Food Quality and Preference 28 (2013) 134–140

Contents lists available at SciVerse ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Enhancing salty taste through odour–taste–taste interactions: Influence of odour intensity and salty tastants' nature

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ARTICLE INFO

Article history:
Received 3 April 2012
Received in revised form 10 July 2012
Accepted 13 July 2012
Available online 20 July 2012

Keywords:
Odour-induced saltiness
Sodium
Potassium
Bitterness
Sourness
Salt reduction

ABSTRACT

Decreasing the sodium content in food products without changing consumer acceptability has become an important challenge for the food industry, and several strategies are currently under investigation to reach this goal. This study investigated the effectiveness of saltiness enhancement by an odour to maintain the perception of saltiness in reduced salt content solutions. In the first experiment, we tested the hypothesis that odour intensity drives the level of saltiness enhancement. The results showed that odour can increase the salty intensity by 25%, while no clear influence of odour intensity either in tasteless solutions or in low-salt content solutions. In a second experiment, we examined whether odour could enhance saltiness in salty solutions containing potassium chloride alone or mixed with sodium chloride and in salty-sour solutions. The results showed that a higher Odour-Induced Saltiness Enhancement occurred when the salty taste relied on potassium chloride as compared to sodium chloride. However, the highest enhancement was observed in the ternary odour–sour-salty solution. These findings suggest that cross-modal odour(s)–taste(s) interactions may be an efficient strategy, in combination with the use of salt replacers, to compensate for sodium reduction in complex food systems.

1. Introduction

Sodium is a key life-sustaining factor because it plays a crucial role in maintaining the proper distribution of water and osmotic pressure in extracellular fluid compartments. Sodium cannot be produced by endogenous process and must be provided to organisms by food intake. However, high sodium intake leads to health issues, such as hypertension, coronary disease and stroke. A high sodium diet leads to water retention and a consequent increase in blood volume that might trigger an elevation in blood pressure (Strazzullo, D'Elia, Kandala, & Cappuccio, 2009). Durack, Alonso-Gomez, and Wilkinson (2008) suggested that excess dietary sodium intake is also linked to the development of kidney disease, aggravation of asthmatic conditions and to the onset of osteoporosis. As a consequence, international recommendations suggest that for the average person, salt (NaCl) intake should be less than 5–6 g per day (WHO, 2007). The average current daily consumption is approximately 10–12 g of NaCl per day, while an intake of 3 g of NaCl per day would be sufficient. Indeed, Flegel and Magner (2009) reported that the Yanomami Indians of the Amazon region consume less than 1 g of salt per day; this group does not have high blood pressure, even with increasing age. In contrast, the Japanese consume approximately 15 g of salt per day and have the highest rate of cardiovascular diseases.

Salt is present in significant quantities in several food product categories, including breads, soups, cheeses and sausages. It not only plays a major role in protecting food against microorganisms (Taormina, 2010) but also in the development of food texture, taste and aroma (Guinee, 2004). As a consequence, decreasing salt in food leads, most of the time, to a decrease in food acceptability by consumers (Breslin & Beauchamp, 1997). Nevertheless, food manufacturers have taken several different approaches to reduce the salt content in foods to align with international recommendations while trying to maintain food acceptability (Busch, Feunekes, Hauer, & Den Hoed, 2010). Ruusunen, Simolin, and Puolanne (2001) suggested through experiments on fresh-coloured food and some prepared meat products that it is possible to substitute sodium chloride with other salting agents, such as potassium chloride. However, potassium chloride confers bitterness and has a weaker salting capacity (Armenteros, Aristoy, Barat, & Toldra, 2012; Hooge & Chambers, 2010); despite these findings, the total or partial substitution of sodium chloride by potassium chloride has been widely used for many foods (Toldrá & Barat, 2009).

The overall perception of food flavour is considered to be an integration of simultaneous sensory inputs that include both taste and odour from available chemical stimuli in the mouth and perceptual intra- and cross-modal interactions (Small & Prescott, 2005; Thomas-Danguin, 2009). Indeed, in-mouth stimuli release was found to be responsible for flavour perception (Guichard, 2002; Lauverjat,

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http://dx.doi.org/10.1016/j.foodqual.2012.07.004

Deleris, Trelea, Salles, & Souchon, 2009), as well as sensory interactions (Saint-Eve, Lauverjat, Magnan, Deleris, & Souchon, 2009), which suggests a complex balance between physico-chemical and perceptual interactions during food consumption.

Perceptual interactions have been observed between taste and smell (Frank & Byram, 1988; Salles, 2006), and it has been shown that odour–taste interactions depend on the association between both stimuli (Valentin, Chrea, & Nguyen, 2006). Neural mechanisms have been highlighted that support the cognitive basis of such interactions (Verhagen & Engelen, 2006). Some odours were thus found to enhance taste (Stevenson, Prescott, & Boakes, 1999), especially salty taste (Djordjevic, Zatorre, & Jones-Gotman, 2004). These findings led Lawrence et al. (2009) to propose Odour-Induced Saltiness Enhancement (OISE) as a strategy to compensate for a reduction in saltiness through multisensory integration mechanisms. These authors showed that salt-associated odours can enhance the saltiness of solutions containing a low level of sodium chloride. They reported that, among twelve aromas suspected to induce saltiness, eight significantly enhanced the saltiness in low salt solutions and also in solid foods of various textures (Lawrence et al., 2011). Moreover, we recently showed that the OISE depends on salt concentration, namely salty intensity (Nasri, Beno, Septier, Salles, & Thomas-Danguin, 2011), but it remains unknown whether aroma intensity also influences OISE. Therefore, in a first experiment, we explored the influence of aroma intensity on saltiness enhancement of water solutions containing sodium chloride.

