Food Quality and Preference 55 (2017) 26–34

Contents lists available at ScienceDirect

Food Quality and Preference

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

Perceptual and affective responses to sampled capsaicin differ by reported intake

Alissa A. Nolden, John E. Hayes *

Sensory Evaluation Center, Department of Food Science, College of Agricultural Sciences, The Pennsylvania State University, University Park, PA, USA

ARTICLE INFO

Article history:
Received 3 May 2016
Received in revised form 6 August 2016
Accepted 8 August 2016
Available online 9 August 2016

Keywords:
Psychophysics
Generalized scaling
Chemesthesis
Capsaicin
Memory
Chili pepper intake
Personality

ABSTRACT

The present study was conducted to a) generate suprathreshold dose-response functions for multiple qualities evoked by capsaicin across a wide range of concentrations, and b) revisit how intensity ratings and liking may differ as a function of self reported intake. Individuals rated eight samples of capsaicin for perceived burn and bitterness, as well as disliking/liking. Measures of reported preference for chili peppers, chili intake frequency, prior experience and personality measures were also assessed. Here, we confirm prior findings showing that burn in the laboratory differs with reported chili intake, with infrequent consumers reporting more burn. We extend these findings by exploring how capsaicin perception varies by reported liking, and measures of variety seeking. We also address the question of whether differences in burn ratings may potentially be an artifact of differential scale usage across groups due to prior experience, and not chronic desensitization, as is typically assumed. By using generalized scaling methods and recalled sensations, we conclude the differences observed here and elsewhere are not likely due to differences in how participants use rating scales.

1. Introduction

The chili pepper (*Capsicum solanaceae*) is widely used as an ingredient in many cuisines around the world (Lembeck, 1986), with consumption frequencies that may exceed once per day. Surprisingly, the etiology of chili pepper preference is still not well understood, despite several decades of study. Different motives and reasons have been proposed to explain the widespread popularity of chili peppers. Some researchers have speculated their wide use may be due to the biological or pharmacological properties of capsaicin (i.e. *anti*-bacterial properties, or gustatory sweating) (Abdel-Salam, 2016; Lee, 1954). Other factors that have been identified include culture (Abdel-Salam, 2016), personality traits (Byrnes & Hayes, 2013; Byrnes & Hayes, 2015; Byrnes & Hayes, 2016; Rozin & Schiller, 1980) and gender (or masochism) (Byrnes & Hayes, 2015; Bègue, Bricout, Boudesseul, Shankland, & Duke, 2015; Rozin & Schiller, 1980; also see Abdel-Salam, 2016). While the relative weight of these reasons as drivers of consumption remains unclear, it is well understood that chilies elicit a burning sensation. This burn, in the mouth and elsewhere on the body, is primarily due to capsaicin (PubChem CID: 1548943) and dihydrocapsaicin (PubChem CID: 107982), the two main capsaicinoids found in chili peppers. These compounds are potent agonists of the heat pain receptor TRPV1.

The term chemesthesis was originally coined to describe touch and pain sensations that are initiated by chemical stimuli (Green, 2016). Examples of oral chemesthesis include tingling, buzzing, cooling, and warming. These sensations are clearly distinct from classical taste sensations (i.e. sweet, sour, salty, bitter, and umami) (Green, 1996). In regard to oral sensation, capsaicin is one of, if not the most, systematically investigated chemesthetic stimulus (e.g., (Green, 1991; Green & Hayes, 2003; Green & Hayes, 2004; Lawless, Rozin, & Shenker, 1985; Prescott & Stevenson, 1995)).

Despite decades of research investigating the oral burn evoked by capsaicin, response to capsaicin across a wide range of concentrations has not been evaluated in a large group of untrained participants using modern scaling psychophysical methods. Within the psychophysical literature, varied concentrations of capsaicin have been used in many previous studies; unfortunately, it is not possible to extract a single suprathreshold dose response function from these reports due to different delivery systems (liquid solution, cotton swab, filter paper, etc.), type of exposure (sip and spit, sip and swallow, regional application, etc.) and characteristics of the task given to study participants (different scales, or different descriptors such as 'overall sensation', 'irritation', 'pepper heat',

* Corresponding author at: Department of Food Science, Pennsylvania State University, 220 Food Science Building, University Park, PA 16802, USA.
E-mail address: jeh40@psu.edu (J.E. Hayes).

http://dx.doi.org/10.1016/j.foodqual.2016.08.003
0950-3293/

'burn', etc.). To identify appropriate doses for use in subsequent experiments in our laboratory, we desired such a function.

