



ORIGINAL RESEARCH ARTICLES

Sensory transfer between handfeel touch and mouthfeel: A guide for developing a tool to describe mouthfeel properties of red wines

María-Pilar Sáenz-Navajas^{1*}, Rubén Barroso-Martínez¹, Carolina Castillo¹, Purificación Fernández-Zurbano¹, Marivel Gonzalez¹, Brezo Alcoceba², Dominique Valentin³

¹ Instituto de Ciencias de la Vid y del Vino (ICV) (UR-CSIC-GR), Carretera de Burgos Km. 6, Finca La Grajera, 26007 Logroño, La Rioja, Spain

² Escuela Superior de Diseño de Madrid (ESDM), Madrid, Spain

³ Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRAE, Université Bourgogne Franche-Comté, Dijon, France

Article number: 8395



*correspondence:
mpsaenz@icvv.es

Associate editor:
Sophie Tempère



Received:
20 November 2024

Accepted:
24 February 2025

Published:
20 March 2025



This article is published under the **Creative Commons licence** (CC BY 4.0).

Use of all or part of the content of this article must mention the authors, the year of publication, the title, the name of the journal, the volume, the pages and the DOI in compliance with the information given above.

ABSTRACT

The importance of mouthfeel in the comprehensive evaluation of red wine quality is widely acknowledged; however, instruments that are capable of differentiating between wines based on this attribute are scarce. The objective of this study was to develop handfeel touch reference materials that can be used to describe mouthfeel characteristics of red wine. This was achieved through a transdisciplinary approach based on the hypothesis that sensory transfer occurs between handfeel and mouthfeel. An initial list of 44 mouthfeel terms was compiled by 193 technical experts, wine sellers and regular consumers, from which 25 terms were selected for further consideration. Applying an art-based methodology, 74 handfeel touch reference standards were developed to exemplify the 25 mouthfeel terms. First, the capacity of the tactile references to differentiate between red wines was validated through a check-all-that-apply (CATA) strategy, with 31 participants describing six red wines. Then a sorting task was conducted on the 74 references, and the 19 most discriminant references were selected for inclusion in a final set of handfeel touch reference materials.

The findings support the initial hypothesis of the study, namely that sensory associations exist between handfeel and wine mouthfeel. The results demonstrate that differences in the mouthfeel properties of wines can be described by the proposed CATA-based approach involving handfeel touch references. This confirms the sensory correspondence of handfeel cues and mouthfeel sensations elicited by red wines. The study provides practical guidelines for the development of reference materials that can be used to describe wine perception and to explore the mouthfeel perceptual space of wines.

KEYWORDS: mechanoreceptors, sensory correspondences, transdisciplinary, art-science, perception

INTRODUCTION

Wine mouthfeel is one of the most important characteristics for wine appreciation, along with appearance and flavour (Araujo *et al.*, 2021; Hopfer & Heymann, 2014; Sáenz-Navajas *et al.*, 2016). While wine researchers have largely invested efforts in disentangling the physicochemical and psychological underpinnings of wine aroma, much less attention has been paid to wine mouthfeel. In this regard, in his book, Rigaux (2015) states that current wine tasting focuses mainly on the olfactory and aromatic attributes of wines, leaving aside wine mouthfeel. The author calls for wine tasting in which wine appreciation focuses on mouthfeel, consistency, suppleness or viscosity to infer wine quality. Scientific studies that relate wine appreciation to wine sensory properties tend to be limited to measuring a few mouthfeel-related terms, such as overall astringency, drying, hot sensation, body and viscosity (Hopfer & Heymann, 2014; Pissoni *et al.*, 2023), which contrasts with the large range of aroma terms used to characterise wines (Noble *et al.*, 1987). Interestingly, an increasing number of studies have been published on this topic in the last decade (Araujo *et al.*, 2021; Pissoni *et al.*, 2020; Rinaldi *et al.*, 2020; Niimi *et al.*, 2017; Sáenz-Navajas *et al.*, 2017; Vidal *et al.*, 2015). In their pioneering work, Gawel *et al.* (2000) published a red wine mouthfeel wheel created by wine experts. The authors provided semantic definitions for each of the terms and defined a limited number of them by giving handfeel touch examples when a consensual verbal definition could not be achieved. Despite the importance of this work for the study and evaluation of wine texture, the use in scientific publications of the mouthfeel vocabulary generated in this work is limited, which could be due to a certain lack of clarity in the terminology, as well as the necessity for extensive panel training. Two main categories appear in the wheel: astringency and non-astringency terms. Within the non-astringency category, six more specific categories are included (flavour, acidity, weight, texture, heat and irritation), which refer to several sensory modalities (aroma, taste and mouthfeel) and could lead to misunderstandings. The astringency category is made up of seven specific terms: particulate, surface smoothness, complex, drying, dynamic, harsh and unripe, whose definitions are somewhat confusing, as some terms are linked to hedonic properties. For example, the complex category is defined as “a positive hedonic grouping consisting of an amalgam of pleasing astringency sensations, flavour and balanced acidity”. Similarly, the terms harsh and unripe are associated with negative hedonic properties. In addition, some of the terms included in the astringency category are related to other sensory modalities that differ from mouthfeel, such as aroma for rich or flesh, or tastes for hard (bitterness), green (acidity), supple (acidity) or sappy (acid, bitter), which leads to multidimensional terms. There are also terms that are defined on the basis of the level of intensity of a given attribute. These include aggressive (excessive astringency), abrasive (excessive astringency of a strongly roughing nature), soft (light and finely textured astringency) or supple (low to moderate astringency). Lawless

and Civille (2013) have already highlighted that terms related to mouthfeel should be reviewed and clarified in order to broaden their application in formal descriptive analysis. In response to this concern, Pissoni *et al.* (2023) reviewed recent publications focused on understanding and describing mouthfeel. They concluded that the scientific community has not yet defined a common vocabulary to communicate oral sensory perceptions, calling for the homogenisation of definitions and references, and consequently of the use of mouthfeel descriptors. The authors conclude by stating: “When we judge a wine, we should all speak the same sensory language”. To achieve this goal, we should start by understanding the concept of mouthfeel, which requires the examination of the processes linked to this concept, namely sensation and perception.

Sensation, in general, can be defined as the input resulting from the activation of receptors in response to a given stimulus (Coren, 2003). The sensation of mouthfeel is based on inputs from mechanoreceptors present in the oral surface that respond to mechanical events, mainly stress and strain caused by indentation and the stretching of tissues (Foegeding *et al.*, 2015). Studies of skin receptors in the human hand (mainly the palmar side of the hand and fingers) provide a basis for understanding human oral receptors, as both surfaces are innervated by very similar nerve fibres (Di Stefano & Spence, 2022). The only known difference between facial and extra-facial afferents are those associated with a class of receptors (Pacinian corpuscles) that have not been observed in most oral tissues (Trulsson & Johansson, 2002). It is important to note that a particular mouthfeel is not the result of the activation of a single mechanoreceptor, but of a combination of signals activated in a receptive field or population of receptive fields (Foegeding *et al.*, 2015). The analogy between oral cavity and fingertip sensation has also been reported for mouthfeel, with the simultaneous activation of multiple mechanoreceptors rather than a single one (Weber *et al.*, 2013).

