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Use of Multi-Intake Temporal Dominance of Sensations (TDS) to Evaluate the Influence of Cheese on Wine Perception

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Abstract: Though the gastronomic sector recommends certain wine–cheese associations, there is little sensory evidence on how cheese influences the perception of wine. It was the aim of this study to dynamically characterize 4 wines as they would be perceived when consumed with and without cheese. The tasting protocol was based on multi-intake temporal dominance of sensations (TDS) coupled with hedonic rating. In the 1st session, 31 French wine and cheese consumers evaluated the wines (*Pacherenc*, *Sancerre, Bourgogne,* and *Madiran*) over 3 consecutive sips. In the following sessions, they performed the same task, but eating small portions of cheese (*Epoisses, Comté, Roquefort*, *Crottin de Chavignol)* between sips. All cheeses were tasted with all wines over 4 sessions. TDS data were mainly analyzed in terms of each attribute's duration of dominance by analysis of variance, multivariate analysis of variance, and canonical variate analysis. Results showed that cheese consumption had an impact ($P < 0.1$) on dominance duration of attributes and on preference for most wines. For example, in *Madiran,* all cheeses reduced dominance duration ($P < 0.01$) of astringency and sourness and increased duration of red fruit aroma. Although the number of consumers was small to make extended general conclusions on wine's preference, significant changes were observed before and after cheese intake.

Keywords: cheese, multisip, temporal dominance of sensations, wine

Practical Application: This paper presents an innovative protocol in terms of sensory data acquisition and analysis which allows the dynamic sensory evaluation of food-on-drink impact using a wine-after-cheese model. This protocol could be a 1st approach toward developing an interesting tool for the food sector which would help to better understand perception of the impact of one food product on another, leading eventually to a better description of a whole meal.

Introduction

Numerous recommendations can be found in the gastronomic and popular literature on what makes a "good" or "bad" wine–cheese combination. However, not that many research papers can be found on the impact of cheese on wine perception. Nygren and others (2002) are some of the few authors who studied this phenomenon on white wine and blue mold cheese. They worked with a trained panel of 9 assessors who first tasted the wine, and then expectorated all of it to assess the intensity of several attributes. Assessors then tasted a cheese sample which they also expectorated before taking a sip of wine to evaluate again the intensity of the given attributes. Between wine and cheese intakes, panelists rinsed their mouth with water. These authors evaluated in the same manner the effect of wine on cheese perception (Nygren and others 2003b). One of their conclusions was that the tasting protocol was crucial and proposed another method where wine and cheese were in the mouth at the same time (mixed compared with sequential tasting; Nygren and others 2003a). In every case, products were expectorated before evaluation. Authors pointed out that further studies should focus on how people actually eat, revealing the need of more research on this subject. In a later work, Madrigal-Galan and Heymann (2006) studied the impact of consuming cheese on the posterior perception of wine by means of quantitative descriptive analysis (QDA) done by a trained panel of 11 assessors. The evaluation was performed using sequential cheese-after-wine tasting; eating a cheese sample, then tasting, expectorating, and evaluating the wine. Although there were significant effects on different attributes, the overall sensory profiles of wines without prior cheese tasting and as affected by cheese were very similar. In all the mentioned works, wine was expectorated instead of swallowed (as in consumption) and a static descriptive method over one wine sip was used. Given that sensory perception is a dynamic phenomenon, the use of a dynamic approach would add information in relation to what happens during consumption. Moreover, the effect of cheese on wine might build up along intakes, making a multisip protocol probably more appropriate.

Temporal dominance of sensations (TDS) is a temporal multidimensional sensory method which consists in presenting to the assessors a list of descriptors from which they can choose the one they consider dominant at every moment of consumption; defining as dominant the most "striking" perception at a given time, not necessarily the most intense one (Pineau and others 2009). TDS has already been used for dynamic sensory characterization of wine on one or multiple sips (Meillon and others 2009; Sokolowsky and others 2015; Vidal and others 2016; Galmarini and others, in press). This dynamic technique could

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Table 1–Evaluated wine samples.

Type of wine	Grapes	Year	Alcohol (vol%)	Total acidity (gH_2SO_4/L)	Reducing sugars (g/L)	Tannins (mg/L)	Total phenolic index
Pacherenc (sweet white)	*Petit Manseng*	2008	12.14	5.55	85.50	–	30.20
Sancerre (dry white)	*Sauvignon blanc*	2013	12.41	4.80	1.86	–	6.40
Bourgogne (red)	*Pinot noir*	2011	13.04	3.41	0.14	2084	46.20
Madiran (red)	*Cabernet Sauvignon, Tannat*	2009	15.20	3.61	1.28	4139	90.60

Table 2–Evaluated cheese samples.

