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Review

Mouthfeel perception of wine: Oral physiology, components and instrumental characterization

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A B S T R A C T

Background: Wine mouthfeel sensations are recognized as important as wine appearance, aroma or taste, although they are not fully understood. The majority of the current research is towards the identification of the wine components but without understanding the influence of human oral physiology and the mouthfeel perception.

Scope and approach: This review provides an integrated synopsis of wine mouthfeel including its oral-related physiology, main wine components, and instrumental characterisation of this sensory perception. Mechanoreceptors and saliva are detailed as key factors in mouthfeel physiology. Influence of ethanol, glycerol, polyphenols and polysaccharides, role in body perception, viscosity, density, and astringency is described. To measure these sensations, different instrumental techniques, not traditionally explored in wine science, such as rheology or tribology are discussed and how their future use could help in the understanding of mouthfeel.

Key finding and conclusion: Although there are studies regarding the change of saliva with astringent components, new advances covering the whole wine matrix are need to identify which wine components are in contact with mouth surfaces, and their mechanisms of perception. Apart of alcohols, polysaccharides play an important role commonly omitted. Whilst ethanol viscosity influence has being proved important, glycerol does not influence sensations at levels present in wines. Independently of its chemical structure, polyphenols produce astringency feelings measured by tribology or potentially by nano-indentation. Future trends in oenology research could be directed to help wine producers to adjust the right mouthfeel characteristics for each wine type or even open a wider market for wine by-products.

Introduction

Wine creates mouthfeel sensations of astringency, body, burning, balance, pricking (Jackson, 2009), warmth and viscosity (Gawel, Oberholster, & Francis, 2000). All of these non-taste sensations are a consequence of oral-tactile stimulations and although they are as important as wine appearance, aroma and taste, currently are not fully understood. In previous works researchers have used different names to characterise them, such as tactile perception, because it is related with the tactile sense (Breslin, Gilmore, Beauchamp, & Green, 1993; Jacobs et al., 2002); mechanical perception, because it is sense by mechanoreceptors (Dresselhuis, Dehoog, Cohenstuart, & Vanaken, 2008); or more generally used mouthfeel (Gawel, Schulkin, Day, Barker, & Smith, 2016; Gawel et al., 2000; Pickering, Simunkova, & DiBattista, 2004; Vidal et al., 2004; van Aken, 2010). In this work the term mouthfeel is the main focus, defined by DeMiglio, Pickering, and Reynolds (2002) as "the *group of sensations characterised by a tactile response in the mouth*", and it is not referred to sapid sensations. Other used terms like tactile perception was not chosen because it is generally a measure of single point sensitivity (Jacobs et al., 2002) and as we wanted to emphasize the role of the salivary pellicle and the whole mouth integration, this term was considered not broad enough. The term mechanical perception was not used because it is often referred to as the study of solid deformation.

Wine mouthfeel could be characterised by a combination of instrumental techniques based on fluid behaviour and frictional forces. The fluid behaviour characterisation has been extensively used by food researchers, however, as Bourne (1975) cited *"the rheological tests describe only a portion of the physical properties sensed in the mouth".*

In order to overcome the rheology limitation and to be able to

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characterise instrumentally more in-mouth sensations, in the last couple of years soft-tribology has been implemented (Chen & Stokes, 2012) and recently it has been proposed to be used to quantify astringency in wine (Brossard, Cai, Osorio, Bordeu, & Chen, 2016). However, as it has been discussed previously, wine sensations are more than flow (i.e. viscosity) or friction (i.e. astringency), and other instrumental techniques are also needed to complete this information.

Opposite of other drinkable liquids, wines' mouthfeel has multiple attributes that appear and remain over time. The need to capture this dynamic process and assemble all of the texture sensations in one picture will help explain the use of sensory analysis techniques. Traditionally, sensory analysis techniques are divided into three primary groups. If the aim is to find overall differences among products, discrimination techniques are used; if there is a need for describing and quantifying products characteristics, descriptive analysis techniques (DAT) are used; however, if the objective is to measure consumer likes and dislikes, affective or hedonic sensory techniques are needed (Lawless & Heymann, 2010).

DAT are generally used to define sensory-instrumental relationships (Lawless & Heymann, 2010). Even though there are many attribute descriptors used in wine, sensory characterisation related to the temporality, attack, length in mouth, persistence or the aftertaste (Meillon, Urbano, & Schlich, 2009) are not able to be recorded by DAT. For that reason, dynamic sensory methodologies such as the "time-intensity" (TI) (Holway & Hurvich, 1937) that measures one attributes intensity over time or Temporal dominance of sensation (TDS), where panellist select the dominant attribute over time up to the moment the sensation ends (Pineau et al., 2009), seems to complement the previous sensory and instrumental techniques.

