Multiple-sip temporal dominance of sensations associated with acceptance test: a study on special beers

Síntia Carla Corrêa Simioni¹ · Michele Nayara Ribeiro¹ · Vanessa Rios de Souza¹ · Cleiton Antônio Nunes¹ · Ana Carla Marques Pinheiro¹

Revised: 30 August 2017 / Accepted: 2 January 2018 / Published online: 5 February 2018
© Association of Food Scientists & Technologists (India) 2018

Abstract In this study, we proposed the use of a multiple-sip temporal dominance of sensations (TDS) test alongside with an acceptance test over repeated consumption for the analysis of special beers, with the aim of contributing to a deeper understanding of consumer behavior regarding temporal descriptions and sensory acceptance. Consumers of special beers sequentially evaluated six sips of a particular type of beer by TDS analysis and an acceptance test was performed for each sip. Four different kinds of specialty beers were evaluated [Bohemian Pilsner (BP), Witbier (WB), Belgian Strong Ale Dubbel (BD), and Russian Imperial Stout (RS)]. In general, the descriptive profile of beers varied temporally, i.e., there was an increased dominance of bitterness and a decreased dominance of fruity, floral, toffee, and coffee attributes. Concurrently, a reduction in sensory acceptance with an increased number of sips, especially the last sip, was observed in two kinds of beers that possessed a strong flavor, BD and RS. BP and WB presented smooth attributes and low notable characteristics, which could have contributed to the maintenance of the acceptance grades as the number of sips increased. The combination of TDS and acceptance over repeated sips can be useful for obtaining detailed descriptions of products that are closer to real time consumption by consumers, and thus aids in ensuring good product performance once released. The information obtained can also help product

development scientists to fine-tune product formulations and ensure acceptability.

Keywords Repeated consumption · Sensory acceptance · Temporal description · Beers

Introduction

The methods used in sensory analysis can be categorized into discriminative methods, responsible for establishing qualitative and/or quantitative differentiation among samples; affective methods that consider the personal opinion of the judge; and descriptive methods that describe the samples in a qualitative and quantitative form (Lawless and Heymann 2010).

Currently, the affective sensory methods are utilized most of the time in association with descriptive sensory methods during product development. For example, these methods were used in the study performed by Morais et al. (2015) that evaluated the influence of prebiotics and sugar replacement in the sensory profile and chemical composition of chocolate dairy desserts by quantitative descriptive analysis (QDA) and acceptance test; Choi et al. (2015) investigated the drivers of liking for traditional and ethnic chicken marinades using QDA and consumer taste tests, incorporating the check-all-that-apply (CATA) method; and Thomas et al. (2015) associated hedonic temporal data and descriptive temporal data to identify drivers of liking in six commercial flavored fresh cheeses, which are attributes that, when cited as dominant, would affect consumer acceptability.

Most studies, such as those presented above, are carried out quickly and consider the intake of food without repetition (e.g., only a single sip or bite). Such punctual sensory

✉ Síntia Carla Corrêa Simioni
correa.sintia@gmail.com

✉ Ana Carla Marques Pinheiro
anacarlamp@dca.ufla.br

¹ Departamento de Ciência dos Alimentos, Universidade Federal de Lavras–UFLA, Campus Universitário, Caixa Postal 3037, Lavras, MG CEP 37200-000, Brazil

analysis of foods may not accurately reflect consumer opinion because the consumer could initially accept the product but with an increase in the number of bites or sips, this product could be rejected and vice versa, and this can occur by adaptation of taste cells (Köster 2003). Therefore, the first bite or sip may not be sufficient to identify and accept the sensory characteristics and the actual perception of the product, particularly for complex products (Zorn et al. 2014).