Name of cheese[a]	Type of milk (unpasteurized in all cases)	Type of cheese (and their usual characterization)
Comté	Cow	Semi-hard Dense, firm, grainy
Crottin de Chavignol	Goat	Hard, soft-ripened
Epoisses	Cow	Soft, smear-ripened Chewy, creamy and firm
Roquefort	Sheep	Semi-soft, blue-veined Creamy and crumbly texture

[a]All cheeses have a Protected Origin Designation (POD).

reveal if the dominant sensations change after cheese intake, widening the knowledge on the complete sensory experience.

A positive aspect of TDS is that, providing that the attributes are simple enough and well explained, it can be used with consumers (Albert and others 2012) since no intensity is rated. Working on wine TDS description, Brachet and others (2014) found that consumers were as discriminating as experts but the resulting profiles were not the same as those obtained by a trained panel (of 15 assessors), showing that what was dominant for them was not necessarily so for the trained assessors. Moreover, recent works have shown the possibility of coupling a temporal qualitative descriptive task to a hedonic evaluation on the same session (Oliveira and others 2015; Thomas and others 2016). We believe that collecting TDS data together with temporal liking (rather than in 2 separate sessions) can help to better understand causality, this is why the present work was carried out with a panel of consumers.

Within this context, this work presents an innovative tasting protocol based on the TDS paradigm coupled with hedonic rating, where consumers characterized and rated their liking for 4 wines over 3 consecutive sips without and with previous cheese intake. It is not within the scope of this paper to elaborate a rule of thumb on wine–cheese combinations but to present a different use of TDS data acquisition and analysis to evaluate the impact of one food product on another.

Materials and Methods

Samples

The study was carried out using 4 different commercial wines and 4 different commercial cheeses described in Table 1 and 2, respectively. They were chosen based on classic gastronomic recommendations such as strong gustative contrast (for example, sweet wine and *Roquefort* cheese; Fletcher 2007) or shared *terroir* (for example, *Sancerr*e and *Crottin de Chavignol)*. Moreover, given the novelty of the tasting technique, wines and cheeses from different categories were chosen in order to evidence a differential (or not) impact of cheese on wine.

For each wine category, different samples were screened by 4 wine professionals from the *Bureau Interprofessionnel des Vins de Bourgogne* and the *Institut Français de la Vigne et du Vin* in order to ensure the good sensory quality of the wines.

Basic chemical characterization of wines is presented in Table 1. Determination of alcohol, total acidity, and reducing sugars was done according to the Association of Analytical Chemists official methods international standards (method nr 920.57, 964.08, and 920.64, respectively; AOAC 1984). Phenolic compounds were determined by spectrophotmetry using the technique presented by Somers and Ziemelis (1985).

Consumer panel

Product evaluation was carried out by a total of 31 frequent wine and cheese consumers from the city of Dijon (Burgundy region), France. They were recruited by means of an online questionnaire from a population registered in the *Chemosens Platform's PanelSens* database (database declared to the Commission Nationale Informatique et Libertés – CNIL – n° d'autorisation 1148039). Consumers had already participated at least once in the past in a sensory test.

According to their answers, consumers were chosen based on their frequency of consumption of: red wine (at least once a week), dry white wine (at least once a week), sweet white wine (at least once a fortnight), *Epoisses, Comté, Roquefort,* and *Crottin de Chavignol* (at least once a month each). The final group was composed of 13 males and 18 women, with a mean age of 50.7 years (min 28, max 65-years-old) and they were compensated monetarily after completing the 5 sessions.

The number of consumers who participated in this study was determined as a compromise between the practical limitations of the experiment and recommendations given for TDS evaluations and in-lab preference tests. Variables such as serving temperature, serving size, sample preparation (wine serving, cheese cutting, and so on) needed to be controlled. For this purpose, the test was done in a sensory laboratory. Moreover, cheese can quickly evolve over time, therefore to make sure that all assessors tried the product in the same condition, they all participated in the same day. As another controlled variable, all consumers performed the test at the same moment of the day (noon), being the capacity of the sensory lab crucial. For the TDS evaluation, we followed the recommendation given by Pineau and Schlich (2014) who state that 30 evaluations can give solid results. On the other hand, for an in-lab preference test, Stone and Sidel (2004) recommend 25–50 responses (p. 263).

Authors are aware that the final group size ($n = 31$) can be small in comparison to a traditional consumer test. However, as stated in the introduction, it was not the aim of this study to do a population projection based on the liking ratings but to present an innovative protocol where TDS data and hedonic ratings are collected on the same session to study the impact of one product (cheese) on the perception and liking of another (wine).

Table 3–Definitions and references of the attributes used to describe the different wines.

