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Perception of carbonation in sparkling wines using descriptive analysis (DA) and temporal check-all-that-apply (TCATA)

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The authors dedicate this paper to the memory of our co-author, collaborator and friend, Mr. Caleb Culver.

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ABSTRACT

Several methods exist in order to profile complex matrices that change over time. In this study, two descriptive methodologies, descriptive analysis (DA) and temporal check-all-that-apply (TCATA) were used to analyze the complex perceptions associated with carbonation and compare the profiles from each method. To accomplish this, eleven sparkling wines of different carbonation (CO_2) levels were prepared through the addition of varying concentrations of dextrose during the winemaking process. Sparkling wines containing 0.0–7.5 g CO_2/L ($p < 0.05$) were evaluated by a trained panel ($n = 11$) using DA for mouthfeel attributes associated with CO_2, as well as taste, aroma, and flavor attributes. From the DA results, canonical variates analysis (CVA) showed that the mouthfeel attributes explained most of the variation among the wine treatments, with increased CO_2 concentrations in the wine treatments resulting in increased intensity of mouthfeel attributes. While DA provides intensity-laden results, carbonation changes with time and as such the sparkling wines were also evaluated by a trained panel ($n = 13$) using TCATA methodology to describe temporal changes in mouthfeel and taste perceptions. TCATA curves suggested a relative grouping of attributes: attributes that were perceived earlier in the evaluation time (peak citation <15 s into evaluation), and attributes with a delayed onset of perception (>15 s into evaluation). Principal component analysis (PCA) was used to obtain wine treatment trajectories and enable the visualization of attribute perception over time. Multiple factor analysis (MFA) showed all the mouthfeel attributes evaluated by both TCATA and DA were highly correlated ($RV = 0.98$; $p < 0.0001$), suggesting that both methods were similar in their ability to distinguish between carbonated wine treatments. The results of this study highlight the application of TCATA methodology to describe CO_2 perception, which produces complex temporal sensations.

1. Introduction

Measurement of carbonation perception is a difficult task for the sensory evaluation professional. Previous studies have demonstrated that the perception of carbonation is auditory (Spence & Zampini, 2006), visual (Liger-Belair, Beaumont, Jeandet, & Polidori, 2007), with nociceptive (Wang, Chang, & Liman, 2010), mechanosenory (Rofes, Cola, & Clavé, 2014), and chemosensory origins (Smith, Martinez-Velazquez, & Ringstad, 2013). Static methods of sensory evaluation are based on the notion that perception is an average of the entire sensory experience. However, as carbonation perception encompasses mouthfeel attributes that evolve and change over time, the application of temporal sensory evaluation methods may possibly provide a more accurate depiction of the full sensory experience. Such temporal methods, including Time-Intensity (TI), have been used previously in wine to study the changing perception of astringency (Guinard, Pangborn, & Lewis, 1986), bitterness (Robichaud & Noble, 1990; Sokolowsky & Fischer, 2012), and wine finish (Baker & Ross, 2014). The information TI provides is the progression and diminution of intensity over time for one or two attributes under study.

While TI provides valuable information regarding the temporality of an attribute, one challenge associated with this method is that the panelist is limited to the evaluation of only one or two attributes at a time, thus risking a halo-dumping effect (Clark & Lawless, 1994). Temporal Dominance of Sensations (TDS) allows each panelist to continually indicate the dominant attribute,

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usually from a list of up to ten attributes (Pineau et al., 2012). Several studies have applied TDS to study wine taste and flavor (Pessina, Boivin, Moio, & Schlich, 2005), to describe subtleties in dealcoholized red wine (Meillon, Urbano, & Schlich, 2009), and to describe bitterness in white wine (Sokolowsky & Fischer, 2012). However, the challenge with TDS is that non-dominant attributes, which are still important to the product profiles, are not captured.

A more recent method, temporal check-all-that-apply (TCATA), allows for the simultaneous identification of both non-dominant and dominant attributes that characterize the products (Castura, Antúnez, Giménez, & Ares, 2016; Castura, Baker, & Ross, 2016). Using this method, panelists are instructed to evaluate the product over time and constantly check and uncheck the attributes as they are or are not perceived, respectively. Researchers have applied TCATA to evaluate a wide range of products, including orange juice and yogurt (Castura, Antúnez et al., 2016; Castura, Baker et al., 2016), cosmetic creams (Boinbaser, Parente, Castura, & Ares, 2015), chocolate milk (Oliveira et al., 2015), salami, cheese, French bread, and marinated mussels (Ares et al., 2015), and red wine finish (Baker, Castura, & Ross, 2016). However, TCATA has not yet been applied to describe the perception of carbonation.

