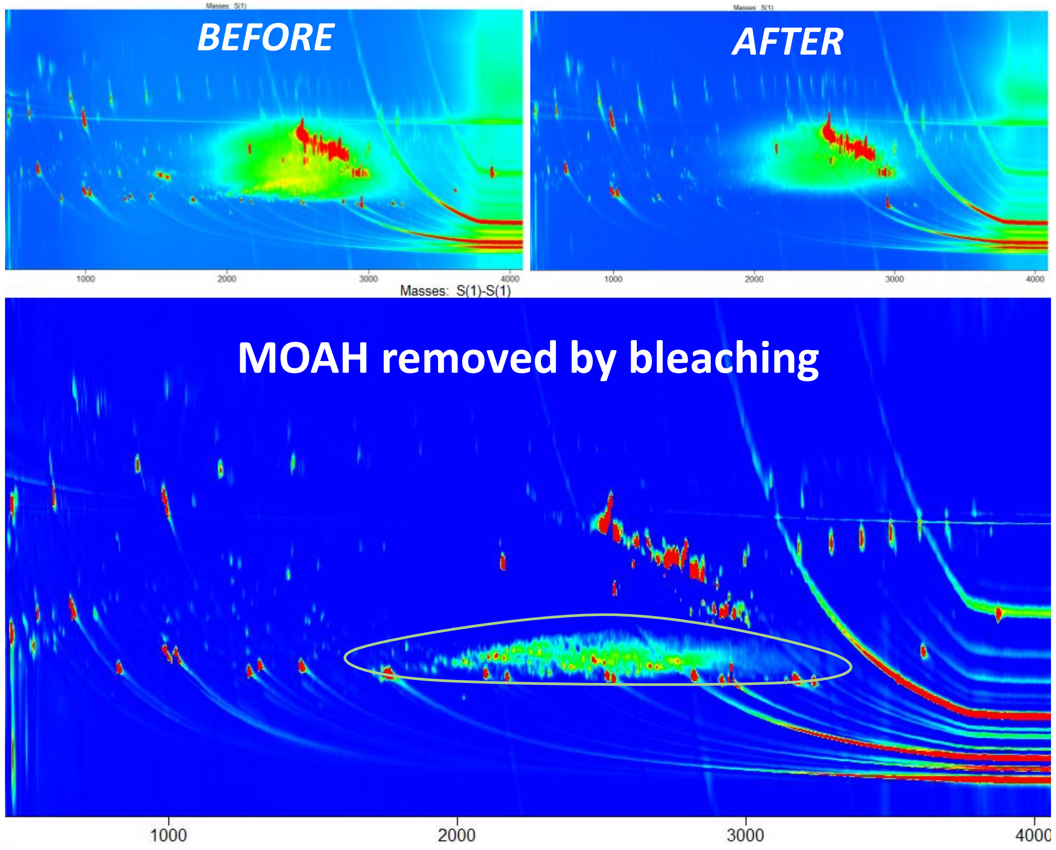
Effect of deodorization and/or bleaching on MOAH