Once a stimulus has interacted with the receptors, and the signals have been generated and integrated to form the corresponding sensation, it must be interpreted by the individual before a perception can be formed (Coren, 2003). To interpret the sensation, several cognitive processes take place in an attempt to extract useful information from the signals elicited by the stimulus. Among these, cross-modal integration between two or more different sensory modalities plays an important role as demonstrated by the McGurk illusion (McGurk & McDonald, 1976), for example. In this illusion, the visual information received from observing a person speaking alters the auditory perception of the sound, due to the incongruence between the visual and auditory inputs (seeing “ga” and hearing “ba” give rise to the perception of “da”). This phenomenon of people connecting inputs from different sensory modalities is also known as sensation transfer (Pramudya *et al.*, 2020). Recently, Pramudya *et al.* (2024) provided empirical evidence of the sensory transfer between handfeel touch and mouth irritation mediated by capsaicin. Sandpaper material was found to be strongly associated

with mouthfeel irritation, whereas materials such as silicone, sponge or stainless steel showed weaker associations. Other authors report cross-sensory influences of handfeel touch cues on oral somatosensory perception (Pramudya & Seo, 2019). For example, Piqueras-Fiszman and Spence (2012) report an increase in crunchiness and hardness of biscuits presented in a container with a rough sandpaper compared to the same biscuit presented in a smooth-coated container.

Given the importance of mouthfeel in overall red wine quality perception, and considering the existence of a sensory transfer between handfeel touch and oral somatosensory perception, it seems plausible to develop a methodology that gives a complete picture of wine mouthfeel properties based on handfeel perception. Many psychological studies have been devoted to the investigation of handfeel perception (*e.g.*, Picard *et al.*, 2003). Most of these studies were based on the sorting of everyday surface textures (*e.g.*, wood, sand paper and fabrics) coupled with multidimensional scaling to explore the handfeel perceptual space. Three main dimensions of texture emerged from these studies: roughness/smoothness, hardness/softness and coldness/warmness. However, Sakamoto and Watanabe (2017) suggest that the previous studies may have been reductive due to the limited number of handfeel dimensions represented. To overcome this shortcoming and to cover all the basic categories within the handfeel perceptual space, they developed a lexicon of touch perception as a guide for collecting materials. They claim that the generation of a detailed and reliable vocabulary is important for meaningful descriptions of perceptual spaces, and thus their strategy for collecting materials illustrating different perceptions of

handfeel was based on the sensory vocabulary generated at the outset. In the present study, a comparable approach was adopted for the development of reference handfeel touch materials, which were created to illustrate the mouthfeel of red wine. This methodology was based on the hypothesis that cross-sensory associations exist between handfeel touch sensations and wine mouthfeel perception. The study built on the renewed interest in the collaboration between the arts and sciences. This transdisciplinary art-science initiative predates the twentieth century, when art and science were clearly linked. A clear example is the Renaissance period, when art and science went hand in hand, the clearest example being the works of Leonardo Da Vinci (Clark *et al.*, 2020).

In this context, the objective of the present study is to develop handfeel touch references capable of describing the mouthfeel properties of red wine through a transdisciplinary approach. We first compiled a large number of mouthfeel terms used to describe red wine by different Spanish wine stakeholders, including people working in the wine sector, such as technical experts (*i.e.*, winemakers) and people involved in wine distribution and sales, as well as regular consumers not working in the wine sector. Reference standards were then designed to illustrate the terms developed in the first step following an art-based strategy, working on the hypothesis that different mouthfeel terms generated by red wines can be illustrated by touch materials. Finally, the ability of the handfeel touch reference materials to discriminate between red wines was validated and a sample of references selected as a working tool for further studies.

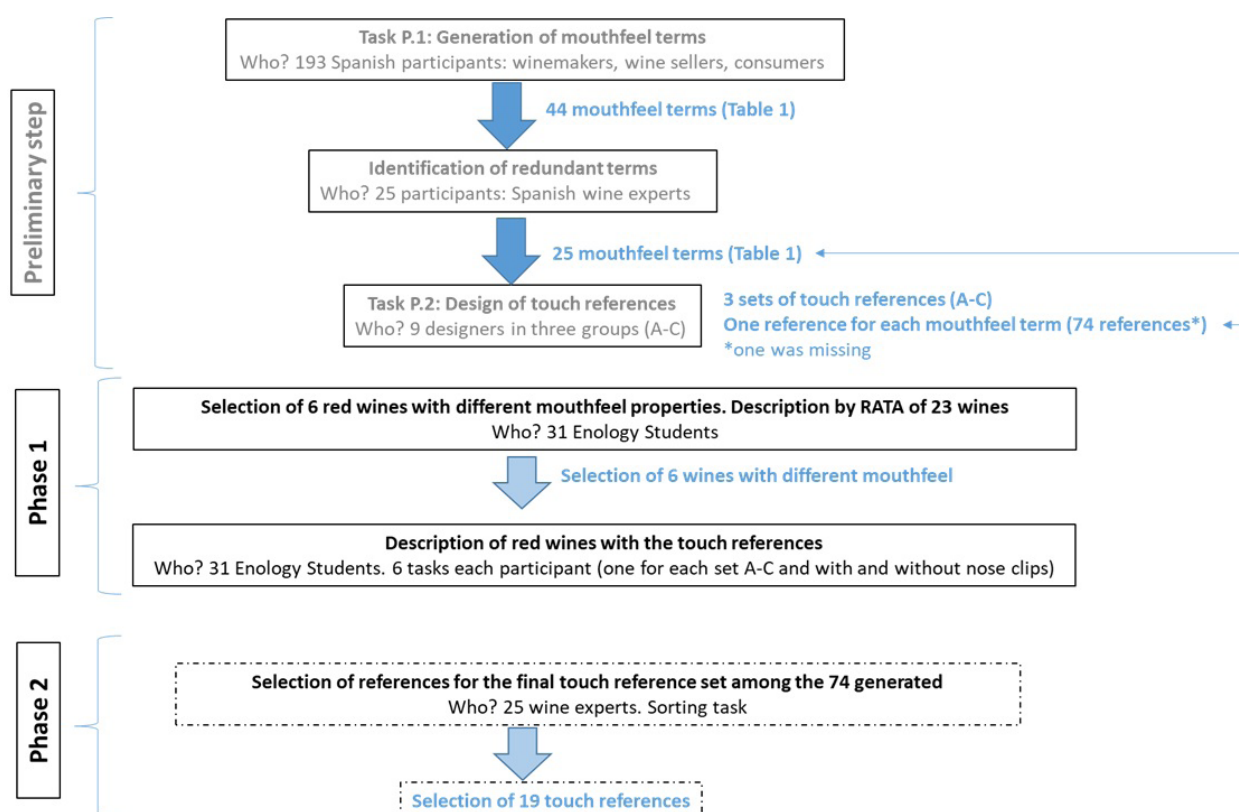


FIGURE 1. Workflow of the study indicating the tasks carried out within the preliminary and main study.

