

Exploring the impact of roasting conditions on hazelnut quality by GC-IMS and sensory analysis

Mazzucotelli M.^{1,2}, Khomenko I.¹, Franceschi P.¹, Betta E.¹, Gabetti E.³, Falchero L.³, Cavallero A.³, Aprea E.², Biasioli F.¹

Hazelnut roasting

- Hazelnuts hold significant industrial importance. Most of their use involves **processed products** derived from **roasted kernels**, such as hazelnut paste.
- The distinctive flavour developed during roasting is a primary factor driving hazelnut consumption and its use in confectionery products.
- The **volatile organic compounds** (VOCs) of roasted hazelnuts play a fundamental role in determining their **sensory quality**.
- **VOCs** are **influenced** by geographical and botanical **origin of kernels**, as well as by **industrial processing** such as storage and roasting.

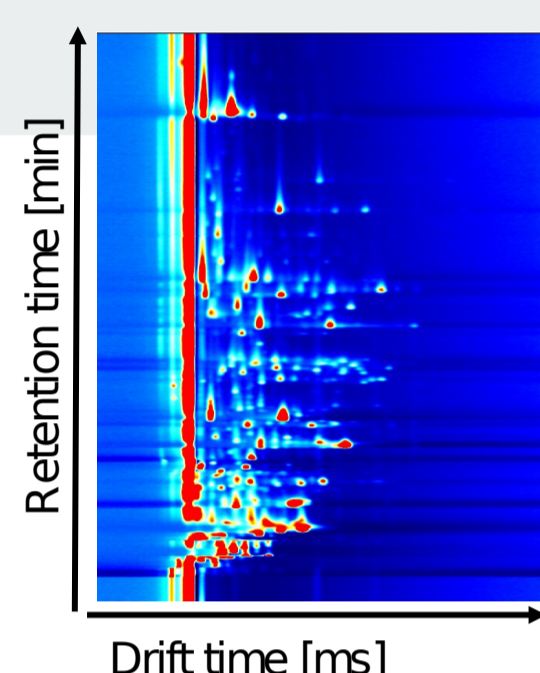
Roasting

- The most used roasting method is **convective heat transfer** (CV) in a hot air oven, where heat is transferred from the surface to the interior of the kernels.
- **Infrared heating** (IR) is an alternative method. In this case the roasting proceeds from the inside of the kernel outward, without ventilation, resulting in more uniform heating.

In this study, hazelnut roasting was investigated by combining analytical and sensory evaluations to assess the impact of **roasting technology, conditions, and storage** on hazelnuts from two different botanical and geographical **origins**.

GC-IMS

- Gas Chromatography coupled with Ion Mobility Spectrometry (GC-IMS) is an analytical technique that is rapidly gaining popularity for **food flavour analysis**.
- The use of static headspace (SHS) sampling results in **no sample preparation**, eliminates the need for preconcentration steps, and leads to relatively **short analysis times**, making SHS-GC-IMS a promising rapid analytical tool for applications where simplified protocols are highly desirable.



In this study on hazelnut roasting, SHS-GC-IMS was employed for **targeted monitoring** of key aroma compounds and for **untargeted volatile fingerprinting**.

A reference hazelnut paste sample was used to monitor the instrumental response over time and to normalize the data, correcting for the analytical batch effect.

