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Gaining deeper insight into aroma perception: An integrative study of the oral processing of breads with different structures

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ABSTRACT

The objective of this study was to investigate for the first time the influence of bread structure, volatile compounds, and oral processing on aroma perception. 3 types of French baguette were created using the same raw ingredients but different bread-making processes; they consequently varied in their crumb and crust structures. We characterized the initial volatile profiles of two bread structural subtypes—namely bread crumb and bread crumb with crust—using proton transfer reaction–mass spectrometry (PTR–MS) headspace analysis. Three types of bread were characterized by thirty-nine ion fragments from m/z 45 to 139. We then conducted a study in which 8 participants scored aroma attribute intensities for the different bread types and subtypes at 3 key stages of oral processing (10, 40, and 100% of individual swallowing time). At these 3 time points, we collected boli from the participants and characterized their volatile profiles using PTR–MS headspace analysis. The results suggest saliva addition dilutes volatile compounds, reducing volatile release during oral processing. Thus, a bread with high porosity and high hydration capacity was characterized by a low volatile release above boli. We examined the relationships between 4 aroma attributes of bread crumb with crust and 24 discriminatory fragment ions found in boli headspace. This study demonstrated for the first time that the perceived aroma of crumb with crust was influenced more by volatile profiles than by crumb texture. It thus contributes to our understanding of aroma perception dynamics and the mechanisms driving volatile release during oral processing in bread.

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1. Introduction

Among the different sensory characteristics, aroma is one of the most important criteria determining consumer acceptance. But, aroma perception is dynamic and complex. It is necessary to better understand the mechanisms underlying aroma perception to design food products with target aromas that correspond to consumer expectations and preferences. Aroma, which is perceived retronasally, depends on several factors linked to the food matrix (e.g., initial chemical composition, structure, and physicochemical interactions involving volatile organic compounds [VOCs]) as well as individual-specific mechanisms involved in oral processing (e.g., mastication and salivation) (Buettner & Beauchamp, 2010; Foster et al., 2011; Taylor & Linforth, 1996; Wilson & Brown, 1997).

This complexity makes it difficult to predict how the different VOCs found in food are released in the mouth and contribute to aroma perception. Nevertheless, some researchers have successfully characterized the relationship between initial volatile profiles, analyzed through rapid and non-invasive techniques such as proton transfer reaction–mass spectrometry (PTR–MS), and sensory characteristics in food (Biasioli et al., 2006; Heenan, Dufour, Hamid, Harvey, & Delahunty, 2009; Ting et al., 2015). In one study, the PTR–MS data were used to construct a model relating volatile profiles and sensory characteristics, namely aroma perceived orthonasally and flavor, in twenty bread varieties (Heenan et al., 2009). However, it is not possible to predict variation in aroma perception over the course of consumption based solely on a food's initial profile; we must also account for oral-processing dynamics.

During oral processing, food structure varies dramatically over time (Hutchings & Lillford, 1988). In the case of solid foods, food items are comminuted by mastication (Chen, 2009), increasing the surface area that can diffuse VOCs, which could thus increase their release in the oronasal cavity (Wilson & Brown, 1997). Saliva also plays a role by hydrating food items. Furthermore, saliva composition and the amount added to the bolus seem to influence the release of VOCs by the food in the mouth. Greater amounts of saliva can i) decrease volatile release in low-fat foods (e.g., French beans (van Ruth & Roozen, 2000) or starch gels (Boland, Buhr, Giannouli, & van Ruth, 2004)) or ii) increase volatile release in high-fat foods (e.g., cheeses (Doyennette et al., 2011)). In the

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former case, dilution is the predominant mechanism, while in the latter case, the modification of the water-to-oil ratio induces changes in the physicochemical properties (such as the partition and transfer coefficients) of the VOCs in the bolus. Saliva composition can also affect volatile release. For example, subjects with a high amount of salivary proteins present a low amount of aroma release in their nasal cavity when eating model cheeses (Feron et al., 2014). In another study, Pagès-Hélary, Andriot, Guichard, and Canon (2014) showed, in model systems, that mucin and alpha-amylase interact with VOCs by hydrophobic effect, and thus impeding the release of hydrophobic compounds.

To better understand aroma perception, it may be helpful to study the underlying mechanisms operating during the oral processing of a low-fat food such as bread. Indeed, the relative part of the two conflicting mechanisms affecting volatile release in bread (i.e., the positive effect of mastication vs. the negative effect of saliva) remains poorly characterized. Bread aroma is composed of hundreds of VOCs; recently, a total of 326 were identified in the wheat-bread family (Pico, Bernal, & Gómez, 2015). These compounds are essentially formed during kneading, fermentation, and baking (Pozo-Bayón, Guichard, & Cayot, 2006). However, only a small number (about 30) ultimately have an impact on aroma perception (Birch, Petersen, & Hansen, 2013; Pico et al., 2015; Pozo-Bayón et al., 2006). Several chemical classes are represented. Aldehydes, ketones, esters, carboxylic acids, and heterocycles such as furans, pyrroles, and pyrazines are commonly found in bread crumb and crust, but alkanes, benzenes, and sulfurs have also been observed (Pico et al., 2015). In addition to its complex chemical composition, bread has a complex structure (a porous crumb surrounded by a rigid crust (Scanlon & Zghal, 2001)), which could also affect the release and perception of the VOCs contributing to aroma.

