Food Research International 109 (2018) 606–613

Contents lists available at ScienceDirect

Food Research International

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

Time-intensity and reaction-time methodology applied to the dynamic perception and liking of bitterness in relation to body mass index

León Bianchi L.[a,b], Galmarini M.V.[a,b], García-Burgos D.[c], Zamora M.C.[a,b,*]

[a] Facultad de Ingeniería y Ciencias Agrarias, Pontificia Universidad Católica Argentina (UCA), Av. Alicia Moreau de Justo 1500, C1107AFF Buenos Aires, Argentina
[b] Member of Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Godoy Cruz 2290, C1425FQB Buenos Aires, Argentina
[c] Department of Psychology, Clinical Psychology and Psychotherapy, University of Fribourg, 2 Rue de Faucigny, CH-1700 Fribourg, Switzerland

ARTICLE INFO

Keywords:
Acceptance
Bitter taste
Overweight
Reaction-time
Time-intensity

ABSTRACT

There are very few studies which have considered perception temporality when relating perceived intensity and hedonic responses in relation to body mass index (BMI; kg/cm^2). The aim of the present study was to determine the relationship between BMI with the dynamic perception and liking of bitter tasting solutions. For this purpose, two different categories of bitter products were applied: 6-n-propilthiouracil (PROP) solutions (0.010, 0.032 and 0.060 mmol/L) and commercial beverages (coffee, *yerba mate* infusion and grapefruit juice). The proposed methodology to evaluate perception and hedonic response was based on the measurement of reaction-time (R-T) and multiple-sip time-intensity (T-I) registers in people with a high BMI (25 < BMI < 30; overweight group) and a normal BMI (< 25; normal-weight control group). The multiple-sip evaluation to describe perception of PROP solutions and liking of beverages was used as a more ecologically valid laboratory methodology to simulate a situation of usual consumption. In this sense, working with a multiple-sip design helped confirm that bitter taste has a cumulative effect since in every case the sip effect was significant when evaluating the maximum intensity; this effect was more important as the bitterness increased. Regarding the body weight group comparisons, the normal BMI group perceived bitter taste more intensely and the time to react to it was shorter (faster reaction) for both PROP solutions and the three beverages. Interestingly, even though the high BMI group rated the bitter taste as less intense, they had a lower level of acceptance than normal BMI. This result suggests that the hedonic rather than the sensory component might be playing a crucial role in the perception of bitter taste in individuals with high BMI.

1. Introduction

High consumption of fruits and vegetables has been associated with a reduced risk of mortality with an average reduction of 5% for each additional serving a day (6% for fruit and 5% for vegetables; Wang et al., 2014). Indeed, the consumption of fruits and vegetables has been reported to reduce obesity, risks of cancer, cardiovascular disease, stroke, Alzheimer disease, cataracts, and some of the functional declines associated with aging (Boeing et al., 2012; Liu, 2003). However, some of these foods such as citrus fruits, cruciferous and green leafy vegetables are bitter (Drewnowski & Gomez-Carneros, 2000) and generally disliked due to the instinctive rejection of the bitter taste (Steiner, 1979).

The relationship between the sensitivity to bitterness and BMI has been suggested to play an important role in obesity. Subjects with a higher sensitivity to bitter tasting foods might be more likely to elicit a stronger rejection and avoidance of unpalatable healthy bitter substances involved in human appetite control and weight regulation (e.g., enhancing satiety; Slavin & Lloyd, 2012).

Gaudette and Pickering (2013) reviewed bitter taste as an important modulator of consumers' behavior; they analyzed new functional ingredients, including polyphenolics, employed in the creation of novel functional foods looking to reduce their aversive bitter taste. Bitterness presents temporal distinctive characteristics since it requires more time to reach maximum intensity in the oral cavity, and it takes longer to return to baseline compared with, sweet taste (Guinard, Hong, & Budwig, 1995). The perceived intensity of bitterness can also increase upon repeated ingestion (Guinard, Pangborn, & Lewis, 1986). This may be particularly important when consuming beverages such as red wine and beer, where the presence of polyphenolics (red wine) and isohumulones (beer) may lead to the increasing bitterness (cumulative effect) of these beverages over the length of an ingestion session (Guinard, Hong, Zoumas-Morse, Budwig, & Russell, 1994; Noble, 1994). Overall, the increase in bitterness of bitter-tasting beverages

* Corresponding author at: Av. Alicia Moreau de Justo 1300, C1107AAZ Buenos Aires, Argentina.
E-mail address: czamora@uca.edu.ar (M.C. Zamora).

https://doi.org/10.1016/j.foodres.2018.05.011
Received 28 February 2018; Received in revised form 28 April 2018; Accepted 6 May 2018
Available online 08 May 2018

over repeated ingestion may negatively impact their acceptance, as excessively bitter-tasting foods are generally undesirable to the consumer (Drewnowski & Gomez-Carneros, 2000; Lesschaeve & Noble, 2005).

In order to overcome methodological issues and better understand the impact of bitterness perception and BMI, advanced methodology that takes into account the temporal changes in taste perception has been suggested. For example, García Burgos and Zamora (2013) using Time-Intensity (T-I) methodology did not find any effect of BMI status on sensory response to bitter intensity of chocolate and grapefruit drink. In this work, participants were classified into two groups: low BMI (BMI < 20) and high BMI (BMI > 23). Moreover, consuming a beverage is not a matter of a single sip and it implies sensory, physiological and psychological phenomena with time (Delarue & Blumenthal, 2015; Galmarini, Loiseau, Visalli, & Schlich, 2016; Rocha Parra, García Burgos, Munsch, Chirife, & Zamora, 2016; Thomas et al., 2017). Therefore, to further explore the sensory and hedonic experience, dynamic changes over several sips in perception and acceptance of bitter taste should be considered. In this sense, it remains to be explored whether the evaluation of the cumulative bitter sensation in multiple sips might be a more sensitive method to detect differences in bitterness perception across different BMI status.

