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Controlling salt and aroma perception through the inclusion of air fillers

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ABSTRACT

Global dietary sodium consumption significantly exceeds the WHO recommended intake levels, although strategies are available for sodium reduction, most are partial product-specific solutions. A wider range of approaches is urgently required to enable food manufacturers to reduce sodium within processed foods. In this study, the addition of air inclusions within hydrogels has been evaluated for its ability to enhance the delivery of sodium and perception of saltiness and was shown, on a volume basis, to achieve an 80% reduction in total sodium with no loss of saltiness perception; the addition of a congruent aroma volatile was shown to enhance overall flavour perception in foamed systems. Air inclusions were shown to increase both the delivery and perception of salt and aroma, in addition to increasing overall flavour perception. This work will be of interest to both academic researchers in this field and industrialists looking for new approaches to mitigate loss of taste quality with sodium reduction.

1. Introduction

Sodium reduction remains as a primary strategy for the improvement of human health. National and international organisations encourage the general population to consume less salt and more importantly food manufacturers to lower sodium content in processed food products.

Although sodium is required for normal body functions, over consumption may lead to adverse health effects (He & MacGregor, 2007). Sodium chloride (salt) is the major source of sodium in human diets (He & MacGregor, 2010) and excessive consumption has been linked to the development of hypertension and adverse cardiovascular health (Brown, Tzoulaki, Candeias, & Elliott, 2009; Kempner, 1948; Page, Vandevert, Nader, Lubin, & Page, 1981; Ramsay et al., 1999). In most countries, the average salt intake is approximately 9–12 g/d (Brown et al., 2009), which far exceeds normal physiological needs and the current recommendations by the World Health Organisation of <5 g/d (WHO, 2007).

Processed and restaurant foods are estimated to account for up to 75% of sodium intake in developed countries, 10–12 % is naturally occurring in foods, whilst only 10–15 % is additionally added as salt during cooking or eating (Mattes & Donnelly, 1991). Thus, participation by the food industry is vital in reducing sodium in the diet (He & MacGregor, 2003).

A range of different approaches have been used to reduce sodium levels, and in general multiple approaches are often the most successful when applied to food products. However, the developed approaches are often product specific and their application may not be applicable to all food products.

A frequent approach to salt reduction is the use of direct substitution with other ingredients to maintain sensory properties such as mineral salts (Desmond, 2006; Gou, Guerrero, Gelabert, & Arnau, 1996; Reddy & Marth, 1991). Although mineral salts are able to trigger a salty sensation, a common disadvantage of these substitutions is the presence of bitter off-tastes, which limits the level of substitution (Kilcast & den Ridder, 2007). The multifunctional nature and unique taste of sodium chloride has yet to be matched by any other chemical (Angus, 2007; Kilcast & den Ridder, 2007; McCaughey & Scott, 1998), adding to the complexity of sodium reduction.

Another approach is the use of congruent aroma volatiles, exploiting taste–aroma interactions (Batenburg & van der Velden, 2011; Bonorden, Giordano, & Lee, 2003; Cliff & Noble, 1990). This effect has been shown to be successful for both sweet (Hort & Hollowood, 2004) and salty tastes (Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009). However, multiple factors can influence taste–aroma interactions, such as prior exposure and pleasantness (Djordjevic, Zatorre, & Jones-Gotman, 2004; Schifferstein & Verlegh, 1996).

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The influence of hydrocolloid thickeners on taste and aroma perception has received much attention. It has been reported that hydrocolloid thickened solutions above a specific viscosity (c*) supress both taste and aroma perception (Baines & Morris, 1987; Cook, Linforth, & Taylor, 2003).

Studies have explored oil-in-water emulsions, using oil droplets as fillers thereby replacing the water phase within the system (Bayarri, Smith, Hollowood, & Hort, 2007; Drewnowski & Schwartz, 1990; Yamamoto & Nakabayashi, 1999). The addition of oil replaces the water, causing an increase in taste perception as the concentration of tastant effectively increases in the aqueous phase. However, the additional oil can lead to mouth coating (Yamamoto & Nakabayashi, 1999) and additional oil in products is undesirable for health, therefore limiting its application.

Control over the temporal delivery of tastants from the bolus to saliva has been previously shown (Rama et al., 2013; Tian & Fisk, 2012) to control taste perception and could act as one approach to enhance sodium perception. It is well known that increasing the concentration of a tastant within a liquid phase will increases perceived taste intensity, therefore techniques where tastant concentrations are effectively increased through substitution of the water phase is an appealing way to reduce sodium in the diet. A previous study reported that overall taste perception was dependant on the tastant concentration in the aqueous phase and was irrespective of the volume fraction of the air inclusions (Goh, Leroux, Groeneschild, & Busch, 2010).