Materials and Methods



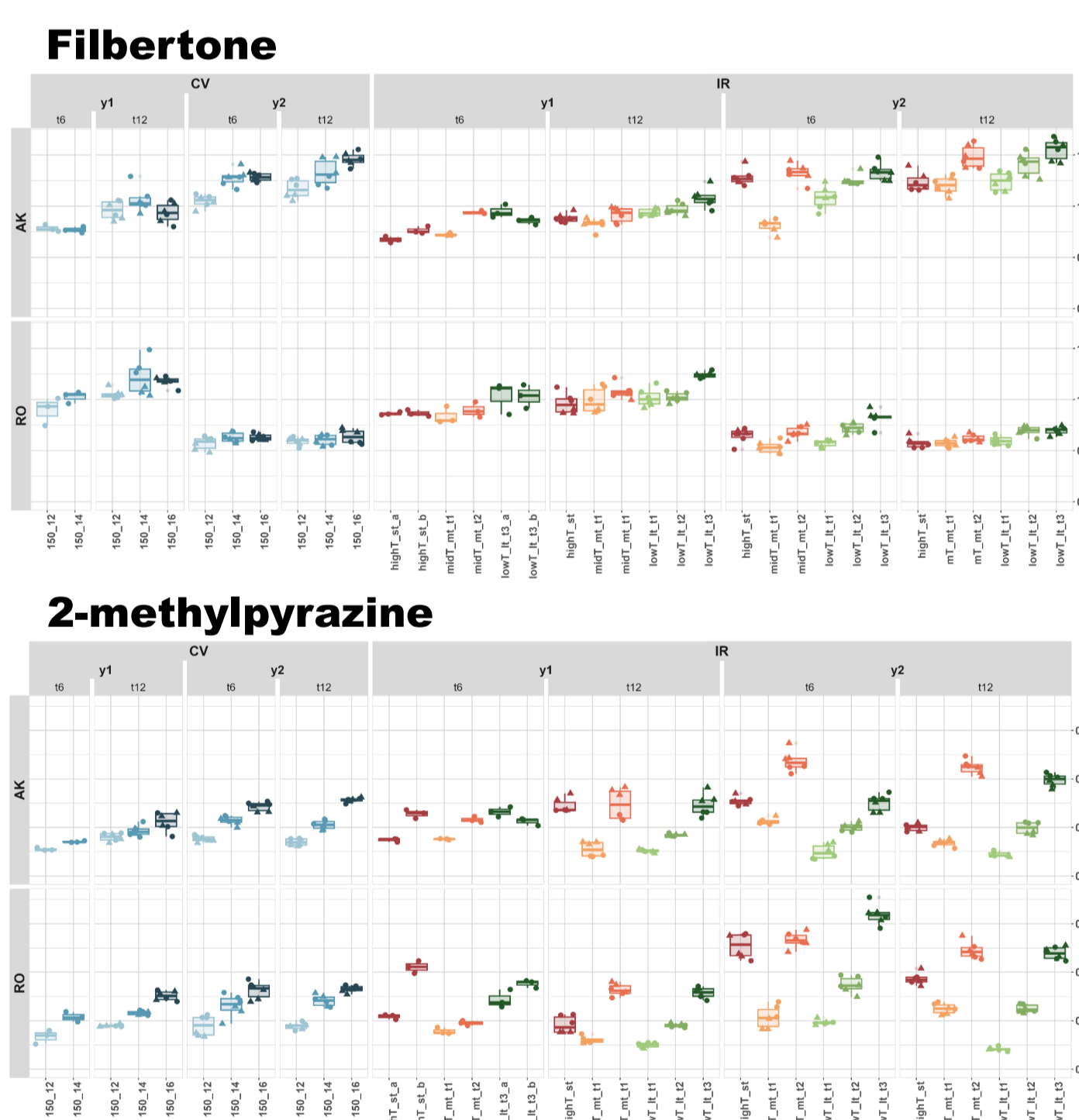
- **Samples**
 - Tonda Gentile Romana monocultivar hazelnuts (**RO**) from Lazio (Italy) and Akçakoca hazelnuts (**AK**) from Turkey
 - Experimental design repeated for two harvest years (2021 - **y1** and 2022 - **y2**).
 - For each harvest year, raw kernels were roasted after two different storage time (6 month - **t6** and 12 months - **t12**)
 - **Roasting**
 - two lab roasting technologies (infrared - **IR** and air convection - **CV**) with different conditions (temperature and time):
 - CV : 150°C (12, 14, 16 min)
 - IR: high temperature_short time (highT_st), mid temperature_mid time (midT_mt) and low temperature_long time (lowT_lt)
 - two technical replicates for each roasting condition
- The roasted kernels were processed to obtain the roasted hazelnut pastes.
- **Measurements**
 - **Roasted kernels:**
 - **moisture content:** by thermogravimetric analysis with thermobalance,
 - **color:** assessed using CIELAB parameters L* (lightness), a* (red-green axis), and b* (blue-yellow axis) → **L_hz, a_hz, b_hz**
 - **Hazelnut pastes:**
 - **color** → **L_paste, a_paste, b_paste**
 - **VOCs analysis** by SHS-GC-IMS
 - **sensory analysis** by a panel trained on hazelnut evaluation (QDA - Quantitative descriptive analysis (ISO 11035), 35 trained assessors) → sensory attributes: **roasted, hazelnut flavour, sweet, bitter, oxidated/old**
 - For IR technology (year 2), the **roasting temperature profile** was accurately monitored using probes that measured the inner temperature of the kernels to evaluate the repeatability of the roasting process for within-batch technical replicates and between-batch replicates. Parameters from temperature profile → max_T_kernel; ts_60, ts_100, ts_140 (thermal sums above 60°C, 100°C and 140°C), roasting_rate.