Regarding the García Burgos and Zamora (2013) study, potential differences were observed at the beginning of the T-I curves, in which low BMI subjects started the curves with zero values (scale 0–100) while approximately 32% of high BMI subjects started with values higher than 30 during the evaluation of the more bitter product. Would it be possible to consider that high BMI subjects can perceive bitter taste faster? To explore such a possibility R-T methodology may be an appropriate measure (Bonnet, Zamora, Buratti, & Guirao, 1999; Guirao & Zamora, 2000). R-T to taste is defined as the minimum time required by a subject to report any taste changes after onset of taste stimulation at low concentration levels (Bonnet et al., 1999). T-I and R-T methods give complementary information (Galmarini, Zamora, & Chirife, 2009) since T-I is a quantitative, dynamic method using a scale while R-T is a qualitative rather than quantitative test (bitter - no bitter). Moreover, they reflect different moments of perception: R-T methodology shows what happens at the beginning of the tasting while T-I methodology depicts the rest of the tasting, allowing the research to explore the entire process of tasting during ingestion.

The aims of the present work were to analyze the relationship between BMI and: a) the perception of bitter taste, b) the hedonic response to bitter beverages. The methodology proposed to evaluate perception and hedonic response was based on the T-I and R-T methodologies of bitter PROP solutions and, three beverages (grapefruit juice, coffee and yerba mate infusions) in people with a high BMI (25 < BMI < 30; overweight group) and a normal BMI (< 25; normal-weight control group). If being overweight has any connection with the rejection of bitter-tasting foods, it would be expected to find a higher bitter intensity by T-I measure and lesser R-T values of bitter taste in high BMI compared to normal BMI group. In this line, perceived bitter intensity should increase at the end of the third sip by cumulative effect, and this effect would decrease the liking of the beverages, especially in high BMI condition.

2. Materials and methods

2.1. Participants

A number of 66 healthy adults from the Pontificia Universidad Católica Argentina (UCA; 34 females, 32 males; 18 to 61 years old) participated in the study. They were asked to report their height and weight, afterwards two groups were formed based on the calculated BMI: normal BMI, consisting of lean subjects (BMI < 25; mean 21.2; $n = 34$; mean age 28.0); and high BMI, encompassing participants that were within the overweight range (25 < BMI < 30; mean 29.0; $n = 32$; mean age = 38.0). The BMI ranges corresponded to the World Health Organization classification according to the nutritional status of adults (OMS, 2003). Exclusion criteria included aversions, smoking (> 5 cigarettes per week; Sato, Endo, & Tomita, 2002), illnesses, a history of eating disorders, diabetes and allergy to the products to be tested in the study. Also, people who described themselves as being on weight-loss diets or actively losing weight were excluded since this might be associated to bias when reporting sensory and affective perceptions of stimuli or might influence the relationship between bitter responsiveness and body weight (Tepper & Ullrich, 2002).

2.2. Tasted samples

2.2.1. PROP solutions

Three concentrations of PROP (Sigma Chemical Company, St Louis, USA) were used: 0.010, 0.032 and 0.060 mmol/L (belonging to the regular PROP series for taste detection thresholds; e.g., Drewnowski, Henderson, & Shore, 1997). All solutions were prepared with distilled water one day before testing.

2.2.2. Beverages

Three beverages (Table 1) were selected based on their different bitter compounds and bitter intensity: coffee (*La Virginia*, Argentina), *yerba mate* infusion (*La Tranquera*, Argentina) and grapefruit juice (*Citric*, Argentina). The coffee and *yerba mate* infusions were prepared the day of the tasting as follows: coffee (three sachets, 7 g each) and yerba mate (two sachets, 3 g each) were put in 200 mL of mineral water at 90 ± 2 °C for 5 min. Both infusions were tasted at 45 ± 2 °C. Grapefruit juice was stored at 4 °C and served directly from the original packaging at 20 ± 2 °C. The beverages were selected for their bitter level; the intensity (high, medium and low) was evaluated prior to the experiment by a trained panel of UCA using a non-structured scale of 15 cm.

2.3. Evaluation procedure

The experiment consisted of two sessions of 90 min each (one per week). In the first session, the participants evaluated bitter intensity of three PROP concentrations by T-I (first) and R-T procedures. In the second session, participants evaluated liking and intensity of the three bitter-tasting beverages using first a T-I liking procedure; then, a R-T liking procedure; and, finally, a bitter intensity by T-I procedure. In all the cases, the T-I procedure was carried out over multiple sips.

Some training was given to the participants regarding the use of T-I

Table 1
Characteristics of the commercial beverages.

Beverages	pH	Protein (%)	Carbohydrate (%)	Caffeine (%)	Bitter Intensity
Coffee	4.7	0.0	20.0	28.0	11.2
Yerba mate	5.9	0.0	0.0	3.8	8.1
Grapefruit juice	3.2	0.6	6.5	0.0	2.7

Note: Nutritional data was obtained from the product packaging and is expressed on product weight basis. Bitter intensity is the mean result obtained by the panel using a non-structured scale (15 cm).