Colonna et al. (2004) evaluated the intensity of astringency of red wine when a single wine is sipped repeatedly or during the evaluation of several red wines in one session and found to be important to remove the residuals from each ‘rinse’ by extensive water rinses before tasting the next wine. Vandeputte et al. (2011) proposed and used the ‘multiple sip or multiple bite’ method to assess the evolution of sensory characteristics during the complete tasting of a product (several bites) and by doing this, obtained a more realistic view of the sensory analysis of products. Pineau (2013) extended this technique for use in the temporal dominance of sensations (TDS) tests in a concatenated form, in multi-bite evaluations. This methodology was used by Zorn et al. (2014) to evaluate the effect of replacing sucrose with low-calorie sweeteners in the dynamic sensory profile of orange juice. However, their methodology did not consider the hedonic perception of consumers during the repeated consumption of these products.

Therefore, in the present study we proposed an association between the temporal descriptive profile and acceptability over sips. TDS was chosen for the descriptive analysis because it is considered more appropriate to explain consumer responses than static descriptive analysis (Di Monaco et al. 2014). In addition, the dynamic information from TDS may contribute to the understanding of liking drivers (Varela et al. 2014). Special beers were chosen as a product that is increasingly being appreciated by consumers globally, and presents complex and differentiated sensory profiles that can change during repeated consumption (François et al. 2006; Guinard et al. 1998; Liu et al. 2012). Thus, we assessed the use of a multiple-sip TDS method and acceptance test to evaluate four different specialty beers with the aim of contributing to a greater understanding of consumer acceptability of products over repeated consumption.

Materials and methods

Beer types

Bohemian Pilsner with 5% alc/vol and IBU 42 (BP), Witbier with 5% alc/vol and IBU 20 (WB), Belgian Strong

Ale Dubbel with 7.5% alc/vol and IBU 26 (BD), and Russian Imperial Stout with 12% alc/vol and IBU 70 (RS) were obtained from the Wals brewery located in Belo Horizonte City, Minas Gerais, Brazil. All samples correspond to the same production lot and were within the expiration date.

Sensory evaluation

The tests were performed in the Sensory Analysis Laboratory of the Department of Food Science at the Federal University of Lavras. Six consumers comprising technicians and teachers from the Department of Food Science, older than 18 years, were enrolled to consume special beers. Samples were evaluated using a focus group (Lawless and Heymann 2010) to determine the attributes that would compose the list of sensations of each type of beer for performing the TDS, besides the descriptions of each attribute that were done by consensus among consumers (Table 1). In this session, total number of sips ($n = 6$), total analysis time (BP and WB = 50 s; BD and RS = 90 s), amount to be ingested by each sip (20 mL) and different attributes for each type of evaluated beer, were determined.

Once test conditions were defined, ninety consumers were recruited to do the final sensory analysis. These panelists consumed special beers at least twice a week and the group was 34.5% female and 65.5% male, 55% aged between 18 and 30 years, 38% between 31 and 45 years, and 7% between 46 and 60 years.

Analyses were carried out in individual booths, under white light and with adequate ventilation. The tasters were acquainted with the SensoMaker software (Nunes and Pinheiro 2012) used to collect the TDS data and with the sensory attributes of each beer to be analyzed.

The four different beers were assessed on four consecutive days. In each sensory analysis session, the ninety consumers analyzed six sips of only one type of beer, i.e., the taster assessed six samples of 20 mL each (volume corresponding to one sip established by pre-test) for each type of beer studied. The samples were served in a balance order among the tasters/days, so that on a given day each taster evaluated a particular beer. In the evaluation of each beer (6 samples for the 6 sips), it was not necessary to serve samples in balanced order once each taster evaluated only one type of beer. Tasters were asked not to wash their palates between sips so that the sensory analysis simulated a scenario of actual beer consumption and time between sips was not allowed. BP and WB were maintained at temperatures between 0 and 4 °C while BD and RS were kept at temperatures of 8 and 12 °C, respectively, as recommended by the manufacturer, and were served in glass cups coded with three digits.

