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Heterogeneous salt distribution in hot snacks enhances saltiness without loss of acceptability

M. Emorine, C. Septier, T. Thomas-Danguin, C. Salles *

CNRS, UMR6265 Centre des Sciences du Goût et de l'Alimentation, F-21000 Dijon, France
INRA, UMR1324 Centre des Sciences du Goût et de l'Alimentation, F-21000 Dijon, France
Université de Bourgogne, Centre des Sciences du Goût et de l'Alimentation F-21000 Dijon, France

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ABSTRACT

Health issues have led worldwide organisations to encourage the food industry to reduce salt in processed foods. Therefore, different strategies for salt reduction have been investigated. Here, the effect of heterogeneous salt distribution on saltiness perception intensity was assessed to compensate for salt reduction in snack foods. Two models of hot-served baked foods were developed. One model is made of two layers that vary in composition (cream-based and cereal-based layers) and salt (NaCl) concentration; the other one is made of four cream-based layers that vary in salt concentrations. Consumer panels rated the saltiness intensity for each product and their liking for the four-layer products only.

A significant enhancement of saltiness was observed in samples with a heterogeneous salt distribution for both types of snacks. In the bi-layer products, salt perception was more dependent on the salt concentration in the cream-based layer than in the cereal-based layer. Moreover, a large contrast in the salt concentrations was required to enhance salt perception for the four-layer products.

Our results show that heterogeneous salt distribution is a powerful strategy to compensate for salt reduction in foods and to design healthier products while optimising taste.

1. Introduction

Sodium-rich diets have been largely demonstrated to promote hypertension, which is a risk factor associated with cardiovascular diseases (Jaitovich & Bertorello, 2010). In Western countries, approximately 75% of the daily salt intake is derived from salt added during food processing (Mattes & Donnelly, 1991). Thus, to reduce the risk of hypertension and the associated healthcare expenditures, many countries and health organisations have encouraged the food industry to reduce salt in processed foods (United State Department of Agriculture, 2011; World Health Organization, 2007). Therefore, different strategies for salt reduction have been developed.

Slight stepwise reductions of salt over 5–10% are not noticed by consumer, thus cumulative stepwise reductions allow significant salt reduction, while maintaining consumer acceptance, for example in bread (Bolhuis et al., 2011). Another strategy is to substitute NaCl with other inorganic salts providing salty taste. Nevertheless, the replacement of greater than 50% of sodium chloride with potassium or magnesium chloride or inorganic salt blends generates undesirable off-tastes in breads or meats (Desmond, 2006; Zanardi, Ghidini, Conter, & Ianieri, 2010). Hence, this strategy for salt reduction is limited. The use of taste enhancers, such as amino acids, or nucleotides, raises the sensitivity of sodium channels and allows a decrease in the salt content, but sodium reduction in foods generally influences global flavour perception due to interactions with the other components of the food matrix (Liem, Miremadi, & Keast, 2011). Aromas have been demonstrated to achieve an odour-induced saltiness enhancement (OISE) in liquids or solid food when the aroma quality is congruent with saltiness perception (Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009; Lawrence et al., 2011; Nasri, Beno, Septier, Salles, & Thomas-Danguin, 2011; Nasri, Septier, Beno, Salles, & Thomas-Danguin, 2013).

A new approach for taste enhancement based on stimuli contrasts has been reported several times in liquid and, to a lesser extent, semi-solid food models for sweetness (Burseg, Camacho, Knoop, & Bult, 2010; Holm, Wendin, & Hermansson, 2009; Mosca, van de Velde, Bult, van Boekel, & Stieger, 2010), saltiness (Busch, Tournier, Knoop, Kooyman, & Smit, 2009; Noort, Bult, Stieger, & Hamer, 2010) and fat perception (Mosca, Rocha, Sala, van de Velde, & Stieger, 2012). If this approach has been applied in liquid, gel or bread models, no study has been conducted on complex food products. Indeed, model foods developed in these studies were produced between a few hours to 3 days prior to being tested at room temperature in order to limit tastant diffusion, a critical factor to maintain the contrast. To the best of our knowledge, even though most processed foods are heat-treated before being eaten, no study was related to frozen-food products reheated at a hot temperature in which tastant diffusion may be an issue. Therefore, the

