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Effects of added fluids on the perception of solid food

Luciano Jose Pereira [a], René A. de Wijk [b], Maria Beatriz D. Gavião [c], Andries van der Bilt [d,*]

[a] Department of Oral Physiology, Dental School of Piracicaba, State University of Campinas (FOP/UNICAMP), Piracicaba SP, Brazil
[b] Wageningen Center of Food Sciences, Wageningen, The Netherlands
[c] Department of Pediatric Dentistry, Dental School of Piracicaba, State University of Campinas (FOP/UNICAMP), Piracicaba SP, Brazil
[d] Department of Oral–Maxillofacial Surgery, Prosthodontics and Special Dental Care, Oral Physiology Group, University Medical Center Utrecht, Str.4.129, P.O. Box 85.060, 3508 AB Utrecht, The Netherlands

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Abstract

The production of sufficient saliva is indispensable for good chewing. Recent research has demonstrated that salivary flow rate has little influence on the swallowing threshold. We examined the hypothesis that adding fluid to a food will influence the chewing process. Twenty healthy subjects chewed on melba toast, breakfast cake, carrot, peanut and Gouda cheese. In addition they chewed on these foods after we added different volumes of tap water or a solution of α-amylase. We measured jaw muscle activity and the number of cycles until swallowing. Furthermore, we obtained visual analogue scale (VAS) scores for texture and sound attributes for all foods and fluid conditions. The additional fluids significantly lowered muscle activity and swallowing threshold for melba, cake and peanut. The effect of α-amylase in the solutions was rather limited. Doubling the volume of tap water had a larger effect. Several texture and sound attributes of melba, cake and peanut were also significantly affected by the additional fluids. For melba, cake, and peanut we observed significant correlations between the physiology parameters and several attributes for the various fluid conditions. This indicates that the added fluid affects both the physiology (muscle activity and number of cycles) and the sensory perception of a number of texture and sound attributes. Adding fluid facilitates the chewing of dry foods (melba, cake), but does not influence the chewing of fatty (cheese) and wet products (carrot).

Keywords: Saliva; Swallow; Mastication; Oral physiology; Sensory attributes

1. Introduction

Chewing is the first step in the process of digestion. The food is prepared for swallowing and further processing in the digestive system. During chewing, the food particles are reduced in size, while saliva is produced to moisten and lubricate the food so that it can be swallowed. The initiation of swallowing, which is voluntary, has been thought to depend on separate thresholds for food particle size and for particle lubrication [1]. Taste and texture of the food are perceived and have their influence on the chewing process.

Large differences exist among subjects in salivary flow rate [2–5]. However, these differences are not or only very weakly correlated with the number of chewing strokes needed to prepare the food for swallowing [5]. Thus, a subject with a relatively high salivary flow rate does not necessarily swallow food after less chewing cycles than a subject with less saliva. Apparently, subjects with high salivary flow rates are used to swallow better moistened food than subjects with lower salivary flow rates. It has been shown that there was also no relationship between a subject's salivary flow rate and sensory ratings [6]. Thus, a subject with a relatively large salivary flow rate during eating did not rate food differently from a subject with less salivary flow. This finding could indicate that subjects are used to their amount of saliva to such a degree that the differences in sensory ratings between subjects cannot be explained by the inter-individual difference in salivary flow rate. However, an artificial increase in the amount of saliva significantly influenced the sensory ratings of a semisolid [7]. Similarly, a subject's own amylase activity did not affect their sensory ratings [7], whereas an artificial increase or decrease of amylase activity did affect ratings [8]. The effect of adding fluid to a

* Corresponding author. Tel.: +31 30 2533096; fax: +31 30 2535537.
E-mail address: a.vanderbilt@med.uu.nl (A. van der Bilt).

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solid food on the sensory ratings is unknown. Adding fluid to a dry food may decrease the salivary flow during chewing as was observed in rabbits eating dry pellets when water was injected [9]. However, the reduction in salivary flow will probably be negligible compared to the additional amount of water. Food properties may be modified by the additional fluid, which may lead to changes in chewing force, mandibular jaw movements, and number of chewing cycles to prepare the food for swallowing. It can be hypothesized that an artificial increase in the amount of saliva mixing with food could also influence the perception of the food.

