Food Research International 87 (2016) 142–151

Contents lists available at ScienceDirect

Food Research International

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

Respective impact of bread structure and oral processing on dynamic texture perceptions through statistical multiblock analysis

S. Jourdren [a,b], A. Saint-Eve [a,*], M. Panouillé [a], P. Lejeune [b], I. Déléris [a], I. Souchon [a]

[a] UMR GMPA, AgroParisTech, INRA, Université Paris-Saclay, 78850, Thiverval-Grignon, France
[b] Lesaffre International, 59700, Marcq-en-Baroeul, France

ARTICLE INFO

Article history:
Received 16 March 2016
Received in revised form 24 May 2016
Accepted 25 June 2016
Available online 29 June 2016

Keywords:
Bolus
Breakdown
Multiblock Partial Least Squares (PLS)
Progressive Profiling
Temporal Dominance of Sensations (TDS)
French baguette

ABSTRACT

Texture perception is a multidimensional and dynamic phenomenon resulting from both the initial structure of food and its breakdown during oral processing. The aim of this study is to identify the respective contribution of food and bolus properties to temporal changes in texture perceptions during bread consumption. For this purpose, the perception dynamics of three French baguettes with dif\ferent structures were assessed through Temporal Dominance of Sensations and Progressive Profiling. Samples of crumb with and without crust were tasted by trained panelists. The intensities of nine texture attributes were evaluated at three key stages of oral processing (10%, 40% and 100% of individual swallowing time) using the Progressive Profiling method. Six of them were related with a Multiblock Partial Least Squares (MB-PLS) regression to the initial bread properties and to some bolus properties measured at these three stages. The evolution during oral processing of some attributes such as "soft", "dry", "doughy" and "sticky" was more influenced by modifications of bolus properties than by the initial characteristics of the breads. Among bolus properties, the MB-PLS highlighted that the hydration and texture properties of the bolus had a greater impact on texture perceptions than bolus structure. The "aerated" perception was more affected by the crumb structure, while the "heterogeneousness" and the "crispiness" were more affected by the presence of crust. This study thus contributes to improving our understanding of dynamic texture perceptions through a statistical model that takes the physical properties of bread and bolus during oral processing into account.

1. Introduction

The primary purpose of eating is to provide calories and nutrients to the human body so that it can sustain its energy levels. To do this, oral processing transforms the food into a bolus that is suitable for swallowing and digestion (Chen, 2009). Oral processing induces structural transformations to food through different complex mechanisms such as comminution, agglomeration, hydration and lubrication by saliva associated with enzymatic hydrolysis (de Wijk, Prinz, Engelen, & Weenen, 2004; Hoebler et al., 1998; Lucas, Prinz, Agrawal, & Bruce, 2002; Witt & Stokes, 2015). Consumers adapt their oral processing to the bolus properties throughout a chewing sequence (Foegeding, Vinyard, Essick, Guest, & Campbell, 2015), depending on the degree of breakdown of the food (Hedjazi, Guessasma, Yven, Della Valle, & Salles, 2013; Mioche, Bourdiol, & Monier, 2003), but also depending on their preferred mouth behavior (Brown & Braxton, 2000). According to Jeltema, Beckley, & Vahalik (2015), consumers are classified in four groups depending on their mouth behavior and in relation with their texture preferences.

