Mapping of gas-phase CO2 in the headspace of champagne glasses by using an infrared laser sensor under static tasting conditions

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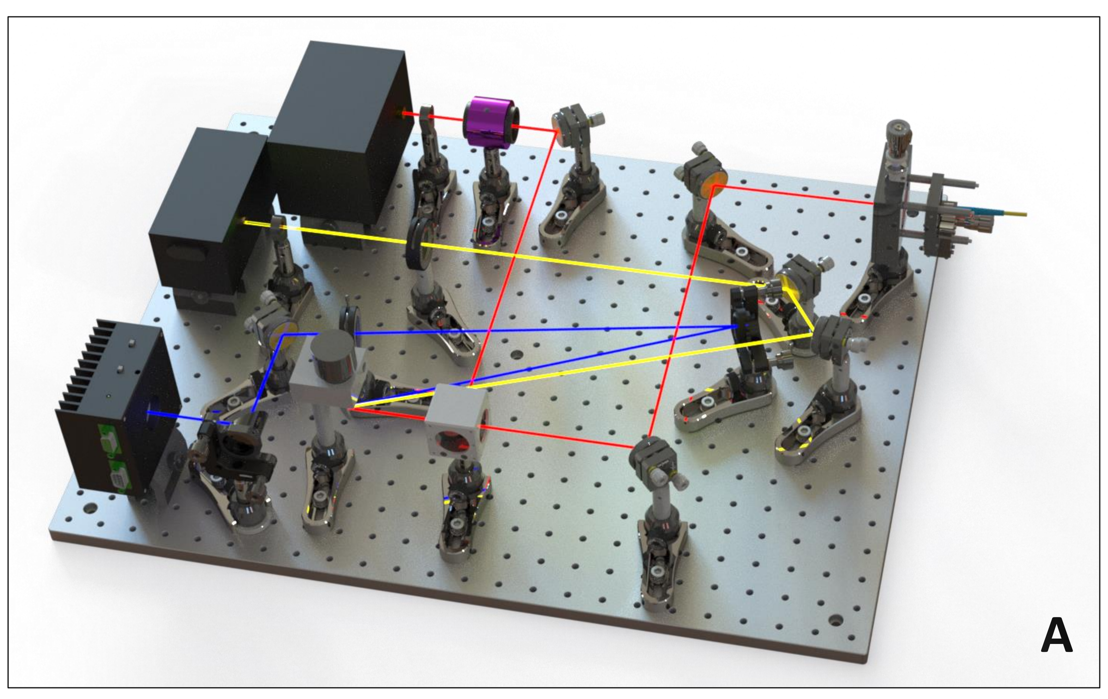
Introduction

During the pouring of champagne in a glass, and throughout the several minutes of tasting, the headspace of the glass is progressively invaded by many chemical species, including **gas-phase CO_2** in large majority. The myriad of bubbles nucleated in the glass and bursting at the champagne surface act as a continuous paternoster lift for CO_2 and aromas [1]. **Nevertheless, inhaling a gas space with a concentration of gaseous CO_2 close to 20% and higher triggers a very unpleasant tingling sensation, the so-called "carbonic bite",** which might completely perturb the perception of the wine's bouquet. To enhance the champagne tasting experience, **monitoring gas-phase CO_2** in the headspace of glasses has thus become a topic of interest over the last dozen years [2-5].

Based on the Tunable Diode Laser Absorption Spectroscopy (TDLAS) technique, **real-time monitoring of gas-phase CO_2 was performed**, in space and time, under static conditions, in the headspace of two glass types showing distinct shapes and volume capacities (namely the **21 cL INAO glass**, a worldwide reference for sensory evaluation, and a brand-new glass recently proposed as a universal glass for the tasting of still and sparkling wines, the **45 cL ŒnoXpert**).