Table 1 Attributes and descriptions of each special beer

Special beers	Attribute	Description
Bohemian Pilsner	Bitter	Primary taste
	Fruity	Flavor sensation resembling fruits (such as pear, apple, grape, pineapple, melon)
	Alcoholic flavor	Flavor sensation of alcohol (medicinal, solvent, ethanol)
	Herbal	Flavor sensation resembling green leaves with refreshing sensation
	Citric	Flavor of citrus fruits (lemon, orange)
Witbier	Bitter	Primary taste
	Fruity	Flavor sensation resembling fruits (such as pear, apple, grape, pineapple, melon)
	Alcoholic flavor	Flavor sensation of alcohol (medicinal, solvent, ethanol)
	Citric	Flavor of citrus fruits (lemon, orange)
	Sweet	Primary taste
	Spices	Flavor sensation resembling clove, cinnamon
Belgian Strong Ale Dubbel	Floral	Flavor sensation resembling eucalyptus flower associated with refreshing sensation
	Bitter	Primary taste
	Alcoholic flavor	Flavor sensation of alcohol (medicinal, solvent, ethanol)
	Toffee	Flavor sweetness resembling caramel
	Coffee	Flavor sensation resembling coffee
	Toasted	Flavor sensation resembling toasted bread, toasted grains, toasted nuts
	Chocolate	Flavor sensation of milk chocolate and/or dark chocolate
Russian Imperial Stout	Spices	Flavor sensation resembling clove, cinnamon
	Bitter	Primary taste
	Alcoholic flavor	Flavor sensation of alcohol (medicinal, solvent, ethanol)
	Toffee	Flavor sweetness resembling caramel
	Coffee	Flavor sensation resembling coffee
	Toasted	Flavor sensation resembling toasted bread, toasted grains, toasted nuts
	Chocolate	Flavor sensation of milk chocolate and/or dark chocolate
	Sweet	Primary taste

The TDS method was then applied. The taster sipped the beer, performed TDS by selecting the dominant attributes over time, and after finishing this test, proceeded to the acceptance test in relation to the overall liking attribute using a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely) (Stone and Sidel 2004). Without the need for quantification, the TDS is a temporal technique that provides an intuitive response which needs less training since no scaling is used (Galmarini et al. 2017). This somewhat playful approach is one of the reasons that facilitates the extension of this technique to working with consumers (Brachet et al. 2014; Schlich 2013; Thomas et al. 2015).

Sensory analysis was conducted after the approval of this project by the Comitê de Ética em Pesquisas com Seres Humanos (COEP) (Committee of Ethics in Research with Human Beings) of the Universidade Federal de Lavras, Brazil (opinion # 42439015.4.0000.5148).

Statistical analysis

To analyze TDS results, we plotted graphs for each sip and for each type of evaluated beer using the SensoMaker software (Nunes and Pinheiro 2012). In these graphs, the x-axis corresponds to the analysis time (s) and the y-axis corresponds to the dominance rate of the attribute. Data was further analyzed by chance and significance lines, which were calculated using the confidence interval of a binomial proportion (Pineau et al. 2009).

The parameter maximum dominance rate obtained from the attributes above the chance line of the TDS, from each sip and each type of beer, were analyzed by PCA and the acceptance was analyzed as a supplementary variable.

The maximum dominance rate was arranged in a matrix of *i* lines (samples) and *j* columns (sensation). PCA was carried out using the R software (R Core Team 2015). Plots of scores and loadings were built from the first two principal components.

The overall liking data were also evaluated by ANOVA and Tukey's Test at $p < 0.05$ using SensoMaker software.