The wine components that are generally cited for providing texture include ethanol, glycerol, residual sugars, polysaccharides, carbon dioxide, and polyphenols. However, from both points of view, instrumental and sensory, the number of published papers in direct relation with the wine mouthfeel response is scarce. Until now the relation between wine components and mouthfeel is not clear. In the future, if wine mouthfeel is instrumentally measured, it could allow wineries to have a faster and cheaper characterisation in comparison to the expensive wine expert panels that are currently used. Furthermore, how to capture all of the sensory feelings with instrumental technique is certainly a difficult task.

With the final goal to contribute to the development of an accurate instrumental measurement of the mouthfeel sensations, this review has two objectives: the first objective is to understand the mouthfeel generated by wine consumption and how its components (ethanol, glycerol, phenolic compounds, and polysaccharides) play different roles in contact with the mouth surfaces. As a secondary objective, this paper reviews the current instrumental techniques that could mimic and quantify these oral feelings and may help with the understanding of wine mouthfeel.

The review objectives will be presented in several sections. Firstly in Section 1, is given a description of the mouth physiology and wine mouthfeel perception for an essential understanding of oro-sensory neurophysiology. Then, Section 2 reviews the published research regarding the main wine components and its association with mouthfeel; this is linked with Section 3 that describes which techniques could characterise the sensory perception. Finally, Section 4 summarizes the finding and proposes future trends for wine mouthfeel understanding and instrumental measurement.

1. Physiology of the mouthfeel sensations: mechanoreceptors and saliva

As occurs with other liquids, the first contact of wines with the oral cavity is with the lips, moving inside the mouth and interacting with most of the oral surfaces (palate, chicks, tongue), these interactions lead to the mouthfeel perception (Kravchuk, Torley, & Stokes, 2012).

In the mouth, coexists four different types of papillae: filiform, fungiform, foliate and circumvallate (Orban & Bhaskar, 1980). It is believed that non-taste papillae (filiform) are responsible for mouthfeel perception. As Fig. 1 shows (fungiform papillae as example for comparison), different to other papillae, filiform papillae are hairy-like, the most numerous and lack taste receptors, that is why they are believed to play an important role in the mechanical perception (Hand & Frank, 2014). Furthermore they are highly innervated by free nerves endings (also called tactile sensors). The filiform papillae are made up of primary papillae with connective tissue, attached at the dorsal surface by a secondary papillae of connective tissue, creating a structure that has a certain grip to hold onto food material (van Aken, 2010). Filiform papillae respond to mechanical, thermal and nociceptive stimulus, that will transfer any sensory input by the trigeminal nerve through the trigeminal ganglion to the brainstem (Jacobs et al., 2002). This would indicate that filiform papillae and mechanoreceptors are the keys of mouthfeel; however literature lacks studies regarding oral epithelium interaction with wine components. To our knowledge, there is just one promising study about procyanidin binding to oral epithelial cells in relation to astringency perception (Payne, Bowyer, Herderich, & Bastian, 2009).

Saliva is the other main physiological component related to mouthfeel. Human saliva is composed of water (99.5%), proteins (mucins, proline-rich proteins and enzymes) (0.3%), and inorganic substances (0.2%). Mucins, acidic proline-rich proteins (PRPs), statherin, histatins (or histidine-rich protein), and cystatins, bind to the enamel surface, forming a salivary pellicle (Hand & Frank, 2014). Although saliva pellicle flows easily as consequences of shear forces, part of the saliva remains on oral surfaces lubricating and protecting them. Additionally, salivary glands are constantly secreting saliva, helping to maintain this saliva pellicle thickness that varies upon mouth location, but is in average 70–100 μm (Collins & Dawes, 1987; Gibbins & Carpenter, 2013).

Salivary proteins secreted by parotid glands have the highest phenol-binding capacity (Bennick, 2002), whilst submandibular and sublingual glands produce mucin for the correct mouth lubrication (Becerra et al., 2003). Salivary pellicle grows in the oral cavity as exposure of saliva increases (Dickinson & Mann, 2006). Its mechanical properties are often studied in dental research as a key point due to its role in the dental plaque development (Dickinson & Mann, 2006) or extrinsic stain on teeth (Gibbins, Proctor, Yakubov, Wilson, & Carpenter, 2015), hypothesized that oral mucosa is hydrophobic until salivary proteins bind, and probably the small proteins (statherin) could act as "precursors" of pellicle proteins. The negatively charged mucins and glycoproteins with abundant bound water, maintain lubrication of oral surfaces, protecting from irritation and abrasion during speaking, chewing and swallowing (Hand & Frank, 2014).

It has been suggested that saliva has an important effect on aroma release from wine and this effect was different depending on wine matrix composition (Munoz-Gonzalez et al., 2014). The interaction of aroma compounds with other proteins, different from mucin or the formation of complexes involving saliva glycoproteins–wine polyphenols–wine polysaccharides and aroma compounds, preferentially for those hydrophobic, seems to be responsible for the observed effect.

There are many studies regarding the change of saliva with astringent components; however to know the saliva alterations in presence of ethanol, glycerol or polysaccharides are yet to be investigated.