MATERIALS AND METHODS

Figure 1 shows the workflow of the study with the preliminary step involving two tasks (Task P.1 and Task P.2) and two main tasks (Phase 1, Phase 2).

1. Preliminary step

1.1. Generation of mouthfeel terms

A list of 44 mouthfeel-related terms (Table 1) was generated by winemakers, wine sellers and consumers in a pre-test using a long-term memory-based task (see Appendix A for information about this task). Synonyms in the list were grouped using an online task. In this task, 25 native Spanish speakers were provided with the 44 terms, and were asked to associate terms that had similar meanings to each other.

The number of times the same two terms were associated with each other was counted. When the same two terms were associated to make a pair by at least 35 % of the participants, they were considered to have a similar meaning. The following pairs of words were thereby identified as having similar meaning: dynamic/agile; watery/light; fine/delicate; soft/velvety; aggressive/sharp; burning/warm; rough/coarse; creamy/fleshy; lubricant/unctuous; viscous/doughy; thick/dense; mouthcoating/full; ample/with volume; firm/robust. One of the terms in each pair was selected and the other discarded. Thus by the end of this task the initial list of 44 was reduced to 25 terms.

1.2. Design of handfeel touch reference materials

The reduced list of 25 terms (marked in bold in Table 1) was given to three groups of Master students of the design school IADE escuela de diseño (Madrid, Spain), each comprising two or three participants. Each group generated an independent set of handfeel touch reference materials and the three sets were compared in order to evaluate the generalisation of the procedure.

The creative process carried out to design the references is illustrated in Figure S1 of Appendix B.

The design students were instructed to find different materials that represented each of the 25 terms in the list. The resulting three sets (coded A-C) of handfeel touch reference materials each contained 25 (sets A and C) and 24 (set B; as set B did not contain a reference material for the term “hard”) items. Each reference material was associated with one of the five following distinct patterns of exploratory hand movements: i) grab (C for *coger* in Spanish), ii) experiment (E), iii) touch (T), iv) push (P), and v) rub (F for *frotar* in Spanish). Each reference material was coded using the letter of the set (A-C), followed by the code letter of the exploratory hand movement (C, E, T, P, F) and then a number from 1 to 10 (Figure 2). For example, reference AP1 belonged to set A and participants had to push to explore it. Images of the references (Figures S2 and S4) and their descriptions (Tables S1 and S3) are provided in Appendix B.

Each reference material was then placed in a homogenised container, which was big enough for a hand to be introduced

TABLE 1. List of terms related to wine mouthfeel elicited in a memory-based strategy (see Appendix A). The 25 terms marked in bold are those selected for the final list after removing redundant terms.

	term (Spanish)	term (English)		term (Spanish)	term (English)
1	astringente	astringent	23	grueso	thick
2	con volumen	with volume	24	denso	dense
3	sedoso	silky	25	acuoso	watery
4	suave	soft	26	agresivo	aggressive
5	untuoso	unctuous	27	amplio	ample
6	áspero	rough	28	consistente	firm
7	cuerpo	body	29	ardiente	burning
8	secante	drying	30	carñoso	fleshy
9	ligero	light	31	cremoso	creamy
10	redondo	round	32	delicado	delicate
11	aterciopelado	velvety	33	duro	hard
12	estructurado	structured	34	envolvente	mouthcoating
13	espeso	thick	35	gomoso	gummy
14	graso	greasy	36	lubricante	lubricant
15	cálido	warm	37	dinámico	dynamic
16	fino	fine	38	pastoso	doughy
17	fresco	fresh	39	polvoriento	dusty
18	rugoso	coarse	40	pulido	polished
19	viscoso	viscous	41	punzante	sharp
20	pesado	heavy	42	ágil	agile
21	anguloso	angular	43	lleno	full
22	fluido	fluid	44	robusto	robust

and explore the item inside. These containers were designed in such a way that the reference materials could be touched blind in order to prevent any visual interaction with them, as they were of different colours and shapes. Figure 2 shows the set-up and procedure for the exploration of the reference materials.

2. Validation of handfeel touch reference materials for the description of red wine mouthfeel

2.1. Selection of six wines with different mouthfeel properties

2.1.1. Procedure

First, 23 commercial wines from different origins (France, Spain, Argentina, Germany and Peru), varieties (Gamay,

Malbec, Mencía, Garnacha Tinta, Merlot, Cabernet-Sauvignon, Syrah, Tempranillo Tinto, Moristel, Pinot noir, Garnacha Tintorera, Monstrell, Tinta de Toro, Bobal, Prieto Picudo and Tannat), and vintages (2015-2021) were selected (Table 2). These wines were chosen in consultation with wine experts for being representative of different mouthfeel properties. Samples were purchased from local wine stores and wineries. Appendix C contains further information regarding the conventional oenological parameters of the studied wines.

Second, a sensory profile was carried out to select a subset of six wines from the initial set of 23 wines. The wines were characterised in February 2022 by 31 Oenology students (48 % males and 52 % women, average age = 26, range

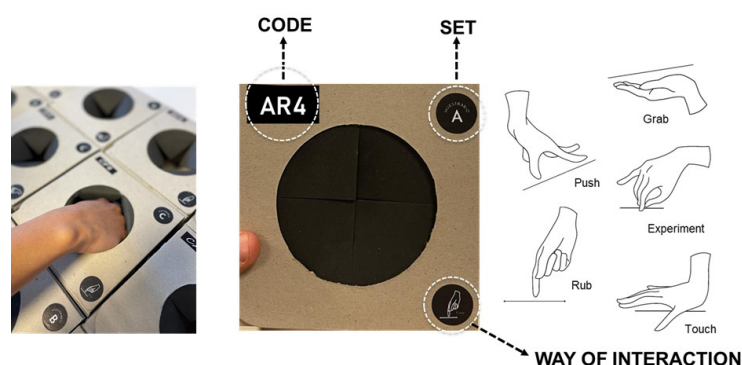


FIGURE 2. Set-up and procedure for the exploration of the handfeel touch reference materials.

TABLE 2. List of wines selected for the screening and identification of 6 wines with marked mouthfeel differences. Selected wines are marked with an asterisk.