Results

Figures 1, 2, 3 and 4 show TDS curves for all sips of each evaluated beer. The data exploration was performed by analyzing the chance and significance levels. The chance line marks the limit of the probability of an attribute checked at random while the significance line is the minimum value for the attribute to be considered as significantly dominant (Pineau et al. 2009). TDS showed that there was a variation in the sensory profile during repeated consumption in all types of evaluated beers. For BP

(Fig. 1), the only attribute significantly dominant in all sips was bitterness. Dominance for the bitter attribute increased slightly with successive sips, starting with values near 0.6 in the first and second sips, evolving to values nearing 0.7 by the fifth sip. In the first sip, fruity attributes presented above the chance line, between 16 and 22 s of analysis, with dominance near 0.2. In addition, in this sip, we noticed a gradual decrease in dominance of the bitter attribute after 30 s. In the third sip, the herbal attribute was above the chance line, for 12 and 21 s, with a maximum dominance rate of 0.26. In the sixth sip, the fruity attribute became significant at 22 s.

For WB (Fig. 2), the significant attributes in the first sip were fruity, with significant perception between 9 and 20 s and a dominance rate of 0.3, and floral with significant

Fig. 1 TDS curves of all sips analyzed (first to sixth) for Bohemian Pilsner beer

Fig. 2 TDS curves of all sips analyzed (first to sixth) for Witbier beer

perception between 25 and 32 s and a dominance rate of 0.25. In this sip, citric and bitter attributes, although not significant, were above the chance line between 8 and 10 s and 13 and 24 s, with dominance rates of 0.16 and 0.20 respectively. In the second sip, the significant attribute was bitter, with significant perception between 28 and 30 s and a dominance rate of 0.22. The fruity, floral, and citrus attributes presented above the chance line between 5 and 32 s with dominance rates close to 0.2. From the third sip, the dominance rate for the bitter attribute increased during the first 5–10 s, appearing above the chance line again around 22 s. In the last sip, bitterness remained consistently above the chance line after 5 s. About the floral

attribute, we found that in the third and fourth sips, this attribute became significant between 10 and 15 s and 12 and 27 s, respectively, and in the fifth and sixth sips, the dominance rate decreased. Regarding the fruity attribute, it was below the significant line in the fifth sip and as in the floral attribute, the dominance rate decreased in the last sip.

Some attributes appeared above the chance line in only a few sips, e.g., the alcoholic flavor attribute was above the chance line in the second and fourth sips after approximately 15 s, and the spices attribute only after approximately 20 s in the fifth and sixth sips. In general, the dominance rate of the attributes was higher in the first sips, and decreased in later sips. In addition, some attributes

Fig. 3 TDS curves of all sips analyzed (first to sixth) for Belgian Strong Ale Dubbel beer

went above the chance line with increasing numbers of sips, e.g., the spices attribute in the fifth and sixth sips.

In the case of BD (Fig. 3), the significantly dominant attributes were toffee and bitterness, with significance in most sips. In the first three sips, the bitter attribute was always dominant at a lower rate and lower intake time than the toffee attribute. The maximum dominance rates of the toffee attribute were 0.36, 0.28 and 0.36 in the first, second, and third sips, respectively, against 0.27, 0.22 and 0.28, respectively, for bitterness. From the fourth sip onward however, there was a change of profile and there was a greater dominance rate for the bitter attribute compared to the toffee attribute. In the fourth sip, the toffee attribute

was considered insignificant. In this case, dominance rates for the bitter attribute were 0.29, 0.36 and 0.38 for the fourth, fifth, and sixth sips, respectively, and the toffee attribute dominance rates were 0.22, 0.32 and 0.28 for these same sips, respectively.

Thus, in BD beer, there was a higher dominance of the bitter attribute and lower dominance of the toffee attribute with an increased number of sips. Moreover, the toasted attribute was above the chance line in all sips between 10 and 50 s. With respect to the alcoholic flavor attribute, it was above the chance line in the third and sixth sips between 25 and 70 s with a dominance rate close to 0.18.