VOCs analysis by SHS-GC-IMS

Targeted

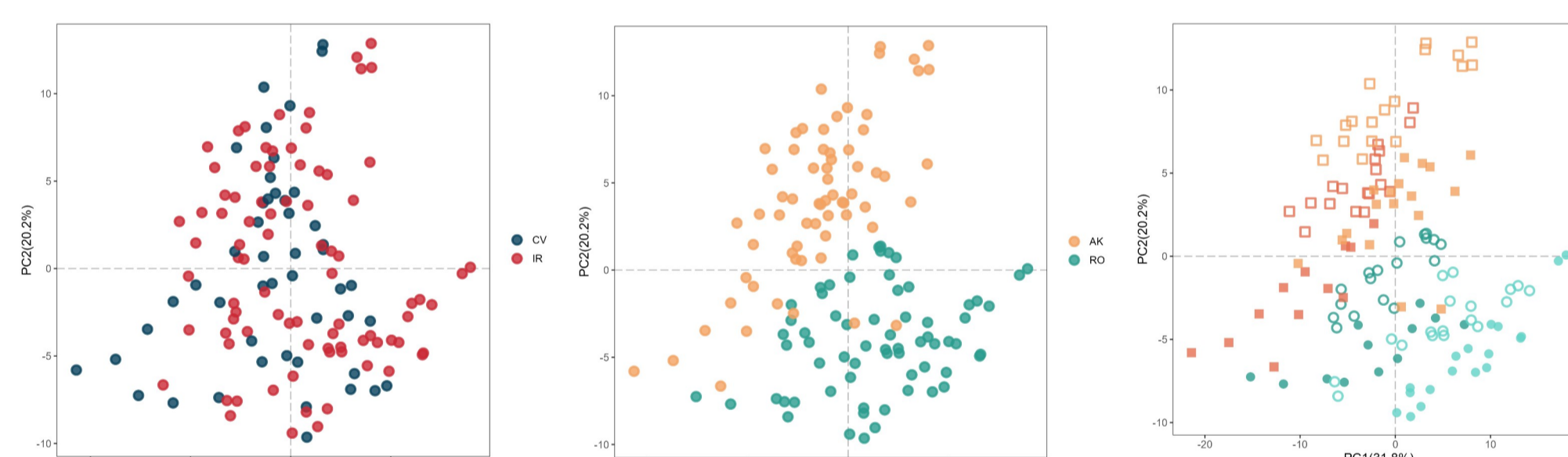
Monitoring of a selection of aroma compounds → Filbertone (hazelnut key odorant) and alkyl pyrazines (roasting markers)

- Boxplots reports intensity (V) of the dimer peaks
- Repeatability of roasting technical replicates → **consistency of the roasting process**
- Differences between botanical/geographical origin, **strongly affected by the harvesting year** (y1 vs y2)
- **No relevant impact of the storage time** of the raw kernels (t6 vs t12) on the development of the **aroma compounds monitored**
- Filbertone: it was not observed a consistent trend in relation to roasting conditions. For IR roasting, however, lower temperature and longer time resulted in higher peak intensity.
- Alkylpyrazines: clear trend in relation to the roasting conditions, similar for all the compound of the class. Strong influence of the roasting time.