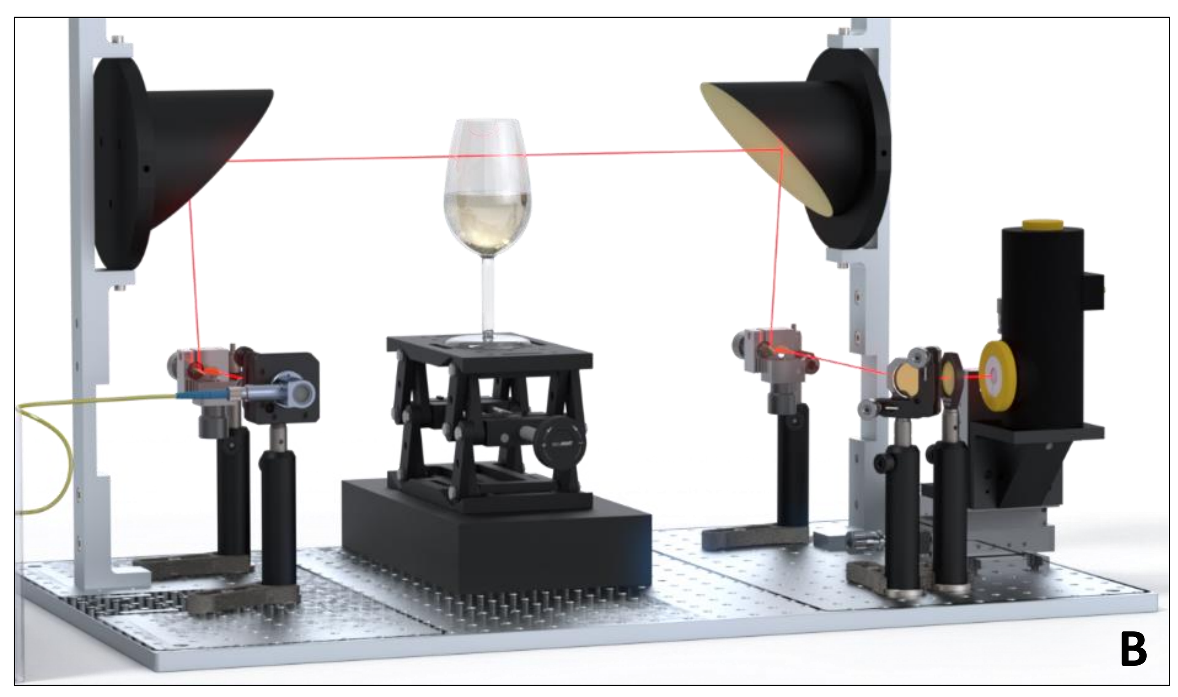


Figure 1: 3D view of the optical part of the CO_2-DLS modeled with SolidWorks©; the blue beam is the optical path of **laser #1** (for measuring a gas-phase mixture with 10%-100% of CO_2); the yellow beam is the optical path of **laser #2** (for measuring a gas-phase mixture with 0-10% of CO_2); and the red beam is the common path followed by the two lasers **(A)**; 3D view of the optical setup dedicated to simultaneously monitor gas-phase CO_2 along a multipoint array in the headspace of champagne glasses **(B)**.

CO_2-DLS description

- A CO_2-Diode Laser Sensor (**CO_2-DLS**) with two distributed feedback (DFB) diode lasers was developed to allow the fine tuning of gas-phase CO_2 over a large concentration range (**Figure 1A**) [3].
- To simultaneously monitor CO_2 along a multipoint array in the headspace of glasses (**Figure 1B**), two couples of **galvanometric mirrors** were combined with a couple of **parabolic mirrors** symmetrically positioned on either side of the glass headspace [4,5].
- A high temporal data acquisition resolution of **168 Hz** was achieved.

Enological application

- A standard **Champagne wine** was used (Henri de Verlaine, Marne).
- To trigger standardized effervescence in glasses, the two glass types (**INAO 21cL** and **ŒnoXpert 45 cL)** were laser-etched with a single laser beam impact done at the bottom of their bowl.
- CO_2 tracking was performed, under various tasting conditions, in the headspace of the glasses **along a central axis** on several **vertically aligned pixels**.

