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Oral processing and bolus properties drive the dynamics of salty and texture perceptions of bread

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ABSTRACT

During food consumption, complex oral processing occurs to progressively transform a solid food into a food bolus, ready to be swallowed. Bolus formation is an important step, not only because it prepares the food product for digestion, but also because it contributes to sensory perception. Using bread as a model food, the aim of this work was to identify the key mechanisms of oral processing for salty and texture perceptions in relation to food breakdown in the mouth. For this purpose, three model breads with the same salt content were prepared, varying in structure and/or composition. The dynamics of bolus formation and of sensory properties during consumption were characterized. Despite inter-individual differences observed on bolus properties, results showed that the three breads displayed different dynamic sensory profiles. Denser bread was perceived as being less salty and displayed a less complex texture perception sequence. For all of the breads, bolus hydration increased slowly and both G′ and G″ moduli decreased during oral processing (from the beginning of mastication until swallowing time). The G′ and G″ values of the dense bread at swallowing were significantly higher than those obtained for the two other breads, suggesting that bolus viscoelasticity is not a key parameter to trigger swallowing. However, results showed that panelists exhibited different masticatory and hydration behaviors regarding both the kinetics of bolus formation and the final bolus properties. This study contributes to a better understanding of food oral processing and the impact of bolus formation on sensory properties.

1. Introduction

During oral processing, food is submitted to complex transformations in the mouth and progressively transformed into a bolus ready to be swallowed (Chen, 2009). Chewing leads to food breakdown in small particles, and food hydration by saliva favors the swallowing step and prepares the gastric phase of digestion. Saliva mucins lubricate the food bolus and the water in saliva moistens food particles, allowing α-amylase to access available starch. The saliva thus plays an important role in food processing, contributing through the mastication process to bolus formation and swallowing. Food oral processing is closely related to texture perception (Koç, Vinyard, Essick, & Foegeding, 2013), but has an influence on other flavor perceptions as well. When dealing with salt release and perception, numerous studies focus on the role of oral processing for different foods (de Loubens et al., 2011; Lawrence, Septier, Achilleos, Courcoux, & Salles, 2012). They notably highlighted the complexity of the phenomena involved. For example, by changing the rheological properties of the bolus and its mixing ability with saliva, α-amylase activity can lead to a decrease in salty perception in starch products (Ferry et al., 2006). It is therefore important to understand bolus formation and its relationship to sensory properties.

The dynamics of bolus formation was studied for different types of products such as cheeses (Drago et al., 2011; Yven et al., 2012), corn flakes (Loret et al., 2011; Peyron et al., 2011) and breads (Bornhorst & Singh, 2013; Le Bleis, Chaunier, Della Valle, Panouillé, & Réguerre, 2012; Tournier, Grass, Zope, Salles, & Bertrand, 2012). All these studies showed that bolus properties depend on both food and subject characteristics, as well as on the oral strategy of the subject eating this specific food product. Bolus formation starts with a decrease in food hardness together with an increase in bolus hydration due to mastication and lubrication by saliva. It ends with an increase in bolus cohesion and stickiness, which could be key factors that trigger swallowing (Loret et al., 2011; Peyron et al., 2011). Biochemical and rheological properties of the bolus can also be influenced by salivary α-amylase activity, as shown on spit bread boluses or mixtures of bread and artificial saliva (Bornhorst & Singh, 2013; Hoebler et al., 1998).

Bread consumption patterns differ widely within the European Union but most countries have an average consumption of 50 kg of bread per person per year (Bakers-Federation, 2013). Whereas bread is a key staple in the diet and provides many of the nutrients required

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for normal development and good health, it also contributes to a large consumption in salt (in the EU, 13% of salt in the diet is contributed by bread (Bakers-Federation, 2013), but can reach up to 25% in France (ANSES, 2012)).

In this context, the objective of this study was to understand bread bolus formation and texture and salty perception from three breads that varied in structure and/or composition. The evolution of hydration and rheological properties of the bolus were characterized and some relationships with the dynamics of sensory perception of texture and saltiness were established. All these complementary methods were used to obtain a better understanding of the link between food oral processing and sensory perceptions.

2. Materials and methods

2.1. Products

Three different breads were produced using a home bread maker (Riviera & Bar), in order to completely control their composition and process. All breads were composed of wheat flour, salt, water and yeast (Table 1). Breads B1 and B2 had the same composition, but bread B2 was produced with shorter kneading (15 min instead of 25 min), fermentation (14 min instead of 2 h and 10 min) and baking (40 min instead of 1 h) times, resulting in a denser structure. Breads B1 and B3 were processed in the same way, but 2% fat (w/w raw ingredients) was added to bread B3. All breads had the same salt content (1.2% w/w raw ingredients). These products and processes were chosen for the simplicity of their preparation and their good repeatability between preparations. Only the bread crumb was analyzed in this study. All bread samples were analyzed on the day they were prepared.

