Food Quality and Preference 60 (2017) 96–104

Contents lists available at ScienceDirect

Food Quality and Preference

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

Physical breakdown of bread and its impact on texture perception: A dynamic perspective

Jing Gao[a], Jane Jun-Xin Ong[b], Jeyakumar Henry[c], Weibiao Zhou[a,*]

[a] Food Science and Technology Programme, c/o Department of Chemistry, National University of Singapore, 3 Science Drive 3, Singapore, 117543, Singapore
[b] Department of Food Science and Agricultural Chemistry, McGill University, 21, 111 Lakeshore, Ste Anne de Bellevue, Quebec H9X3V9, Canada
[c] Clinical Nutrition Research Center, Singapore Institute of Clinical Science, 30 Medical Drive, Singapore, 117609, Singapore

ARTICLE INFO

Keywords:
Bread
Dynamic oral processing
Temporal dominance of sensation
Bolus formation
Electromyography

ABSTRACT

This study aimed to understand the impact of bread structure and its dynamic transformation on people's chewing behaviour and texture perception. Results from 20 trained panellists showed that bread crust/skin was the dominating factor in oral processing. This 'outer layer' introduced a mechanical contrast which increased chewing effort, lowered swallowing thresholds but did not elicit more a complex texture sensation. Furthermore, a single-panellist study was conducted as a proof-of-concept to demonstrate a new temporal correlation method. Progressive fragmentation and hydration diminished the differences between heterogeneous and homogeneous samples, leading to converged bolus properties and chewing effort. However, the differences in texture perception and chewing frequency due to the presence of the crust/skin were not diminished and even became larger throughout oral processing. Hence, chewing force and chewing rhythm might have different modulation mechanisms. Overall, bolus hydrated sensation was largely used by the panellist to gauge the swallowing point while bolus texture was used in a feedback control to regulate the mastication behaviour.

1. Introduction

Oral processing not only prepares solid food for swallowing and further digestion, but also is essential for the sensory perception. Several recent reviews have emphasized that understanding the formation of food bolus is essential to explain people's eating behaviour, sensory perception, consumers' acceptance and linking of food products (Chen, 2015; Koç, Vinyard, Essick, & Foegeding, 2013; Stieger & van de Velde, 2013; Witt & Stokes, 2015). Calling for a multidisciplinary approach to understand sensory perception in the context of oral processing, with a consideration of chewing pattern and bolus formation, has repeatedly been proposed (Foster et al., 2011; Hutchings & Lillford, 1988).

An increasing effort has been made to link in-mouth food transformation with people's sensory perception. Young, Cheong, Hedderley, Morgenstern, and James (2013) and Devezeaux de Lavergne, Derks, Ketel, de Wijk, and Stieger (2015) used the mechanical and rheological properties of boluses to explain panellists' texture perception of biscuit and emulsion filled gel, respectively. Studies have also been done to identify the key mechanism of sweet perception of gel (Mosca, van de Velde, Bult, van Boekel, & Stieger, 2015), the saltiness and texture perception of bread (Panouillé, Saint-Eve, Déléris, Le Bleis, & Souchon, 2014) and cheese (Saint-Eve, Panouillé, Capitaine, Déléris, & Souchon, 2015) in relation to their intrinsic properties and breakdown in the mouth. Results of these studies confirmed the dynamic nature of sensory perception and its dependency on bolus characteristics.

Texture perception is dynamic. It arises from the continuous sensing of the changes in food properties through oral mechanoreceptors as well as the force and position of the mandibles (Szczesniak, 2002). It depends on both food structure and complex oral manipulation that converts food into a bolus (Pascua, Koç, & Foegeding, 2013). Foods with mechanical contrasts exhibited more complex oral breakdown behaviour and elicited more complex texture perception than the homogenous ones (Scholten, 2017). Like many food products, bread is macroscopically heterogeneous: the crust of the bread has contrasting mechanical properties as compared to its crumb. However, most of the previous studies only used bread crumb (Panouillé et al., 2014; Pentikäinen et al., 2014; Tournier, Grass, Septier, Bertrand, & Salles, 2014). Until recently, Jourdren, Panouille, et al. (2016), Jourdren, Saint-Eve, et al. (2016) demonstrated the respective contributions of baguette crust and crumb on bolus formation and texture perception, but in two separate studies. To understand the role of bread bolus formation in texture perception, further study will be necessary to correlate dynamic changes of these two factors in the context of oral

* Corresponding author.
E-mail address: chmzwb@nus.edu.sg (W. Zhou).

http://dx.doi.org/10.1016/j.foodqual.2017.03.014
Received 3 May 2016; Received in revised form 5 March 2017; Accepted 28 March 2017
Available online 30 March 2017
0950-3293/

processing.

The present study aimed to provide insights on the texture perception of bread, in connection with its intrinsic properties, bolus formation and people's chewing behaviour, using a correlative and temporal approach. Firstly, the impact of initial bread properties on oral processing was studied by engaging a group of trained panellists. Secondly, the kinetics of bolus formation was correlated with changes in chewing behaviour and texture perception at progressive stages of oral processing. Because we are more interested in how to establish the correlation analysis in a dynamic manner among different aspects of the oral processing and are less concerned about the inter-individual differences at this stage, a single panellist was used as a proof-of-concept in the second stage of this study. The proposed method will ultimately be applied to a wider range of studies in which it can help to explain the difference in consumer's sensory perception in relation to their oral processing behaviour.

