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Research report

Variation in saltiness perception of soup with respect to soup serving temperature and consumer dietary habits ☆

Jeong-Weon Kim [a,b], Shilpa S. Samant [a], Yoojin Seo [a,c], Han-Seok Seo [a,*]

[a] Department of Food Science, University of Arkansas, 2650 North Young Avenue, Fayetteville, AR 72704, USA
[b] Department of Science and Technology Education for Life, Seoul National University of Education, Seoul 137-742, Republic of Korea
[c] Department of Food Science and Nutrition, Dankook University, Yongin, Gyeonggi 448-701, Republic of Korea

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ABSTRACT

Little is known about the effect of serving temperature on saltiness perception in food products such as soups that are typically consumed at high temperature. This study focused on determining whether serving temperature modulates saltiness perception in soup-base products. Eight trained panelists and 62 untrained consumers were asked to rate saltiness intensities in salt water, chicken broth, and miso soup, with serving temperatures of 40, 50, 60, 70, and 80 °C. Neither trained nor untrained panelists were able to find significant difference in the saltiness intensity among salt water samples served at these five different temperatures. However, untrained consumers (but not trained panelists) rated chicken broth and miso soup to be significantly less salty when served at 70 and/or 80 °C compared to when served at 40 to 60 °C. There was an interaction between temperature-related perceived saltiness and preference; for example, consumers who preferred soups served at lower temperatures found soups served at higher temperatures to be less salty. Consumers who frequently consumed hot dishes rated soup samples served at 60 °C as saltier than consumers who consumed hot dishes less frequently. This study demonstrates that soup serving temperature and consumer dietary habits are influential factors affecting saltiness perception of soup.

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Introduction

Overconsumption of dietary salt has become a hot world-wide human health issue (World Health Organization, 2007). The World Health Organization (2007) recommends a 5-g maximum daily intake of dietary salt (2 g as sodium) for adults. However, the estimated mean daily sodium intake (about 3.4 g) of the U.S. population greatly exceeds these recommended levels (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). About 90% of U.S. residents aged 2 years and older consume more sodium than the amount recommended for a healthy diet, according to a report (2012) by the Centers for Disease Control and Prevention (CDC).

Excessive intake of sodium increases the risk of stroke, total cardiovascular diseases, and renal diseases (for a review, see Aburto et al., 2013; He & MacGregor, 2009), and in turn leads to an increase in the cost of health care. To reduce excessive consumption of sodium, many campaigns and educational programs have been initiated around the world. For example, the United Kingdom has successfully established a salt-reduction program, Consensus Action on Salt and Health (CASH) (MacGregor & Sever, 1996), resulting in significant reduction in salt consumption (He, Brinsden, & MacGregor, 2014).

Notably, a large portion (estimated 75%) of sodium consumed in both European and North American countries comes from processed food products and restaurant-prepared foods (He, Jenner, & MacGregor, 2010). In an effort to reduce excessive consumption of sodium, food manufacturers and food-service industries have increasingly been trying to develop low-sodium products. However, it is difficult to achieve a significant salt reduction in processed food products because salt plays a major role in processing, preservation, and sensory acceptability of such products (Desmond, 2006). Strategies for reducing sodium content in food products can be classified into three categories: 1) chemical mechanisms at a peripheral level, 2) food structure modification, and 3) cognitive mechanisms (Busch, Yong, & Goh, 2013). First, there are alternative salts (e.g., potassium chloride) that, while not containing sodium, can increase saltiness taste perception at a peripheral level (Busch et al., 2013; Grummer, Karalus, Zhang, Vickers, & Schoenfuss, 2012). Second, structure of food products can be optimized to produce maximum stimulation to taste receptors by sodium ions (for a review, see Busch et al., 2013). For example, inhomogeneous spatial

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* Corresponding author.
E-mail address: hanseok@uark.edu (H.-S. Seo).

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distribution of salt in breads can result in taste contrast and less taste adaptation, thereby enhancing saltiness perception (Noort, Bult, Stieger, & Hamer, 2010). Finally, saltiness perception can be increased at a cognitive level by using salty-congruent odors/flavors (Busch, Batenburg, van der Velden, & Smit, 2009; Djordjevic, Zatorre, & Jones-Gotman, 2004; Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009; Seo et al., 2013), umami tasting substances (Kremer, Mojet, & Shimojo, 2009; Mojet, Heidema, & Christ-Hazelhof, 2004; Yamaguchi & Takahashi, 1984), sour taste (Keast, Canty, & Breslin, 2004), and viscosity (Koliandris et al., 2010).

