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Short Communication

# The sensory optimum of chicken broths supplemented with calcium di-glutamate: A possibility for reducing sodium while maintaining taste ☆

Brett E. Carter *, Pablo Monsivais, Adam Drewnowski

*Nutritional Sciences Program, School of Public Health, The University of Washington, Seattle, WA 98195, United States*

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ABSTRACT

This study examined the effects of calcium di-glutamate (CDG) supplementation on the sensory and hedonic characteristics of chicken broth. Thirty-four normal weight men and women aged 20–35 years tasted 12 soups containing 4 different concentrations of sodium chloride (.16%, .53%, .85%, and 1.7% w/w) and three concentrations of CDG (0%, .17%, and .33% w/w). Participants tasted all the soups twice over 2 days and used computer-administered visual analog scales to record taste intensity and hedonic ratings. Soups were presented in random order, at least 3 min apart to allow for taste ratings and mouth rinsing. Data were analyzed using repeated measures analysis of variance. Response surface methodology (RSM) was used to determine the hedonic optima for sodium chloride and CDG. Results indicated that CDG could partly replace sodium chloride at constant levels of liking and pleasantness. These data provide evidence that lower sodium broths can be made more palatable with CDG supplementation.



## 1. Introduction

Dietary recommendations urge consumers to reduce their sodium intakes (USDA/DHHS, 2010). However, foods that are low in salt (sodium chloride) may be less preferred (Breslin & Beauchamp, 1997). The inclusion of other tastes or flavors may allow manufacturers to reduce the sodium content of foods, without sacrificing palatability (Kremer, Mojet, & Shimojo, 2009). Based on its sensory profile, the amino acid glutamate, in particular, may provide an effective way to enhance the palatability of reduced-sodium soups (Ball, Woodward, Beard, Shoobridge, & Ferrier, 2002; Roininen, Lähteenmäki, & Tuorilla, 1996; Yamaguchi & Takahashi, 1984).

The ability of glutamate to enhance the sensory quality of certain savory foods is well established (Bellisle, 1998) and discovery of a taste receptor pathway (Nelson et al., 2002), indicates that the umami sensation provided by glutamate is a distinct taste in its own right. Laboratory-based sensory studies have shown that monosodium glutamate (MSG) can potentiate the perceived savoriness of broths and improve hedonic response overall (Daget & Guion, 1989; Okiyama & Beauchamp, 1998; Roininen et al., 1996; Yamaguchi & Takahashi, 1984).

However, MSG may not be the best vector for sodium reduction since lowering the content of sodium chloride would be partly offset by the higher content of MSG. While sodium-free salts of glutamate would be preferable, their sensory qualities have not been extensively studied.

Calcium di-glutamate (CDG) provides a sodium-free alternative. CDG is one of the 5 glutamate salts internationally accepted as food flavor enhancers (Jinap & Hajeb, 2010). In one study, the addition of CDG to lower-sodium soups helped to maintain hedonic value (Ball et al., 2002). However, that study did not identify the optimum sensory combination of sodium chloride and CDG. Sensory qualities of the taste mixtures with respect to the 5 taste sensations (i.e. sweet, sour, salty, bitter, and umami or savory) were also not measured. This study was designed to assess the sensory optimum as well as those attributes.

This study examined the sensory characteristics of a range of values of sodium chloride and CDG added to a low sodium chicken broth. The sodium values included those that the US Food and Drug Administration uses to classify soups as "reduced sodium" and "low sodium"(Kurtzweil, 1994).

## 2. Materials and methods

### 2.1. Participants

Thirty-four men and women aged 20 and 35 participated in the study. Participants were normal weight (body mass index 18.5–24.9). Participants were recruited on campus and the surrounding neighborhood through fliers, campus newspapers, and online postings.

Candidates were invited to attend one preliminary screening session in the lab where they completed a written consent form.

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* Corresponding author. Address: Center for Public Health Nutrition, 327 Raitt Hall, University of Washington, Box 353410, Seattle, WA 98195, United States. Tel.: +1 206 897 1475; fax: +1 206 685 1696.
*E-mail address:* brettc2@u.washington.edu (B.E. Carter).

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After the consent, each candidate's weight and height were measured to verify BMI. Potential subjects were also screened to verify the eligibility criteria and to determine whether they were willing to consume the soups given in the study. Potential participants were excluded if they were taking medication, were smokers, had food allergies or restrictions, disliked chicken soups or broths, or if their personal schedule did not permit regular scheduled attendance. All aspects of the study were approved by the Institutional Review Board of the University of Washington.

### 2.2. Protocol

The study followed a within-subject, repeated measures design, with each participant serving as his or her own control. Participants were required to refrain from eating at least 2 h prior to their testing session.

Participants arrived at 1420 h on the first testing session and sat in separate cubicles in the sensory evaluation room. They were briefed on study protocols and asked to remain seated for the length of the study. During the first laboratory visits, participants tasted and rated four sodium chloride (NaCl) solutions in deionized water (10 ml approx.), ranging in concentration from .16% to 1.7% w/w and served in 15 ml sample cups at room temperature (22–25 °C). Participants were asked to hold the sample in their mouths for 5 s and to complete computer-based visual analog scale (VAS) ratings.