The objective of this study is to evaluate the impact of air as a filler particle within hydrogels and its impact on the temporal delivery of salt and congruent aroma delivery in-nose, and its resulting impact on saltiness and overall flavour perception.

2. Material and methods

2.1. Sample preparation

An aqueous solution of containing 2 g/100 mL type B bovine gelatine (Sigma–Aldrich Ltd., Dorset, UK), 5 g/100 mL whey protein isolate (Davisco, Minnesota, USA) and between 0.6 g/100 mL and 3.3 g/100 mL sodium chloride (Sigma–Aldrich Ltd., Dorset, UK) was stirred and heated to 60 °C. 1-octen-3-ol, a mushroom aroma volatile (Log P 2.73), was then added to samples S6, S7 and S8 as indicated in Table 1 producing a concentration of 0.8 μL/L. The solution was immediately placed into an ice bath and sheared at 3000 rpm using a high shear overhead mixer (L5M, emulsor screen, Silverson, Chesham, UK). Different durations were used to achieve the required volume. Air inclusion fraction was calculated by subtracting the original volume of the solution before shearing from the volume of the solution after shearing. The foams were stored at 4 °C and were stable for up to 24 h, all samples were prepared and analysed within 14 h Table 1 displays the formulations of the gel samples that were used for sensory testing.

2.2. Sodium concentration

Flame photometry (Sherwood Scientific Ltd., Model 410, Cambridge, UK) was used to evaluate sodium concentration, sodium standards (0–1 μL/L) were prepared for calibration. The calibration curve demonstrated repeatability ($R^2 > 0.99$), and linearity up to 1 μL/L, wavelength 589 nm. The sodium data was collated in triplicate and converted to sodium chloride concentration (×2.5).

2.3. Sensory evaluation

96 untrained panellists (aged 19–61; 55 females and 41 males) were recruited to conduct a series of paired comparison (PC) tests (BS EN ISO 5495:2007). The same volume of sample (6 mL) was prepared individually on plastic spoons and left to equilibrate at room temperature (21 °C). For each sample, panellists were required to place the sample in their mouth for 10 s, the tongue was moved up and down three times before swallowing. The samples were presented in pairs on plastic spoons each labelled with a random three-digit code and panellists were asked to select the sample they perceived as saltiest overall, each sample was evaluated against every other sample in a balanced design resulting in 3 PC tests. The first set of samples, S1, S2 and S3, contained equal concentrations (6.6 g salt/L) of salt in the aqueous phase and 0%, 40% and 80% air inclusions respectively, (S1, S2 and S3 contained total sodium contents of 198 mg, 118.8 mg and 39.6 mg respectively). The following series of samples, S1, S4 and S5, contained increasing air inclusions from 0 % to 40 % and 80% respectively whilst overall weight amount of salt was kept constant (198 mg). Again each sample was evaluated against every other resulting in a further 3 PCs. Finally, panellists were asked to perform PCs selecting the sample that was perceived to be most intense in overall flavour, where a mushroom aroma volatile was applied. Samples S6, S7 and S8 were used in these tests and contained the same concentration of 1-octen-3-ol aroma volatile (0.8 μL/L) and the same overall salt concentration (6.6 g/L) in all samples (samples varied in air inclusion, 0%, 40% and 80% respectively).

The test was used in forced-choice mode, so panellists were required to give an answer even if the perceived difference was negligible. Plain crackers (99% Fat Free, Rakusen's, Leeds, UK) and mineral water (Evian, France) was supplied for panellists to palate cleanse between samples, rest breaks were given between every 3 PC. All tests were carried out within individual sensory booths under northern hemisphere lighting and controlled temperature and humidity. Consensual answers were compared to data tables to determine significance (BS EN ISO 5495:2007), $\alpha = 0.05$ for difference testing, $\alpha = 0.2$, $\beta = 0.05$ and $p_D = 30\%$ for similarity testing.

2.4. Sodium ion release

The rate of dissolution of sodium from a 6 mL sample to a beaker of deionised water (200 mL) was evaluated every 10 s over 150 s,

Table 1
Formulation of samples used for sensory testing.

Sample code	Air inclusion (%v/v)	Solution (mL)	Salt (mg)	Air inclusion (mL)	Total volume (mL)	Salt concentration in aqueous phase (g/L)	1-octan-3-ol (μL/L)
S1	0	30	198	0	30	6.6	0
S2	40	18	118.8	12	30	6.6	0
S3	80	6	39.6	24	30	6.6	0
S4	40	18	198	12	30	11	0
S5	80	6	198	24	30	33	0
S6	0	30	198	0	30	6.6	8.0
S7	40	18	118.8	12	30	6.6	8.0
S8	80	6	39.6	24	30	6.6	8.0