Current Opinion in Colloid & Interface Science 18 (2013) 334–348

Contents lists available at SciVerse ScienceDirect

Current Opinion in Colloid & Interface Science

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

Microstructure, texture and oral processing: New ways to reduce sugar and salt in foods

Markus Stieger [a,b], Fred van de Velde [a,c,*]

[a] TI Food and Nutrition, P.O. Box 557, 6700 AN Wageningen, The Netherlands
[b] Wageningen University and Research Centre, Agrotechnology & Food Sciences Group, P.O. Box 8129, 6700 EV Wageningen, The Netherlands
[c] NIZO Food Research, P.O. Box 20, 6710 BA Ede, The Netherlands

ARTICLE INFO

Article history:
Received 4 March 2013
Received in revised form 16 April 2013
Accepted 17 April 2013
Available online 24 April 2013

Keywords:
Food oral processing
Jaw movement
Tongue movement
Microstructure
Mixed biopolymer gels
Soft- and semi-solid foods
Fracture behaviour
Sensory perception
Texture
Taste enhancement

ABSTRACT

Food oral processing as the bridge between food texture, microstructure and sensory perception has gained enormous interest in the last decade. This review provides an overview of the role of the microstructure of soft- and semi-solid foods in food oral processing and sensory perception. Phase separated mixed protein–polysaccharide gels and emulsion-filled gels are described as suitable model foods to investigate food oral processing systematically. Special attention is given to the sensory perception of texture, taste and interactions thereof. Several approaches to reduce the salt and sugar content of semi- and soft-solid foods without compromising taste are reviewed. These reduction approaches are based on an understanding of food oral processing in relation to the microstructure of the foods and its breakdown.

1. Introduction

Food oral processing is a daily activity of all of us. It is an essential process as it is the first step in the food intake and metabolism process that delivers energy and essential nutrients to our body. Food oral processing also brings joy to our lives as oral processing is one of the key processes contributing to sensory perception and the appreciation of foods. For a long time the role of oral processing has not been studied with respect to perception. Although the importance of thorough mastication was postulated already a century ago by Horace Fletcher (nicknamed "The Great Masticator"; 1849–1919), the dynamic nature of food oral processing in relation to texture perception was first described by Hutchings and Lillford [1••]. They postulated a model describing the food oral breakdown path over three axes: degree of structure, degree of lubrication and mastication time (see Section 2). Hutchings and Lillford were ahead of their time. Their proposed model of dynamic oral processing was cited 11 times in the first decade after its publication. The scientific impact of the fundamental model of Hutchings and Lillford was clearly demonstrated in the last decade, during which their paper was cited more than 110 times. The citation history of the Hutchings and Lillford paper nicely reflects the scientific interest in food oral processing in relation to sensory perception over the last couple of decades.

The role of food oral processing as the bridge between food texture and sensory perception has been the focus of many publications, reviews and books over the last few years [2•,3••,4•,5,6]. The main objective of the current review is to provide an overview of the role of food microstructure in oral processing and sensory perception. By understanding the role of microstructure and oral processing in sensory perception, the mechanisms identified can be applied to design and develop food products that support a healthy lifestyle. This review summarises some of the latest developments in the design of sugar- and salt-reduced foods based on an understanding of the role of microstructure in oral processing and sensory perception. Four categories of food products can be defined based on their rheological and sensory properties: liquids, semi-solids, soft-solids and hard-solids [7]. Although these four categories are not universally accepted nor precisely defined by specific rheological properties, they provide a useful classification framework. It is generally accepted that: 1. Liquids flow and do not require chewing before swallowing, although liquids are orally processed (e.g. milk, beverages, yoghurt drinks); 2. Semi-solids are predominantly squeezed between tongue and palate during oral processing without the use of the molars (e.g. pudding, custard); 3. Soft-solids require (initial) chewing between

* Corresponding author at: NIZO Food Research, P.O. Box 20, 6710 BA Ede, The Netherlands. Tel.: +31 318 659 582; fax: +31 318 650 400.
E-mail address: fred.vandevelde@nizo.com (F. van de Velde).

1359-0294/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cocis.2013.04.007

the molars, but do not elicit "crispy" sensations (e.g. cheese, processed meat); 4. Hard-solids are crispy, require chewing between the molars and generally produce an acoustic sound emission during oral processing (e.g. crackers, raw vegetables, apples) [3••]. The current review is limited to semi-solid and soft-solid foods.

2. Food oral processing of semi- and soft-solid foods

Food oral processing is generally regarded as the manipulation of food in the mouth. Signals generated by the different receptors in the mouth during the oral processing are integrated by our brain leading to the perception of texture and mouthfeel. Different receptors are present in the human mouth: mechano-, thermo-, nocice- and chemical receptors [8]. Mechanoreceptors provide the brain with information about pressure, movement, slip and vibration during eating and speaking. The mechanoreceptors are not only relevant for the perception of food texture, but also for the safe handling thereof as the brain controls the motor behaviours, such as biting and chewing, based on information from the mechanoreceptors. The thermoreceptors of the lips and tongue respond to small changes in temperature and provide information about the temperature of the food [9]. Nocicereceptors generate the sensation of pain and warn against injury that may result in tissue damage as a result of, for example, extreme temperature, high pressure or burning chemicals. In normal eating this pain sensation is called trigeminal sensation and contributes to the pungency perception of spicy foods (for example capsaicin). Chemical receptors are important for the sensation of taste and smell. The taste receptors are located in the taste cells and respond to chemical components in food that interact with the receptors. Five taste modalities are distinguished: salt, sweet, sour, bitter and umami. Of all the receptors present in the oral cavity, the mechanoreceptors play the dominant role in food oral processing.