The aim of the present study was to investigate the influence of adding fluids to various solid foods on physiology parameters of the chewing process, and on the perception of the food. We used tap water or a solution of α-amylase. The α-amylase may help to break down the starch in the food. Five foods differing largely in characteristics were used: melba (hard and dry), cake (soft and dry), carrot (hard and wet), peanut (hard and fat), and cheese (soft and fat). We determined muscle activity, jaw movement, and the number of chewing cycles needed to prepare the food for swallowing. Furthermore, we obtained VAS (visual analogue scale) scores for texture and sound attributes. We studied the relationship between oral physiology and sensory perception for all foods and all fluid conditions.

2. Material and methods

2.1. Subjects

Twenty healthy subjects (15 females and 5 males) participated in the study. Their age ranged from 19 to 41 years (mean = 24.8 ± 6.3 years). They all had a natural dentition at least up to the second molars without evident defect of dental structures, periodontal conditions or severe malocclusion. The subjects were divided into a morning and afternoon group based on their availability. Each single subject was, however, always tested on the same time of the day. The Ethics Committee of the University Medical Center Utrecht approved the protocol. Written informed consent was obtained from each subject after a full explanation of the experiment.

2.2. Test foods

We used the following natural foods, all of them with the same calculated volume (8 cm^3): melba toast (melba toast, Buitoni, Italy, www.buitoni.com); breakfast cake (Right, Peijnenburg, the Netherlands, www.right.nl); carrot; peanut and Gouda cheese. The physical characteristics of the natural foods (e.g. density, water and fat percentages and yield point) were previously published (Table 1 of Engelen et al. [5]). Both melba toast and breakfast cake contain high percentages of starch (40% and 35.6%, respectively).

2.3. Procedure

The subjects chewed on the 5 foods while different volumes of tap water (5 and 10 ml), and α-amylase solution (5 ml; *Bacillus subtilis* – Sigma-Aldrich) were added. As a control the subjects also chewed the foods without added fluid. We chose an α-amylase activity of 200 U/ml, which is of the same magnitude found during chewing [3]. The α-amylase solution was prepared freshly prior to each experiment. The α-amylase solution was tasteless, so subjects could not tell the difference between the experiments with tap water and with the α-amylase solution. The amounts of fluid were based on the saliva secretion in response to food stimulation [4]. The liquids were added in the mouth right after the food. During 2 sessions of 1 h (on 2 separate days) the subjects were presented with duplicates of the samples. All combinations of fluids, volumes and food were administered in random order. Prior to the experiments, foods were brought to room temperature (20 °C). The subjects were asked to chew and swallow the food in their usual manner. In between the samples, subjects were allowed to sip water.

2.4. Jaw movement and surface electromyography

During all chewing sequences the jaw gape was measured by recording the position of two infrared light emitting diodes (one on the chin and one on the forehead) with an optical motion analysis system (Northern Digital Optotrak®; www.ndigital.com). The electrical activity of the m.masseteres and the m. temporales anteriores was recorded by means of bipolar electrodes (Blue sensor, Medicotest, Ølstykke, Denmark; diameter 6 mm; inter-electrode distance 18 mm). The maximum deflection location of the electrodes was determined by palpation while the subjects intermittently clenched their teeth. An electrode on the forehead served as a ground reference. The electromyographic (EMG) signals were amplified and sampled at 1500 Hz. Off-line the EMG signals were full-wave rectified and filtered (low pass at 35 Hz). We determined the area of the EMG bursts for all chewing cycles for each muscle. The results of the chewing cycles were averaged. Then the values obtained for the right and left masseter and temporalis muscles were summed. Furthermore, we determined the number of chewing cycles until swallowing from the movement signal. Results of duplicate measurements were averaged.

2.5. Attributes

In a third session we evaluated the attributes. Twenty-two texture and sound representative attributes were selected from a set of 64 attributes developed for the sensory profiling of crispy and crunchy foods [10]. In this session the subjects received one sample of each combination of food and fluids used in the previous 2 sessions, and also the food without fluid. The order of the samples was randomized. Texture and sound attributes were rated for all food–fluid combinations on a 100-mm visual analogue scale (VAS), ranging from “very little” to “very much”. The attributes were divided into “at first bite” and “during chewing” categories. The definitions of the attributes are given in Table 1. Prior to the distribution of the samples, the subjects received an explanation of all the items. During the