Untargeted volatile fingerprinting

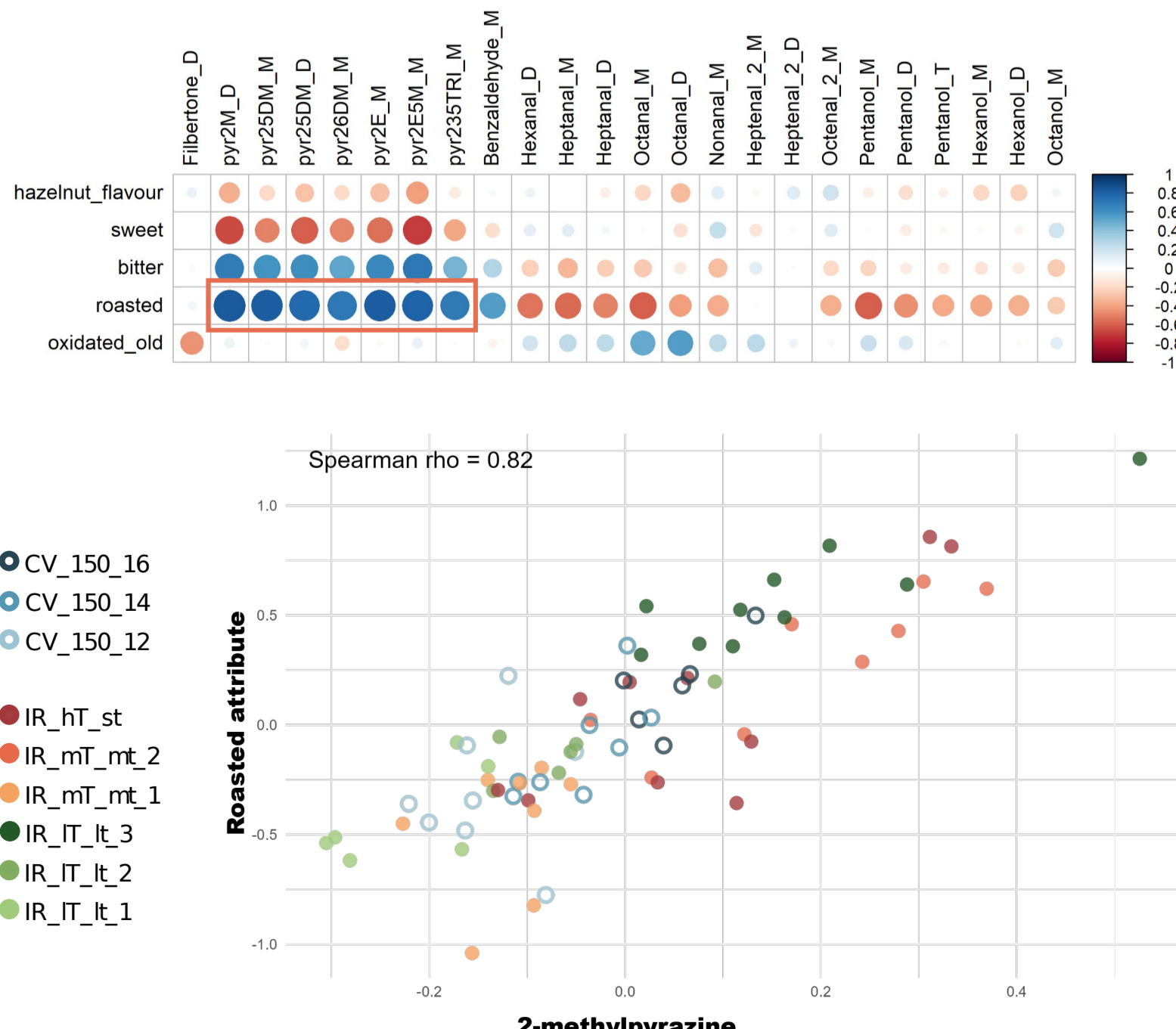
Automated peak detection workflow implemented in R → **153 peaks**
 PCA score plot with samples colored according to the variable of interest:



- **Roasting technology**
IR vs CV
 - The untargeted approach was used to investigate the impact of the experimental variables on the entire volatile profile of the samples.
 - From data exploration of fingerprinting profiles, differences were observed between storage duration.

Correlation with sensory analysis

A Spearman correlation analysis was conducted to explore the relationships between sensory attributes (roasted, hazelnut flavour, sweet, bitter, oxidated/old) and volatile organic compounds (VOCs) in the samples.