Deodorization



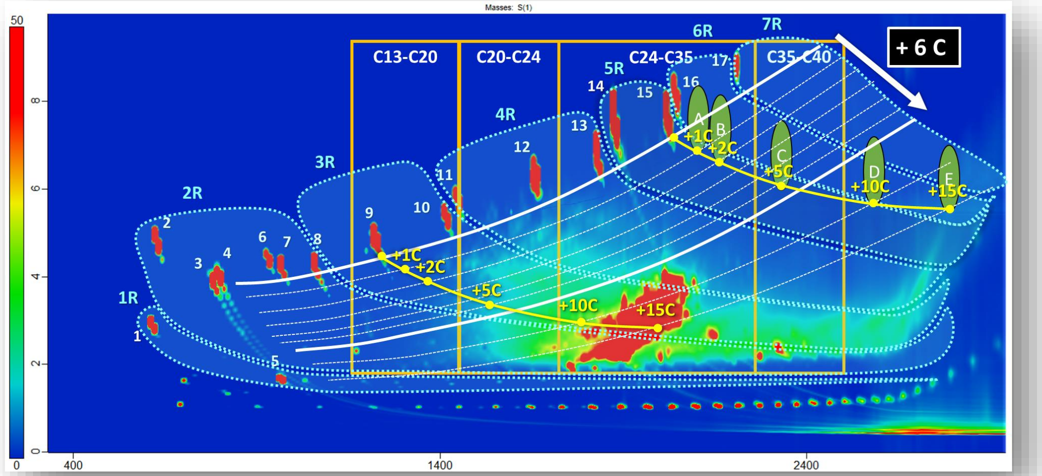
240°C – 4h; 1mbar

Bleaching

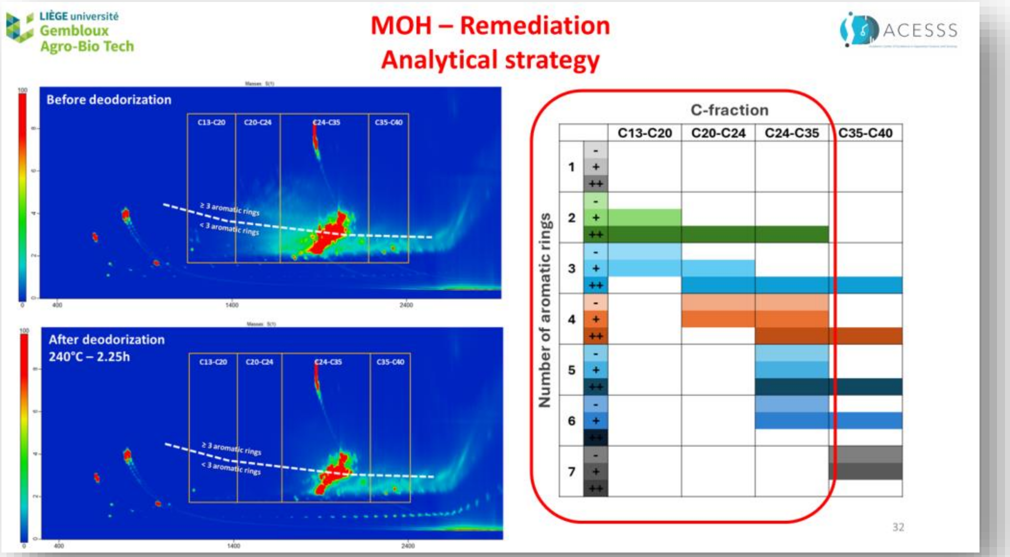


CONCLUSION

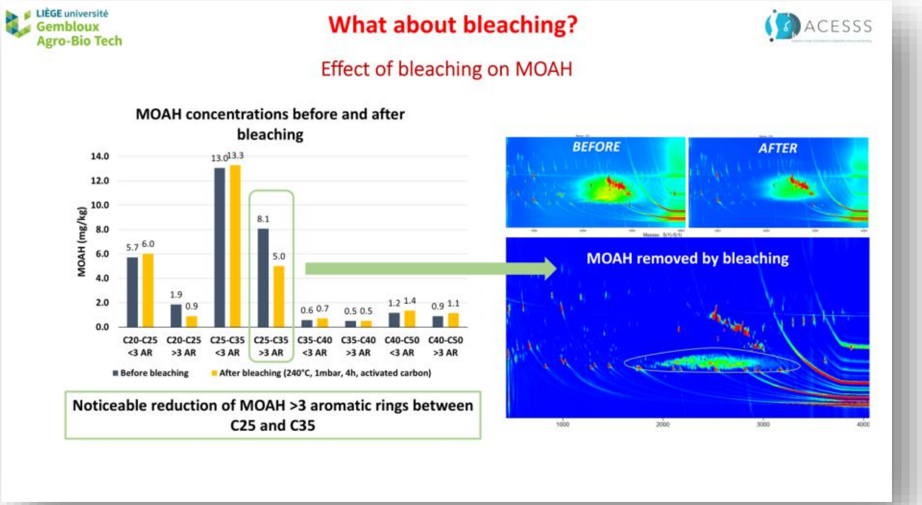
➢ **GC×GC** is a **strategic tool**, not only for getting more insight on the profile of the MOSH & MOAH contamination but also to elucidate the role of **remediation strategy**.



➢ **Deodorization** significantly remove MOH contamination depending on the **T/t** and **pressure** applied



➢ **Bleaching** significantly reduce **MOAH >3 aromatic rings between C25 and C35**



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June, 12-13

3rd ADVANCES IN SEPARATION SCIENCE WORKSHOP

Gembloux, Belgium


J. Pawliszyn


C. Cordero


G. Hopfgrtaner


H. Mol


B. Bojko


E. Leitner


P. Tranchida


E. Rosenberg


K. Schug


H.-G. Janssen


E. Gionfriddo

June, 11: 1-day course in

- **SPME**
- **GC**

Adv Sep Sci 2025

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AOCS Since 1909 Your Global Fats and Oils Connection

ACESSS Academic Center of Excellence in Separation Science and Sensing

My research group:

Sophie Vancraenenbroeck

Paula Albendea

Damien Eggermont

Aleksandra Gorska

Donatella Ferrara

Damien Pierret

Carlo Bellinghieri

LECO EMPOWERING RESULTS

RESTEK Pure Chromatography

SHIMADZU Excellence in Science

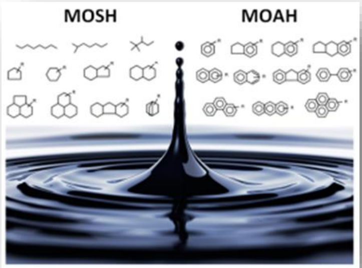
SepSolve Analytical

MARKES international

MILESTONE HELPING CHEMISTS

TRAJAN

GL Sciences



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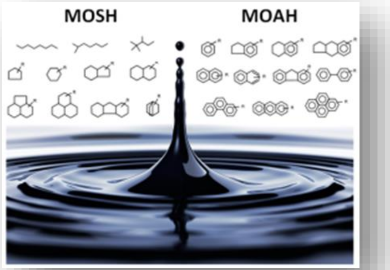

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