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Metodologias sensoriais utilizadas em estudos descritivos com consumidores: *Check-All-That-Apply* (CATA) e suas variações

Sensory methodologies used in descriptive studies with consumers: Check-All-That-Apply (CATA) and variations

Metodologías sensoriales utilizadas en estudios descriptivos con consumidores: *Check-All-That-Apply* (CATA) y sus variaciones

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Resumo

Os alimentos apresentam atributos sensoriais que podem ser identificados, descritos e quantificados usando métodos sensoriais descritivos. Estas metodologias têm sido utilizadas para o desenvolvimento de novos produtos, controle de qualidade, alterações na formulação e para a avaliação do prazo de validade na indústria de alimentos. As técnicas descritivas tradicionais possuem como limitações a necessidade de avaliadores treinados, devido ao alto grau de dificuldade/complexidade dessas avaliações. Outra desvantagem é o tempo necessário para realizar o treinamento, tornando o método muito caro. Para reduzir o tempo de análise e

os custos das técnicas descritivas tradicionais, pesquisas recentes buscam desenvolver e validar metodologias que possibilitem descrever os alimentos por meio do uso de consumidores, evitando a necessidade de formação de painéis treinados. O objetivo foi descrever os avanços da metodologia descritiva denominada *Check-All-That-Apply* (CATA) e suas variações, bem como suas vantagens e limitações.

Palavras-chave: Análise sensorial; Consumidores, Limitações; Vantagens; Questionários.

Abstract

Food presents sensory attributes that can be identified, described and quantified using descriptive sensory methods. These methods have been used to developing of new products, quality control, formulation changes and to the evaluation of shelf life in the food industry. Traditional descriptive techniques have as limitations the requirement of trained evaluators since they present high degree of difficulty/complexity of these evaluations. Another disadvantage is the time needed to conduct the training, making the method very expensive. To reduce the time analysis and costs of traditional descriptive techniques, recent research is seeking to develop and validate methodologies that make possible to describe foods through the use of consumers, avoiding the need of trained judges. The objective was to describe the advances of the descriptive methodology named Check-All-That-Apply (CATA) and their variations, as well as their advantages and limitations.

Keywords: Sensory analysis; Consumers; Limitations; Advantages; Questionnaire.

Resumen

Los alimentos presentan atributos sensoriales que pueden identificarse, describirse y cuantificarse utilizando métodos sensoriales descriptivos. Estos métodos se han utilizado para desarrollar nuevos productos, control de calidad, cambios en la formulación y para evaluar la vida útil en la industria alimentaria. Las técnicas descriptivas tradicionales tienen como limitaciones el requisito de los evaluadores capacitados, ya que estas evaluaciones presentan un alto grado de dificultad/complejidad. Otra desventaja es el tiempo necesario para realizar la capacitación, lo que hace que el método sea muy costoso. Para mejorar la reducción del tiempo de análisis y los costos de las técnicas descriptivas tradicionales, la investigación reciente busca desarrollar y validar metodologías que permitan describir los alimentos mediante el uso de los consumidores y evitando la necesidad de jueces capacitados. El objetivo era describir los avances de la metodología descriptiva denominada *Check-All-That-Apply* (CATA) y sus variaciones, así como sus ventajas y limitaciones.

Palabras clave: Análisis sensorial; Consumidores; Limitaciones; Ventajas; Cuestionario.

1. Introduction

The modern food industry is seeking for the development of new food products and the definition of the sensory properties of the product is a fundamental part of the development process and consequent commercial success when launched or modified (Kemp, 2013). In the food industries, descriptive sensory methodologies are widely used to trace the sensory profile of new food products, to modify formulations, in the quality control and also to evaluate products during shelf life. Classical descriptive methods are flexible, comprehensive and able of providing detailed information about the sensory properties of a food (Alcantara & Freitas-Sá, 2018).

Traditionally, the sensory profile of food products is developed using Quantitative Descriptive Analysis (QDA). This is a standardized methodology that involves the qualitative and quantitative assessment of product sensory characteristics. The results obtained with the QDA are accurate and, therefore, the technique requires a high degree of training and respective maintenance of the judging team, evaluated for its repeatability and discriminating ability (Drake, 2007). However, QDA has limitations, as time for sensory panel training, availability of people to participate in analysis, definition of reference products that translate judges' perceptions, development and definition of terminology for sensory profile, which is unique to each particular food class (Cadena et al. 2014). Also, depending on the product complexity, more training may be required and thus more time invested, which can be restrictive as the industry today seeks more versatile and faster sensory responses that are easily understood and applied. All of these limitations reflect the cost of maintaining a trained sensory panel.

Considering the economic aspect and the time required for training and maintaining teams of evaluators to obtain accurate, reliable and consistent answers, recent studies have presented advanced descriptive methodologies in consumer sensory science to meet the demand of food industries for more versatile tests and agility in obtaining answers. In this context, the CATA (Check-All-That-Apply) methodology has been widely studied in an attempt to replace the traditional descriptive analysis bringing the possibility of using trained consumers and non-judges. However, their results provide only a qualitative and non-quantitative aspect of product description such as QDA and, as a result, data obtained with the application of CATA do not become so reliable.

The objective is to review alternative methods to descriptive ones, based on the CATA methodology (Check-All-That-Apply) and its variations: RATA (Rate-All-That-Apply), TCATA (Temporal Check-All-That-Apply), TCATA fading (Temporal Check-All-That-Apply Fading) and CATA-I (Optimal Check-All-That-Apply), addressing their advantages and limitations, as well as data analysis.

2. CATA (Check-All-That-Apply)

The interest in methodologies based on the consumer for sensory characterization as an alternative tool for classical descriptive analysis has increased, and among the alternative methods, CATA is arousing growing interest (Varela & Ares, 2012, Ares & Varela, 2017). CATA is an alternative method, to descriptive methods, easy to execute and understand. This method is carried out with consumers and provides quick responses, meeting the demand of the food industry (Asioli et al., 2017). The CATA questionnaire aims to establish the sensory profile of food (Varela & Ares 2012).

Initially, the CATA questionnaire was used in consumer marketing research with the nomenclature “Check-All-That-Apply”, with the objective of the consumer “marking” the product's attributes in a preterm list. Currently, untrained judges are consumers who are given a multiple-choice list of words that apply to the product they are evaluating. To carry out the CATA questionnaire, three main steps are necessary: a) consensual survey of the descriptors; b) preparation of the CATA questionnaire; c) evaluation of samples with consumers (Rasinski, Mingay & Bradburn, 1994).