In addition to its nutritional value, when eaten, food also provides pleasure through perceived sensations such as aroma, taste and texture. These perceptions vary continuously during consumption, notably because of the breakdown of food, the modification of the bolus structure and the progressive release of the different stimuli. To better characterize foods during their consumption, different dynamic sensory methodologies have been established to study the changes in perceptions over time. Reference methods such as Time–Intensity (TI) or dual TI have been designed to continuously monitor the intensity of one or two selected attributes during food consumption (Cliff & Heymann, 1993). Even if the TI method seems to be well adapted to monitoring one specific attribute, the differences in the panelists' signatures are difficult to process (Vázquez-Araújo, Parker, & Woods, 2013). Progressive Profiling (PP) can be used to evaluate the intensities of many attributes at chosen discrete points in time during food oral processing. This method was first used to study variations in texture perceptions in the case of cheddar (Jack, Piggott, & Paterson, 1994): the intensity scores of some texture attributes were recorded at each chew during consumption. New sensory methodologies such as the Temporal Dominance of Sensations (TDS) method (Pineau et al., 2009) and the Temporal Check-All-That-Apply method (Castura, Antúnez, Giménez, & Ares, 2016) have emerged in the past few years, and are lowly time-consuming (Delarue, Lawlor, &

* Corresponding author.
E-mail address: anne.saint-eve@agroparistech.fr (A. Saint-Eve).

http://dx.doi.org/10.1016/j.foodres.2016.06.021
0963-9969/

Rogeaux, 2014). The TDS method has often been used to describe changes in texture perceptions during food consumption (Laguna, Varela, Salvador, & Fiszman, 2013; Lenfant, Loret, Pineau, Hartmann, & Martin, 2009). For example, in Laguna's study (Laguna et al., 2013), biscuits were perceived at first to be “hard”, and then “crispy” or “crunchy” depending on their fat content. Moreover, the dominant sensation at the end of mastication was “dry mouthfeel” for biscuits with added fiber only.

Texture perceptions are not only impacted by the initial properties of food, but also by the oral processing and the kinetics of bolus formation, as shown by numerous recent studies and reviews (Chen, 2014; Cheong et al., 2014; Foegeding et al., 2015; Koç, Vinyard, Essick, & Foegeding, 2013). Oral processing plays a greater role in the breakdown of solid foods than for semi-solid and liquid foods (Hutchings & Lillford, 1988). For solid food products, a distinction can be made between moist and dry foods. Moist foods are mainly broken down into particles but are still moderately hydrated by saliva at the end of mastication. For example, in the case of emulsion-filled agar/gelatin gels, the moist and refreshing sensations were not correlated with the incorporation of saliva in the bolus. However, the firmness perception was correlated with the mechanical properties of boli obtained at the early stages of mastication (Devezeaux de Lavergne et al., 2015b). In contrast, dry foods such as cake, biscuits and bread have higher hydration capacities (Motoi, Morgenstern, Hedderley, Wilson, & Balita, 2013). For example, at the middle stage of biscuit mastication, the absorption of saliva had a greater impact than the fracture properties of biscuits, leading to dominance in dry perception (Young, Cheong, Hedderley, Morgenstern, & James, 2013). In the case of bread, sticky and hydrated attributes were perceived to be dominant at swallowing time, whereas the G′ and G″ moduli of the expectorated boli decreased and their water content increased until that time (Panouillé, Saint-Eve, Déléris, Le Bleis, & Souchon, 2014).

Bread is an essential part of our diet. A European consumer eats an average of 59 kg of bread per year (AIBI, 2015). With its low fat content, bread consumption ensures a relatively significant part of the recommended daily amount of carbohydrates, proteins and fibers. Even if nutritional properties are an important criterion for consumers, sensory properties are also known to be key factors for product acceptability. For French consumers in particular, texture criteria (such as crumb firmness and crust crispiness) have a great impact on bread acceptability (Martin, Courcoux, Chiron, & Issanchou, 2008). To be consistent with consumer expectations and preferences, a better understanding of the variation of texture perceptions during consumption constitutes a real challenge for manufacturers.

In this context, this study aimed at identifying the respective contributions of bread and bolus properties to dynamic texture perceptions during consumption. For this purpose, two dynamic sensory methods (PP and TDS) were used. Sensory data were linked to the instrumental properties of bread and boli to determine the drivers at the origin of the texture perceptions of bread.