To date and to our knowledge, no study investigates the links between the VOCs released above expectorated bread bolus, collected at different stages of oral processing, and the dynamics of bread aroma perceptions. In this study, the objectives were thus as follows: i) to better understand the role of oral processing in volatile release and dynamics of aroma perception and ii) to clarify how bread structure and volatile profiles influence the dynamics of perceived aroma.

2. Materials and methods

2.1. Bread samples

In this study, we used three types of parbaked, then frozen French baguettes, which were called B1, B2, and B3 (Table 1). They were manufactured by Lesaffre International (Marcq-en-Baroeul, France) using the same raw ingredients but different bread-making processes, resulting in breads with different crumb and crust structures. The main differences between the three bread-making processes are summarized in Table 1. The methodology used to characterize the three bread types has been described elsewhere (Jourdren et al., 2016a; Mathieu et al., 2016). The breads were allowed to cool 2 h and were then used within the next 2 h.

2.2. Analyses of the volatile profiles of bread crumb and crust by PTR–MS

To describe the initial volatile profiles of the bread types (B1, B2 and B3) and the bread subtypes (namely crumb only and crumb with crust), we used PTR–MS with direct headspace injection. We also used gas chromatography–mass spectrometry (GC–MS) coupled with two extraction methods: (a) solvent-assisted flavor extraction (SAFE) and b) purge-and-trap extraction. The GC–MS results (presented in Supplementary material section) were used to generate hypotheses regarding the origins of the fragment ions observed via PTR–MS.

Five-gram CO or CC samples were cut by knife into 1-cm squares and frozen at −80 °C in glass vials. First, the samples were left at −20 °C for at least 30 min (enough time to reach a core temperature of −20 °C). They were then transferred to 100-mL Schott flasks, equipped with valved caps (GL 45, Duran Group, Wertheim, Germany), and stored at 20 °C for 1 h, during which time samples were allowed to slowly defrost and VOCs reached equilibrium between the bread and the headspace. The mass spectrometry data were collected using a high-sensitive PTR–MS apparatus (Ionicon Analytik, Innsbruck, Austria) in SCAN mode over a mass spectrum of m/z 21 to 150; dwell time was 100 ms per peak. The vial valves were connected to a circuit (Lauverjat, de Loubens, Déléris, Tréléa, & Souchon, 2009), which made it possible to: i) draw in ambient air for 78 s (6 cycles); ii) switch between ambient air and flask headspace; and iii) purge the headspace for 260 s (20 cycles) at a mean flow rate of 28 mL/min. The PTR–MS instrument drift tube had the following parameter settings: P = 195 Pa; T = 60 °C; U = 600 V (E/N = 156 Td).

2.3. Analyses of boli obtained at three oral-processing stages

2.3.1. Panel and experimental design

Eight volunteers (4 women and 4 men; 24–37 years old) were recruited for the study based on their motivations for participating and their discrimination abilities. They gave their free and informed consent and received compensation for their participation. They were asked to not eat or drink for at least 1 h before the study sessions.

Over the course of the aroma perception study, we examined the following: i) the panelists' sensory evaluation of bread aroma and texture; ii) the structural and textural properties of the panelists' expectorated boli; and iii) the volatile profiles of these boli. All measurements were performed at T1 = 10%, T2 = 40%, and T3 = 100% of individual swallowing time (Jourdren et al., 2016a) for the three bread types (B1, B2, and B3) and two bread subtypes (CO and CC).

The perceptions of bread aroma and texture were assessed separately using progressive profiling (PP). During a given study session, panelists were asked to assess 1) the aroma of the CO sample; 2) the aroma of the CC sample; 3) the texture of the CO sample; and 4) the texture of the

Table 1
The three bread types, the main characteristics of their bread-making processes, and the structural properties of their crumbs (Young modulus and porosity, values presented in the paper of Mathieu et al., 2016).

Name	Visual appearance	Amount of yeast g/100 g of flour	Fermentation time hours	Baking temperature °C	Young modulus of crumb kPa	Porosity of crumb %
B1		0.5	15	250	7.7 ± 1.7	75.99
B2		3	1.75	230	3.3 ± 0.3	87.23
B3		3	1.33	250	6.9 ± 1.1	77.78

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