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Time to first fracture affects sweetness of gels

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ABSTRACT

The aim of this study was to investigate the influence of the breakdown behaviour on sweetness intensity of gelled model foods. Emulsion-filled gelatine/agar gels varying mainly in fracture strain (ε_F) were used. The fracture strain was modified by changing either the ratio between gelatine and agar concentration or the size of the oil droplets embedded in the gel matrix. The sugar content of all gels was kept constant at 6 wt%. The fracture strain of the gels varied between $\varepsilon_F = 37\%$ and $\varepsilon_F = 72\%$. The number of gel fragments (n) obtained after uniaxial compression of a gel specimen increased with decreasing fracture strain from $n = 10$ ($\varepsilon_F = 72\%$) to $n = 200$ ($\varepsilon_F = 37\%$). A quantitative descriptive analysis sensory study revealed that the sweetness intensity perceived after first fracture of the gel in the mouth was higher for gels with lower fracture strain. The sweetness intensity of the most brittle gel (Isweet = 65; $\varepsilon_F = 37\%$) was almost twice as high as the sweetness intensity of the least brittle gel (Isweet = 36; $\varepsilon_F = 72\%$). In addition, the panelists determined the time after which the maximum sweetness intensity was perceived (t_{max}). The maximum sweetness intensity of brittle gels was perceived after $t_{max} = 6$ s ($\varepsilon_F = 37\%$), whereas for less brittle gels the maximum sweetness intensity was perceived after $t_{max} = 15$ s ($\varepsilon_F = 72\%$). The temporal evolution of sweetness intensity after the maximum sweetness intensity was comparable for all gels. The results suggest that the velocity of formation of new surfaces of the food in contact with the taste buds influences sweetness intensity in addition to the total surface which is generated during breakdown of the food.

1. Introduction

Consumers are sensitive to small variations in sweetness. This has been established for several foods, ranging from sugar solutions to cookies (Drewnowski & Greenwood, 1983; Drewnowski, Nordensten, & Dwyer, 1998; Drewnowski & Schwartz, 1990; Monneuse, Bellisle, & Louissylvestre, 1991; Salbe, DelParigi, Pratley, Drewnowski, & Tataranni, 2004). Therefore, reduction of sugar when developing sugar reduced foods remarkably affects the taste of the products. This can have repercussions on the choice of the consumer. Successful strategies to reduce sugar aim at maintaining the taste intensity of the reformulated low sugar product unvaried as compared to the original high sugar food.

Taste–texture interactions have been reported in polymer solutions, pourable model foods and gelled systems. An inverse correlation between viscosity of fluid foods and taste intensity has often been reported (Clarck, 2002; Morris, 1995). In hydroxyl propyl methyl cellulose (HPMC) solutions an increase of the polymer concentration (i.e. an increase in viscosity) resulted in a decrease of the perceived sweetness (Hollowood, Linforth, & Taylor, 2002). The same effect of polymer concentration on saltiness was observed for HPMC and λ-carrageenan solutions (Cook, Linforth, & Taylor, 2003). By submitting samples to shear-treatment it was possible to produce custard desserts with varying viscosity at constant composition (Tournier et al., 2009). An inverse correlation was found between viscosity and taste perception. In solutions of random-coil polymers a suppression of taste intensity with increasing polymer concentration is reported to start at the critical concentration at which coil overlap and entanglements occur (Morris, 1993). A reduced rate of transport of tastants from the interior of the sample, where they cannot be perceived, to the exterior has been suggested as the underlying mechanism for the suppression of taste intensity by an increased viscosity.

Gel formation has been related to the suppression of mixing between thickener and tastants molecules and thus to the inhibition of migration of tastants to the taste buds. An inverse correlation between taste intensity and the hardness of soft solid foods has

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been reported (Clarck, 2002). In a study comprising several different types of biopolymer gels and containing 16% sucrose a negative correlation was found between the overall flavour perception and both the mouthfeel attribute thick and gel hardness as measured in compression experiments (Clarck, 2005). In κ-carrageenan and gellan gum gels with different gelling agent concentrations and containing either sucrose (15 wt%), caffeine (0.06 wt%), sodium chloride (0.5 wt%) or a mixture of citric acid (0.15 wt%) and sodium citrate (0.2 wt%) to obtain samples representing the basic taste modalities an inverse correlation was found between gel strength and taste intensity (Costell, Peyrolon, & Duran, 2000). Sweetness and saltiness intensity was higher in gellan gels as compared to κ-carrageenan gels with the same strength, indicating differences in tastant release properties between different hydrocolloids. The authors suggested that these differences are caused by the high amount of water released by gellan gels upon mastication. The results found in literature on the relationship between gel hardness/stiffness and taste and aroma perception are not univocal. In pectin gels sweetness intensity was found to increase with increasing storage modulus taken as an indicator of gel hardness (Holm, Wendin, & Hermansson, 2009).

A study carried out with gels covering a wide range of fracture properties proposed a convincing mechanistic model on the relationship between texture and taste perception based on gel brittleness instead of gel strength (Morris, 1993). In this work taste and aroma intensity were found to be negatively correlated to both yield stress (i.e. perceived firmness) and yield strain (inversely correlated to perceived brittleness). However, for gels with equivalent perceived firmness but higher brittleness the scores for perceived taste and aroma intensity were remarkably higher. It was concluded that taste and aroma intensity in gels dependents not on hardness, but on brittleness. The mechanism proposed for the release of tastants and aroma molecules in these systems would involve the formation of fresh surfaces upon chewing. The conclusions of Morris were confirmed in a study on gellan, κ-carrageenan and locust bean gum gels with different gelling agent concentration containing sodium chloride and ethyl butyrate in which the release of tastant and aroma were instrumentally measured (Koliandris, Lee, Ferry, Hill, & Mitchell, 2008). In this study an inverse correlation was found between fracture strain and both salt release and maximum nose space volatile concentration of ethyl butyrate.