2. Material and methods

2.1. Materials

Three breads, B1, B2 and B3 (par-baked and frozen French baguettes), were investigated. They were manufactured with the same raw materials but using different baking processes in order to obtain breads with different crumb and crust structures. The final baking of the par-baked and frozen breads, B1, B2 and B3, took place in a Wiesheu Minimat oven (Wiesheu GmbH, Germany) at 220 °C for 9, 7 and 8 min, respectively (Jourdren et al., 2016), in order to reach the same core temperature (95 °C). Some instrumental parameters such as Young's modulus and density were controlled after each batch was baked to check production repeatability. The breads were served to panelists after 2 h of cooling and within a 2-hour interval.

2.2. Sensory assessment

2.2.1. Sensory tasting conditions

A panel of 14 volunteers (ten women and four men, with an average age of 32.9 ± 12.9 years) was recruited based on their motivation and discrimination abilities. They gave their free and informed consent and received compensation for their participation. All sensory analyses were carried out in an air-conditioned room (20 °C), in individual booths, under white light. Bread samples were presented in pre-cut vertical slices (thickness: 2.5 cm) in plastic boxes labeled with randomly selected three-digit numbers. Just before the evaluation, panelists were asked to cut samples of crumb only (CO) or crumb with crust (CC) themselves from the pre-cut slice according to a well-defined protocol (Jourdren et al., 2016), and with the instruction to be reliable between samples. A warm-up product was introduced at the beginning of each session to prepare the panelist for the test. The samples were presented in randomized order across panelists to avoid a bias in the results. Panelists were provided with mineral water (Evian, Danone, France) to rinse their mouths.

2.2.2. Experimental design

The bread samples were evaluated for both aroma and texture perceptions using two different sensory tests: the Temporal Dominance of Sensations (TDS) and the Progressive Profiling (PP). During one session of sensory evaluation (TDS or PP), the panelists assessed 1) the aroma of crumb, 2) the aroma of crumb with crust, 3) the texture of crumb and 4) the texture of crumb with crust. So, for TDS and PP, four different lists of attributes were used to assess texture and aroma of CO or CC samples. The present article focuses only on texture perceptions, so only texture data are presented here.

In addition to sensory evaluation, supplementary sessions of bolus collection were performed later, to assess their instrumental properties (detailed in the Subsection 2.3.2). This data has been published in Jourdren et al. (2016).

2.2.3. Temporal Dominance of Sensations (TDS)

The panelists were trained during five training sessions of 45 min each. During the four first sessions, the panelists first generated sensory attributes based on the differences between the products and then worked on the attribute definitions and the associated protocols to assess these attributes. The last session was devoted to TDS training. This session was used to introduce the notion of dominance to the panelists, defined as the sensation that triggers the most attention at a given time (Lenfant et al., 2009). TDS evaluation was performed on six samples (three breads, B1, B2 and B3, with and without crust) using Fizz Acquisition software (Version 2.47A, Biosystemes, France) during a single session, which was triplicated. Panelists were asked to click on the “start” button when they introduced the bread sample into their mouth. They were then able to select the dominant attributes until the end of perception (“stop” button). By a click on an “I'm swallowing” button, they indicated when they swallowed the product. Seven texture attributes were selected for TDS evaluation of CO samples and eleven texture attributes were selected for CC samples (Table 1). The list of attributes was presented in randomized order for each panelist, but was always the same for a given panelist.

2.2.4. Determination of three key times of oral processing

Three key times of bread eating (T1 = 10% of swallowing time, T2 = 40% of swallowing time, and T3 = swallowing time) were identified. These three times corresponded to the first manipulations of the product in the mouth (T1), the swallowing time (T3) measured with TDS, and an intermediary time (T2). The latter time was chosen from TDS profiles and corresponds to the time when clear differences between the three breads were observed for both CO and CC samples. The three times were calculated for each panelist. To simplify the experiments, the mean swallowing time per subject of the three breads was