Survey of descriptive sensory attributes can be generated by a panel of trained evaluators or they can be selected by considering results from previous focus groups or from a prior list of quantitative consumer studies (Dooley, Lee & Meullenet, 2010). In addition, the descriptors are not limited to sensory attributes (salty, gummy, crunchy), but may also contain non-sensory terms (good for family consumption, healthy, good for a quick snack) and be related to product use, fit concept, and hedonic attributes (Varela & Ares, 2012). The CATA questionnaire was used by Ares et al. (2017) to identify how products differ from the ideal product expected by consumers, including terms in the CATA questionnaire with hedonic intensity connotations (e.g., not too sweet, too sweet) and applying the CATA questionnaire to characterize experienced products and ideal (or idealized) products.

The selection of the descriptors and the quantity of terms that will be part of the CATA questionnaire are fundamental points and include the main challenges of the methodology.

Jaeger et al. (2015) analyzed seven studies involving a total of 735 individuals and five different product categories (crackers, cheese, fruit drinks, chocolate and dairy dessert). The use of short or long lists (10 to 17 terms versus 20 to 28 terms) had a small impact on product sensory characterization. However, the results pointed to a dilution effect on citation frequency when long lists created using synonym/antonym words were used, confirming the expectations of consumer perception idiosyncrasies or reducing the discriminative capacity of the term list. The authors concluded that when designing the terms of the list, practitioners should, instead of using too many terms, include different terms that refer to the relevant sensory characteristics in order to recognize consumer heterogeneity.

Ares & Jaeger (2013b) demonstrated that the order of the terms in a CATA questionnaire influences consumer response, as found by Castura (2009). The authors mentioned that the attributes located closer to the top of the list tend to be more used. In a subsequent study, Ares & Jaeger (2015) recommend that the order of presentation of terms in the questionnaire should be balanced between inter and intra-evaluators, minimizing the influence of biases on consumer responses and maintaining their attention throughout the task. However, Meyners & Castura (2016) suggested that the benefits of inter-rater balancing outweigh the benefits of intra-rater balancing. If the attributes are randomized and their order is changed in the CATA questionnaire, within the same evaluator, in different samples, the lack of familiarity with the questionnaire with each sample the evaluator tastes will trigger remarkable visual attention just to find the attributes in the sample questionnaire, but not related to an actual product evaluation.

On the other hand, if the attribute list is not randomized intra-rater, a lesser cognitive effort is required to complete the questionnaire, because the consumer has the benefit of the familiarity of terms and their location of the questionnaire. Alcantara & Freitas-Sá (2018) recommend the randomization of attribute orders to the evaluators rather than to the samples. Jaeger et al. (2017) investigated whether evocation contexts influenced the hedonic discrimination and the sensory characterization of the product using the CATA questionnaire, showing that the CATA questionnaire continues to result in highly reproducible responses, even if the test with consumers was in evoked context or not.

The sensory characterization using CATA questionnaire uses a number of samples from 1 to 12, depending on the specific purpose of the study and the sensory characteristics of the samples (Ares, 2015). However, sensory fatigue must be taken into consideration. Samples are presented in monadic sequence, coded with random three-digit numbers, following a balanced randomization order to avoid influence of sample ordering.

The evaluation form should consider the number of consumers in the study, being the pattern of consumer's number for product sensory characterization using the CATA questionnaire normally from 50 to 100 (Dooley, Lee and Meullenet 2010, Ares et al. 2010, Plaehn 2012). Ares et al. (2014a, 2014b) evaluated the influence of the consumer's number on the stability of samples and descriptor configurations obtained using CATA. The results suggested that working with notably different samples, 60-80 consumers may be considered an adequate number to obtain reproducible statistical results. However, studies are still needed to assess how the degree of difference between samples affects the minimum number of consumers required to achieve stable configurations in the statistical analysis. In addition, the required number of consumers may change depending on the size of the differences between samples, increasing if the sample differences are small (Ares, 2015). CATA questionnaire responses can also be used as supplementary data in hedonic tests seeking to find answers that lead to greater acceptability (Adams et al., 2007, Dooley, Lee & Meullenet, 2010, Ares et al., 2010, Jaeger et al., 2013). In this case, the minimum number of consumers required to obtain reliable overall CATA scores should also take into account the minimum number of judges required for hedonic testing. For this reason, when CATA questions are elicited at the same time with general acceptability scores, the usual number of consumers in hedonic tests (100-120) is appropriate (Mammasse & Schlich 2014).

The reproducibility of the CATA questionnaire was evaluated by Ares et al. (2014a, 2014b) in the sensory characterization of different products by introducing a second evaluation session. In all studies, the same consumers evaluated the same set of samples under identical conditions in both sessions. The study revealed that the technique proved to be highly reproducible, quite capable of detecting differences and characterizing different products.

2.1. Analysis of data obtained in CATA forms

The CATA questionnaire data consists of binary data, whose unit can assume only two possible states (traditionally labeled as 0 and 1) indicating whether each consumer has selected (1) or not (0) a given term to describe each of the samples included in the study (Ares 2015).

The relevance of each term included in the CATA question to describe each sample is determined by calculating the selection frequency. Data are often summarized using contingency tables (Table 1) that contain the consumer's number who selected each term to describe each sample. Data can be displayed using counts or percentages, but the latter is more common (Meyners, Castura & Carr, 2013).

Table 1: Contingency table example for CATA evaluation and average scores of 3 samples of whole salted crackers.

Atribute	Sample A	Sample B	Sample C	Total
Gummy (G)	4	8	4	16
Crunchy (CR)	52	31	48	131
Gooey (GR)	14	12	0	26
Salty taste (ST)	33	36	31	100
Presence of whole grains (PWG)	36	0	1	37
Presence of bran (PB)	15	23	27	65
Brittle (B)	20	7	13	40
Dry (D)	29	18	11	58
Buttery Flavor (BF)	17	18	24	59
Feed Flavor (FF)	6	13	1	20
Toasted Flavor (TF)	13	15	7	35
Yellowish color (YC)	40	33	34	107
White color (WC)	13	1	0	14
Melting sensation in the mouth (MSM)	9	15	22	46
...	...	...	...	...
Total	n	n	n	n

Source: Adapted from Candaten et al. (2018).

Discrimination between samples is verified by applying the Cochran's Q non parametrical test, widely used in CATA list attribute frequency data, to verify the inference of product differences by attribute (Meyners & Castura, 2014).