Fig. 4 TDS curves of all sips analyzed (first to sixth) for Russian Imperial Stout beer

Finally, for RS (Fig. 4) all attributes (coffee, chocolate, toffee, bitter, sweet, toasted, and alcoholic flavor) appeared at least once above the chance line. In the first two sips, the result was similar to the result presented for BD beer, but the toffee attribute replaced the coffee attribute. Thus, the coffee attribute had a higher dominance rate than the bitter attribute, with values of 0.39 and 0.29 on the first and second sips for coffee, respectively and 0.21 and 0.27, respectively, for the bitter attribute. In the third sip, the dominance rates of these two attributes were close to 0.26. From the fourth sip onward, the situation was reversed and the bitter attribute was more dominant than the coffee attribute, and the values presented were 0.45, 0.40 and 0.28

on the fourth, fifth, and sixth sips, respectively for bitter against 0.19, 0.25 and 0.24 in fourth, fifth, and sixth sips, respectively, for coffee.

Many other attributes contributed to the characterization of this type of beer and were above the chance line in most of the sips. The chocolate attribute, for example, appeared above the significant line in the first sip between 5 and 10 s, with a dominance rate of 0.25 and in the other sips this attribute appeared as the first attribute above the chance line between about 3 and 8. In addition to this, the toffee attribute appeared between approximately 8 and 35 s in all sips. The sweet attribute presented above the chance line only in the first sip, at 12 s, while the alcoholic flavor

and toasted attributes varied greatly among the sips, despite their low dominance rates.

Among all the attributes analyzed, we determined that the major changes in the RS beer were due to the increased dominance of bitterness with increasing sip number, at the same time the dominance of the peculiar coffee attribute decreased.

Figure 5 shows graphs of PCA generated from the data of maximum dominance rate of the attributes that reached at least the chance line and data of overall liking as a supplementary variable for each evaluated beer. In these figures, we verified the drivers of liking of sips in each beer type and this analysis aimed to show the sips that were

distinguished in acceptance and the attributes that favored their acceptability.

As seen from the PCA scores and loading plots for BP beer (Fig. 5a), intermediary sips 2, 3 and 4 were more accepted possibly due to the high dominance rate of the herbal attribute and mainly low dominance rate of the bitter attributes.

Regarding the PCA scores and loadings plots for WB (Fig. 5b), the first sip presented higher acceptance than the other sips, which could be due to the high dominance rate of the fruity and floral attributes and low dominance rates of the citric, spices, alcoholic flavor, and bitter attributes.

For BD (Fig. 5c), scores and loadings showed that the first and second sips were distinguished in relation to

Fig. 5 PCA scores and loadings for the maximum dominance rates from beer TDS curves. Overall liking was considered a supplementary variable. Numbers S1 through S6 represent the number of sips.

a Bohemian Pilsner, **b** Witbier, **c** Belgian Strong Ale Dubbel, **d** Russian Imperial Stout

acceptance, which could be due to the high dominance rates of the toasted and toffee attributes and low dominance rates of the alcoholic flavor and bitter attributes.

With respect to PCA scores and loading plots for RS (Fig. 5d), the first sip had higher acceptability than the other sips, possibly due to the high dominance rates of the sweet, coffee, and chocolate attributes and low dominance rates of the alcoholic flavor, toasted, toffee, and bitter attributes. In general, it was observed through PCA that the herbal, fruity, floral, toasted, toffee, chocolate, coffee, and sweet attributes contributed to high acceptance in the first sips, even if not all attributes were significant in TDS analysis. The bitter, spices, alcoholic flavor, and citric attributes, however, appeared to be responsible for decreased acceptance with increased number of sips.

The evaluation of the overall liking behavior in various sips in each type of beer, which was performed by analysis of variance followed by Tukey test (Table 2) showed that although there was a numerical reduction in the grades of overall liking with increased number of sips, this behavior was not significant for the beer types BP and WB; there were no significant differences among different sips. As for the BD and RS beers, significant differences were observed between the first and last sips for BD, and for RS the first sip differed from the fifth and sixth sips.