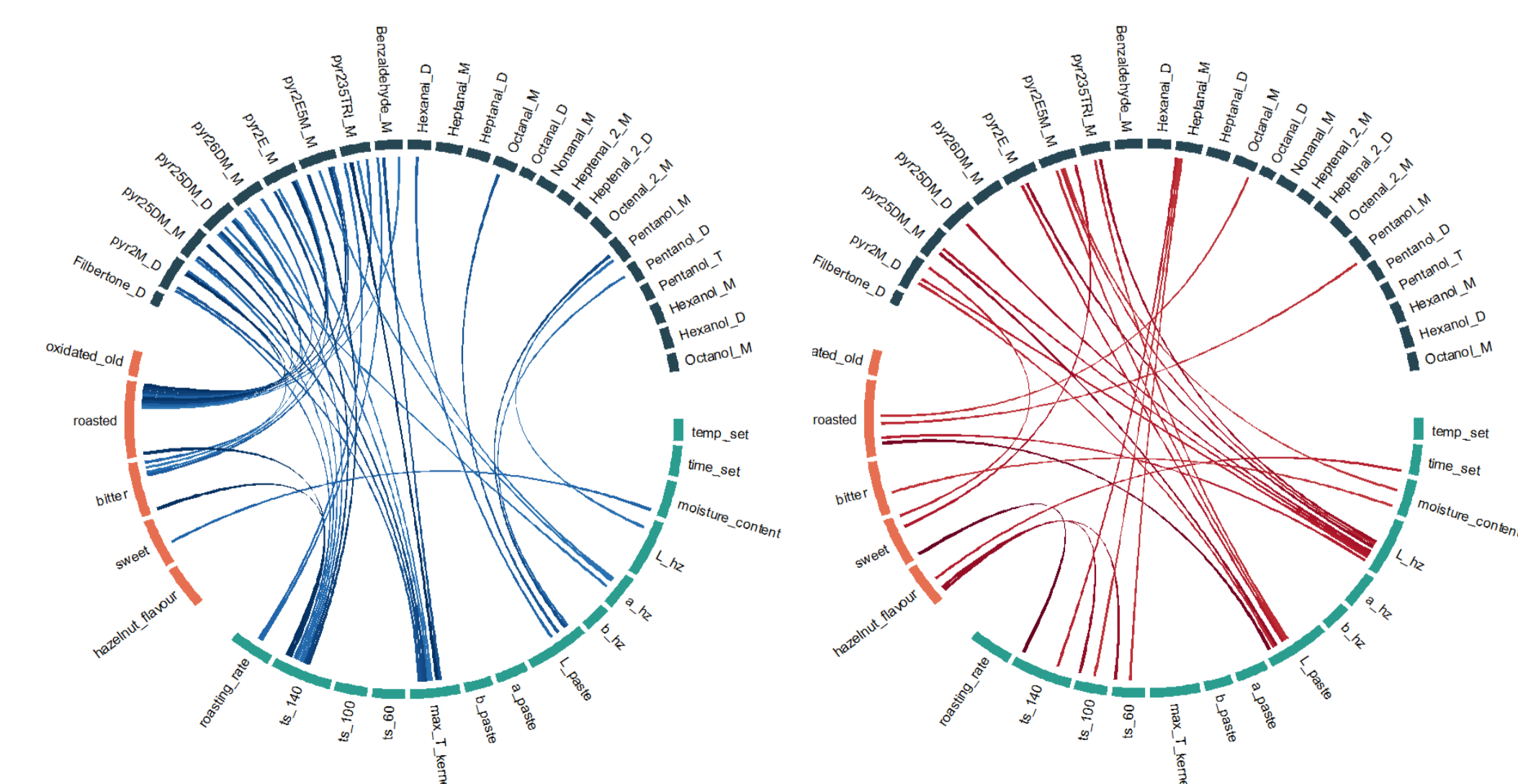
- The correlation matrix, visualized as correlogram, shows the strong **positive correlation** between **alkylpyrazines** and the **“roasted”** sensory attribute, while, interestingly, no significant correlation was observed between the filbertone peak and any of the sensory attributes investigated
 - The scatter plot illustrates the correlation between the **roasted attribute** and the **2-methylpyrazine** peak intensity.
 - Point shapes - roasting technology and point colors - roasting conditions → assessment of how these factors influence the relationship between the two variables.
- To control for year-to-year variability, the data were demeaned by subtracting the mean value for each year.

Acknowledgement

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...and other measured parameters

Other measured parameters (color, roasting temperature profile, moisture content), were included in the Spearman correlation analysis. The chord plots provides an integrated view of the relationships across all variables, clearly illustrating **positive correlations** and **negative correlations**.



Conclusions

The study demonstrates the feasibility of using SHS-GC-IMS for efficient monitoring of industrial hazelnut roasting, highlighting the links between color assessment, roasting profile, sensory evaluation, and VOC analysis. The use of both targeted and untargeted approaches provides a more comprehensive and informative VOC profile