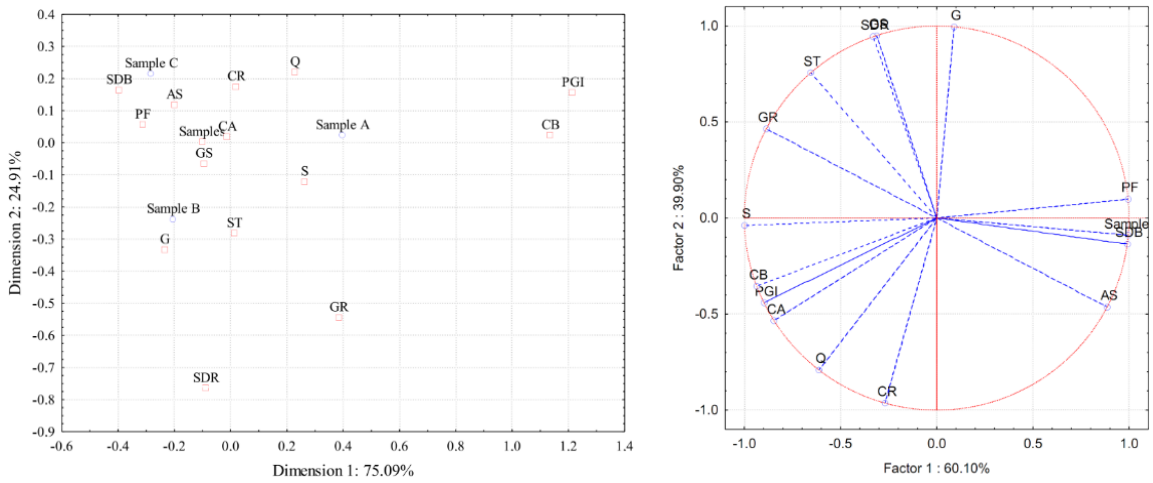
The Cochran's Q test assesses whether consumers have detected significant differences between samples for each of the terms applied in the CATA questionnaire. According to Tate and Brown (Tate & Brown, 1970), to apply the Cochran's Q test the number of consumers times

the number of products must be greater than 24, while Meyners & Castura, (2014) indicated that at least 15 evaluators should be used when comparing 2 or 3 samples.

Correspondence analysis (CA) is widely used to treat data of a contingency table, and can be considered as a generalization of principal component analysis (PCA) for common data. The method projects the data into orthogonal components to maximize the sequential representation of variation in the data. Usually only the graph of the first two components (x and y) is displayed. Sometimes, due to the little variation explained, additional dimensions are plotted as well. Correspondence analysis can be used to obtain a sensory map of CATA samples and terms as exemplified in Figure 1a. This map allows the visualization of similarities and differences between them, as well as their main sensory characteristics. This is a statistical method that allows simple and fast visualization of rows and columns of bidirectional contingency tables as points (Greenacre, 2007). Similar to principal component analysis (Figure 1b), contingency table data are projected into orthogonal dimensions that sequentially represent as much variation as possible from experimental data (Abdi & Williams, 2010). The positions of the points corresponding to the rows and columns in the space dimensions are consistent with their associations in the contingency table.

Figure 1: Example of CATA questionnaire data analysis:

a) Correspondence Analysis (CA); b) Principal Component Analysis (PCA).



(a) (b)

Source: Adapted from Candaten et al. (2018).

In some studies, involving the application of the CATA questionnaire, the objective is to verify the difference or similarity of a particular product developed in comparison with the

product considered ideal. This data is called penalty analysis. Statistical analysis of these data consists of methods based on the differences between actual and ideal products and the discussion of which attributes are relevant and mandatory for a given product to be considered ideal (Ares, 2015, Meyners, Castura & Carr, 2013).

The analysis of sensory data through PCA method sometimes leads to obtaining main factors clearly defined by the sensory attributes, within sensory parameters of texture, appearance, or taste and odor, for example. However, sometimes, the main components arising from the analysis lead to factors referring to representative descriptors of various sensory attributes, requiring the deep technical knowledge by the food product developer in relation to the influence of the process on the sensory parameters, enabling a discussion and interpretation data beyond statistics analysis.

2.2. Advantages and limitations

The CATA questionnaire is a simple and versatile tool to collect information on consumer perception regarding sensory and non-sensory characteristics of products (Alcantara & Freitas-Sá, 2018). It is efficient and easily applied in projects in which time and financial resources are restrictive factors due to the ease of analysis and quick responses, allowing to describe and discriminate differences between the products analyzed. Studies reported that CATA is a fast and non-stressful method for consumers, providing valid and reproducible information when compared to the classical descriptive analysis (Dooley, Lee & Meullenet, 2010, Ares & Jaeger, 2013b, Ares et al., 2010, Jaeger et al., 2013, Bruzzone, Ares, & Gimenez, 2012, Ares et al., 2011).

The CATA questionnaire is a multiple-choice list and allows multiple options to be selected to better describe products rather than limiting consumers to select only one answer or forcing them to focus their attention and evaluate specific attributes (Dos Santos et al., 2015). Therefore, emotional and conceptual associations of consumers in relation to food products are perceived and allow the exploration of how these associations can be shaped or influenced by the sensory and non-sensory characteristics of the evaluated product.

Compared to other sensory methods, CATA can be applied to gather information on the sensory characteristics of small sample sets or to evaluate large sample sets at different sessions due to the fact that the presentation is monadic (Ares, 2015). Another advantage of the CATA questionnaire is that it does not require deep cognitive processing, making it an easy and preferred method to perform (Jaeger et al., 2013).

Some studies have compared the sensory maps generated by the CATA questionnaire and those provided by the classic descriptive analysis with panel of trained evaluators reporting similar results (Dooley, Lee& Meullenet, 2010, Ares et al., 2010, Bruzzone, Ares & Gimenez, 2012). Other studies comparing the efficiency of the CATA questionnaire in relation to the use of trained evaluators report high correlations detected between evaluations, showing that consumers are able to evaluate sensory attributes in a similar way (Ares et al., 2010, Bruzzone, Ares & Gimenez, 2012). CATA can be easily applied when there is a large number of samples with a large number of attributes to be evaluated (Ares & Jaeger, 2015).

The CATA questionnaire is a very versatile method that allows application in any food sector and has been applied in the development of numerous products such as dairy products (functional yogurts, ice cream and dairy desserts (Cadena et al., 2014, Dooley, Lee & Meullenet 2010 and Ares et al., 2010, respectively), savory snacks (Adams et al., 2007), strawberry cultivars (Lado et al. 2010), orange flavored powdered drinks (Ares et al., 2011), citrus-flavored sodas (Plaehn, 2012). CATA was also applied in the aesthetic area evaluating the development of cosmetics (Parente, Ares & Manzoni, 2011).

However, the characterization of sensory products obtained using the CATA questionnaire cannot be considered as a substitute for classical descriptive analysis with trained evaluators. The latter methodology will always be more accurate due to the fact that evaluators are extensively trained in identifying and accurately quantifying sensory attributes. A study by Alexi et al. (2018) compared 3 methodologies: classic descriptive analysis (DA) with trained panel of judges, CATA with semi-trained consumers in an hour session with physical representation of the attributes and the CATA methodology with untrained consumers. The introduction of short training has not only increased the similarity of results with DA, but has also reduced the number of participants needed to acquire a reliable sensory profile from CATA (around 37 consumers). This is suggesting that the semi-trained variation of CATA is a valuable research tool when a trained panel cannot be sustained and a more descriptive sensory profile of the samples is required. This study allowed us to affirm that with an hour of training, the performance of consumer subjects changed bringing the results of the semi trained CATA closer to the descriptive analysis (DA), obtaining 95% similarity in the results.