Discussion

The most significant change to BP was a slight increase in the dominance of the bitterness as sip number increased. Meanwhile, in WB, the fruity, floral, and citric attributes were above the chance line during the first sips, and decreased in dominance with increased intake besides a slight increase in the bitterness perception concurrently

over repeated consumption. For BP and WB beers, we observed few changes over repeated consumption; these beers presented smooth attributes and low notable characteristics, which could have contributed to the maintenance of the acceptance grades with increased number of sips. BD and RS showed similar behaviors, where there was a higher dominance of the bitter attribute in both and a lower dominance of the toffee and coffee attributes for BD and RS, respectively, as sip number increased. These contributed to the decrease in acceptance grades of the sixth sip for BD, and fifth and sixth sips for RS. Also, the reduction of the maximum dominance rate of the toasted and chocolate attributes with increased number of sips may have contributed to the decrease in acceptance grades for BD and RS beers, respectively.

Multiple mechanisms are responsible for the perception and transduction of bitterness (Brand 1997; Schiffman 2000). Some of these mechanisms, such as the receptors, may be common to the perception of both bitter and sweet (Schiffman 2000; Schiffman et al. 1995). Small changes in chemical structure can convert bitter compounds to intensely sweet or vice versa (Drewnowski 2001). Calvino et al. (1993) showed that sweetness can be suppressed by tastes that evoke bitterness. For BD and RS beers, the reduction in the perception of toffee and chocolate attributes, both sweetness flavors, and the higher perception of bitter attributes with the increase in the number of sips in BD and RS, respectively, suggests that there was a saturation of substances at the receptor sites, promoting increased perception of the bitter attribute.

Additionally, there was a probable influence of the alcohol content, time of analysis, and temperature on increased perception of the bitter attribute in these beers since BD (7.5% alc) and RS (12.5% alc) presented higher alcohol contents than BP and WB (both 5% alc); the total analysis time for BD and RS was 90 s, while BP and WB were analyzed for 50 s. About temperature, BD and RS (8–12 °C) were analyzed in a temperature range higher than BP and WB (0–4 °C).

In relation to the influence of temperature on bitterness, McBurney et al. (1973) reported that the taste thresholds for quinine sulfate (bitter) were lowest between 22 and 32 °C and that thresholds rose above these temperatures in the test range of 17–42 °C. Additionally, red wines presented at room temperature or slightly cooler exhibit enhanced wine aroma while perceived bitterness and astringency diminish (Jackson 2009).

Other studies evaluated sensorial attributes that most influenced beer acceptance and concluded that the sweetness and fruity attributes positively influenced product acceptance while bitterness had a negative influence (Giacalone et al. 2013; Donadini et al. 2014). Additionally, the sensorial acceptance of special beers is independent of

Table 2 Averages of the overall liking grades of each sip of special beers

Beers/sips*	1st	2nd	3th	4th	5th	6th
BP ¹	6.58 ^{ns}	6.23 ^{ns}	6.42 ^{ns}	6.39 ^{ns}	6.23 ^{ns}	5.93 ^{ns}
WB ²	7.56 ^{ns}	7.4 ^{ns}	7.4 ^{ns}	7.12 ^{ns}	7.08 ^{ns}	6.98 ^{ns}
BD ³	7.44 ^b	7.03 ^{ab}	7.00 ^{ab}	6.93 ^{ab}	6.89 ^{ab}	6.65 ^a
RS ⁴	7.51 ^b	7.07 ^{ab}	6.79 ^{ab}	6.65 ^{ab}	6.41 ^a	6.44 ^a

^{ns} no significant

*Different letters in horizontal indicate a significant difference among sips $p < 0.05$ according to Tukey's test

¹Bohemian Pilsner

²Witbier

³Belgian Strong Ale Dubbel

⁴Russian Imperial Stout

genre or social class (Donadini and Porretta 2017; Donadini et al. 2014) and its considered a product with a large target audience.

