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Taste enhancement in food gels: Effect of fracture properties on oral breakdown, bolus formation and sweetness intensity

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A B S T R A C T

This study investigates the effects of fracture strain and fracture stress on oral breakdown, bolus formation and sweetness intensity of semi-solid food gels containing sucrose heterogeneously distributed in layers.

The sweetness intensity of gels was mainly affected by the total surface area of gel fragments formed upon chewing. Gels with low values of fracture strain and fracture stress broke down into a large number of small fragments. These gels were perceived sweeter than gels with high values of fracture strain and fracture stress. Fracture strain had a larger impact on oral breakdown behavior and sweetness intensity than fracture stress. Results indicate that the oral breakdown behavior (i.e. formation of a large number of small fragments, which leads to an increase in the total surface area) is the driving factor for taste perception in semi-solid gels that have a heterogeneous distribution of sucrose.

We suggest that the differences in sweetness intensity in gels containing sucrose heterogeneously distributed in layers and differing in fracture properties result from differences in the frequency of stimulation of taste receptors. An increase in the total surface area of fragments containing sucrose facilitates the release of tastants and increases the frequency of stimulation of taste receptors. Consequently, the taste intensity of gels is enhanced.

1. Introduction

The demand for low-sugar and low-salt food products has increased as a response to the growing concerns towards the current overconsumption of sugar and salt (tastants). As the sensory properties of products are usually affected by reductions of tastants, low-sugar and low-salt products tend to have a low acceptability in the market. Therefore, food manufacturers search for tastant reduction strategies that do not compromise the overall quality of products.

A tastant reduction strategy based on the modulation of the spatial distribution of tastants in food matrices showed a potential to avoid undesirable changes in sensory properties and in consumer preference. Several studies reported that tastant concentration differences, which result from an inhomogeneous distribution of sugar and salt in food matrices, enhance taste intensity (Holm, Wendin, & Hermansson, 2009; Konitzer et al., 2013; Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010, 2012; Noort, Bult, & Stieger, 2012, Noort, Bult, Stieger, & Hamer, 2010). This strategy was shown to allow for a 20% sucrose reduction in gelled products and for a 28% salt reduction in breads without compromising sweetness and saltiness intensity. Besides maintaining taste intensity, this strategy also allows to maintain consumer preference. Semi-solid gels, breads and sausages containing tastants heterogeneously distributed were equally or more preferred than products in which tastants were homogeneously distributed (Mosca, Bult, & Stieger, 2013). Similarly, a heterogeneous distribution of salt in hot snack foods enhanced saltiness without loss of consumer acceptability (Emorine, Septier, Thomas-Danguin, & Salles, 2013). These results give evidence that the reduction strategy based on the inhomogeneity concept can be applied in commercial food products.

When semi-solid foods are chewed, the structure is broken down into fragments, which are then reduced in size, mixed and lubricated with saliva and fluids released from the product to form a bolus

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suitable to be swallowed (Hutchings & Lillford, 1988; Prinz & Lucas, 1997). The oral breakdown contributes to the release of tastants from the food matrix and enables the contact of tastants with taste receptors. It has been demonstrated that a facilitated release of tastants through the generation of new surfaces during oral breakdown affects the perception of taste and aroma. Products that yielded more fragments upon chewing showed higher intensities of taste and aroma than products that yielded less fragments (Koliandris, Lee, Ferry, Hill, & Mitchell, 2008; Morris, 1994). The strain at fracture, which is related to brittleness and thereby to the number and size of fragments formed upon chewing, was shown to be the main mechanical parameter that affects taste and aroma perception (Morris, 1994). Fracture strain has also been demonstrated to influence the temporal dynamics of taste perception (Sala & Stieger, 2013). The maximum sweetness intensity of brittle gels (i.e. gels with low values of fracture strain) was perceived earlier during oral processing in comparison with less brittle gels.

The oral breakdown of semi-solid foods with inhomogeneous distributions of tastants leads to the formation of fragments containing different concentrations of tastants. The presence of tastant concentration differences (i.e. taste contrast) in mouth exposes taste receptors to a discontinuous stimulation. The intensity of the discontinuous stimulation and the number of receptors stimulated were shown to affect the magnitude of taste enhancement. Layered gels that yielded a large number of small fragments upon chewing had the highest sweetness enhancement (Mosca et al., 2010). The frequency of discontinuous stimulation of receptors, which is affected by the oral breakdown behavior, was suggested to be the driving factor for the enhancement of taste that results from an inhomogeneous distribution of tastants (Mosca, 2012). In order to get a better understanding of taste enhancement as a function of frequency of receptor stimulation, the relationship between fracture properties, oral breakdown and taste perception should be further investigated in semi-solid foods exhibiting an inhomogeneous distribution of tastants.