* Corresponding author at: INRA, Centre des Sciences du Goût et de l'Alimentation, 17 rue Sully, F-21000 Dijon, France. Tel.: +33 380 69 30 79; fax: +33 380 69 32 27.
E-mail address: salles@dijon.inra.fr (C. Salles).

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robustness of the strategy of heterogeneous salt distribution for frozen food products, which require a long shelf-life and quick reheating, remains to be explored, as does the consumers' liking for such products.

The aim of this study was to investigate the effect of heterogeneous salt distribution on saltiness enhancement and consumer acceptability in a hot-served layered snack food.

First, we examined whether salt distribution could affect salt perception in a salty baked food composed of two different layers (cereal-based and cream-based layers). Second, we investigated whether a heterogeneous distribution of salt in a four-layer cream-based model food could affect sodium perception. Third, we assessed the consumer liking of the four-layer cream-based snack food.

2. Materials and methods

2.1. Experimental food products

2.1.1. Materials

Whipping cream (30% fat) (LNA, Le Moulin Henry, France), pasteurised eggs (Blanchard, Lannergat, France), Emmental cheese (Tippagral, Dijon, France), modified food starch (Colflo 67, National Starch & Chemical, Hamburg, Germany), T80 wheat flour (Elevia, Faymoreau, France), table salt (Salin du Midi, Aigues-Mortes, France), and mineral water (Evian, France) were used in the preparation of the cream-based layers. The cereal-based layers were composed of T80 wheat flour, butter (80% fat) (Lactalis, Isigny, France), mineral water (Evian, France) and table salt. The same batch of raw materials was used to produce all the products for each study.

2.1.2. Bi-layer product preparation

The salty baked products comprised a cream-based layer and a cereal-based layer. Three levels (0%, 0.3%, and 1% [w/w]) of added salt were tested within each layer, according to a full factorial design.

The salty baked products were prepared at room temperature using the laboratory mixing equipment. For the preparation of the cereal-based layer, all the ingredients were mixed for 5 min at 80 rpm (spiral mixer VMI, Montaigu, France) and then mixed for 1 min at 1500 rpm (cutter Stephan Um 24, Hameln, Germany). The dough was laminated until a layer of 2.5 cm was obtained (laminating apparatus, Seewer Rondo, Burgdorf, Switzerland). For the cream-based layer, the ingredients were mixed for 1 min (mixer 450 Watt, Seb, Selongey, France). The two layers were manually assembled and pre-cooked for 6 min at 180 °C in a conveyer oven gas (Lincoln, Impinger, Fort Wayne, IN, USA). Then, they were cut into squares of 2.5∗2.5 cm (9 g) with a double guitar cutter (Mallard Ferrière, Noisy-le-Sec, France), and the samples were frozen at −20 °C until use. The products were heated for 4 min at 240 °C and then cooled at room temperature for 20 min before being analysed. The mean weight of cereal- and cream-based layers was 3.3 g and 3.7 g per sample, respectively.

2.1.3. Four-layer cream-based product preparation

The overall added salt was 8‰ (w/w) in each product, but the salt distribution varied throughout the four layers, according to 4 modalities: homogeneous distribution (R), and 3 different levels of heterogeneity of salt distribution within the four layers. Products with a low level of heterogeneity were composed of two layers at 4‰ added salt and two layers at 12‰ (L products), products with a medium level of heterogeneity were composed of two salt-free layers and two layers at 16‰ added salt (M products), and products with a high level of heterogeneity were composed of three salt-free layers and one salty layer at 32‰ added salt (H products). Moreover, a homogeneous product containing 25% more added salt was used as the saltier reference (R+). The products, presented in Table 2, were coded as a function of the level of heterogeneity of salt distribution (S, L, M, H products). Numbers $_1$ to $_4$ refers to the spatial location of the higher added salt concentrations in the products: for example $L_{1,3}$ refers to the product with the 2 layers containing 12‰ in the top layer (1) and the third layer (3).