Several studies have sought to describe the relationship between CO_2, the source of effervescence in sparkling wine, and the perception of specific sensory properties. This has been approached through the development of descriptive lexicons for the perception of carbonation. Recently, a sparkling wine-specific lexicon was developed to further detail the complex perceptions related to this style of wine, with attributes including nasal pungency aroma, as well as the mouthfeel attributes of bubble pain, creamy, and foamy (Le Barbé, 2014). Moreover, a mouthfeel wheel for white wine was developed and incorporated attributes related to carbonation, such as tingle and mousse dynamics (Pickering & Demiglio, 2008). Other profiling studies developed vocabulary to describe carbonation-related attributes for non-wine beverages, with terms including bite, burn, numbing, and carbonation for lemon-lime sodas (Kappes, Schmidt, & Lee, 2006) and bubbly, bubble size, bubble sound, and gas expansion for carbonated water (Harper & McDaniel, 1993).

The overall objective of the present study was to describe the sensory aspects associated with carbonation in sparkling wines using both static (DA) and dynamic (TCATA) sensory evaluation methods, with a comparison offered between these two methods. Ultimately, this study will provide further insight into the complexity of CO_2 perception over time and allow for the comparison of results collected using static and dynamic sensory methods.

2. Materials and methods

2.1. Wine samples

Details about the production and final wine chemistry of the sparkling wines maybe found in another publication (McMahon, Culver, & Ross, 2017). The CO_2/L concentrations of the sparkling wines were 0, 1.2, 2.0, 2.8, 3.1, 4.0, 4.6, 4.9, 5.8, 6.7, and 7.5 g CO_2/L. The CO_2/L concentrations were measured using an Anton-Paar CarboQC device (Ashland, VA, USA). Wines were stored at 4.4 °C until analysis and transferred to a 3 °C refrigerator for 24 h prior to sensory evaluation.

2.2. Sensory Analysis Facility

Evaluation took place in individual tasting booths under white lights at Washington State University's (WSU) Sensory Evaluation Facility, a member of the Compusense Academic Consortium (Guelph, Canada). The use of human subjects for this study was approved by the Washington State University Institutional Review Board (IRB #13422-003).

2.3. Descriptive analysis (DA)

2.3.1. Demographic overview

Eleven volunteers were recruited from the Pullman, WA community using electronic advertisements (*e.g.* listserv, emails, and school advertisements). Past experience in wine, beer, or sensory evaluation was a requirement for participation in the trained panel. The panel consisted of eight males and three females (mean age of 25.4 years) who all indicated they consumed sparkling wine at least several times per year, or less than once a month. Additionally, all panelists indicated that they liked sparkling wines. All panelists expressed interest in learning more about sparkling wine. Panelists received a small nonmonetary compensation for their participation at the end of each training session.

2.3.2. Training

Panelists were trained over eight, one-hour sessions. During the first session, demographic information was collected and the evaluation protocol was introduced. More detailed instructions included no swirling of the glass, holding the stem of the flute, and no gurgling or swishing the wine in-mouth. This protocol was based on preliminary bench trials to minimize CO_2 loss during evaluation and considered other studies documenting the effect of surface area, temperature, and kinetic motion of CO_2 loss (Liger-Belair et al., 2010; Yau & McDaniel, 1990: Yau, McDaniel, & Bodyfelt, 1989).

Panelists were trained using commercial and experimental sparkling wines of different carbonation levels, varietal, and dosage level, including non-dosed, *brut*, Vinho Verde, *Methodé Champenoise*, and Charmat style sparkling wines. Initial training of panelists identified and evaluated salient mouthfeel attributes associated with sparkling wines. Subsequent training sessions expanded the attribute list to include appropriate aroma, flavor, and taste attributes. The definition and reference standard for each attribute are shown in Table 1. These attributes and definitions were developed in reference to published literature (Harper & McDaniel, 1993; Kappes et al., 2006; Le Barbé, 2014; McLellan, Barnard, & Queale, 1984; Pickering & Demiglio, 2008), benchwork prior to training sessions, and panel consensus on attribute definitions. All attributes were evaluated using an unstructured 15-cm line scale, anchored with "low" at 1.5 cm and "high" at 13.5 cm. Panelist training and performance were monitored for discrimination and consistency among the panelists when blindly presented with reference standards prepared in wines, as well as a range of treatment wines. During training sessions, repeatability was also assessed using replicate samples.

2.3.3. Evaluation sessions

For profiling of the sparkling wine samples, four formal evaluation sessions were conducted over two days, allowing for replicate evaluations of each treatment by each panelist. Wine samples (~30 mL) were labelled with three-digit codes and served at 8–9 °C in wine flute tasting glasses (SKU: 71086, Cardinal International, Inc., Pine Brook, NJ) covered with a petri dish. Wines were presented using a randomized complete block design blocked by session (Boinbaser et al., 2015; Castura, Antúnez et al., 2016; Castura, Baker et al., 2016). During each evaluation session, two randomly selected bottles of each CO_2 treatment were opened. Each bottle served no more than eight panelists so as to avoid significant CO_2 losses from the kinetics of pouring. Moreover, wines were poured beer-style into sparkling wine flutes to minimize CO_2 losses (Liger-Belair et al., 2010). Beer-style pouring involves tilting the glass at a 45° angle and pouring the wine down the side