Code	Variety	Origin	Vintage
GAM_FR_17	Gamay	Morgon (Beaujolais, France)	2017
MAL_AR_17	Malbec	Mendoza (Argentina)	2017
MEN1_BI_17	Mencía	Valtuille de Abajo (El Bierzo, Spain)	2017
MEN2_BI_17	Mencía	Valtuille de Abajo (El Bierzo, Spain)	2017
GAR_ZA_18*	Garnacha Tinta	Lécera (Zaragoza, Spain)	2018
MER_HU_18	Merlot	Salas Bajas (Huesca, Spain)	2018
CAB_ZA_18	Cabernet-Sauvignon	Fuendejalón (Zaragoza, Spain)	2018
MER_HU_18*	Syrah	Fuendejalón (Zaragoza, Spain)	2018
TEM_RJ_18	Tempranillo Tinto	Aldeanueva de Ebro (La Rioja, Spain)	2018
TEM_RJ_17	Tempranillo Tinto	Moreda (Álava, Spain)	2017
GAR_RJ_17	Garnacha Tinta	Alcanadre (La Rioja, Spain)	2017
TEM_ALB_15	Tempranillo Tinto	Villamalea (Albacete, Spain)	2015
MOR1_HU_16*	Moristel	Barbastro (Huesca, Spain)	2016
MOR2_HU_16	Moristel	Barbastro (Huesca, Spain)	2016
PIN_GER_19*	Pinot noir	Wachenheim an der Weinstraße (Germany)	2019
GAR_MON_20	70% Garnacha Tintorera; 30% Monastrell	Almansa (Albacete, Spain)	2020
TIN_TR_18	Tinta de Toro	Valdefinjas (Zamora, Spain)	2018
GAR_NA_19	Garnacha Tinta	Corella (Navarra, Spain)	2019
MON_JU_19	Monastrell	Jumilla (Murcia, Spain)	2019
BOB_REQ_18	Bobal	Requena (Valencia, Spain)	2018
PIN_ALL_18	Pinot noir	Alicante (Spain)	2018
PRI_LE_19*	Prieto Picudo	Valdevimbre (León, Spain)	2019
TAN_PR_19*	Tannat	Ica (Peru)	2019

of age = 21-63) in their 3rd and 4th year of a bachelor's or master's degree (Universidad de La Rioja) following the RATA methodology. A list of 20 mouthfeel terms previously developed by Sáenz-Navajas *et al.* (2017) to describe mouthfeel properties of red wines was used. Fifteen mL of samples were served in dark wine glasses labelled with 3-digit random codes and covered with petri dishes. The order of presentation of the 23 samples was different for each participant. Nose clips were worn when evaluating the samples to avoid aroma interaction and to help participants focus on the taste and mouthfeel properties of wines. The participants were asked to taste the wine samples and to select the terms they associated with each sample from the RATA list, and then to rate their intensity using a 7-point scale (where 1 = very low and 7 = very high). The order of presentation of the terms was randomised and different for each participant.

The task was carried out in a ventilated and air-conditioned tasting room (at approximately 20 °C) and the wine samples served at room temperature. After each wine had been tasted and evaluated, the participants followed a mandatory rinsing protocol with mineral water and pectin (1 g/L) before tasting the next sample. Every six samples, a 5-min pause was imposed to minimise the carry over effects.

2.1.2. Data analysis

Data were analysed using two-way ANOVAs for each of the 20 terms and considering the participants as random and the wines as fixed factors. A normalised principal component analysis (PCA) with varimax rotation was then carried out with the mean intensity scores of the significant attributes (N = 13). A hierarchical cluster analysis (HCA) with the Ward criteria was finally applied to the scores of the wines on the four varimax-rotated dimensions with an eigenvalue greater than 1. The six wines that differed the most were selected for the next step (see appendix D for selection criteria and sensory characterisation of wines).

2.2. Description of the red wines using the handfeel touch references

2.2.1. Procedure

Based on the results of Section 2.1., the six wines were described after the participants had first assessed a warm-up sample, which was then discarded. The six selected wines (marked with an asterisk in Table 2) deemed to capture maximal variability in terms of mouthfeel among the sample set selected. They were made from 6 different grapevine varieties: Tannat, Garnacha Tinta, Prieto Picudo, Merlot, Moristel and Pinot noir, and were diverse in origin: Peru (South America), Germany and three different regions in North Spain: Huesca (close to Pyrenees), Zaragoza (North East) and León (North West) (see Appendix C, Table S1).

Wine samples of 15 mL were presented to each participant in dark glasses coded with three-digit codes in a monadic and randomised order. The task was carried out in a ventilated, air-conditioned tasting room (approximately 20 °C) and the wine was served at room temperature.

Thirty students in their second and third years of the bachelor's or master's degree in Oenology and Viticulture at the Universidad de La Rioja (Spain) (50 % male and 50 % female, average age = 26, age range = 21-63) participated in six sessions over three different days in March 2022. A 30 min pause between two sessions held on the same day was imposed. In the first three sessions, the seven samples were described using the three sets of handfeel touch references (A-C) without nose clips, and in the next three sessions the same procedure was carried out with nose clips. The order of presentation of the reference sets was randomised among participants. In each session, the participants were first familiarised with the handfeel touch references. They were instructed to interact with each of the 24-25 references following the exploring procedure indicated next to the reference (Figure 2) and group the references according to their perceived similarity. After familiarisation, they were presented with the seven red wines and asked to taste each sample and to describe it by selecting all the handfeel references that they considered appropriate to describe the sample following a Check-all-that-Apply (CATA) methodology (Figure 3). A rinsing protocol, consisting of three rinsing steps: 1) water, 2) pectin (1 g/L), and 3) water, was imposed between samples.

2.2.2. Data Analysis

2.2.2.1 Validation of the reference sets

To evaluate the overall efficiency of the three sets of reference materials in discriminating between the wine samples, a first analysis was carried out independently of the tasting conditions (*i.e.*, with and without noseclip). For each set, the number of times each handfeel touch reference was used to describe each wine was counted. Three frequency tables with six rows (six wines) and 25 columns (references) for sets A and C, and 24 columns for set B were created.

A Cochran-Q test was carried out on each handfeel touch reference material in each set in order to evaluate its discrimination capacity. Further, a chi-squared test was carried out on each set in order to evaluate its overall ability to discriminate between the six evaluated wines. For this analysis, only references with a significant cochran-Q value were used. Data from both conditions (with and without nose clips) were considered as replicated responses. In both tests, alpha was set to 5 %.

In order to visualise the projection of wines based on the CATA responses of the three sets and to compare them with the RATA responses obtained in the verbalisation phase, a Multi Factor Analysis (MFA) on mixed data (frequency data for CATA and continuous data for RATA) was performed. Only references used by at least 15 % of participants were considered for this analysis.

2.2.2.2 Evaluation of the effect of the nose clip

In order to evaluate the effect of nose clips on CATA descriptions, the number of times each handfeel touch reference material was used to describe each wine was counted separately for each reference material set and each



FIGURE 3. Photograph of the description task carried out by a participant using one of the reference material sets without a nose clip.

of the tasting conditions. Six frequency tables with six rows (six wines) and 25 columns (handfeel reference materials) for sets A and C (with and without nose clip), and 24 for set B (with and without nose clip) were generated.