Therefore, acceptance grades may change during repeated consumption according to the type of beer. For example, for BP and WB beers, consumers could consume a large quantity without changes in acceptance grades while for BD and RS beers, a decrease in acceptance grades was observed as the number of sips increased. Such information could be used by companies to define the form of marketing, volume, and packaging to be presented to consumers.

In this way, the multiple-sip TDS methodology associated with sensory acceptance identified changes in the sensory profile and in the acceptance of BD and RS beers with an increase in the number of sips, indicating that a punctual analysis may not accurately reflect actual consumer perception. On the other hand, this same methodology identified changes in the sensory profile without identifying changes in the acceptance of BP and WB beers. In this case, a punctual analysis may be reliable, although the use of repetitive consumption allows for a more detailed analysis of the sensorial profile of the product.

Furthermore, the results suggest that there was a strict association between TDS and sensory acceptance throughout the repeated consumption. In general, TDS showed a decrease in the perception of the compound attributes that characterized the flavor of each beer, and an increase in the bitterness perception concurrently with decrease in overall acceptability of the beer over repeated consumption.

Importantly, the results of this study were obtained for special beers, which are complex products. Therefore, further studies are needed in other food matrices since different products may yield different results. Besides, just like Colonna et al. (2004) developed a protocol for minimising or eliminating astringency carry-over in evaluations of astringent samples, studies for minimising or eliminating bitterness in evaluations of a single beer are required.

In agreement with results from previous studies, the present study extends the multiple sip/bite methodology, proposing its use in association with an acceptance test. This new use resulted in an enhanced understanding of the dominant sensory characteristics and their association with acceptability over repeated consumption of special beers. Thus, the combined use of the TDS and acceptance methods over repeated bites or sips can enable researchers and companies to have more knowledge about their products and make changes in their formulations to promote better acceptance of the products by the consumers.

Conclusion

Multiple-sip TDS associated with an acceptance test promoted an enhanced understanding of consumer behavior regarding temporal description and sensory acceptability over repeated consumption. There was a variation in the sensory profile and acceptance of special beers as sip number increased in all evaluated beer types. In general, there was a decrease in the perception of the compound attributes that characterized the flavor of each beer, and an increase in the bitterness perception concurrently with decrease in overall acceptability of the beer over repeated consumption. The combination of TDS and acceptance over repeated sips or bites will enable researchers and companies to have more knowledge about their products and make changes in their formulations to promote better consumer acceptance of many products.

Acknowledgements The authors thank UFLA-MG and development agencies FAPEMIG, CAPES, and CNPq for financial support.

References

- Brachet S, Galmarini M, Chatelet B, Loiseau AL, Cordelle S, Lempereur V (2014) Evaluation de la dominance temporelle des sensations de vins rouges de bourgogne et du beaujolais par un panel d'experts et de consommateurs. In: 37th World congress of wine and wine and 12th general assembly of the OIV. EDP Sciences
- Brand JG (1997) Biophysics of taste. In: Beauchamp GK, Bartoshuk L (eds) Tasting and smelling. Handbook of perception and cognition, 2nd edn. Academic Press, San Diego
- Calvino AM, Garcia-Medina MR, Cometto-Muniz JE, Rodriguez MB (1993) Perception of sweetness and bitterness in different vehicles. *Percept Psychophys* 54:751–758
- Choi J, Gwak M, Chung S, Kim K, O'Mahony M, Ishii R, Bae Y (2015) Identifying the drivers of liking by investigating the reasons for (dis)liking using CATA in cross-cultural context: a case study on barbecue sauce. *J Sci Food Agric* 95:1613–1625
- Colonna AE, Adams DO, Noble AC (2004) Comparison of procedures for reducing astringency carry-over effects in evaluation of red wines. *Aust J Grape Wine Res* 10:26–31
- Di Monaco R, Su C, Mais P, Temporal SC (2014) Dominance of sensations: a review. *Trends Food Sci Technol* 38:104–112
- Donadini G, Porretta S (2017) Uncovering patterns of consumers' interest for beer: a case study with craft beers. *Food Res Int* 91:183–198
- Donadini G, Fumi MD, Newby-Clark IR (2014) Consumers' preference and sensory profile of bottom fermented red beers of the Italian market. *Food Res Int* 58:69–80
- Drewnowski A (2001) The science and complexity of bitter taste. *Nutr Rev* 59:163–169
- François N, Guyot-Declercq C, Hug B, Callemien D, Govaerts B, Collin S (2006) Beer astringency assessed by time–intensity and quantitative descriptive analysis: influence of pH and accelerated aging. *Food Qual Prefer* 17:445–452
- Galmarini MV, Visalli M, Schlich P (2017) Advances in representation and analysis of mono and multi-intake temporal dominance of sensations data. *Food Qual Prefer* 56:247–255

