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The effect of inhomogeneous quinine and hydrocolloid distributions on the bitterness of model gels

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ABSTRACT

This study investigated the effect of inhomogeneous distributions of quinine on bitterness intensity of gelatine–agar composite gels. It also investigated the effect of inhomogeneous distributions of the gel's hydrocolloid constituents (the gelatine and agar) on the bitterness intensity of the quinine. Fifty-two screened subjects participated in four paired comparison tests comparing inhomogeneous designs of quinine (with a homogeneous hydrocolloid distribution) and inhomogeneous designs of the hydrocolloids (with a homogeneous quinine distribution), against a homogeneous control of identical overall quinine and hydrocolloid composition. Using the same gel designs, a mastication trial was undertaken where ten subjects were asked to chew each gel system until the point of swallowing, and eleven subjects participated in a time-intensity trial where bitterness intensity was monitored during mastication and after expectoration. Paired comparison tests showed that the inhomogeneous distribution of quinine increased bitterness intensity, while inhomogeneous distributions of the hydrocolloids did not. Mastication was not influenced by changes in the distribution of quinine or the hydrocolloids. Time intensity curves showed the gels having an inhomogeneous distribution of quinine had greater bitterness intensity throughout mastication, however no differences in bitterness intensity were observed between any gel designs in the latter stages of aftertaste measurements. Time intensity curves also showed a slight delay in time to maximum bitterness intensity for the gels with inhomogeneous distributions of hydrocolloids. Results suggest a homogeneous distribution of bitter compounds is the most suitable structure for minimising bitterness perception.

1. Introduction

The modification of food structure to reduce bitterness perception is of great interest to food manufacturers seeking to incorporate bitter tasting compounds within functional foods. Traditional methods of masking bitterness, such as the addition of sugar (Calvino, García-Medina, & Cometto-Muniz, 1990; Lawless, 1986) salts (Frijters & Schifferstein, 1994; Keast, Canty, & Breslin, 2004), and fats (Metcalf & Vickers, 2002) are often not practical in products where health properties are a vital characteristic. Other approaches such as the addition of hydrocolloids to reduce bitterness perception can also induce a reduction in desired taste sensations (Pangborn, Gibbs, & Tassan, 1978; Pangborn, Trabue, & Szczesniak, 1973). Novel techniques such as bitter blockers (e.g. cyclodextrins) show promise but tend to elicit sensory side effects at higher concentrations (Gaudette & Pickering, 2013), and food manufacturers are also challenged with legislative and 'clean label' issues.

Significant advancement has been made in recent years in the area of taste enhancement through the use of food structure without changing ingredient composition (Holm, Wendin, & Hermansson, 2009; Mosca, van de Velde, Bult, van Boekel, & Stieger, 2015; Stieger, 2011). In particular inhomogeneous distributions of sucrose (Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010) and sodium chloride (Konitzer et al., 2013; Noort, Bult, & Stieger, 2012; Noort, Bult, Stieger, & Hamer, 2010) increase the perception of sweetness and saltiness, respectively. This altered sensory experience has been attributed to an effect known as discontinuous temporal stimulation (Burseg, Brattinga, de Kok, & Bult, 2010; Busch, Tournier, Knoop, Kooyman, & Smit, 2009; Meiselman & Halpern, 1973).

However, less is known about how food structure can be manipulated to reduce bitterness perception without changing ingredient composition. While Le Berrre, Boucon, Knoop, and Dijksterhuis (2013) demonstrated that perceived bitterness intensity can be reduced by varying bitter compound concentration from bite to bite

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Table 1
Composition of the gels.

	Agar (g/100 mL)	Gelatine (g/100 mL)	Quinine hydrochloride (mM)	Thickness of layer (mm)
Control (gel 1)	0.8	6	0.3	1.33
	0.8	6	0.3	4.0
	0.8	6	0.3	1.33
	0.8	6	0.3	4.0
Inhomogeneous quinine (gel 2)	0.8	6	1.2	1.33
	0.8	6	0	4.0
	0.8	6	1.2	1.33
	0.8	6	0	4.0
Inhomogeneous quinine (gel 3)	0.8	6	0	4.0
	0.8	6	1.2	1.33
	0.8	6	1.2	1.33
	0.8	6	0	4.0
Inhomogeneous hydrocolloids (gel 4)	1.6	12.0	0.3	1.33
	0.53	4.0	0.3	4.0
	1.6	12.0	0.3	1.33
	0.53	4.0	0.3	4.0
Reduced quinine (gel 5)	0.8	6	0.23	1.33
	0.8	6	0.23	4.0
	0.8	6	0.23	1.33
	0.8	6	0.23	4.0

(to alter sensory expectation), it is unknown how bitterness intensity changes if bitter ingredients within a solid structure are distributed in an inhomogeneous way. Bitterness differs from other basic taste sensations as it is detected by Type 2 taste receptors (TAS2R), it is not perceived as quickly (tends to lag), and often generates a longer aftertaste (Guinard, Hong, & Budwig, 1995). Only Morris et al. (2010) have shown that pulsed delivery of potassium chloride solution results in increased bitterness perception.