One of the limitations of CATA is that it does not provide quantitative information, only frequency data (how many times a term has been chosen by the evaluators) that are binary responses (1/0), which may lead to less analytical data, not allowing a measurement of the intensity of the sensory attributes evaluated, which hinders detailed descriptions and product discrimination especially when the samples have subtle differences in terms of their

characteristic sensory attributes (Varela & Ares, 2012, Dooley, Lee & Meullenet, 2010, Ares & Jaeger, 2015, Antúnez et al., 2017, Vidal et al., 2018). However, it is known that the frequency of mentioning the terms of the reported CATA questions is closely related to the intensity of the attribute. Because of this, compared to other techniques (polarized sensory positioning, projective mapping), it may have less discrimination power (Antúnez et al. 2019). However, it is known that the frequency of mentioning the terms of the reported CATA questions is closely related to the intensity of the attribute (Vidal et al., 2018). Because of this, compared to other techniques, it may have less discrimination power (Antúnez et al., 2017, Vidal et al., 2018).

In marketing, when using market research, Sudman & Bradburn (1982) indicated that respondents may not select a term in mark-all-that-apply because of three main reasons: because they think the term does not apply, because they are neutral or undecided about this term, or because they paid no attention to it. Therefore, if consumers do not select a term in a CATA questionnaire it cannot be concluded that they consider that it does not apply to the product. In addition, it was reported that respondents do not usually engage in an in-depth processing and quick responses tend to select terms that appear near the top of the list rather than those near the bottom of the list (Krosnick, 1999). This effect was also reported for the CATA questionnaire on sensory characterization of food products. Considering that CATA questions do not encourage in-depth involvement of evaluators, there are several aspects related to how the methodology is implemented that deserves further exploration. In this regard, further research into the discriminative ability of CATA questions when working with highly similar products is needed (Ares et al., 2013a).

In addition, the criteria used to select the terms that will be part of the CATA questionnaire can also be the subject of studies, as well as the type and number of terms and the evaluation of layout to enable valid sensory characterization of products with different complexities. The minimum number of evaluators according to each product analyzed remains one of the challenges of the methodology to obtain a relevant statistical analysis (Jaeger et al., 2015).

Taking into account the advantages and limitations of the method, it would be interesting to apply the CATA questionnaire to track sensory terms relevant to a given product and still produce sensory characterization of highly complex products, such as wine, coffee and milk tea. This was exemplified by Campo et al. (2008), Heo et al. (2019) and Choi & Lee (2019), who used long lists, but forced evaluators to select only the most discriminating.

Alternatively, CATA questions could be used to track a large number of product descriptors to select a more detailed sensory subset.

3. Variants of the CATA method

3.1. RATA (Rate-All-That-Apply)

RATA questions are a variant of CATA questions, as consumers are asked to rate the intensity of terms that are applicable to describe the food product (Ares et al., 2014a, 2014b). Overall, the comparison between RATA and CATA shows that both methods provide very similar information as presented by Reinbach et al. (2014), but RATA has a higher discriminative capacity, according to Ares et al. (2014a, 2014b). The method RATA increases the number of selected attribute terms to describe the samples and leads to a small increase in the percentage of terms, which is identified as a significant difference (Meyners, Jaeger & Ares, 2016). Still, the RATA method, an intensity-based CATA variant is more indicated for samples that have subtle differences (Oppermann et al., 2017).

In RATA, when evaluating a sample, the consumer first decides whether a given product attribute applies or not. If applicable, it will also evaluate its intensity. Two rating scales are applicable to this method: a 3-point scale, where 1 = low, 2 = medium and 3 = high and another 5-point scale, to which 1 = slightly applicable and 5 = very applicable. However, when it is identified that a given sample is not applicable, the 3-point RATA scale becomes a 4-point scale (0 = unselected attribute; 1, 2, 3 = selected attribute and intensity classified as 'low', 'medium' and 'high' respectively). Similarly, for scales with a different number of points, such as the 5-point scale, that turns to 6 (Meyners, Jaeger & Ares, 2016).

Vidal et al. (2018) compared the responses obtained with RATA and CATA. With the RATA methodology, a greater number of terms was selected. The authors attributed this difference to the greater effort required to select the terms and classify, compared to simply selecting the terms, which is the routine used at CATA. They mentioned that the fact that judges can select terms and indicate that their intensity is 'low' may lead consumers to select more terms compared to CATA, in which they only need to indicate whether the terms are applicable or not. Thus, in CATA forms, it is possible for consumers to select only the most representative attributes of the samples, whereas in RATA, consumers are stimulated to provide a broader characterization of the samples, with the selection of a greater number of attributes and later indicating their intensity. Thus, the difference between RATA and CATA would not be an

improvement over the questionnaire itself in discriminating the sample, but rather an additional assessment, which according to Ares et al. (2014a, 2014b), would be a methodological superiority. Similarly, Antúnez et al. (2019) mentioned that RATA requires greater cognitive effort, presenting greater discrimination between samples, due to the fact that it has two stages (selection of the terms and after discrimination of intensity).

Analysis of variance (ANOVA) is widely available and the most commonly used tool for investigating sample differences. It also offers an easy approach to properly analyze RATA data, where F tests are used for comparisons of 3 or more products, while t tests are used for paired comparisons (Meyners, Jaeger & Ares, 2016).

The limitation imposed by RATA is related to parametric approximations, which do not imply that the joint scale can surely be considered as continuous (ranging from 0 to the maximum of the scale, to guarantee an attribute). This would, for example, be a problem if the difference between 0 and 1 (not guaranteeing an attribute (0) or guaranteeing it at the lowest level (1)) were interpreted differently by consumers (Vidal et al., 2017).

In this way, it is verified that sensory methods based on consumers, such as CATA and its variants, have developed over time, in order to obtain, in addition to qualitative information, some quantitative information on sensory attributes. Sensory methods with trained judges allow this quantification, although they present the disadvantage of the need for training.

3.2. TCATA (Temporal Check-All-That-Apply)

Interest in assessing the temporal aspects of sensory perception has grown as they offer more realistic data or a complete picture of sensations caused by food products (Rizo et al., 2019, Kemp et al., 2019, Wu et al., 2019). The TCATA is an extension of the classic CATA method, adding a time dimension to the assessment (Meyners & Castura, 2018).