One conventional method for estimating perceived heat from chilies is the Scoville Test, which generates an estimate of perceived intensity in units known as Scoville Heat Units (SHU) (Scoville, 1912). However, due to methodological problems with the classical Scoville Test (see (Gillette, Appel, & Lego, 1984; Govindarajan, Shanthi, & Dhanaraj, 1977; Todd, Bensinger, & Biftu, 1977), efforts have been made to improve the method of estimating the burn produced by chili peppers and capsaicinoids. Because there is a simple ordered relationship between perceived burn and capsaicinoid concentration, instrumental methods using high performance liquid chromatography-mass spectrometry (HPLC-MS) and gas chromatograph-mass spectrometry (GC–MS) to determine the capsaicinoid content in chili peppers and chili pepper containing foods have been developed (e.g. (Gillette et al., 1984; Othman, Ahmed, Habila, & Ghafar, 2011; Peña-Alvarez, Ramírez-Maya, & Alvarado-Suárez, 2009; Todd et al., 1977; Welch, Regalado, Welch, Eckert, & Kraml, 2014). These instrumental methods, which have been validated with human sensory data, are often used as a standard method to estimate heat from various foods or ingredients. One example is work by Gillette and colleagues (Gillette et al., 1984), who used a trained panel (n = 10) with fixed references for 'slight', 'moderate', and 'approaching strong' stimuli to estimate a dose response function for N-Vanillylnonanamide, a synthetic capsaicin analog, as well as extracts of ground peppers (chilies); however capsaicin itself was not included in their report. Their report later inspired two standard methods from the American Society for Testing Materials (e.g., ASTM E1083-00 and E1396-90), but again, these methods were based on trained panels using fixed intensity references. Additionally, many prior studies in this area have focused solely on burn, irritation or bite; however, capsaicin is known to elicit bitterness in addition to burning in some individuals (e.g. Green & Hayes, 2003; Nolden, McGeary, & Hayes, 2016). Accordingly, we chose to address this specific gap in the literature by obtaining intensity estimates for multiple qualities across a wide range of capsaicin concentrations, similar to recent work conducted on ethanol (Nolden & Hayes, 2015).

Greater liking or frequency of chili pepper consumption has been associated with reductions in the reported burn of sampled capsaicin (Cowart, 1987; Lawless et al., 1985; Prescott & Stevenson, 1995; Stevenson & Yeomans, 1993). Based on these data, it widely assumed that regular consumption of chili pepper results in chronic capsaicin desensitization, based on observations that desensitization can occur with exposure in the laboratory and can last over days (reviewed in Hayes, 2016). However, Stevenson and Prescott put forth an alternative explanation that remains untested; namely, observed differences between intake groups may be due to prior experience that influences scale usage rather than true desensitization (Stevenson & Prescott, 1994). This hypothesis suggests that individuals who frequently consume chili peppers have a larger frame of reference outside of the laboratory regarding chili burn compared to those who do not eat chili peppers regularly; thus, when given the same stimuli in the laboratory, frequent consumers use the scale differently, and rate the stimuli as less intense. It remains untested whether differences in capsaicin responses (i.e., perceived burn) across chili pepper intake groups are a result of desensitization due to repeated dietary exposure or merely due to prior context that alters use of the rating scale.

The primary aims of the present study were to a) generate a dose-response curve for capsaicin over a wide concentration range using untrained participants without fixed references, and b) reevaluate associations between perceived burn, bitterness and liking of sample capsaicin and chili pepper consumption groups, and investigate whether this relationship is due to diet-induced desensitization or possible context effects. As secondary aims, we also explored the relationship between sampled capsaicin and a trait-based measure of food adventurousness, operationalized via the VARSEEK scale. Here, individuals evaluated eight samples of capsaicin for their bitterness and burning intensity, along with liking/disliking. They also answered questions regarding chili pepper preferences, intake frequency, prior experience, and personality. This study confirms prior work, and extends current knowledge regarding capsaicin perception.

2. Materials and methods

2.1. Participants

Adults were recruited from The Pennsylvania State University and surrounding community to participate in two 30 min visits that were scheduled one week apart at the Sensory Evaluation Center at Penn State. Interested individuals completed a brief online questionnaire to see if they met the following study criteria: not pregnant nor breast feeding, non-smoker, no tongue, cheek or lip piercing, no difficulty swallowing or history of choking, no known taste or smell defect, not taking prescription pain medication, no hyperactive thyroid and no history of chronic pain. Individuals meeting these criteria answered additional questions regarding their liking and intake of foods containing chili peppers. Recruitment was stratified by gender and by liking and intake of chili peppers. These groups included no/low, medium, and high liking, and intake of chili peppers. Participants' self-reported liking of spicy foods, and frequency of intake for a variety of foods containing chili pepper were used to bin participants into groups. At the end of the study, 82 participants (34 men) had completed both sessions, with an average age of 32 (±0.9) years. A majority of participants reported Caucasian ancestry (n = 72), with low representation from Asian (n = 7) and Black (n = 2) individuals; one individual chose not to disclose ancestry. Procedures were IRB approved, informed consent was obtained, and participants were compensated for their time with a small cash payment.

2.2. Stimuli and sampling procedure

Sampled stimuli included 0.11, 0.275, 0.55, 1.1, 2.75, 5.5, 11 and 22 ppm natural capsaicin from Sigma-Aldrich (Sigma #360376). This natural product actually contains a mix of capsaicin and dihydrocapsaicin (~65%/~35%, respectively, with small variations from lot to lot), but due to their very similar potency, and Sigma's nominal branding as capsaicin, it will be referred to simply as capsaicin for the remainder of the document. In each visit, participants sampled 4 different concentrations of capsaicin, with each participant rating all 8 concentrations across the two visits. Sample sets were counterbalanced across participants, and presented in increasing and alternating order, with two possible orders (0.11, 0.55, 2.75, and 11; and 0.275, 1.1, 5.5 and 22 ppm). This order was chosen both to limit simple carry-over (by presenting lower concentrations first, as is commonly done in threshold testing), and to reduce the potential for sensitization. Prior data (Green, 1991) indicates greater sensitization occurs following higher concentrations (30 ppm) relative to lower concentrations (3 ppm), so the presentation order used here should minimize sensitization, as the highest stimulus is presented last. Further considerations regarding sensitization are discussed in more detail below.

All stimuli were made from a single stock solution where capsaicin was dissolved in 95% USP grade ethanol. This stock was diluted with reverse osmosis (RO) water to reach the final concentrations, and supplemented with ethanol to standardize all stimuli to equal ethanol concentration of 0.1% (v/v). All stimuli were