A direct correlation between brittleness and taste intensity could be mediated by the extension of the surface of the product in contact with the taste buds present on the tongue. Brittle gels breakdown in a larger amount of smaller fragments, i.e. result in a bolus with a larger surface (Sala, Leclert, van de Velde, & Stieger, 2009). We hypothesise that a larger surface of the fragments in contact with the mouth tissues is likely to lead to an increase of the migration of tastants to the taste buds, with an enhancing effect on taste intensity. This hypothesis seems to be supported by the finding of a study on the link between bitterness perception and chewing pattern of gelatine gels. Assessors who chewed the gels more gave higher scores for bitterness intensity (Alfonso, Neyraud, Blanc, Peyron, & Dransfield, 2002). In order to test our hypothesis, a set of emulsion-filled gelatine/agar gels varying mainly in brittleness was used. With these gels a quantitative descriptive analysis (QDA) sensory study was carried out and the time after which the sweetness intensity reached its maximum was determined by the assessors.

2. Materials and methods

2.1. Materials

Porcine skin gelatine PBG 07 (bloom 280, isoelectric point 8–9) was kindly provided by PB gelatines (Vilvoorde, Belgium). Agar was from Organic Flavour Company B.V. (Veenendaal, The Netherlands). Powdered whey protein isolate (WPI, Bipro™) was obtained from Davisco International Inc. (La Sueur, MN, USA). Sunflower oil and sucrose were obtained from local shops. Vanilla flavour was donated by Danisco (Grindsted, Denmark). All materials were used without further purification. All samples were prepared with demineralised water.

2.2. Sample preparation

2.2.1. Emulsions

Emulsions stabilised with whey protein isolate (WPI) were used for gel preparation. WPI solutions were prepared by adding the protein to the required amount of water. The solutions were stirred for 2 h. Stock emulsions, consisting of 40 wt% sunflower oil and 60 wt% aqueous phase containing 1 wt% WPI, were prepared by pre-homogenising the ingredients using an Ultra Turrax (Polytron, Kinematica AG, Lucerne, Switzerland). Pre-emulsions were further processed using a laboratory homogeniser (Ariete, Model NS1001L 2K – Panda 2K, Niro Soavi S.p.A, Parma, Italy). In the present study the oil droplet size of the emulsions was varied. The emulsions were homogenised at different pressures in order to obtain the desired droplet size. The droplet size distribution of the emulsions was determined using a Malvern Mastersizer 2000 (Malvern Instruments Ltd., Malvern, UK). The droplet volume-surface average or Sauter diameter ($d_{3,2}$) varied between 0.4, 1.0 and 3.3 μm depending on the homogenisation pressure (see Table 1).

2.2.2. Gels

The composition of all gels is summarised in Table 1. Gels were prepared with gelatine (4 wt%), and two mixtures of gelatine and agar with varying ratio of gelatine to agar (2.5 wt% gelatine and 0.3 wt% agar; 1.75 wt% gelatine and 0.4 wt% agar). The gelling agents were added to solutions of 6 wt% sucrose and 0.05 wt% vanilla at 95 °C. The samples were stirred until complete solution of the gelling agents and subsequently cooled to 45 °C in a water bath. After reaching 45 °C, 25 wt% emulsions were added to the samples to reach an oil concentration of 10 wt% oil in the gel. Prior to the addition of the emulsion its temperature of the emulsions was raised to 45 °C to avoid local decrease of the temperature of the gelling agents solution.

The samples were allowed to gel at room temperatures in 60 ml plastic syringes (internal diameter 26.4 mm) coated with a thin film of paraffin oil (samples for analytical determinations) or in sterile jars with a capacity of 50 ml (samples for sensory analysis).

2.3. pH measurements

The pH of the gels was measured with a Knick Portamess 911 pH pH-meter (Knick Elektronische Messgeräte, GmbH & Co. KG, Berlin,

Table 1
Overview of the composition, oil droplet size (Sauter diameter $d_{3,2}$) and pH of all mixed gelatine/agar gels.

Sample number	Gelatine (wt%)	Agar (wt%)	Sugar (wt%)	Vanilla (wt%)	Emulsion (wt%)	$d_{3,2}$ (μm)	pH
1	4	0	6	0.05	25	3.3	5.70 ± 0.05
2	2.75	0.3	6	0.05	25	3.3	6.00 ± 0.05
3	1.75	0.4	6	0.05	25	3.3	6.20 ± 0.05
4	4	0	6	0.05	25	1.0	5.70 ± 0.05
5	2.75	0.3	6	0.05	25	1.0	6.00 ± 0.05
6	1.75	0.4	6	0.05	25	1.0	6.20 ± 0.05
7	4	0	6	0.05	25	0.4	5.70 ± 0.05
8	2.75	0.3	6	0.05	25	0.4	6.00 ± 0.05
9	1.75	0.4	6	0.05	25	0.4	6.20 ± 0.05