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Temperature of served water can modulate sensory perception and acceptance of food

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ABSTRACT

Cross-cultural differences exist in the typical temperature of water served with meals. North American people typically drink iced water/beverages while eating, whereas European or Asian people show a preference for room temperature water or hot water/tea, respectively. It has been reported that food perception and acceptance are influenced by oral temperature, as well as by serving temperature of food. Based on the fact that the iced or hot water served with meals can alter the oral temperature, the present study aimed to determine whether the temperature of served water can affect the sensory perception and acceptance of food subsequently consumed. Following a mouth rinse with water served at 4, 20, and 50 °C for 5 s, two different types of food, dark chocolate and cheddar cheese, were evaluated in terms of sensory intensity and overall liking. For the dark chocolate, the intensity ratings for sweetness, chocolate flavor, and creaminess were significantly lower when following water at 4 °C than when following water at either 20 or 50 °C. However, the modulatory effect of water temperature on sensory perception was not obtained with cheddar cheese. In addition, the temperature of served water altered the acceptance for the foods subsequently presented. Specifically, the overall liking for the dark chocolate was significantly lower when following water at 4 °C than when following water at either 20 or 50 °C. In conclusion, the present study demonstrates new empirical evidence that the consumption of iced water can decrease perceived intensities of sweetness, chocolate flavor, and creaminess for subsequently consumed chocolate. Our findings may provide one of plausible answers to the question of why North American people, who are more used to drinking iced water, show a strong preference for more highly sweetened foods.

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1. Introduction

One of the cross-cultural differences in meal patterns is observed in the temperature of water served with meals. North American people, as a whole, are used to drinking iced water while they are eating. However, in many European countries, people typically drink water at almost room temperature. Furthermore, Asian people are used to drinking hot water or tea with meals. The drinking of iced (or hot) water can decrease (or increase) the inner temperature of the oral cavity (see Engelen et al., 2003). Owing to that fact, the culture-induced difference in the temperature of served water may lead to the cultural difference in the "oral temperature" during the meal.

It has been proven that serving temperature does influence the acceptance of foods and beverages (Brown & Diller, 2008; Cardello & Maller, 1982; Lee & O'Mahony, 2002). Cardello and Maller (1982) have shown that food samples were rated as significantly more acceptable when served in the temperature range where they are usually consumed. For instance, in everyday life, ice cream is assumed the most pleasant when consumed cold, while tomato soup is considered the most acceptable when consumed hot. In addition, the serving temperature affects the perception of sensory attributes in foods and drinks (Drake, Yates, & Gerard, 2005; Engelen et al., 2003; Kähkönen, Tuorila, & Hyvönen, 1995; Rosett, Hamill, Morris, & Klein, 1997; Ross & Weller, 2008). Kähkönen et al. (1995) demonstrated that cheese odor and overall odor, in cheese soup, were perceived to be stronger when it was served at 63 °C than when presented at 33 or 48 °C. Drake et al. (2005) showed that sour taste intensity in cheddar cheese increased with its serving temperature (e.g., 5, 12, and 21 °C).

Using basic taste solutions, a series of psychophysical studies have shown the influence of solution temperature on taste intensity; however, there are inconsistent results across the studies (Bartoshuk, Rennert, Rodin, & Stevens, 1982; Calviño, 1986; Green & Frankmann, 1987, 1988; Hahn & Günther, 1932; McBurney, Collings, & Glanz, 1973; Moskowitz, 1973; Prescott, Allen, & Stephens, 1984; Schiffman et al., 2000 see also Talavera, Ninomiya, Winkel,

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Voets, & Nilius, 2007). In the earlier study conducted by Hahn and Günther (1932), a detection threshold for dulcin solution (sweetness) was the lowest (i.e., the most sensitive) between 34.5 and 37.0 °C; but the threshold increased below or above that range. Also, the thresholds for sodium chloride (NaCl; saltiness) and quinine sulfate (QSO_4; bitterness) increased with temperature (19–40 °C); however, the threshold for hydrochloride (HCl; sourness) was not affected by temperature. With a methodological modification, McBurney et al. (1973) followed up Hahn and Günther's study. The detection thresholds for the above four compounds showed a similar pattern, a U-shaped curve having a minimum threshold (i.e., the most sensitive) between 22 and 32 °C, as temperature rose (between 17 and 42 °C). However, in another study by Moskowitz (1973), the solution temperature did not affect perceived intensity of quinine sulfate (bitterness) or citric acid (sourness), but taste intensity of sodium chloride (saltiness) and glucose (sweetness) increased with temperature.