Building on such sodium-reducing strategies, this study attempts to examine the possibility of enhancing saltiness by adjusting the serving temperature of liquid foods, particularly soups. Earlier research has demonstrated that saltiness perception can be modulated in taste solution and food products by modification of serving temperature (Maurizi & Cimino, 1961; McBurney, Collings, & Glanz, 1973; Rosett, Hamill, Morris, & Klein, 1997). For example, McBurney et al. (1973) demonstrated that detection thresholds for sodium chloride (NaCl) solution followed a U-shaped curve with a minimum threshold (i.e., maximum sensitivity) lying between 22 and 32 °C as solution temperature rose from 17 to 42 °C. Similarly, Pangborn, Chrisp, and Bertolero (1970) showed that when NaCl solution was presented at 0, 22, 37 and 55 °C, trained panelists were more sensitive to the solutions at temperatures of 22 and 37 °C than those at 0 or 55 °C. In a more recent study by Rosett et al. (1997), when experienced participants familiar with the evaluation procedures were provided with reduced-sodium chicken broths at two different temperatures (22 and 60–65 °C), the samples at 22 °C were perceived saltier than the ones at 60–65 °C. However, in another study by Moskowitz (1973), saltiness intensity increased monotonically with a rise in temperature from 25 to 50 °C. Likewise, temperature-induced saltiness perception in salty taste solutions has not been observed consistently in previous studies. In addition, most of the earlier research on saltiness perception was conducted at lukewarm temperature range (e.g., up to 50 °C).

Therefore, this study aims to examine the effect of serving temperature on saltiness intensity ratings of salty-taste solutions and soup-base products over a wider temperature range extending from room temperature (e.g., 25 °C) to a "hot" temperature (e.g., 80 °C). Soup-base products were chosen because they are known to be one of the main sources of dietary sodium intake in many countries (Son, Park, Lim, Kim, & Jeong, 2007; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). Given previous findings, we hypothesized that saltiness intensity in soup-base products would decrease with increase in serving temperature.

Materials and methods

Ethics statement

This study was conducted in conformance with the Declaration of Helsinki for studies on human subjects. The protocol was approved by the University Institutional Review Board of the University of Arkansas (Fayetteville, AR, USA).

Participants

Trained panelists

Eight descriptive panelists (six females and two males), trained by the Spectrum® method (Sensory Spectrum Inc., Chatham, NJ, USA), participated in this study. The panelists' experiences with descriptive analysis of foods, including soup products, ranged from 7 to 20 years at the University of Arkansas Sensory Service Center. Before participating in the experiment, all trained panelists had orientation/training sessions to become familiarized with experimental procedure and the saltiness intensity of soup products to be tested.

Consumer panelists

A total of 62 healthy volunteers (32 females and 30 males), with ages ranging from 30 to 40 years, participated in this study. All participants (51 Caucasians and 11 Asians) reported that they had no clinical history of major disease and that they had normal senses of smell and taste as determined by a "taste spray" test (Burghart Instruments, Wedel, Germany; Vennemann, Hummel, & Berger, 2008). Participants were also asked to complete a questionnaire regarding their demographics (e.g., gender, age, and ethnicity) and dietary habits associated with cold and hot dishes. That is, participants were asked to rate their acceptability of either cold or hot dishes ("*How much do you like or dislike cold food/beverage in general?*" and "*How much do you like or dislike hot food/beverage in general?*") on two nine-point hedonic scales ranging from 1 (dislike extremely) to 9 (like extremely). In addition, participants were asked to self-estimate their frequency of consuming hot dishes ("*Among 10 times of meal, how often do you consume hot dishes on average?*"); the participants were asked to write down the number of frequency.

Samples and preparation

Three types of soup-base products were tested: salt water (0.88% salt; Morton Salt, Inc. Chicago, IL, USA), chicken broth (0.73% salt), and miso soup (0.84% salt). The chicken broth and miso soup were prepared using commercially-available products: Swanson chicken broth with 33% less sodium (Campbell Soup Company, Camden, NJ, USA) and Kikkoman instant tofu miso soup (Kikkoman Corp. Tokyo, Japan), respectively. The chicken broth was used directly without modification, while for the miso soup solid components like tofu and kelp were removed to minimize their potential influence on temperature-induced saltiness perception. Each sample was heated in a microwave oven (Model No: JES1160DPWW 1100 W, General Electric, Fairfield, CT, USA) to the five targeted temperatures: 40, 50, 60, 70, and 80 °C. The salinity of each sample at each of these different temperatures was measured in triplicate using the salinometer (EcoSense® EC300A, YSI Inc., Yellow Springs, OH, USA) allowing measurement in a temperature range from −10 to +90 °C with a high accuracy (for salinity, 0.2%). Salinity did not differ significantly among the samples at the five temperatures ($P > 0.05$).

Procedure

This study was comprised of three sessions over either 2 (for trained panelists) or 3 (for consumer panelists) consecutive days. During each session, panelists tasted one of three samples (i.e., salt water, chicken broth, or miso soup) at each of the five different temperatures: 40, 50, 60, 70, and 80 °C, in random order. Test samples were presented one at a time to ensure soup was tasted by panelists at a temperature as close to the target as possible. Trained panelists evaluated each sample in duplicate over 2 consecutive days and consumer panelists evaluated each sample one time over 3 consecutive days.

A room-temperature sample (25 °C) was additionally provided as a reference. Each 30-mL sample was presented in a 60 mL soufflé cup identified with a three-digit code. To minimize variation in sample temperature, panelists were asked to taste samples immediately after receiving them. Because the temperature of the samples dropped rapidly at high serving temperature (e.g., 70 and 80 °C), the samples were presented 2 to 4 °C above the target temperature (e.g., 72 or 84 °C) based on the preliminary tests.

Throughout the test, both trained and consumer panelists were asked to rate saltiness of each test sample compared to the saltiness of the reference sample (i.e., the room-temperature sample).