Crumb water content, density and rheological properties were measured for the three breads. Results are summarized in Table 1.

2.2. Sensory analysis

2.2.1. Panel and training

The study was conducted with 12 healthy subjects (19–50 years old, 5 women, 7 men) recruited from among the in-house personnel of the research unit, according to their motivation. Subjects signed consent and confidentiality forms and were remunerated for the study.

The first four training sessions focused on the identification and the intensity evaluation of texture and saltiness while eating. Vocabulary and associated definitions were selected by consensus between panelists (Table 2), who were then trained on the use of the Time–Intensity (TI) interface on Fizz software (Biosystèmes®, 1999). Finally, panelists were trained to use the Temporal Dominance of Sensations (TDS) method, with the definition of the dominance concept ("that triggers the most attention", (Lenfant, Loret, Pineau, Hartmann, & Martin, 2009)), made aware of the sequence of sensations through the evaluation of commercial breads and shown how to use the TDS interface on Fizz software (Biosystèmes®, 1999).

2.2.2. Tasting protocol and sensory methods

Sensory evaluation was conducted in an air-conditioned room (19 °C), in separate booths under white light. Products were presented with random 3-digit codes in closed and opaque plastic cups. Sample weight was controlled and corresponded to 4 g (±0.1 g).

First, the evaluation of the intensity of salty perception of each sample was performed on an unstructured linear scale from low to high intensity. Then, the Time–Intensity test was performed to evaluate the variation of salty perception during the consumption of one piece of bread. Subjects were instructed to click on the left extremity of a horizontal unstructured scale (corresponding to no sensation) when they put the sample into their mouth. They then had to move the cursor along the scale as the salty sensation evolved until they perceived no salty sensation. Data were collected on a computer screen with FIZZ software and the acquisition frequency was fixed at 250 ms.

The Temporal Dominance of Sensation method was used to describe the dynamics of texture and salty perceptions during bread consumption, i.e., by describing the dominant perception at each moment of consumption. Subjects had to take a sample in the mouth while clicking on the "start" button. They then had to select the attribute perceived as dominant (i.e., that triggers the most attention). An attribute was considered as dominant until another attribute was selected. A "stop" button was proposed to stop acquisition when no sensation appeared. Data were collected on a computer screen with FIZZ software and the acquisition frequency was fixed at 250 ms.

For TI and TDS measurements, four products were tested during one session: one "warm up" product followed by the three products from the study. A 75 second break between samples was imposed on subjects. They were provided with mineral water and apple as palate cleansers between samples. The TI profile and TDS measurements were triplicated and sample presentation order was randomized across subjects within a session following a Williams Latin square. Attribute order was randomized across subjects, but one subject had the same order for each TDS session.

2.3. Bolus sampling and characterization

The kinetics of bread bolus formation was studied by measuring bolus hydration and rheological properties at different moments of consumption.

2.3.1. Bolus collection

The study of bolus properties was performed with eight panelists selected from among the 12 involved in sensory analysis, depending on their motivation and availability. The selection of a reduced number of panelists in regard with the sensory panel was required by organizational reasons, due to the high numbers of measurements to perform on bolus. A piece of bread crumb (4 g ± 0.1 g) was given to the panelists. They were asked to chew it as naturally as possible and spit out the bolus after 5 s, 10 s or just before swallowing. The bolus was characterized immediately after collection, in order to avoid its evolution due to amylase activity in saliva. Each panelist was asked to produce 11 boluses during one session, which lasted approximately 10 min.

2.3.2. Bolus water content

Bread and bolus water contents were determined after dehydration in an oven at 103 °C over 24 h, and the difference between the weight of the sample before and after dehydration was calculated. Three repetitions were made for each condition (bread or bread/panelist/moment combination).

Table 1
Composition, structural and textural properties of the crumb of the three breads. Letters a, b and c indicate means that significantly differ at $p < 0.05$ (Student–Newman–Keuls test).

	Fat content (% w/w raw ingredients)	Water content after baking (% w/w bread)	Density (g/cm^3)	Young modulus (kPa)
Bread 1 (B1 — reference bread)	0	45.1 ± 0.1 a	0.22 ± 0.01 c	14 ± 3 b
Bread 2 (B2 — dense bread)	0	43.7 ± 0.9 b	0.50 ± 0.03 a	34 ± 7 a
Bread 3 (B3 — fat bread)	2	42.5 ± 0.5 b	0.27 ± 0.01 b	9 ± 2 b