A vertical stratification of gas-phase CO_2 in the headspace of the two glass types

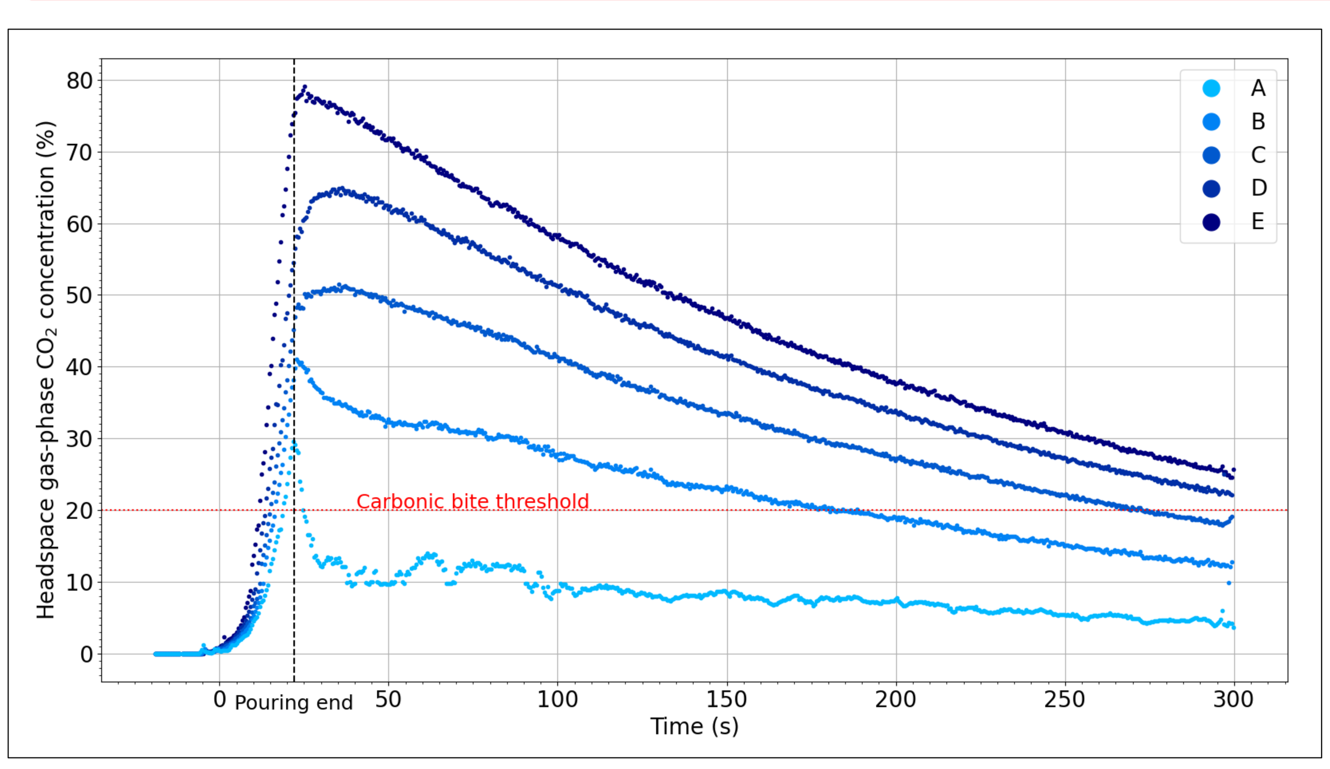
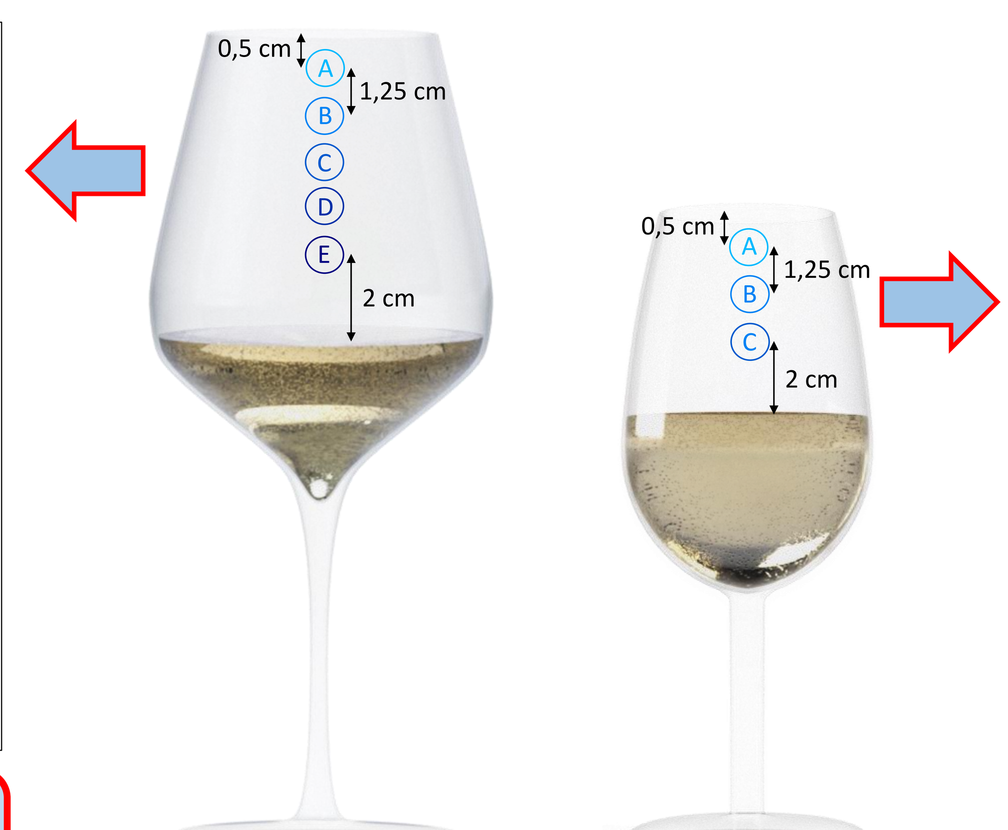