In this context, the aim of this study was to investigate the combined effects of fracture properties and spatial distribution of tastants on taste perception of semi-solid layered gels. We hypothesize that taste enhancement can be maximized through the modulation of fracture strain and fracture stress in products containing tastants heterogeneously distributed. Layered gels were composed of 2 layers containing 0% sucrose and 2 layers containing 40% sucrose (w/w). Four types of 40% sucrose layers differing in the magnitude of fracture strain and fracture stress and 1 type of 0% sucrose layer with constant fracture properties were prepared. Gels were characterized by their fracture properties, oral breakdown behavior, sucrose release and taste perception.

2. Materials and methods

2.1. Materials

Gelatin (PBG 07 bloom 270–290) was purchased from PB Gelatins (Vilvoorde, BE). Titanium dioxide (TiO_2) suspension (30% suspension of TiO_2 in glucose syrup stabilized with gum acacia and preserved with potassium sorbate) (Overseal, Avignon, FR) was purchased from Tefco Ingredients (Bodegraven, NL). Agar powder (Organic flavor B.V, Veenendaal, NL), black food colorant (Americolor, Placentia, USA) and sucrose were obtained from local retailers. Water purified by reverse osmosis (RO) was used.

2.2. Sample preparation

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. The solution was then removed from the water bath and sucrose was added. For the gels that required colorant, the solution was cooled down to 60 °C after the addition of sucrose and the colorant was added. Black food colorant (0.1% w/w) was added to the 40% sucrose gels and TiO_2 suspension (0.5% w/w) was added to the 0% sucrose gels. These colorants were added to the gels to obtain a color contrast between layers with and without sucrose. The color contrast was needed for the image analysis of fragments formed upon chewing. The solution was stirred for 5 min and water was added to compensate for the amount that evaporated during heating.

The concentrations of agar and gelatin were varied to obtain 4 types of 40% sucrose gels differing in fracture strain and fracture stress. One type of 0% sucrose gel with intermediate fracture properties was prepared. The composition of gels is shown in Table 1.

Gel layers were prepared by pouring solutions of agar/gelatin/sucrose into plastic Petri dishes. After storage overnight at 5 °C, gel layers were cut into squares. The length and width of each square layer were 20 mm. The thickness of the 0% sucrose layers was 6 mm and the thickness of the 40% sucrose layers was 2 mm.

Samples (layered gels) consisted of 4 square layers (2 layers containing 0% and 2 layers containing 40% w/w sucrose) placed on top of each other as shown in Fig. 1. Layers were prepared on a mass basis to ensure an overall sucrose concentration of 10% w/w in all samples. Layered gels were assembled less than 30 min prior to the sensory tests to minimize diffusion of sucrose through the layers (Mosca et al., 2010).

2.3. Compression measurements

Uniaxial compression measurements were performed using an Instron 5543 test system (Instron Int., Edegem, BE). Cylindrical gel pieces of 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 and up to a linear compression strain of 80%.

The specimen's absolute deformation was expressed as the Hencky's or true strain (ε_H) (Peleg, 1984):

$$\varepsilon_H = \int_{H_0}^{H} \frac{1}{H} dH = \ln\left(\frac{H}{H_0}\right)$$

where H_0 is the initial specimen height and H is the final height after deformation. The overall stress acting on the sample during compression was expressed as true stress σ_t:

$$\sigma_t = \frac{F}{A}$$

where F is the force measured during compression and A is the actual cross-sectional area of the sample during compression

Table 1
Composition of gels.

Gel type	Fracture stress (σ)	Fracture strain (ε)	Sucrose (% w/w)	Agar (% w/w)	Gelatin (% w/w)
Hσ/Lε	High	Low	40	0.7	0
Hσ/Hε	High	High	40	0.4	2.7
Lσ/Lε	Low	Low	40	0.4	1
Lσ/Hε	Low	High	40	0.2	1.8
Mσ/Mε	Medium	Medium	0	0.43	2.8