2. Materials and methods

2.1. Bread sample

Three types of bread, including western baked bread, oriental steamed bread and French baguette, were prepared using the same formulation but different processing methods (Gao, Wong, Lim, Henry, & Zhou, 2015). The specific volume, moisture content, crust/skin to crumb ratio and texture were characterised using the methods described previously (Gao et al., 2015). Water holding capacity was calculated as the ratio between water absorbed and the dry solid content (Jourdren, Panouille, et al., 2016). All bread samples were prepared freshly on the same day of the experiment and were cut into standardised volume (~13 mL) and shape. Each type of bread was served in two forms, i.e., with and without the crust (for the baked bread and the baguette) or the skin (for the steamed bread). Bread samples were placed in a plastic container labelled with a random 3-digit number and given to the panellists in a randomised order.

2.2. Study protocol

2.2.1. Phase 1

The aim of phase 1 was to investigate the impact of original bread prosperities on texture perception, chewing behaviour and swallowing thresholds. Twenty healthy adults (13 females and 7 males, 20–27 years old, mean age 23.1 ± 1.9) were recruited. All panellists have healthy dentition and normal occlusion. They were required to undergo two training sessions and a formal session, lasted 1 h each. The first training session was used for temporal dominance of sensation (TDS) training. The second training session was used to familiarise the panellists with electromyography (EMG) recording coupled with TDS evaluation. In the formal session, the panellists were asked to chew three sets of each type of bread sample until they feel the urge to swallow and then spit out the bolus into containers provided. Collected boluses were immediately transferred for analysis. Written informed consents were obtained from all panellists. This study was approved by the Institutional Review Board of National University of Singapore.

2.2.2. Phase 2

The aim of phase 2 was to examine the dynamics of bolus formation and its impact on texture perception and chewing behaviour. It served as a proof-of-concept to demonstrate the temporal correlation method proposed. For this purpose, a single panellist (male, 23 years old) with good chewing efficiency and good repeatability was selected from the twenty panellists. He participated in additional three sessions of the chew-and-spit experiment on three different days. The panellist was asked to chew naturally during the three sessions without the application of the EMG and the TDS monitoring. The average number of chews required by the panellist in the phase 1 of the study was considered as his 100% chewing level. Numbers of chews corresponding to 10, 25, 50 and 75% chewing levels were then calculated proportionally. The experiment coordinator counted his number of chews and gave him instructions on when to stop and spit out the bolus. In each session, one bolus of each type of bread at each chewing level was collected. A total of 90 boluses (6 bread types × 5 chewing levels × 3 replicates) were collected over these three sessions. Collected boluses were immediately transferred for analysis.

2.3. Temporal dominance of sensation (TDS)

In the first training session, the principle of TDS analysis was introduced to the panellists according to the method of Pineau et al. (2009) with modifications. A pool of texture attributes that were used to describe similar cereal products were firstly collected from the literature (Hutchings, Foster, Hedderley, & Morgenstern, 2014; Laguna, Varela, Salvador, & Fiszman, 2013; Panouillé et al., 2014) and explained to the panel using several types of commercial bread including white sandwich bread, bagel, sourdough rye bread, steamed bun and batard purchased from a local supermarket in Singapore. The panel tasted the six types of sample bread used in this study together with the commercial bread to evaluate the suitability of each attribute. A list of eight texture attributes applied to the sample bread was selected by the panel through discussion (Table 1).

The panellists were trained to perform the TDS analysis using the Fizz sensory software (Version 2.01, Biosystem, Counternon, France). The order of the attributes was randomised for each panellist but stayed the same for the same panellist across products and sessions. The panellists were asked to pick up the texture attributes that were perceived as dominant and were free to change to another dominant attribute whenever they felt so during the continuous chewing process. The panellists did not have to choose all attributes and were free to choose one attribute more than once. A total of three assessments were carried out for each type of sample bread. The total chewing time was normalised to be from 0 (start chewing) to 100 (ready to swallow). The dominance rate, chance level, significance level and maximum dominance rate, time of the maximum dominance rate and time range when the dominance rate is larger than 90% of the maximum dominance rate were determined as defined by Pineau et al. (2009). TDS curves were plotted using MATLAB software (R2013a, the MathWorks Inc., Massachusetts, USA). The sensory trajectory was constructed at ten equally spaced mastication levels of 10% to 100%, according to the method described by Lenfant, Loret, Pineau, Hartmann, and Martin (2009).

2.4. Electromyography (EMG)

The superficial masseter and anterior temporalis on both side of the face were located by palpation. The application area of panellists' face was cleaned carefully using 70% alcohol swab to reduce its impedance. Two surface electrodes (Red Dot™ Micropore Monitoring Electrodes, 3M Health Care, Minnesota, USA) were placed 2 cm apart along the length of each muscle. An additional earth electrode was put on the

Table 1
List of texture attributes and their definitions used in TDS evaluation of bread.

Attribute	Definition
Soft	Less force required to bite through sample between teeth
Chewy	Longer time (in s) required to chew the bread to reduce it to a consistency suitable for swallowing
Dense	Describe a solid containing little cells filled with gas; high density
Aerated	Describe a solid containing cells filled with gas; low density
Dry	Sensation of dryness due to lack of saliva; absence of water
Hydrated	Sensation of wetness due to secretion of saliva; presence of water
Crunchy	Low pitch sound produced on crust fracture during mastication
Sticky	Adhere to the palate and the teeth during chewing