Figure 2: CO_2 concentrations monitoring (in %) during the five minutes following pouring, along a central axis composed of five vertically aligned pixels in the headspace of **ŒnoXpert 45 cL** for **100 mL** of champagne dispensed at **12°C**.



ŒnoXpert 45cL **INAO 21cL**

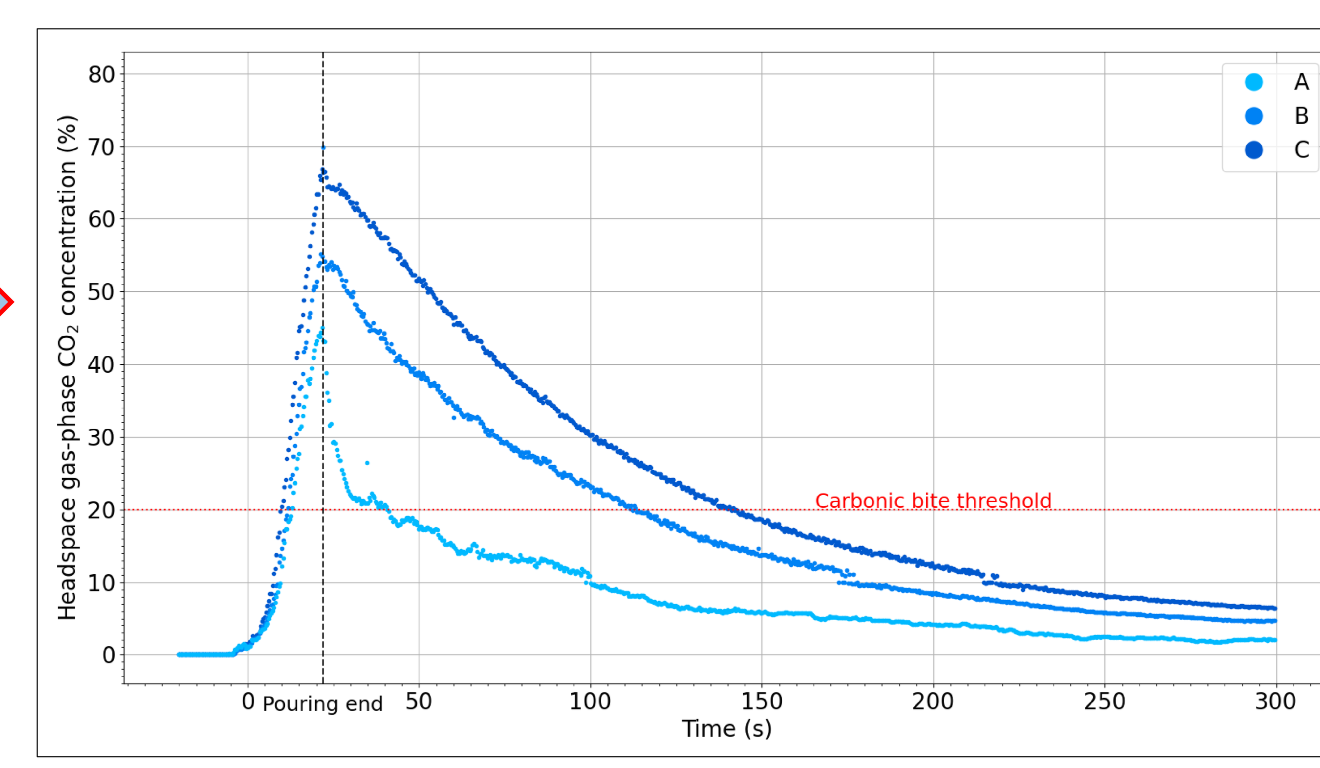


Figure 3: CO_2 concentrations monitoring (in %) during the five minutes following pouring, along a central axis composed of three vertically aligned pixels in the headspace of **INAO 21 cL** for **100 mL** of champagne dispensed at **12°C**.

Following the time series data recordings displayed in **Figures 2** and **3**, a **vertical stratification of gas-phase CO_2** unambiguously appears in the headspace of both glasses, with decreasing CO_2 concentrations while moving away from the champagne surface and as time elapses. Immediately after pouring, the concentration of CO_2 reached 0,5 cm below the glass edge (at pixel A, close to the taster's nose) is **higher** for **INAO 21 cL** than for **ŒnoXpert 45 cL**. But, for both glasses, the peak CO_2 concentration exceeds the carbonic bite threshold close to 20%. Nevertheless, the drop in the CO_2 concentration level happens much faster in the ŒnoXpert glass than the INAO glass. This observation is due to the larger volume capacity of ŒnoXpert glass, which then allows a better dilution of CO_2 in the gaseous phase in its headspace.

The **impact of the volume of champagne dispensed** on the level of gas-phase CO_2 time recordings was examined in the headspace of **ŒnoXpert glass** (at pixel A), as seen in **Figure 4**. For 50 mL of champagne dispensed, the peak CO_2 concentration never exceeds about 5% (i.e., a concentration much below the carbonic bite threshold). The **impact of the champagne temperature** was also examined in the headspace of **ŒnoXpert glass** (at pixels A and E), as seen in **Figure 5**. Unambiguously, higher champagne temperatures increase the level of gas-phase CO_2 in the headspace of the glass.