A Cochran-Q test was calculated for each reference within each set to find significant differences between the two conditions (with and without nose clips). An overall independent chi-squared test was then carried out on each set and on each of the conditions using the reference materials for which Cochran-Q was significant.

To visualise the effect of using a nose clip an MFA for frequency data was performed. The frequency tables obtained for the two tasting conditions were concatenated to form three matrices with twelve rows each and 25 columns (reference materials) for set A and C, and 24 for set B. Each wine sample is thus represented twice in these matrices, once in the “without nose clip” (noted WNC) and once in the “with nose clip” (NC) conditions.

3. Selection of references for the final touch reference set

3.1. Procedure

Twenty-five individuals (44 % males and 56 % women, average age = 36, age range = 24-58), all belonging to the ICVV, participated in a sorting task. They were presented with the total 74 handfeel reference materials from all three sets simultaneously. Participants were asked to group references based on their handfeel similarity, building as many groups as they wanted and leaving out any reference materials that did not belong to any of the groups. No time restriction was

imposed. Once they had finished the task, they recorded the results on a paper ballot.

3.2. Data Analysis

The sorting results of each participant were entered in an individual similarity matrix (reference materials × reference materials) using a code: 1 stood for two reference materials in the same group and 0 for two reference materials each in a different group. All the individual matrices (i.e., of all the participants) were then summed; the resulting co-occurrence matrix represents the overall similarity matrix in which the larger numbers indicate higher similarity between references.

4. Ethical approval

Ethical approval for the involvement of human subjects in this study was granted by CSIC Research Ethics Committee on 17/11/2021 with Reference number 180/2021.

RESULTS

1. Phase 1

1.1. Validation of handfeel touch references for the description of red wine mouthfeel

The Cochran-Q test results (Table 3) show that 11 and 8 of the 25 reference materials in sets A and C respectively, and 9 of the 24 materials in set B significantly discriminated between the six wines, suggesting that participants perceived differences in the sensory characteristics of the evaluated wines. The Chi-squared test performed on the significant descriptors of each set showed that the three sets had the same overall capacity to differentiate the samples, with values

ranging from 83.78 for set A to 133.5 for set C ($p < 0.0001$ in all three cases); this suggests that the CATA strategy using handfeel touch reference materials was efficient, regardless of the set employed.

Figure 4 shows the first two dimensions (67 % of the variance) of the MFA performed on the CATA (sets A, B and C) and the RATA data. Figure 4a shows that sets B and C and RATA contribute mostly to the first dimension, whereas set A contributes more to the second dimension (54 %). The proximity of sets B and C to each other indicates that the wine samples were described similarly by these two reference sets. Moreover, the proximity of these two sets to RATA also suggests a similarity with the verbal descriptions (employed in the RATA methodology) given by the experts.

The difference between set A and the other two sets was mostly due to samples Mer_Hu_18, Mor1_Hu_16, Gar_Za_18, and PRI_LE_19 (Figure 4b). This can be explained by the fact that more significant references were identified in the Cochran-Q tests (11 for set A versus 9 and 8 for sets B and C). In addition, the RV coefficients confirm the notably high similarity between the results for RATA and set B and for (to a lesser extent) RATA and set C: 0.94 for RATA-set B and 0.87 for RATA-set C. Meanwhile, the RV coefficients for the other combination of components were: 0.89 for sets B-C, followed by slightly lower values for sets C-A (0.77), then RATA-set A (0.69) and sets B-A (0.66). These significant RV coefficients confirm the correlation between handfeel touch reference materials and the mouthfeel RATA descriptions of the same wines.

Figure 4c shows the correlation circle of all three sets of handfeel touch reference materials and the 13 significant descriptors used in the vocabulary-based RATA approach. Only reference materials that had been associated with at least one wine by at least 50 % of the participants facilitated

the interpretation of the results. Table 4 summarises the descriptions of the wines.

The MER_HU_18 wine, made from the Merlot variety from Huesca (Spain), was mainly characterised by the touch references AF5, AA4, AF2, BF3, BF4, BE2, BA5, CF2, CF10, CF4, CA7 and CF3, along with the RATA terms drying, sticky, grainy, coarse, burning, prickling, and persistent (Figures 4b and 4c). In the first component, this sample and its descriptors are opposite the wines MOR1_HU_16, made with Moristel from Huesca (Spain), and PIN_GER_19, produced with Pinot noir from Germany (Figure 4b). The Moristel wine was mainly characterised by the touch references AA4, BE3, BF5, CA7, CE6, and CT1 and the descriptors silky, watery, prickling, and puckering, while the Pinot noir was associated with the reference materials AF9, BA3, BF3, CA3, and CE3 and the term oily; both these wines shared the attributes silky, watery, and prickling.

For the second component, wines made from Garnacha Tinta (GAR_ZA_18) and Prieto Picudo (PRI_LE_19) are plotted in the lower part of the graph (Figure 4b), and are opposite to the Merlot and Pinot noir wines described above. Garnacha Tinta was mainly described using the terms sticky, burning and prickly together with the reference materials AE3, AF2, AF9, AF8, BF4, CA7, and CF4, meanwhile, Prieto Picudo was also found to be sticky and was associated with the reference materials AF2 and CF4, but it was also described as grainy and silky, being characterised by the reference materials BE2, BF3, BA4, BF9, BE5, CF10, tyand CA3.

1.2. Effect of using nose clips on wine descriptions

Figure 5 shows the overall projection (from the perspective of all three reference sets together) of the wine samples on the first two dimensions (43 % of variance) of the MFA. Each wine is represented twice on this map: once for the “without

TABLE 3. Results of the Cochran-Q test performed on the CATA descriptions of the six red wines. Only references with a significant Q value ($\alpha = 5\%$) are indicated. The last row indicates the overall capacity of each set to discriminate between the wines (Chi-square tests performed on the significant references).

SET A		SET B		SET C	
Reference	p-value	Reference	p-value	Reference	p-value
AA2	0.078	BA2	0.025	CE3	0.076
AA4	<0.0001	BT1	0.001	CE6	0.013
AC2	0.021	BF3	<0.0001	CA3	0.073
AF1	0.015	BF4	0.007	CA7	0.013
AF5	0.007	BF5	0.003	CT1	0.029
AF8	0.010	BF7	0.034	CF2	<0.0001
AF9	0.008	BE2	0.002	CF3	0.017
AE3	0.001	BE3	0.003	CF10	0.043
AE8	0.080	BE7	0.063		
AE9	0.040				
AE10	0.058				
X² (35)	p-value	X² (40)	p-value	X² (50)	p-value
83.78	<0.0001	117.13	<0.0001	133.50	<0.0001

TABLE 4. Description of the six wines based on the handfeel touch reference materials in sets A-C and the RATA attributes. Only the reference materials employed by at least 50 % of participants to describe each wine and the RATA terms that significantly differed among the wines according to the ANOVA results are shown.