Beginning at 1500 h, 12 NaCl/CDG concentration combinations of chicken broth were tested at 3-min intervals to allow for mouth rinsing between samples. Each 10–12 ml serving broth was served in 15 ml sample cups served warm (50–60 °C). After all 12 combinations were evaluated, participants were allowed to leave. The sequence of NaCl/CDG concentrations was randomized for each participant. Each participant was exposed to the 12 combinations of NaCl and CDG twice over 2 days, separated by at least 1 week.

### 2.3. Test broth characteristics

All broths were prepared in the laboratory using "Kitchen Basics Unsalted Chicken Stock" (Kitchen Basics Inc. Brecksville, OH). Chicken stock was purchased from a single lot at a local supermarket to assure consistency and contained .16% w/w NaCl (150 mg sodium per 240 ml serving). This base chicken stock allowed for upward adjustment of the total sodium concentration by the addition of CDG and NaCl. This product also allowed this study to examine a product that meets the FDA standards for a "reduced sodium" product (i.e. at least 25% less sodium than the original product) and that is close to the standard for the product label "low sodium" (i.e. 140 mg or less sodium per serving). The range of CDG concentration for the test broths was 0–.33% w/w and the range for NaCl concentration was .16–1.7% (see Table 1). CDG was obtained from Ajinomoto Co., Inc. and added to the chicken stock to achieve the desired concentrations. Diamond Crystal® Pure Natural Kosher Salt (Cargill Inc., Minneapolis, MN) was added to each condition to achieve the desired sodium concentrations.

The energy density (ED) was .1 kcal/g for all broth vehicles. Samples of the plain broth were sent to Sillicker Inc. (Sillicker Food Safety and Quality Solutions Inc., Chicago Heights, Illinois) for laboratory ascertainment of sodium and glutamic acid concentrations. Analyses were conducted using the AOAC 984.27 method (AOAC, 2002). Analyses showed that the base broth contained no glutamic acid (<.05% w/w) (detection limit = .01% w/w) and very little sodium (68 mg/100 g), consistent with the amount listed on the label.

### 2.4. Taste and hedonic evaluations

Taste intensity and hedonic ratings were assessed using a semi-anchored VAS presented on the computer screen. Each scale had opposing extremes, i.e. "not at all savory" versus "extremely savory." Participants used a computer mouse to position a cursor along a 100 mm line that best described their sensation at that time. The questions were:

Please rate the intensity of the following characteristics for this broth: "sour", "bitter", "salty", "savory", "sweet", and "pleasant". The term savory was used to describe the "umami" taste because the "umami" flavor is often interpreted in western cultures to be "savory" (Ninomiya, 2002). Participants were also asked to rate how much they liked each broth using the same 100 mm scale.

### 2.5. Data analyses and sensory optimization modeling

Data analysis used the statistical package for the social sciences (SPSS) version 17.0. Saltiness intensity ratings of NaCl solutions were analyzed using repeated measures analyses of variance (ANOVA) with NaCl concentration as the repeated measure and gender as the between subjects factor. Sensory and hedonic ratings for chicken broths were analyzed using repeated measures ANOVA, with NaCl-glutamate combinations as a within-subjects factors and gender as between-subjects factors. For the sensory and hedonic responses where ANOVA's indicated a significant effect of condition, Bonferroni correction was applied. Given that no main effects of gender were observed for any taste variables, data were pooled across men and women.

Sensory and hedonic ratings were then used to construct three-dimensional response surfaces for estimating sensory optima. Response surface methodology (RSM) is an approach to analyzing flavor or tastant interactions that can reveal optimal combinations beyond those that were tested directly (Drewnowski & Moskowitz, 1985; Soukoulis & Tzia, 2009). The method relies on quadratic algorithms and is well established in sensory analysis (Drewnowski, Brunzell, Sande, Iverius, & Greenwood, 1985; Yamaguchi & Takahashi, 1984). For the present study, the quadratic equations took the form of:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2$$

where $Y$ = sensory rating, $X_1$ = % NaCl and $X_2$ = % CDG.

The RSM models were run using Design-Expert version 8.0 for Windows (Stat-Ease Inc., Minneapolis, MN).

### 2.6. Sample size

Sample size calculations were based on expected largest difference in liking ratings (mm VAS) between any two conditions. The sample size was 34 adults and was based on a mean (±SD) effect size of 8 (±23) mm and a power level of 80% and $\alpha = .05$ using a standard formula for cross-over study designs (Rosner, 2000).

## 3. Results

### 3.1. Participant characteristics

The mean BMI was 23.0 (±1.7) kg/m$^2$ for the 17 males and 21.6 (±1.9) kg/m$^2$ for the 17 females. Mean age was 24.2 (±3.8) years for males and 22.8 (±3.5) years for females.

### 3.2. Aqueous solutions

Analyses of taste responses for NaCl solutions showed a significant main effect of NaCl concentration, $F(3,30) = 103.48$ ($p < .001$).