Impact of volume dispensed

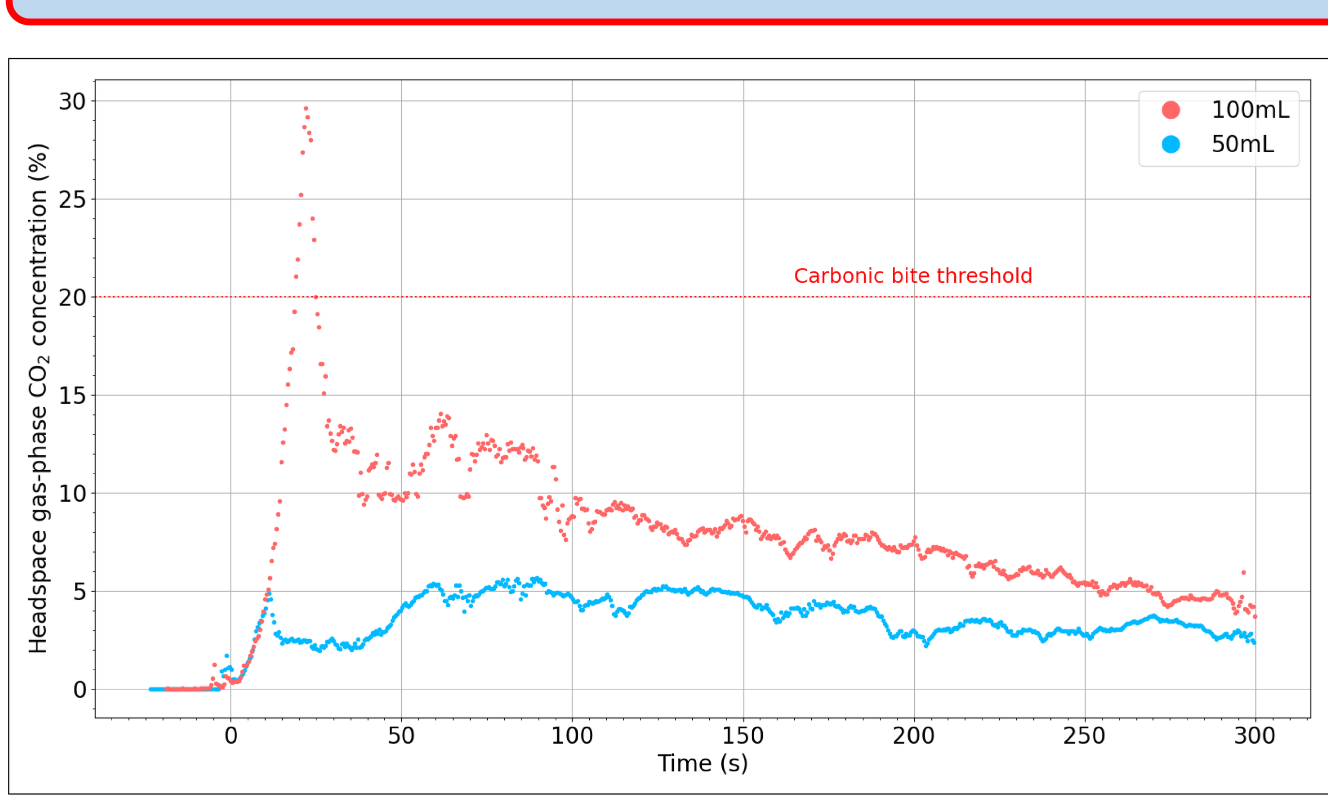


Figure 4: CO_2 concentrations monitoring (in %) in the headspace of **ŒnoXpert** glass (**at pixel A**, 0,5 cm below the glass edge), during the five minutes following the beginning of pouring champagne at **12 °C**. The impact of two different volumes of champagne dispensed was examined (i.e., **50 ml** and **100 mL**) .