Wine	References set A	References set B	References set C	RATA attributes
GAR_ZA_18	AE3*, AF2, AF9*, AF8*	BF4*	CA7*, CF4	sticky, burning, prickling
MER_HU_18	AF5*, AA4*, AF2	BF3*, BF4*, BE2*, BA5	CF2*, CF10*, CF4, CA7*, CF3*	drying, sticky, grainy, coarse, burning, prickling, persistent
MOR1_HU_16	AA4*	BE3*, BF5*	CA7*, CE6*, CT1*	silky, watery, prickling, puckering
PIN_GER_19	AF9*	BA3, BF3*	CA3*, CE3*	oily, silky, watery, prickling
PRI_LE_19	AF2	BE2*, BF3*, BA4, BF9, BE5	CF10*, CF4, CA3*	sticky, grainy, silky
TAN_PR_19	AF2, AF1*, AF9*	BF3*, BE2*, BE8	CF10*, CF4	sticky, oily, burning, persistent

*reference materials showing significant differences among the six wines in the Cochran-Q test performed on the CATA results.

two references that were similar to each other were merged in the lowest part of the dendrogram). The question being at which point two different references can be considered as redundant. To address this question we partitioned the dendrogram at different heights. The resulting grouping of the references was evaluated by three experimenters whose task was to select the best partition (*i.e.*, a partition yielding maximal differences in terms of reference materials). The partition which provided 33 groups of references was consensually selected to be the optimum (Table 4).

The most representative reference material of each group was then selected by the three experimenters to form the final handfeel touch reference material set (underlined and in bold in Table 5). The criteria used for the selection of the most representative references within a group were: i) they must

have obtained a significant Cochran-Q in the previous task, and ii) they can be easily reproduced. Therefore, references with a significant Cochran-Q were prioritised over non-significant references. Moreover, references that were easier to replicate were also selected as representative. Table 4 shows the final list of reference groups. Nineteen (marked with an asterisk in Table 3) of the 33 groups of references with marked handfeel differences contained at least one reference that had obtained a significant Cochran-Q in Phase 1. While the final reference set of touch references can be formed by these 19 references, the 14 remaining groups of references were not totally discarded as they may have been able to explain the differences among the other wine sets that differed to those of Phase 1.

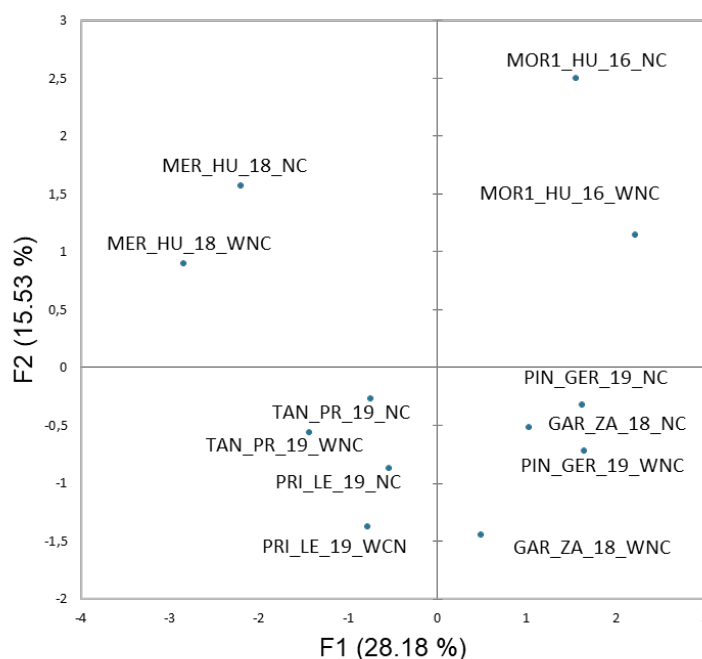


FIGURE 5. General projection in the first two dimensions of the MFA of the six wines evaluated without (WNC) and with (NC) nose clips, calculated from the three matrices derived from the CATA description of the wines and using the three reference material sets (A-C).

DISCUSSION

The present results corroborate the initial hypothesis of the existence of an association between handfeel touch sensations and mouthfeel elicited by red wine. This constitutes a significant finding, as it confirms that sensory transfer can be used for product description and marketing. It also adds to the substantial body of literature examining sensory associations and sensory transfer (Di Stefano & Spence, 2022), which has demonstrated the impact of handfeel touch evoked by extrinsic cues (primarily in the form of packaging or container designs) associated with food or beverage products on consumer experiences and product perception (Piqueras-Fiszman & Spence, 2012). Similarly, the literature shows the influence of handfeel touch on flavour perception, encompassing aroma, taste (Di Stefano & Spence, 2022), and trigeminal sensations (Pramudya *et al.*, 2024). In contrast with the limited research on sensory correspondence between handfeel touch and mouthfeel investigated in the field of product description, as is the case with the present work.

Our results confirm that it is possible to discriminate between red wine mouthfeel properties by means of handfeel touch reference materials using a CATA-based approach. They can thus be used to provide practical guidelines for developing effective reference materials for describing wine perception and exploring the mouthfeel perceptual space of wines. We worked under the hypothesis that the sensations perceived with the hand by touching are similar to the mouthfeel elicited in the buccal cavity by red wine, which is based on the fact that both the buccal and hand surfaces contain similar mechanoreceptors (Foengending *et al.*, 2015).

The first important step was the generation of handfeel touch reference materials by first developing an extensive vocabulary related to red wine mouthfeel - involving more than 170 participants - in order to explore as broad a perceptual mouthfeel space as possible. The collection of touch materials was based on sensory vocabulary suggested by Sakamoto and Watanabe (2017). An initial non-redundant list of 25 mouthfeel-related terms was generated (Table 1), and provided to designers that developed three sets of 24-25 handfeel touch reference materials (Figure 2). The capacity of these materials to describe the mouthfeel space of very different red wines by means of the generated touch references was evaluated relative to a vocabulary-based approach (*i.e.*, RATA) carried out by wine experts (Figure 4). The results show that a higher variability in mouthfeel characterisation can be attributed to one of the sets of handfeel touch reference materials (Table 3). These results confirm that it is possible to use handfeel touch reference materials for wine mouthfeel descriptions, as well as to identify maximal variability in mouthfeel.