During consumption, a food usually elicits a bouquet of tastes, and taste–taste perceptual interactions have also been reported to impact saltiness (Keast & Breslin, 2002). Salt and sour tastes were found to enhance each other at low intensity levels; Breslin (1996) reported that citric acid enhances the saltiness at a low level of sodium chloride. In contrast, asymmetrical suppression was more often observed at high sodium chloride levels (Schifferstein, 1995). The saltiness was not found to be affected by bitter tastes, but bitterness was suppressed by salt (Breslin, 1996); moreover, saltiness was found to enhance sweetness at low concentrations, whereas mutual suppression was usually observed at higher intensity levels (Breslin, 1996).

Considering that a combination of several strategies to compensate for sodium content reduction could be advantageous, we set out to examine whether odour could enhance the saltiness of solutions containing mixtures of sodium and potassium salts in a second experiment. Moreover, because food usually elicits several tastes that could interact at a perceptual level, we evaluated whether an OISE could be observed in salty-sour solutions containing potassium and sodium salts along with citric acid.

2. Materials and methods

2.1. Subjects

Sixty-one panellists (aged 18–65 years, 38 women, 23 men) participated in a 1-h sensory session that was divided into two blocks, each corresponding to a distinct experiment (experiments 1 and 2). Participants reported normal ability to perceive smell and taste. They signed an informed consent form, but the aim of the experiment was not revealed. They received 10€ for their participation and were requested not to smoke or to eat 1 h before the session.

2.2. Stimuli

2.2.1. Experiment 1

A sardine aroma (Givaudan, Argenteuil, France) was chosen for its saltiness enhancement properties (Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009; Nasri et al., 2011). Following a 4×2-full-factorial design, the aroma was used at a concentration of 0, 0.25, 0.50 or 1 g/L and diluted either in Evian® mineral water (“without salt” condition) or in Evian water containing sodium chloride (NaCl; Jerafrance, Jeufosse, France) at a 0.02 M concentration (“with salt” condition). Additionally, a reference solution including 25% more sodium chloride (0.025 M in Evian water) was used. All solutions were made 24 h prior to testing and were stored in glass bottles at 4 °C until use. The samples were served at room temperature (21 °C). All concentrations were chosen according to their perceived intensity and acceptability (Lawrence et al., 2009; Nasri et al., 2011).

2.2.2. Experiment 2

Thirteen samples were prepared corresponding to a full 2×6 factorial design with aroma (no aroma or the sardine aroma) and taste (no tastant, 3 single tastants and 2 mixtures) as factors, plus a reference solution with 25% more sodium chloride (0.025 M in Evian water). The sardine aroma was used at a concentration of 0.5 g/L for the “sardine” condition. The taste factor in the factorial design relied on Evian water (no tastant), sodium chloride (20 mM in Evian water), citric acid (2.5 mM; Sigma–Aldrich, Saint-Quentin Fallavier, France), potassium chloride (40 mM; Sigma–Aldrich, Saint-Quentin Fallavier, France) and the following two mixtures: citric acid + sodium chloride and potassium chloride + sodium chloride. All solutions were made 24 h prior to testing and were stored in glass bottles at 4 °C until use. The samples were served at room temperature (21 °C).

2.3. Experimental procedure

In each experiment, stimuli were presented monadically, following a Williams Latin square design, to the panellists who were in separate booths in a room dedicated to sensory analysis (21 °C). Twenty millilitres of each sample was presented in an 80 ml plastic cup. The interval between each sample was 60 s. For each sample, panellists were asked to place the entire sample in their mouth and to rate the aroma intensity and the taste intensity (sourness, bitterness, saltiness, and sweetness) on dedicated linear scales from 0 to 10 (0 = none and 10 = extremely strong; Lawrence et al., 2009; Nasri et al., 2011). Panellists were asked to cleanse their mouth with Evian water. Data acquisition was performed with FIZZ software (Biosystèmes, Couternon, France).

2.4. Data analyses

Data analyses were performed using SAS release 9.1.3-SP4 (SAS Institute Inc., Cary, NC, USA). An analysis of variance (ANOVA) was performed using a mixed model (GLM procedure) with the panellists as a random factor and the stimuli as a fixed factor. Student–Newman–Keuls (SNK) tests were used for multiple comparisons of the means. The OISE (Odour-Induced Saltiness Enhancement) was calculated for each aroma solution, including water only or water with salt. For each panellist, the OISE corresponded to the difference between the saltiness of the solution containing an aroma and the saltiness of the aromaless solution containing the same amount of sodium chloride. We evaluated the OISE significance using Student’s t-tests to assess whether the OISE means were different from 0.

In experiment 2 only, an analysis of co-variance (ANCOVA) was performed on OISE using a mixed model (GLM) with panellists as a random factor, stimuli as a fixed factor and aroma intensity and salty intensity as covariates. To analyse the correlations between variables, Pearson’s correlation coefficients were calculated.

For all data analyses, the effects were considered significant when $p < 0.05$.