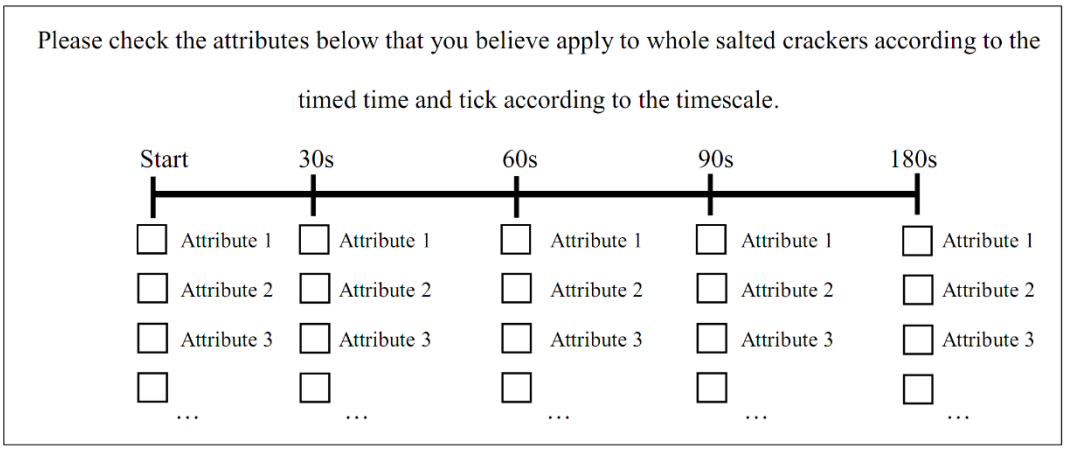
Different temporal sensory methods have been developed to provide an understanding of the sequence of mouth sensations during consumption. This is relevant for many products, especially those with complex matrices, such as wine (Rizo et al., 2019, McMahon et al., 2017), beer (Ramsey et al., 2018, Mitchell et al., 2019), ice cream (Varela, Pintor & Fiszman, 2014), chocolate (Rasinski, Mingay & Bradburn, 1994), lemonade (Rizo et al., 2019), or dairy products (Esmerino et al., 2017).

The most commonly applied temporal sensory method so far has been the Temporal Dominance of Sensations (TDS), originally proposed as a multi-attribute method that has scaled the intensities of a sequence of dominant attributes (Le Calvé et al., 2019). This test is based

only on the selection of the dominant sensation from a list of terms at each moment during the consumption of the product (Schlich, 2017). New variants of the original TDS have been proposed, such as modal TDS (M-TDS) where texture and taste sensations are evaluated separately (Nguyen, Nas & Varela, 2018), or temporal taste drivers (TDL) (Thomas et al. 2015) that uses TDS in conjunction with consumer acceptance (Rizo et al. 2019).

TCATA is, therefore, a similar methodology to those cited, which evaluates the characteristics over time. According to a study by Mitchell et al. (2019), the TCATA method initially consists of selecting some attributes to assemble the questionnaire. These attributes are selected from an initial panel, usually performed by trained evaluators or acquired from some previously conducted study. After selecting the attributes, the participants had to taste a volume of beer sample to their mouths and at the same time pressing the start button of the analysis. The list of sensory attributes (based on cookies) was presented on a digital screen and the evaluators must immediately select all the attributes that they were experiencing at that time (Figure 2). The liquid was kept in the mouth without any mouthwash in order to better approximate normal drinking behavior. After holding the sample in their mouth for ten seconds, participants were asked to swallow with an on-screen reminder and continue clicking on all the attributes they were experiencing. Participants were advised that each term selected disappears after a period of five seconds, and to reselect the term if it still applies at that time. If participants were no longer experiencing sensations at any time, they should not click on any attributes. The total duration of each sample evaluation lasted approximately ninety seconds.

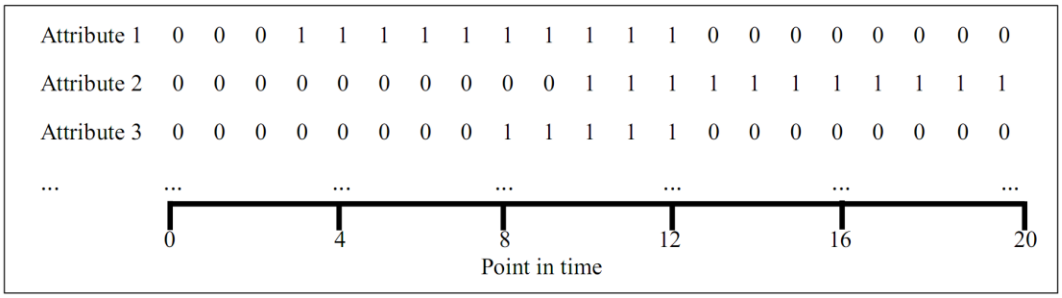
Figure 2: Example of the TCATA questionnaire.



Source: Developed by the authors.

In computational alternatives, a "1" indicates that the corresponding attribute was dominant at its point in time, while a "0" indicates that it was not dominant at that time. By design, each column contains exactly one "1" and "0". Only a single attribute can be dominant at any point in time by constraints imposed by the TDS task. For the TCATA methodology, a simultaneous selection of attributes occurs, so data can no longer be expressed as a sequence of attributes. However, TCATA data can be arranged in a matrix, as shown in Figure 3, very similar to the organization of TDS data showed by Meyners & Pineau (2010), except that the frequency of "1" in a column is not more restricted to a maximum of 1 attribute.

Figure 3: TDS data matrix, with application a TCATA assessment.



Source: Adapted from Meyners & Pineau (2010) and Rizo et al. (2019).

Multivariate analysis test methods have been proposed for TDS data analysis (Meyners & Pineau 2010), and are proposed to analyze TCATA data, while other less intensive alternatives apply to standard methods for TDS and CATA by time point (Rizo et al. 2019). One of the simple and quick ways to analyze TCATA data is to build TCATA curves, one per attribute, as suggested by Castura et al. (2016) and Rizo et al. (2019).

Like any other method, TCATA has its disadvantages, for example: evaluators find it difficult to evaluate because they have to pay attention to two tasks simultaneously (attribute selection and deselection). Larger proportions of this problem were detected at the end of the evaluation (Castura et al., 2016), suggesting that when using TCATA evaluators tend to focus more on continuous selection than term deselection and some attributes may remain selected. even when they are no longer applicable (Ares et al., 2016).

Faced with the disadvantage addressed, a new version of TCATA called TCATA Fading was proposed by Ares et al. (2016). In this TCATA variant, term deselection is automatic and progressive over a predefined duration of a few seconds, so when participants still perceive a term after it has been automatically deselected, they need to select it again (Jaeger et al., 2018).

Therefore, TCATA Fading seems to provide a more accurate description of the sensory dynamics of products during consumption and to improve sample discrimination compared to TCATA (Ares et al. 2016). So far, TCATA Fading has only been used in few studies of different solid food products (Rizo et al., 2019, Ares et al., 2016, Jaeger et al., 2018). For all these studies, the default fading duration was eight seconds, selected by different authors as the most appropriate period to facilitate the evaluator's task.

CATA search lists are known to range from 10 to 30 terms, but in temporal methods the lists are shorter because they require more from evaluators, who must continually focus on the sensory characteristics of samples throughout the evaluation period (Cadena et al., 2014).