Impact of champagne temperature

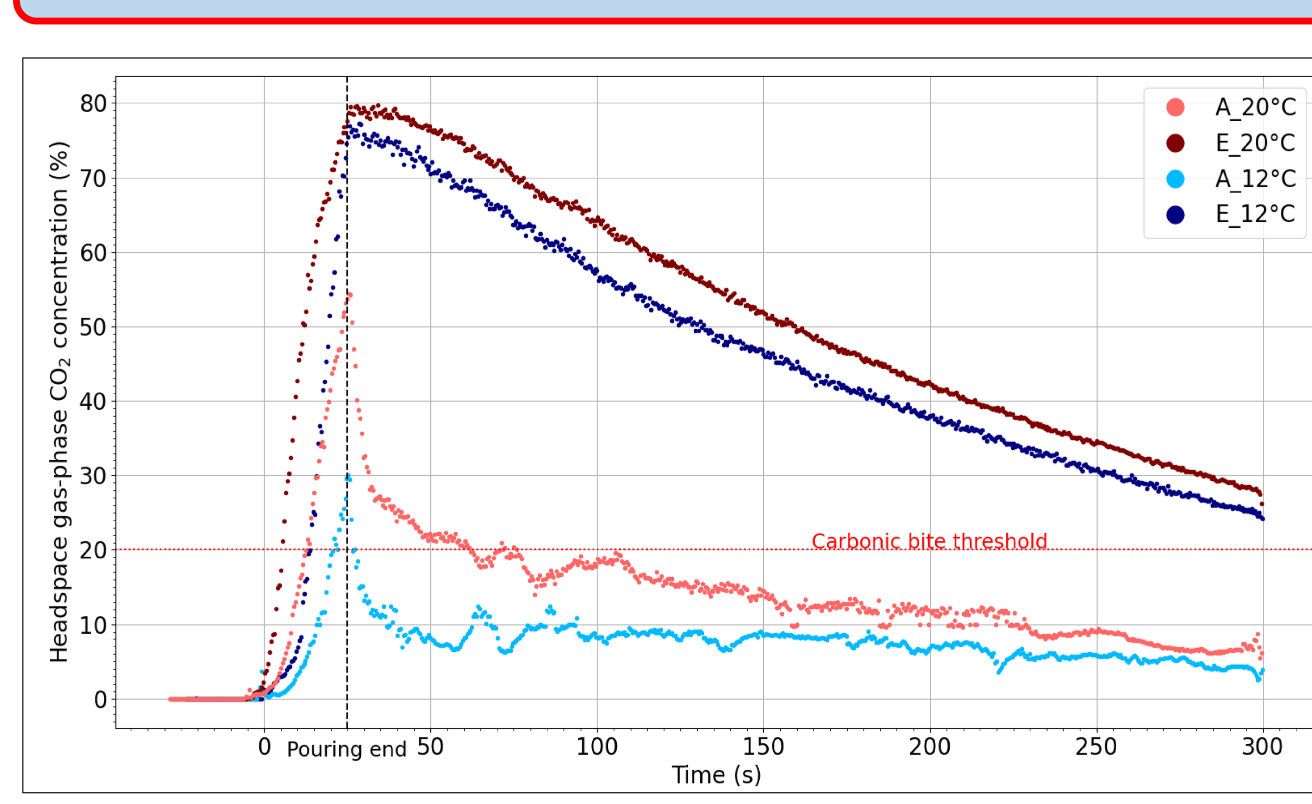


Figure 5: CO_2 concentrations monitoring (in %) in the headspace of **ŒnoXpert** glass (**at pixels A and E**), during the five minutes following the beginning of pouring **100 mL** of champagne. Two different champagne temperatures were examined (i.e., **12 °C** and **20 °C**) .

References:
[1] G. Liger-Belair et al., Unraveling different chemical fingerprints between a champagne wine and its aerosols, *Proc. Nat. Acad. Sci. USA*, *106*, 16545-16459 **(2009)**
[2] C. Cilindre et al., Simultaneous monitoring of gaseous CO_2 and ethanol above champagne glasses via micro-gas chromatography (μGC), *J. Agric. Food Chem.*, *59*, 7317-7323 **(2011)**
[3] A.-L. Moriaux et al., Development and validation of a diode laser sensor for gas-phase CO_2 monitoring above champagne and sparkling wines, *Sens. Actuators B*, *257*, 745-752 **(2018)**
[4] A.-L. Moriaux et al., A first step towards the mapping of gas-phase CO_2 in the headspace of champagne glasses, *Infrared Phys. Technol.*, *109*, 103437 **(2020)**
[5] A.-L. Moriaux et al., How does gas-phase CO_2 evolve in the headspace of champagne glasses? *J. Agric. Food Chem.*, *69*, 2262-2270 **(2021)**

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