- Giacalone D, Bredie WL, Frøst MB (2013) “All-In-One Test”(AI1): a rapid and easily applicable approach to consumer product testing. *Food Qual Prefer* 27:108–119
- Guinard J, Yip D, Cubero E, Mazzucchelli R (1998) Quality ratings by experts and relation with descriptive analysis ratings: a case study with beer. *Food Qual Prefer* 10:59–67
- Jackson RS (2009) *Wine tasting: a professional handbook*, 2nd edn. Elsevier Academic Press, New York
- Köster EP (2003) The psychology of food choice: some often encountered fallacies. *Food Qual Prefer* 14:359–373
- Lawless HT, Heymann H (2010) *Sensory evaluation of food. Principles and practices*. Springer, New York
- Liu C, Dong J, Wang J, Yin X, Li Q (2012) A comprehensive sensory evaluation of beers from the Chinese market. *J Inst Brew* 118:325–333
- McBurney DH, Collings VB, Glanz LM (1973) Temperature dependence of human taste responses. *Physiol Behav* 11:89
- Morais EC, Lima GC, Morais AR, Bolini HMA (2015) Prebiotic and diet/light chocolate dairy dessert: chemical composition, sensory profiling and relationship with consumer expectation. *LWT-Food Sci Technol* 62:424–430
- Nunes CA, Pinheiro ACM (2012) *SensoMaker*, version 1.9. UFLA, Lavras
- Pineau N (2013) Extension of TDS to multi-bite evaluation. In: 10th Pangborn sensory science symposium. Rio de Janeiro, Brazil
- Pineau N, Schlich P, Cordelle S, Mathonnière C, Issanchou S, Imbert A, Rogeaux M, Etiévant P, Köster E (2009) Temporal dominance of sensations: construction of the TDS curves and comparison with time–intensity. *Food Qual Prefer* 20:450–455
- Schiffman SS (2000) Taste quality and neural coding: implications from psychophysics and neurophysiology. *Physiol Behav* 69:147–159
- Schiffman SS, Booth BJ, Losee ML et al (1995) Bitterness of sweeteners as a function of concentration. *Brain Res Bull* 36:505–513
- Schlich P (2013) TDS with untrained consumers in lab and at home. In 10th Pangborn sensory science symposium. Rio de Janeiro, Brazil
- Stone H, Sidel J (2004) *Sensory evaluation practices*. Elsevier Academic Press, USA
- Thomas A, Visalli M, Cordelle S, Schlich P (2015) Temporal drivers of liking. *Food Qual Prefer* 40:365–375
- Vandeputte A, Romans J, Pineau N, Lenfant F (2011) Innovative methods to assess the evolution of the sensory characteristics during the tasting of a full product portion (several bites). In: 9th Pangborn sensory science symposium. Toronto, Canada
- Varela P, Pintor A, Fiszman S (2014) How hydrocolloids affect the temporal oral perception of ice cream. *Food Hydrocoll* 36:220–228
- Zorn S, Alcaire F, Vidal L, Giménez A, Ares G (2014) Application of multiple-sip temporal dominance of sensations to the evaluation of sweeteners. *Food Qual Prefer* 36:135–143