Food oral processing is the combination of oral movements that prepares the food for being ready and safe to swallow. The importance of food oral processing was pointed out in 1988 by Hutchings and Lillford [1••]. They described the dynamic breakdown pathway of the initial food to a bolus that is ready to be swallowed for different food products. Hutchings and Lillford indicated the degree of structure and the degree of lubrication as the two main parameters that together with mastication time form the three-dimensional oral processing model (Fig. 1) [1••]. To be able to safely swallow the bolus, the requirements of enough reduction in structure and enough lubrication should be fulfilled. Hutchings and Lillford illustrated their model with the transition curves of different food products. Fig. 1 shows four of their curves. Curves 1 and 2 show the difference between a juicy steak and a dry, tough piece of meat. A juicy steak (1) first passes the "lubricated enough to swallow" plane and only needs further disintegration of the structure before the bolus is ready to be swallowed. The dry, tough piece of meat (2) requires more oral processing to prepare the bolus. After the structure has been reduced, sufficient oral processing is needed to ensure the lubrication of the bolus. A dry sponge cake (3) needs only little effort to reduce the degree of structure, but requires additional oral processing to lubricate the product. Although the residence time of liquids (4) in the oral cavity is in general rather short and typically starts already in the "lubricated enough to swallow" plane, the structure of the liquid might change during oral processing and consumers can distinguish very well between the texture and mouthfeel of, e.g., full-fat and fat-reduced beverages.

The oral processing model of Hutchings and Lillford was mentioned in several well-cited publications on food physics, oral physiology and the sensory perception of texture [10,11]. Nowadays, the model is well accepted and appreciated in the field of oral processing and sensory perception of food. The model has been used to describe the influence of product and oral characteristics on swallowing [12], the oral processing of dairy-based foods [13] and food oral processing in relation to sensory perception of gels and emulsion-filled gels [3••]. Oral processing is of considerable importance for the perception of liquid and semi-solid products despite their short residence time in the oral cavity during oral processing [14]. Upon oral processing, semi-solids are mixed with saliva, heated or cooled to body temperature, brought into contact with oral surfaces and sheared between palate and tongue. Shearing is an important oral movement to perceive mouthfeel attributes, such as creaminess. In this process a frictional force is generated between palate and tongue. The liquid or semi-solid food product acts as a lubricant in the contact area between tongue and palate. The lubrication behaviour therefore plays an important role in texture and mouthfeel perception of liquid and semi-solid foods [15–21•]. The impact of specific tongue movements on the sensory properties of semi-solids has been studied by training subjects to apply specific tongue movements during sensory evaluation [22]. These tongue movements ranged from no movement at all, to normal movements without specific instructions, to movements in which the food was smeared with the tongue over the palate in the shape of an eight. In general it was shown that the texture perception became more intense as the complexity of the movement increased. Moreover, certain

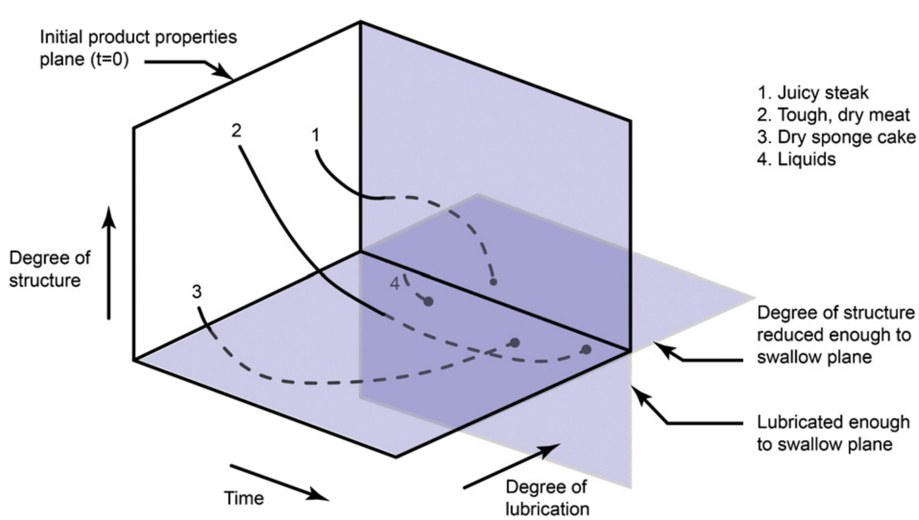

Fig. 1. Schematic representation of the dynamic breakdown pathway of different foods according to Hutchings and Lillford (redrawn from Hutchings and Lillford [1••]).