Another methodological outcome of the study was that, when using handfeel touch reference materials to characterise the mouthfeel properties of red wine, wearing a nose clip did not markedly influence the perception of mouthfeel, or at the very least, its description (Figure 5). Thus, when wearing a noseclip, participants appeared to rely primarily on mouthfeel sensations to establish relationships between handfeel and wine sensations perceived in the mouth. This indicates that the utilisation of nose clips, which can be onerous, can be circumvented when describing the palate properties of wines through handfeel touch reference materials. However, we

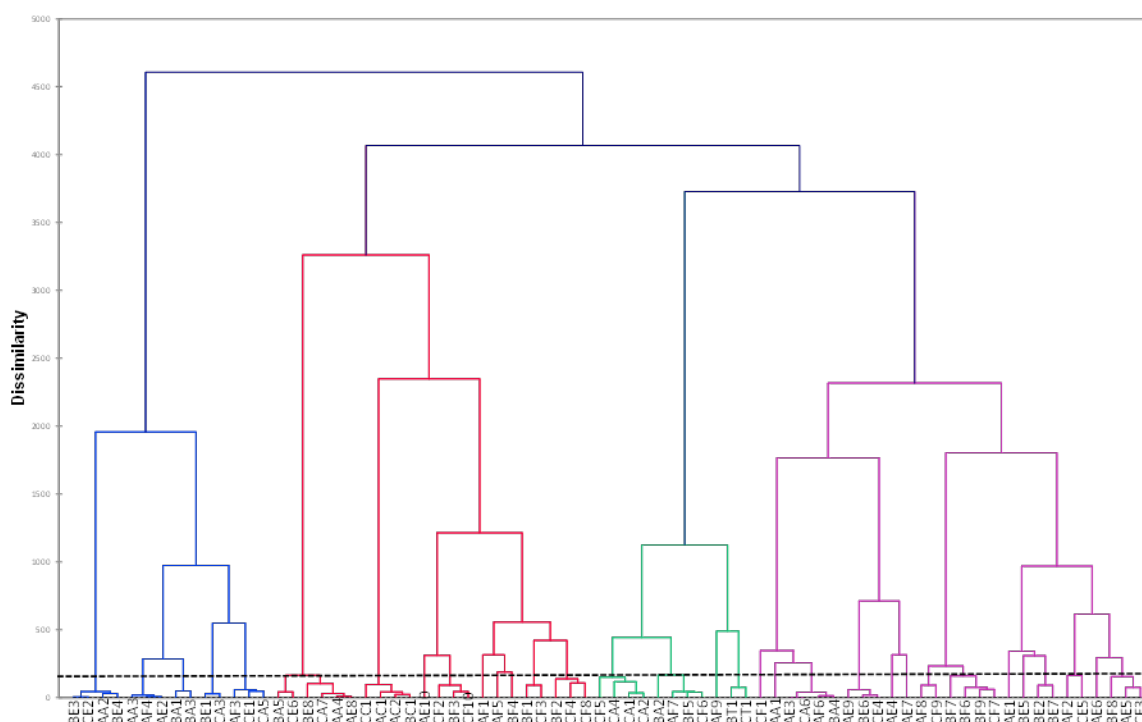


FIGURE 6. HCA calculated on the 4-dimension MDS map derived from the sorting task and based on 25 individuals and 74 handfeel touch reference materials. The dotted line represents the cut-off point, leaving 33 groups of samples below the line.

TABLE 5. Groups of references with similar properties identified in a sorting task carried out on 74 touch reference materials and by 25 participants. For each group, one reference (in bold and underlined) was selected to be representative for each touch sensation (*i.e.*, each group). Groups marked with an asterisk indicate references that enabled differences to be highlighted among the 6 evaluated wines.

Group	References	Group	References
1*	<u>AA2</u> , BE3, BE4, CE2	17*	<u>BF5</u> , CF6, BA2, AF7
2	AA3, AF4, AE2	18*	<u>AF9</u>
3	BA1, BA3	19*	<u>CT1</u> , BT1
4*	<u>CA3</u> , BE1	20	CF1
5	AF3, CE1, CA5	21	AA1
6*	<u>CE6</u> , BA5	22*	<u>AE3</u> , CA6, BA4, AF6,
7*	<u>AA4</u> , AE8, CA7, BE8	23*	<u>AE9</u> , CE4, BE6
8*	<u>AC2</u> , CC1, AC1, BC1,	24	AE4
9*	<u>AE10</u>	25	AE7
10*	<u>CF2</u> , CF10, BF3	26*	<u>AF8</u> , CF9
11*	<u>AF1</u>	27*	<u>BF7</u> , CF7, BF9, BF6
12*	<u>AF5</u>	28	AE1
13*	<u>BF4</u>	29	BE5
14*	<u>CF3</u> , BF1	30*	<u>BE2</u> , BE7
15	CF8, CF4, BF2	31	AF2, CE5
16	CA1, CA2, CA4, CF5		

considered it essential to corroborate these findings, given the potential for cross-sensory interactions between touch and aroma to influence the description of mouthfeel in wines when nose clips are not worn, as has been previously reported. Therefore, six red wines were described in triplicate under two types of conditions: with (NC) and without (WNC) nose clips, and by means of three sets of touch reference materials produced in the first step of the study (Figure 5). In former conditions no aroma stimulus could reach the receptors of the tasters, and in the latter, aroma stimuli were present. The three distinct sets (sets A-C) of handfeel touch reference materials were used to facilitate the generalisation of the findings. The absence of effect associated with the use or not of nose clips could be due to the participants giving all their attention to in-mouth properties, as they were explicitly instructed to do. Similar outcomes have been observed in previous studies on descriptions of the palate properties of red wines, with no or limited effect of nose clip use being reported (Sáenz-Navajas *et al.*, 2020).

CONCLUSIONS

Our study confirms that sensory associations exist between handfeel tactile sensations and red wine mouthfeel, and it explores these associations further by using a variety of handfeel touch reference materials. We propose an original guiding principle based on preliminary vocabulary-based strategies for the development of handfeel touch reference materials, which can then be integrated into a multidisciplinary strategy that incorporates artistic elements. In contrast to classical strategies, our proposal focuses on the development of handfeel touch references

that enable the complete characterisation of the mouthfeel properties of red wines without the use of vocabulary, in order to avoid any potential misinterpretations or idiosyncrasies that may arise from the use of language. This work has significant implications for wine industry with regard to the communication of sensory perceptions. It addresses the limitations of classical vocabulary-based approaches, which are characterised by two main drawbacks: the inefficiency of identifying independent dimensions to fully characterise the sensory space of red wine mouthfeel (Sáenz-Navajas *et al.*, 2020), and the fact that interpreting idiosyncratic vocabulary is challenging and panel-dependent (Gawel *et al.*, 2000). The approach proposed here has proved to be very promising; however, its application is presently limited by the difficulties associated with reproducing handfeel touch reference materials, which could impede its general use in wine industry when describing mouthfeel. It would therefore be beneficial for future research to focus on selecting materials that can be applied universally and extrapolated to other contexts. In addition, it would be useful to carry out research to assess the potential of applying our strategy in a variety of contexts (education, marketing and technical support, among others) and in the absence of the vocabulary of wine professionals and consumers, a fact that needs to be proven and opens up an interesting field of research.

FUNDING

This research was funded by the Spanish Ministry of Science and Innovation, the Spanish Research Agency and FEDER

with grant number PID2021-126031OB-C22, and by CSIC through the JAE Programme (JAE INTRO 2021 grant for RBM).

