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Effect of successive stimuli on sweetness intensity of gels and custards

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ABSTRACT

Variations of tastant concentration during the consumption of food products were shown to enhance taste intensity. The aim of this study was to investigate the relation between the frequency at which tastant concentration is varied during the consumption of products and the occurrence of taste enhancement. For this purpose, the sweetness intensity of sequences of 4 successive sweet stimuli represented by cubes of a semi-solid gel or spoons of a model custard dessert was assessed. The intensity and the order of the stimuli within the sequences were varied to obtain 4 types of sucrose concentration profile (decreasing, increasing, middle peak and boundary peak) at 2 magnitudes of concentration differences (small and large). Sequences of 4 stimuli containing a constant sucrose concentration were used as a reference. The sweetness intensity of the sequences of successive stimuli was assessed using line scale and time-intensity ratings.

Line scale ratings showed that the type of sequence had an effect on sweetness intensity. A sweetness enhancement relative to the reference was observed in sequences that ended with high-intensity stimuli, whereas sweetness suppression was observed in sequences that ended with low-intensity stimuli. The observed sweetness enhancement and suppression were attributed to serial position effects (i.e. recency effects).

Time-intensity ratings indicated that each stimulus in the sequences was evaluated individually by the assessors. Sequential effects seem to have occurred during the continuous evaluation of successive stimuli, since preceding stimuli in the sequences affected the evaluation of posterior stimuli. Furthermore, the overall sweetness intensity of the different sequences was not enhanced in relation to the reference. The lack of taste enhancement in sequences exhibiting variations of sucrose concentration was attributed mainly to the long period at which sucrose concentration was varied during the evaluation of the sequences. It was confirmed that the frequency of variation of tastant concentration affects the occurrence of taste enhancement.

1. Introduction

The modulation of the spatial distribution of tastants within a product is among the strategies developed in an attempt to reduce sugar and salt in processed foods. Studies have shown that an inhomogeneous distribution of tastants, which leads to variations of tastant concentration during consumption, enhances taste intensity of several types of food (Holm, Wendin, & Hermansson, 2009; Mosca, Bult, & Stieger, 2013; Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010; Noort, Bult, Stieger, & Hamer, 2010). As a consequence, sugar and salt can be reduced without decreasing taste intensity.

During the oral breakdown of (semi-)solid foods containing tastants heterogeneously distributed, taste receptors are exposed to an asynchronous discontinuous stimulation (Mosca et al., 2010). The intensity of the stimulation was shown to be an important factor for the occurrence of taste enhancement, given that large tastant concentration differences were required to enhance taste intensity significantly (Holm et al., 2009; Mosca et al., 2010; Noort et al., 2010). The frequency of stimulation of receptors, which is related to the frequency of variation of tastant concentration, was also shown to be an important factor for the occurrence of taste enhancement in a variety of (semi-)solid foods (Mosca, 2012). In liquids, the frequency of temporal variations of tastant concentration, which can be controlled by a pulsatile delivery of tastant solutions, was also identified as a determinant factor for the occurrence of taste enhancement (Burseg, Brattinga, de Kok, & Bult, 2010; Busch, Tournier, Knoop, Kooyman, & Smit, 2009; Meiselman & Halpern, 1973). The highest taste enhancement was

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observed around the taste fusion period (TFP), which is the pulsation frequency at which pulses of tastant solutions are no longer consciously perceived as discontinuous pulses (Burseg et al., 2010). For different taste modalities, taste enhancement by pulsatile delivery was stable below (i.e. 0.5×) and above (i.e. 2×) the TFP (Burseg, Camacho, & Bult, 2012; Burseg et al., 2010). However, as the frequency of pulsation was decreased or increased in relation to the TPF (i.e. frequencies lower than 0.5×TFP or higher than 2×TFP), the magnitude of taste enhancement decreased. This indicates that the frequency of stimulation of taste receptors can be optimized in order to maximize taste enhancement. We hypothesize that low stimulation frequencies do not enhance taste intensity because the variations of tastant concentration are perceived as distinct stimuli, which limits the occurrence of a discontinuous stimulation of taste receptors. In the case of high stimulation frequencies, enhancement is not observed because the discontinuous stimulation merges into a continuous stimulation without contrast.