The disadvantage found in TCATA Fading is that evaluators may forget to reselect the disappearing attributes, but still apply to the focal sample, resulting in gaps in the dynamic sensory profile (Vidal et al., 2017). However, increased test duration and a longer list of attributes may increase the tendency of evaluators to forget to recheck terms (Rizo et al., 2019). Another drawback for TCATA Fading data is the difficulty of determining whether a term was applied continuously during an interrupted interval or not for a short period. For example, evaluators may perceive an applicable attribute to describe the focal sample at two different times during the evaluation, but not in the period between them.

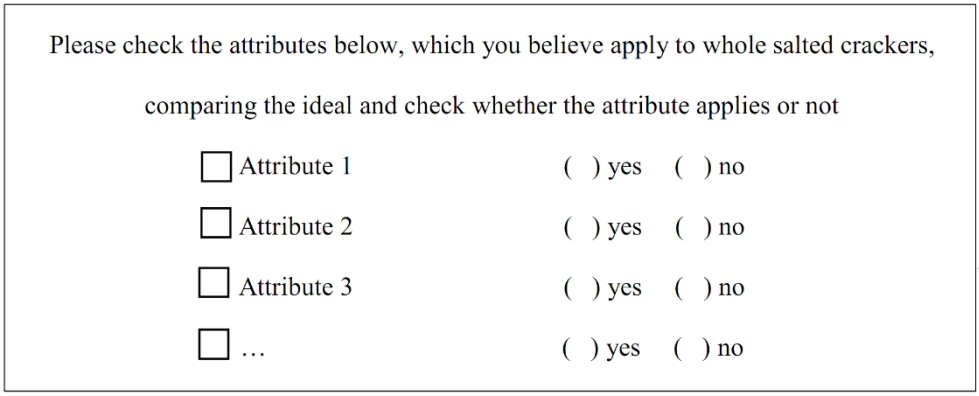
3.3. CATA-I (Optimal Check-All-That-Apply)

One of the CATA variants is CATA-I, which asks consumers to characterize proven products and compare with the ideal product with a questionnaire close to the ideal profile method (IPM) (Worch & Punter, 2015). The CATA-I questionnaire has been used in consumer studies to more easily determine sensory attributes characteristic of a specific product. Several studies were conducted in this line, using products such as: wheat crackers and snacks (Ares et al., 2014c), dairy products (Bruzzone et al., 2015, Ruark et al., 2016) and ham (Henrique, Deliza & Rosenthal 2015). In this test, evaluators use a CATA Yes/No variation for each product compared to the ideal sample (Ruark et al., 2016), as shown in Figure 4.

In a study, Ares et al. (2014c) showed that respondents tend to select the first acceptable response options they read, perhaps not worrying about going through the full list of terms. Because of this, the order of presentation of CATA-I attributes must be balanced in order to force consumers to engage in information processing, as they must meet the entire term list at a time to make their selection. Another limitation was reported by Bruzzone et al. (2015), to

which participants complained about the monotony of evaluating the ideal product after each sample.

Figure 4: Example of CATA-I questionnaire.



Source: Developed by the authors.

Ruark et al. (2016) suggested the consumption of one product per day, making product analysis an acceptable exploratory approach, as it is unlikely that a carryover effect from one product to another will occur beyond sensory tiredness. In contrast, the study ends up becoming longer and longer. In the same study, regarding the comparison of ideal methods (IPM and CATA-I). The authors concluded that CATA-I was the easiest method to use, based on perceived difficulty scores and elapsed time.

4. Final Considerations

The methods presented provide sensory configurations similar to those obtained by conventional descriptive analysis and are efficient in describing products. The use of consumers favors the application of simple methodologies, such as the CATA questionnaire, while the methods TCATA Fading and CATA-I were the easiest among consumers, with smaller limitations and more accurate information, among CATA variants.

In conclusion, the ease of the method is inversely proportional to the ability to discriminate between samples. Therefore, to avoid irreproducible responses, before applying any methodology, the study must take into account the differences between the samples, the complexity of the product itself (whether it is familiar to consumers or not), form of assessment (frequency or intensity).

However, for samples with small differences in intensity of specific attributes, classical descriptive analysis remains the best option, due to the higher accuracy of results, compared to extensively trained evaluators, who work in the identification and clear quantification of defined sensory attributes.

The performance of comparative sensory studies between the results obtained from CATA (and its variations) and the results from classic methods of descriptive analysis can contribute to a better definition of when to use methods based on consumers or trained judges. Consumer-based methods may have more space in the development of new products and in the control of processes in the food industry, in situations involving complaints from customer service, and their relationship with operational process conditions. However, certain off-flavors and more specific characteristics, which depend on small variations in the concentrations of food components and which cause slight changes in sensory attributes, are better perceived by trained judges using conventional methods of descriptive analysis.

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References

Abdi, H., & Williams, L. J. (2010). Correspondence analysis. In: Salkind, N. J., Dougherty, D. M., & Frey, B., Encyclopedia of Research Design, Thousand Oaks, Sage, 267–278.

Adams, J., Williams, A., Lancaster, B., & Foley, M. (2007). Advantages and uses of check-all-that-apply response compared to traditional scaling of attributes for salty snacks. In: 7th Pangborn sensory science symposium.

Alcantara, M. D., & Freitas-Sá, D. D. G. C. (2018). Rapid and versatile sensory descriptive methods–an updating of sensory science. *Brazilian Journal of Food Technology* 21, e2016179.

Alexi, N., Nanou, E., Lazo, O., Guerrero, L., Grigorakis, K., & Byrne, D. V. (2018). Check-All-That-Apply (CATA) with semi-trained assessors: Sensory profiles closer to descriptive analysis or consumer elicited data? *Food Quality and Preference* 64, 11-20.

Antúnez, L., Machín, L., Ares, G., & Jaeger, S. R. (2019). Visual attention to rate-all-that-apply (RATA) questions: A case study with apple images as food stimuli. *Food Quality and Preference* 72, 136-142.

Antúnez, L., Vidal, L., Saldamando, L., Giménez, A., & Ares, G. (2017). Comparison of consumer-based methodologies for sensory characterization: case study with four sample sets of powdered drinks. *Food Quality and Preference* 56, 149-163.

Ares, G. (2015). Methodological challenges in sensory characterization. *Current Opinion in Food Science* 3, 1-5.

Ares, G., Andrade, J. C., Antúnez, L., Alcaire, F., Swaney-Stueve, M., Gordon, S., & Jaeger, S. R. (2017). Hedonic product optimization: CATA questions as alternatives to JAR scales. *Food Quality and Preference* 55, 67-78.

Ares, G., Castura, J. C., Antúnez, L., Vidal, L., Giménez, A., Coste, B., & Jaeger, S. R. (2016). Comparison of two TCATA variants for dynamic sensory characterization of food products. *Food Quality and Preference* 54, 160-172.