REFERENCES

- Araujo, L. D., Parr, W. V., Grose, C., Hedderley, D., Masters, O., Kilmartin, P. A., & Valentin, D. (2021). In-mouth attributes driving perceived quality of Pinot noir wines: Sensory and chemical characterisation. *Food Research International*, *149*, 110665. doi: 10.1016/j.foodres.2021.110665
- Clark, S. E., Magrane, E., Baumgartner, T., Bennett, S. E. K., Bogan, M., Edwards, T., . . . Wilder, B. T. (2020). 6&#amp;#6: A Transdisciplinary Approach to Art–Science Collaboration. *BioScience*, *70*(9), 821–829. doi: 10.1093/biosci/biaa076
- Coren, S. (2003). Sensation and Perception *Handbook of Psychology* (pp. 85–108).
- Di Stefano, N., & Spence, C. (2022). Roughness perception: A multisensory/crossmodal perspective. *Attention, Perception, and Psychophysics*, *84*(7), 2087–2114. doi: 10.3758/s13414-022-02550-y
- Foegeding, E. A., Vinyard, C. J., Essick, G., Guest, S., & Campbell, C. (2015). Transforming structural breakdown into sensory perception of texture. *Journal of Texture Studies*, *46*(3), 152–170. doi: 10.1111/jtxs.12105
- Gawel, R., Oberholster, A., & Francis, I. L. (2000). A mouth-feel wheel: terminology for communicating the mouth-feel characteristics of red wine. *Australian Journal of Grape and Wine Research*, *6*, 203–207.
- Hopfer, H., & Heymann, H. (2014). Judging wine quality: Do we need experts, consumers or trained panelists? *Food Quality and Preference*, *32*, 221–233. doi: 10.1016/j.foodqual.2013.10.004
- Lawless, L. J. R., & Civille, G. V. (2013). Developing Lexicons: A review. *Journal of Sensory Studies*, *28*(4), 270–281. doi: 10.1111/joss.12050
- McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature* *264*, 746–748. doi: 10.1038/264746a0
- Niimi, J., Danner, L., Li, L., Bossan, H., & Bastian, S. E. P. (2017). Wine consumers’ subjective responses to wine mouthfeel and understanding of wine body. *Food Research International*, *99*, 115–122. doi: 10.1016/j.foodres.2017.05.015
- Noble, A. C., Arnold, R. A., Buechsenstein, J., Leach, E. J., Schmidt, J. O., & Stern, P. M. (1987). Modification of a standardized system of wine aroma terminology. *American Journal of Enology and Viticulture*, *38*(2), 143–146.
- Paissoni, M. A., Motta, G., Giacosa, S., Rolle, L., Gerbi, V., & Rio Segade, S. (2023). Mouthfeel subqualities in wines: A current insight on sensory descriptors and physical–chemical markers. [Review]. *Comprehensive Reviews in Food Science and Food Safety*, *22*(4), 3328–3365. doi: 10.1111/1541-4337.13184
- Paissoni, M. A., Waffo-Teguo, P., Ma, W., Jourdes, M., Giacosa, S., Segade, S. R., . . . Teissedre, P. L. (2020). Sensory assessment of grape polyphenolic fractions: An insight into the effects of anthocyanins on in-mouth perceptions. *Oeno One*, *54*(4), 1059–1075. doi: 10.20870/oeno-one.2020.54.4.4142
- Picard, D., Dacremont, C., Valentin, D., & Giboreau, A. (2003). Perceptual dimensions of tactile textures. *Acta Psychologica*, *114*(2), 165–184. doi: https://doi.org/10.1016/j.actpsy.2003.08.001
- Piqueras-Fizman, B., & Spence, C. (2012). The influence of the feel of product packaging on the perception of the oral-somatosensory texture of food. *Food Quality and Preference*, *26*(1), 67–73. doi: https://doi.org/10.1016/j.foodqual.2012.04.002
- Pramudya, R. C., & Seo, H. S. (2019). Hand-feel touch cues and their influences on consumer perception and behavior with respect to food products: A review. *Foods*, *8*(7). doi: 10.3390/foods8070259
- Pramudya, R. C., Choudhury, D., Zou, M., & Seo, H. S. (2020). “Bitter Touch”: Cross-modal associations between hand-feel touch and gustatory cues in the context of coffee consumption experience. *Food Quality and Preference*, *83*, 103914. doi: 10.1016/j.foodqual.2020.103914
- Pramudya, R. C., Choudhury, D., Zou, M., & Seo, H. S. (2024). “Spicy Touch”: Cross-modal associations between hand-feel touch and capsaicin-induced oral irritation. *Food Research International*, *194*, 114889. doi: 10.1016/j.foodres.2024.114889
- Rigaux, J. (2015). *La dégustation géo-sensorielle: Terre en vues*.
- Rinaldi, A., Moine, V., & Moio, L. (2020). Astringency subqualities and sensory perception of Tuscan Sangiovese wines. *Oeno One*, *54*(1), 75–85. doi: 10.20870/oeno-one.2020.54.1.2523
- Sáenz-Navajas, M. P., Avizcuri, J. M., Echávarri, J. F., Ferreira, V., Fernández-Zurbano, P., & Valentin, D. (2016). Understanding quality judgements of red wines by experts: Effect of evaluation condition. *Food Quality and Preference*, *16*, 216–227. doi: 10.1016/j.foodqual.2015.10.001
- Sáenz-Navajas, M. P., Avizcuri, J. M., Ferrero-del-Teso, S., Valentin, D., Ferreira, V., & Fernández-Zurbano, P. (2017). Chemo-sensory characterization of fractions driving different mouthfeel properties in red wines. *Food Research International*, *94*, 54–64. doi: 10.1016/j.foodres.2017.02.002
- Sáenz-Navajas, M. P., Ferrero-del-Teso, S., Jeffery, D. W., Ferreira, V., & Fernández-Zurbano, P. (2020). Effect of aroma perception on taste and mouthfeel dimensions of red wines: Correlation of sensory and chemical measurements. *Food Research International*, *131*. doi: 10.1016/j.foodres.2019.108945
- Sakamoto, M., & Watanabe, J. (2017). Exploring tactile perceptual dimensions using materials associated with sensory vocabulary. *Frontiers in Psychology*, *8*(APR). doi: 10.3389/fpsyg.2017.00569
- Trulsson, M., & Johansson, R. S. (2002). *Orofacial mechanoreceptors in humans: Encoding characteristics and responses during natural orofacial behaviors*. Paper presented at the Behavioural Brain Research.
- Vidal, L., Giménez, A., Medina, K., Boido, E., & Ares, G. (2015). How do consumers describe wine astringency? *Food Research International*, *78*, 321–326. doi: 10.1016/j.foodres.2015.09.025
- Weber, A. I., Saal, H. P., Lieber, J. D., Cheng, J. W., Manfredi, L. R., Dammann Iii, J. F., & Bensmaia, S. J. (2013). Spatial and temporal codes mediate the tactile perception of natural textures. *Proceedings of the National Academy of Sciences of the United States of America*, *110*(42), 17107–17112. doi: 10.1073/pnas.1305509110