In the studies that investigated the effects of modulation of tastant spatial distribution on taste perception of (semi-)solids, an inhomogeneous distribution of tastants was achieved using layers varying in tastant concentration (Mosca, van de Velde, Bult, van Boekel, & Stieger, 2012; Mosca et al., 2010; Mosca et al., 2013; Noort et al., 2010) or encapsulated tastant crystals (Noort, Bult, & Stieger, 2012). In this way, tastant concentration was varied in the mouth within chews of a single bite of the product (high frequency of variation of tastant concentration). Little information is available on the effectiveness of enhancing taste intensity when tastant concentration is varied during the consumption of several bites of a product (low frequency of variation of tastant concentration). Therefore, this study investigates the relation between a low frequency of variation of tastant concentration and the occurrence of taste enhancement using sequences of successive stimuli. When taste intensity is assessed after the consumption of a sequence of stimuli varying in tastant concentration, serial position effects such as recency and primacy might occur. Primacy effects are related to the recall of the first items presented in a list or to the expression of the first acquired memories. Recency effects are related to the recall of the last items presented in a list or to the expression of the last acquired memories (Glanzer & Cunitz, 1966; Neath, 1993). Moreover, when the taste intensity of successive stimuli is continuously assessed, the response to a stimulus in the sequence might be affected by the preceding stimuli and their responses (Le Berre, Boucon, Knoop, & Dijksterhuis, 2013). This is referred to as sequential effects (Schifferstein & Frijters, 1992). We hypothesize that: 1. The occurrence of taste enhancement depends on the time scale at which tastant concentration is varied during oral processing; 2. The perceived taste intensity of sequences of successive stimuli depends on the type of sequence. The aim of this study was therefore to get a better understanding of the relation between the frequency of variation of tastant concentration and taste enhancement in foods by extending the time scale of variation of tastant concentration from within bites (as investigated in previous studies) to between bites.

2. Materials and methods

2.1. Materials

Gelatin (PBG 07 bloom 270–290) was purchased from PB Gelatins (Vilvoorde, BE). Agar powder (Organic flavour company B.V., Veenendaal, NL), sucrose, milk and corn starch were obtained from local retailers. Samples were prepared with water purified by reverse osmosis.

2.2. Sample preparation

2.2.1. Gel

A solution of agar and water was heated to boiling. Gelatin was added after the solution cooled down to 80 °C. The solution was kept in a water bath at 80 °C under stirring for 15 min. After the removal of the solution from the water bath, sucrose and water (to compensate for the amount that evaporated during heating) were added. The final solution was poured into Petri dishes. After cooling overnight, gels were cut into cubes that were stored at 5 °C until further use in the sensory test. The dimensions of the cubes were approximately 20 × 20 × 10 mm (length × width × height). The effects of addition of sucrose on the density and on the mechanical properties of gels were taken into account during sample preparation as previously described by Mosca et al. (2010). To obtain cubes of similar weight (4.0 ± 0.1 g), the volume of solution poured into Petri dishes was varied according to the sucrose concentration in the gel. To avoid differences in the mechanical properties (i.e. fracture stress and fracture strain), the concentration of gelatin was decreased with increasing sucrose concentration. The concentration of the ingredients and the volumes used to prepare the gels are listed in Table 1.

2.2.2. Model custard dessert

Milk was heated to boiling under stirring. After boiling, the milk was removed from the heat plate, sucrose was added and the solution was stirred for 1 min. The solution was then placed back on the heat plate and corn starch, which was previously dissolved in 5 mL of cold milk, was gradually added under constant stirring. The solution was stirred for 3 min and cooled to 40 °C. Water was added to compensate for losses due to evaporation. The final solution was poured into plastic containers and stored in a cold room at 5 °C until further use in the sensory test. The concentration of all ingredients used to prepare the model custards is listed in Table 1.

2.3. Compression measurements of gels

Uniaxial compression measurements were performed using an Instron 5543 test system (Instron Int., Edegem, BE) as described by Mosca et al. (2010). Cylindrical pieces of gel (approximately 25 mm diameter and 25 mm height) were compressed between two parallel plates (150 mm diameter) lubricated with a thin layer of paraffin oil. Compression was applied at a crosshead velocity of 1 mm/s up to a linear compression strain of 80%. All measurements were performed at ambient temperature (23 ± 1 °C). The mean values of fracture strain and fracture stress were calculated from the measurements of 8 replicates (4 gel pieces from 2 gel specimen).

2.4. Rheological characterization of custards

The flow curves of custards were determined using a Haake RV 20 rheometer equipped with a concentric cylinder geometry (Thermo Instruments, NL). Custards were removed from the cold room and were allowed to equilibrate to room temperature. About 55 mL of each sample was poured into the rheometer, which was previously equilibrated at 23 °C. The shear rate was increased from 1–400 s^{-1} in 5 min and then decreased from 400 to 1 s^{-1} in 5 min. Four replicates of each custard sample were analyzed.

2.5. Sensory study

2.5.1. Subjects

Seventeen subjects (15 female; average age = 51, SD = 8) participated in this study. A taste test was performed to select the subjects based on their ability to identify tastes. In order to be