Ares, G., Dauber, C., Fernandez, E., Gimenez, A., & Varela, P. (2014a) Penalty analysis based on CATA questions to identify drivers of liking and directions for product reformulation. *Food Quality and Preference* 32: 65-76.

Ares, G., Deliza, R., Barreiro, C., Giménez, A., & Gámbaro, A. (2010). Comparison of two sensory profiling techniques based on consumer perception. *Food Quality and Preference* 21: 417-426.

Ares, G., Etchemendy, E., Antúnez, L., Vidal, L., Giménez, A., & Jaeger, S. R. (2014b). Visual attention by consumers to check-all-that-apply questions: Insights to support methodological development. *Food Quality and Preference* 32, 210-220.

Ares, G., Jaeger, S. R., Bava, C. M., Chheang, S. L., Jin, D., Gim, E., Nez, A., Vidal, L., Fiszman, S. M., & Varela, P. (2013a). CATA questions for sensory product characterization: Raising awareness of biases. *Food Quality and Preference* 30, 114-127.

Ares, G., & Jaeger, S. R. (2013b). Check-all-that-apply questions: Influence of attribute order on sensory product characterization. *Food Quality and Preference* 28, 141-153.

Ares, G., & Jaeger, S. R. (2015). Check-all-that-apply (CATA) questions with consumers in practice: Experimental considerations and impact on outcome. In: Delarue J, Lawlor B (eds) Rapid sensory profiling techniques. Woodhead Publishing, Cambridge. pp 227-245.

Ares, G., Tarrega, A., Izquierdo, L., & Jaeger, S. R. (2014c). Investigation of the number of consumers necessary to obtain stable sample and descriptor configurations from check-all-that-apply (CATA) questions. *Food Quality and Preference* 31, 135-141.

Ares, G., & Varela, P. (2017). Trained vs. consumer panels for analytical testing: Fueling a long lasting debate in the field. *Food Quality and Preference* 61, 9-86.

Ares, G., Varela, P., Rado, G., & Gimenez, A. (2011). Are consumer profiling techniques equivalent for some product categories? The case of orange flavoured powdered drinks. *International Journal of Food Science & Technology* 46, 1600-1608.

Asioli, D., Varela, P., Hersleth, M., Almli, V. L., Olsen, N. V., & Naes, T. (2017). A discussion of recent methodologies for combining sensory and extrinsic product properties in consumer studies. A discussion of recent methodologies for combining sensory and extrinsic product properties in consumer studies. *Food Quality and Preference* 56, 266-273.

Bruzzone, F., Ares, G., & Gimenez, A. (2012). Consumers texture perception of milk desserts. II – Comparison with trained assessor's data. *Journal of Texture Studies* 43, 214-226.

Bruzzone, F., Vidal, L., Antúnez, L., Gimenez, A., Deliza, R., & Ares, G. (2015). Comparison of intensity scales and CATA questions in new product development: Sensory characterization and directions for product reformulation of milk desserts. *Food Quality and Preference* 44, 183-193.

Cadena, R. S., Caimi, D., Jaunarena, I., Lorenzo, I., Vidal, L., Ares, G., Deliza, R., & Giménez, A. (2014). Comparison of rapid sensory characterization methodologies for the development of functional yogurts. *Food Research International* 64, 446-455.

Campo, E., Do, B. V., Ferreira, V., & Valentin, D. (2008). Aroma properties of young Spanish monovarietal white wines: a study using sorting task, list of terms and frequency of citation. *Australian Journal of Grape and Wine Research* 14, 104-115.

Candaten, S., Langaro, L., Vicenzi, C. B., Cavalli, N. C., Colla, L. M. (2018). Avaliação sensorial de biscoitos integrais utilizando questionário CATA. *Anais do Simpósio de Alimentos* 10, 1-6.

Castura, J. C. (2009) Do panellists donkey vote in sensory choose-all-that-apply questions. In: 8th Pangborn Sensory Science Symposium, 26-30, Florence.

Castura, J. C., Antúnez, L., Giménez, A., & Ares, G. (2016). Temporal Check-All-That-Apply (TCATA): A novel dynamic method for characterizing products. *Food Quality and Preference* 47, 79-90.

Choi, Y., & Lee, J. (2019) The effect of extrinsic cues on consumer perception: A study using milk tea products. *Food Quality and Preference* 71, 343-353.

Dooley, L., Lee, Y. S., & Meullenet, J. F. (2010). The application of check-all-that-apply (CATA) consumer profiling to preference mapping of vanilla ice cream and its comparison to classical external preference mapping. *Food Quality and Preference* 21, 394-401.

Dos Santos, B. A., Campagnol, P. B., Da Cruz, A, G., Galvão, M. T. E. L., Monteiro, R. A., Wagner, R., & Pollonio, M. A. R. (2015). Check all that apply and free listing to describe the sensory characteristics of low sodium dry fermented sausages: Comparison with trained panel. *Food Research International* 76, 725-734.

Drake, M. A. (2007). Invited review: sensory analysis of dairy Foods. *Journal of Dairy Science* 90, 4925-4937.

Esmerino, E. A., Castura, J. C., Ferraz, J. P., Tavares Filho, E. R., Silva, R., Cruz, A. G., & Bolini, H. M. (2017). Dynamic profiling of different ready-to-drink fermented dairy products: A comparative study using Temporal Check-All-That-Apply (TCATA), Temporal Dominance of Sensations (TDS) and Progressive Profile (PP). *Food Research International* 101, 249-258.

Greenacre, M, (2007). Correspondence analysis in practice. Chapman and Hall/CRC, London.

Henrique, N. A., Deliza, R., & Rosenthal, A. (2015). Consumer Sensory Characterization of Cooked Ham Using the Check-all-that-apply (CATA) Methodology. *Food Engineering Reviews* 7, 265-273.

Heo, J., Choi, K. S., Wang, S., Adhikari, K., & Lee, J. (2019). Cold Brew Coffee: Consumer Acceptability and Characterization Using the Check-All-That-Apply (CATA) Method. *Foods* 8, 344.

Jaeger, S. R., Alcaire, F., Hunter, D. C., Jin, D., Castura, J. C., & Ares, G. (2018). Number of terms to use in temporal check-all-that-apply studies (TCATA and TCATA Fading) for sensory product characterization by consumers. *Food Quality and Preference* 64, 154-159.

Jaeger, S. R., Beresford, M. K., Paisley, A. G., Antúnez, L., Vidal, L., Cadena, R. S., Giménez, A., & Ares, G. (2015). Check-all-that-apply (CATA) questions for sensory product characterization by consumers: Investigations into the number of terms used in CATA questions. *Food Quality and Preference* 42, 154-164.

Jaeger, S. R., Fiszman, S., Reis, F., Chheang, S. L., Kam, K., Pineau, B., Deliza, R., & Ares, G. (2017). Influence of evoked contexts on hedonic product discrimination and sensory characterizations using CATA questions. *Food Quality and Preference* 56, 138-148.