Furthermore, consumers experience a multitude of sensations when consuming food, and these sensations are well known to perceptually interact with each other (Delwiche, 2004). Colour (Spence, Levitan, Shankar, & Zampini, 2010) and sound (Spence & Shankar, 2010) can influence other sensory experiences, and more specifically odours (Stevenson, Prescott, & Boakes, 1999) and irritants (Delwiche, 2004) have been shown to influence taste. In some cases, the manipulation of viscosity can change flavour perception without influencing the diffusion of volatile and non-volatile compounds to taste and olfactory receptors (Cook, Hollowood, Linforth, & Taylor, 2003; Hollowood, Linforth, & Taylor, 2002). However, it is unknown if inducing the sensation of a complex texture (by manipulating the distribution of non-taste components of a food structure without changing overall food composition) can alter the taste sensations via perceptual interactions.

Lastly, it is well known that the way people masticate foods can influence sensory perception (Buettner & Schieberle, 2000; Wilson & Brown, 1997) and that sensory perception can also alter masticatory behaviour (Neyraud, Peyron, Vieira, & Dransfield, 2005). Understanding the influence of inhomogeneous bitter tastants and inhomogeneous structures on masticatory behaviour could provide greater understanding of sensory effects.

The aim of this study was therefore to assess the influence of inhomogeneous distributions of a bitter compound (quinine) and the inhomogeneous distributions of hydrocolloids (agar and gelatine) on bitter perception in solid food gels. The study also aimed to investigate any differences in natural mastication behaviour between these solid gel systems.

2. Methodology

2.1. Test gels

The test gels were made of composite gel layers of beef gelatin (250 bloom, 30 mesh) (Rousselot, Son, the Netherlands) and agar (AppliChem, Darmstadt, Germany), based on research published by Mosca et al. (2010) (but with modifications in agar and gelatine content). The gels layers were 20 mm × 20 mm in width and height, with a depth of approximately 1.33 mm or 4.0 mm. Quinine hydrochloride (Sigma Aldrich®, Steinheim, Germany) was used as the bitter compound (90% purity). De-mineralised water (VWR Chemicals®, Dublin, Ireland) was used throughout the gel making process. Table 1 summarises the composition of the gels. Gels were designed to create differences in bitterness distribution (gels 2 and 3), or differences in hydrocolloid distribution (gel 4), without changing the overall content of the gel in comparison with the control (gel 1). Only gel 5 differed in quinine concentration (a 25% lower quinine concentration).

The gel layers containing different levels of quinine and hydrocolloids were prepared by bringing agar and 190 mL de-mineralised water to 100 °C, followed by the addition of gelatine. Once the mixture cooled to 65 °C, the required amount of quinine solution (0.53 g/100 mL) was added. De-mineralised water was added until the mixture reached 200 mL (thus achieving the desired concentration for each formulation). Gel layers were formed by pouring the mixture into plastic petri dishes of 14 mm in diameter. Gel layers were set overnight in a refrigerator at 4 °C, before being equilibrated to 20 °C before serving to participants. Gel layers were disposed of after a maximum of four days in the refrigerator to ensure product consistency and safety.

To prepare the gels for serving to a participant, layers were cut individually using stainless steel cutters into 20 × 20 mm squares, approximately 30 min before a tasting session. Gels were compiled by assembling four layers on top of each other as described in Table 1. To avoid diffusion of quinine between layers, layers were not assembled until immediately before serving to each participant (approximately 1–2 min). All trials in this study tested subjects individually to achieve this.

2.2. Paired comparison testing methodology

Fifty-two subjects were selected for the paired comparison sensory tests ($m = 11$, $f = 41$), with an average age of 28 years (age range 19–50 years). No subjects suffered any known difficulties with taste or any health issues which might affect oral processing. All subjects gave informed consent to take part, and the study was approved by the University College Dublin Human Ethics Committee (Application LS-14-21).