The cream-based layer was prepared at room temperature. Each layer was independently prepared and assembled at the end of the preparation, according to the different combinations. The ingredients were mixed for 2 min (mixer 450 Watt, Seb, Selongey, France), and then a texturing agent (Rhodigel, Danisco Ingredient, Trappes, France) was added. The dough was mixed again for 2 min. The layers were formed in silicon moulds (Flexipat, Demarle, Wavrin, France) and baked at 140 °C for 17 min in a vertical convection oven (Tecnox, Inoxtrend, Lucia Di Piave, Italy). After cooking, the layers were cooled for 30 min to room temperature. The four layers were then assembled and maintained at −20 °C for 30 min to keep the layers together. The resulting four-layer cream-based product was cut into portions of 2.5∗2.5 cm (approximately 10 g of product) with a double guitar cutter (Mallard Ferrière). The samples were then stored at −20 °C until further analysis. The products were heated for 4 min at 240 °C and then cooled at room temperature for 20 min before being analysed.

2.2. Physico-chemical analyses

2.2.1. Dry matter content

The dry matter was determined for each product (in 3 replicates) with a Desiccator XM 120 (PRECISA, Dietikon, Switzerland). A piece of product (approximately 2 g) was distributed in a thin, uniform layer on an aluminium dish and heated at 150 °C for 2 min and then at 180 °C until the dry matter weight was constant.

2.2.2. Salt content

The overall amount of sodium in the product was determined through HPLC Ionic Chromatography using a Dionex ICS Chain 3000 (Dionex, Voisins-le-Bretonneux, France).

Three replicates were performed for each product and for each layer of the four-layer cream-based products. A piece of sample (approximately 1 g) was homogenised in 15 mL MilliQ water using an ultra-Turrax® apparatus (Ika, Werke, Sweden) for 1 min at 13500 rpm. The obtained solution was centrifuged for 15 min at 10,000 *g*. The recovered supernatant was diluted 20-fold with MilliQ water before being filtered (pore size 0.45 μm, CIL, Sainte-Foy-la-Grande, France). The injection loop was set at 20 μL for all samples. The sodium was analysed by ionic chromatography with an IonPac CS12A column 5 μm to 25 °C and detected by a conductivity suppressor CSRS 300 2 mm. The elution was performed in an eluent of 11 mM H_2SO_4 at a rate of 0.5 mL/min.

Data acquisition was performed on UCI-100 Chromeleon software (version 6.8). Furthermore, quantification was performed with standard solutions of sodium (from 0.4 to 1.6 mM of Na^+).

2.2.3. Texture profile analyses

Two-cycle compression tests were conducted as control test to ensure that the physical nature of the salt and repartitioning did not influence the rheological properties of the products.

The measurements consisted of 3 replicates for each product (bi-layer and four-layer cream-based products) and were performed in a controlled temperature room (20.5 °C) with a Texture Analyser TA HD plus (Stable Micro Systems, Surrey, England).

During the test, the samples were compressed to a maximum deformation of 75% by a 10-cm diameter cylindrical probe with a cross head speed of 0.5 mm/s. When the compression stroke was completed, the plunger abruptly reversed direction and started its upward stroke at 1.5 mm/s. Then, a second down-and-up cycle was run on the same sample. The force developed by the food sample was measured with a load cell (30 kg) and recorded according to the position of the top plate. The limits of displacement were the same for the two successive compression cycles. Four replicates per snack sample were performed. From the data, four rheological parameters were determined: hardness (N), cohesiveness (dimensionless), springiness (Nmm) and adhesiveness (Nmm).