Jaeger, S., Leang-Chheang, S., Yin, J., Bava, C. M., Gimenez, A., Vidal, L., & Ares, G. (2013). Check-all-that-apply (CATA) responses elicited by consumers: within-assessor reproducibility and stability of sensory product characterizations. *Food Quality and Preference* 30, 56-67.

Kemp, S. E. (2013). Consumers as part of food and beverage industry innovation. In: Martinez MG (ed) Open innovation in the food and beverage industry. Woodhead Publishing, Cambridge, 109-138.

Kemp, B., Trussler, S., Willwerth, J., & Inglis, D. (2019). Applying temporal check-all-that-apply (TCATA) to mouthfeel and texture properties of red wines. Journal Sensory Studies 34: e12503.

Krosnick JA (1999) Survey research. *Annual Review of Psychology* 50, 537-567.

Lado, J., Vicente, E., Manzzioni, V., & Ares, G. (2010). Application of a check-all-that-apply question for the evaluation of strawberry cultivars from a breeding program. *Journal of the Science of Food and Agriculture* 90, 2268-2275.

Le Calvé, B., Saint-Léger, C., Gaudreau, N., & Cayeux, I. (2019). Capturing key sensory moments during biscuit consumption: Using TDS to evaluate several concurrent sensory modalities. *Journal of Sensory Studies* 34, e12529.

Mammasse, N., & Schlich, P. (2014). Adequate number of consumers in a liking test. Insights from resampling in seven studies. *Food Quality and Preference* 31, 124–128.

McMahon, K. M., Culver, C., Castura, J. C., & Ross, C. F. (2017). Perception of carbonation in sparkling wines using descriptive analysis (da) and temporal check-all-that-apply (TCATA). *Food Quality and Preference* 59, 14-26.

Meyners, M., & Castura, J. (2014). Check All That Apply Questions. Novel Techniques in Sensory Characterization and Consumer Profiling.

Meyners, M., & Castura, J. C. (2016). Randomization of CATA attributes: Should attribute lists be allocated to assessors or to samples? *Food Quality and Preference* 48, 210-215.

Meyners, M., & Castura, J. C. (2018). The analysis of temporal check-all-that-apply (TCATA) data. *Food Quality and Preference* 67, 67-76.

Meyners, M., Castura, J. C., & Carr, B. T. (2013). Existing and new approaches for the analysis of CATA data. *Food Quality and Preference* 30, 309-319.

Meyners, M., Jaeger, S. R., & Ares, G. (2016). On the analysis of rate-all-that-apply (RATA) data. *Food Quality and Preference* 49, 1-10.

Meyners, M., & Pineau, N. (2010). Statistical inference for temporal dominance of sensations data using randomization tests. *Food Quality and Preference* 21, 805-814.

Mitchell, J., Castura, J. C., Thibodeau, M., & Pickering, G. (2019). Application of TCATA to examine variation in beer perception due to thermal taste status. Food Quality and Preference 73, 135-142.

Nguyen, Q. C., Nas, T., & Varela, P. (2018). When the choice of the temporal method does make a difference: TCATA, TDS and TDS by modality for characterizing semi-solid foods. *Food Quality and Preference* 66, 95-106.

Oppermann, A. K. L., Graaf, C., Scholten, E., Stieger, M., & Piqueras-Fiszman, B. (2017). Comparison of Rate-All-That-Apply (RATA) and Descriptive Sensory Analysis (DA) of model double emulsions with subtle perceptual diferences. *Food Quality and Preference* 56, 55-68.

Parente, M. E., Ares, G., & Manzoni, A. V. (2011). Application of two consumer profiling techniques to cosmetic emulsions. *Journal of Sensory Studies* 2, 685-705.

Plaehn, D. (2012). CATA penalty/reward. Food Quality and Preference, 24, 141-152.

Ramsey, I., Ross, C., Ford, R., Fisk, I., Yang, Q., Gomez-Lopez, J., & Hort, J. (2018). Using a combined temporal approach to evaluate the influence of ethanol concentration on liking and sensory attributes of lager beer. *Food Quality and Preference* 68, 292-303.

Rasinski, K. A., Mingay, D., & Bradburn, N. M. (1994). Do respondents really “mark all that apply” on self-administered questions? *Public Opinion Quarterly* 58, 400-408.

Reinbach, H. C., Giacalone, D., Ribeiro, L. M., Bredie, W. L., & Frost, M. B. (2014). Comparison of three sensory profiling methods based on consumer perception: CATA, CATA with intensity and Napping®. *Food Quality and Preference* 32, 160-166.

Rizo, A., Peña, E., Alarcon-Rojo, A. D., Fiszman, S., & Tárrega, A. (2019). Relating texture perception of cooked ham to the bolus evolution in the mouth. *Food Research International* 118, 4-12.

Ruark, A., Vingerhoeds, M. H., Kremer, S., Nijenhuis-de Vries, M. A., & Piqueras-Fiszman, B. (2016). Insights on older adults' perception of at-home sensory-hedonic methods: A case of Ideal Profile Method and CATA with ideal. *Food Quality and Preference* 53, 29-38.

Schlich, P. (2017). Temporal Dominance of Sensations (TDS): A new deal for temporal sensory analysis. *Current Opinion in Food Science* 15, 38-42.

Tate, M. W., & Brown, S. M. (1970). Note on the Cochran Q test. Journal of the American Statistical Association 65, 155-160.

Thomas, A., Visalli, M., Cordelle, S., & Schlich, P. (2015). Temporal drivers of liking. *Food Quality and Preference* 40, 365-375.

Varela, P., & Ares, G. (2012). Sensory profiling, the blurred line between sensory and consumer science. A review of novel methods for product characterization. *Food Research International* 48, 893-908.

Varela, P., Pintor, A., & Fiszman, S. (2014). How hydrocolloids affect the temporal oral perception of ice cream. *Food Hydrocolloids* 36, 220-228.

Vidal, L., Ares, G., Hedderley, D. I., Meyners, M., & Jaeger, S. R. (2018). Comparison of rate-all-that-apply (RATA) and check-all-that-apply (CATA) questions across seven consumer studies. *Food Quality and Preference* 67, 49-58.

Vidal, L., Castura, J. C., Coste, B., Picallo, A., Jaeger, S. R., & Ares, G. (2017). Analysis of TCATA Fading data: Imputation of gaps in temporal profiles. *Food Quality and Preference* 59, 114-212.

Worch, T., & Punter, P. H. (2015) Ideal profiling as a sensory profiling technique. In: Delarue J, Lawlor JB, Rogeaux M (eds) Rapid Sensory Profiling Techniques, Woodhead Publishing, Cambridge, pp. 307-332.

Wu, A. Z., Lee, R. W., Le Calvé, B., & Cayeux, I. (2019). Temporal profiling of simplified lemonade using temporal dominance of sensations and temporal check-all-that-apply. *Journal Sensory Studies* 34, e12531.

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