One of the plausible explanations for the conflicting data across former studies is that the temperature of the tongue had not been consistently controlled over sensory testing (Delwiche, 2004; Green & Frankmann, 1987). In fact, Green and Frankmann (1987) have demonstrated that cooling both the tongue and the taste solutions from 36 °C to either 20 or 28 °C led to decrement in the taste intensity of sucrose (sweetness) or caffeine (bitterness) solution. The perceived sweetness of glucose or fructose was reduced more by cooling the tongue than by cooling the taste solution (Green & Frankmann, 1988). In addition, Cruz and Green (2000) observed that warming the anterior tip, innervated by the chorda tympani nerve, of the tongue produced sweetness (but not bitterness), whereas cooling the tip elicited sourness and/or saltiness. The thermal taste was also obtained on the lateral edge, innervated by the glossopharyngeal nerve, of the tongue in a different manner. That is, while warming failed to induce detectable sweetness, cooling the lateral edge evoked bitterness or sourness. These associations between thermal taste and tongue area indicate that two nerves, the chorda tympani and glossopharyngeal nerves, involve different taste transduction mechanisms having different sensitivities to temperature (Green, 2002). In fact, previous animal studies using electrophysiological recordings have shown that cooling-sensitive gustatory neurons are likely to be sensitive to sour (HCl) or salty (NaCl) substances, whereas warming-sensitive neurons are likely to be sensitive to sweet substances (sucrose) (Ogawa, Sato, & Yamashita, 1968; Sato, Ogawa, & Yamashita, 1975). These findings are, to some extent, in accordance with a previous human study where warm temperature had a specific qualitative relationship with sweetness and bitterness, whereas cold temperature had a relationship with saltiness and sourness (von Békésy, 1964). Further, recent functional neuroimaging studies support the association between oral temperature and taste (Guest et al., 2007; for a review see Rolls, 2010). Guest et al. (2007) demonstrated that temperature-controlled (5, 20, and 50 °C) solutions that were administered into the mouth activated the insular taste cortex (which was also activated by the taste of a glucose solution), as well as a part of the somatosensory cortex, the orbitofrontal cortex, the ventral striatum, and anterior cingulate cortex.

Taken together, early research has shown that the oral temperature can modulate the perceived intensity of basic taste solutions. However, only a few studies have shown effects of oral temperature on sensory perception in food/beverage models (Engelen et al., 2003; Mela, Langley, & Martin, 1994). Mela et al. (1994) investigated whether the oral or sample temperature affects fat perception in a liquid emulsion. The fat perception was altered neither by sample temperature nor by oral temperature. A more relevant study by Engelen et al. (2003) attempted to answer the question whether oral or sample temperature can influence texture or flavor perception in two semi-solids: custard dessert and mayonnaise. The semi-solids were prepared with a low or high level of fat, respectively. Each sample was evaluated for odor, flavor, and texture attributes at 10, 22, and 35 °C, in combination with oral temperatures of 27, 35, or 43 °C. Oral temperature failed to affect perceived intensities of odor and flavor attributes in both food samples. However, the increase in oral temperature significantly amplified intensity ratings for the melting mouth-feel in the custard dessert and for the heterogeneous and smooth mouth-feel in the mayonnaise.

In order to build on these findings, the present study aimed to determine whether the temperature of served water can affect the sensory perception or acceptance of subsequently presented foods. Based on the cross-cultural difference in the temperature of water served with meals, we wanted to examine whether three water temperatures (i.e., 4, 20, and 50 °C) can alter sensory perception or acceptance in two different types of food: cheddar cheese and dark chocolate.

2. Materials and methods

This study was conducted according to 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).

2.1. Participants

Thirty-eight healthy volunteers (25 females) with an age range between 20 and 40 years [mean age ± standard deviation (SD) = 31 ± 5 years] participated in this experiment. All participants confirmed that they had no clinical history of major diseases and that they had normal senses of smell and taste. All participants had no impairment in smell or taste function based on the results of the following tests: the "Sniffin' Sticks" screening test (Burghart Instruments, Wedel, Germany; for details see Hummel, Konnerth, Rosenheim, & Kobal, 2001) and the "taste spray" test (Burghart Instruments, Wedel, Germany; for details see Vennemann, Hummel, & Berger, 2008). The experimental procedure was explained to all participants in detail and an informed written consent was obtained before participation.

2.2. Samples

To test temperature effects of served water on food perception and acceptance, spring water was presented at three serving temperatures: 4, 20, and 50 °C.

Two different types of food, mild medium cheddar cheese (Sargento Foods Inc., Plymouth, WI) and 70% dark chocolate (Lindt & Sprüngli USA Inc., Stratham, NH), were used. These were selected on the basis of the taste quality targeted (e.g., cheddar cheese for salty taste; dark chocolate for sweet and bitter tastes) and differences in food composition and matrix. The food samples were purchased from a local supermarket the day before sensory evaluation and the cheese was placed in a refrigerator (4 °C). One hour before the evaluation, the cheese sample was taken out and allowed to warm to room temperature. The dark chocolate sample was stored at room temperature until served.

2.3. Procedure

The experiment was conducted in a sensory booth room maintained at approximately 20 °C. For experimental setting and data collection, a computerized sensory data acquisition system, Compusense® five (Release 4.6-SP3, Compusense Inc., Guelph, ON, Canada), was employed.