Attribute	Definition	Presented reference	Descriptor for
Sour	Basic taste related to sour products such as lemon juice.	0.08% citric acid solution	Sancerre Pacherenc Madiran Bourgogne
Bitter	Basic taste related to bitter products such as endives or dark chocolate.	0.05% caffeine solution	Sancerre Pacherenc Madiran Bourgogne
Sweet	Basic taste related to sucrose.	2% sucrose solution	Sancerre Pacherenc Madiran Bourgogne
Astringent	Sensation related to drying of mouth coating.	Concentrated green tea	Sancerre Pacherenc Madiran Bourgogne
Alcoholic	The burning sensation related to alcohol.	*No physical reference was provided*	Sancerre Pacherenc Madiran Bourgogne
Woody	The aroma related to wine aged in wooden barrels.	Wood chips	Sancerre Pacherenc Madiran Bourgogne
Floral	An aroma representing the floral family.	Violet scent	Sancerre Pacherenc Madiran Bourgogne
Grilled	The aroma related to grilled foods.	Grilled bread	Pacherenc Madiran
Honey	The aroma of honey.	*Miel du Portugal*	Pacherenc
Yellow fruits	The aroma related to white and yellow fruits: apple, peach, pear, apricot, and so on.	A mixture of peach and pear syrups.	Sancerre Pacherenc
Citric	Aroma related to grapefruit, orange, lemon, lime.	Concentrated citric syrup.	Sancerre Pacherenc Bourgogne
Spicy	Aroma related to pepper, nutmeg, cinnamon, clove, and so on.	A mixture of grains of pepper, nutmeg and clove.	Sancerre Madiran Bourgogne
Red fruits	Aroma related to all berries (strawberry, cranberry, raspberry, blackberry, and so on).	A mixture of concentrated blackberry, blackcurrant and raspberry syrups	Madiran Bourgogne
Vegetal	Related to fresh vegetables	A mixture of green and black olives with green peperbell	Sancerre Madiran Bourgogne

Sensory method

The whole experiment took place over 6 sessions, each of them 1-h long, scheduled around noon. The 1st session had as its aim the presentation of the method and the attributes used. The 2nd session was devoted to wine evaluation in multiple sips, aiming to characterize the 4 wines over multiple intakes. The successive 4 sessions had as their goal the evaluation of wine in multisip but with cheese ingestion between each wine sip (a same cheese with the 4 different wines in each session). In this way, the impact coming from successive consumption of wine and cheese was evaluated. The tasting protocol used in the different sessions is described in the subsections below.

Presentation of the method to consumers. During the 1st session consumers worked on the vocabulary to be used and on the sensory method. Since TDS uses a limited list of descriptors, it was important to assure that the provided attributes meant the same for all consumers and that they agreed on their meaning. For this purpose, they were presented the list of descriptors with their definitions and a set of gustatory and olfactory references (Table 3).

The references for sour, bitter, sweet, and astringent were presented coded with a random 3-digit number and consumers were asked to try them and state to which sensation corresponded each solution. Solutions were correctly identified. Being part of the

Chemosens database, consumers had already been screened for basic taste perception at least once in the past, also explaining that none of the recruited consumers showed bitter blindness. Afterward, they were presented the olfactory references and they were explained that those aromas represented the different aromatic families, for example, for floral they were presented a violet scent but they were instructed that any aroma in relation to other flowers such as roses, gardenias, and so on, could be considered as floral.

All attributes were not applied to all wines given that they were very different in style and composition and that the aim of the work was not to compare profiles among wines but to compare the changes (or not) of each wine after multiple intake and also due to cheese consumption. The final descriptors used for each wine (a total of 11) are presented in Table 3.

A short presentation was given to explain the method as well as the definition of dominant sensation as "the sensory attribute which catches the most your attention at a given moment" (Pineau and others 2009). Finally, consumers tried the method by evaluating 3cl of a white wine (a training sample, not presented in Table 1) over 3 consecutive sips. This was performed in individual sensory evaluation booths at 20 °C and data were acquired by means of the TimeSens® software (INRA, CSGA, Dijon, France).

Wine evaluation by multisip TDS and alternated hedonic test. The 4 wines presented in Table 1 were dynamically described by multisip TDS alternated with hedonic tests (Thomas and Schlich 2014; Thomas and others 2016). Figure 1A shows a global description of the tasting protocol along time. In Figure 2A and B, the different screens for data acquisition are presented.

For the TDS test, assessors were instructed to click on the "START" button (Figure 2A) as soon as they had the wine in their mouth. They could then successively select the attributes that most triggered their attention from the provided list. Clicking on one attribute at a time, they could change as many times as they wanted whenever a new sensation became dominant and they were free to choose an attribute several times. The wine was swallowed whenever participants felt like it and the evaluation went on until no sensation was perceived as dominant. At this moment, they were instructed to click on the "STOP" button to indicate the end of the TDS evaluation of this sip. There was no pre-established time limit for the evaluation. Attribute order within the list was randomized across the panel (Pineau and others 2012). Each consumer had the same order for the 3 consecutive sips, but this order changed from wine to wine.

After the TDS evaluation, they were presented a new screen (Figure 2B) and they were asked to rate their liking (on a continuous visual analogue scale [VAS]) for the wine sip they had just evaluated. The same steps (TDS + hedonic rating) were followed for the 2nd and 3rd sip. In this way, 3 TDS profiles and 3 hedonic ratings were obtained for each wine.

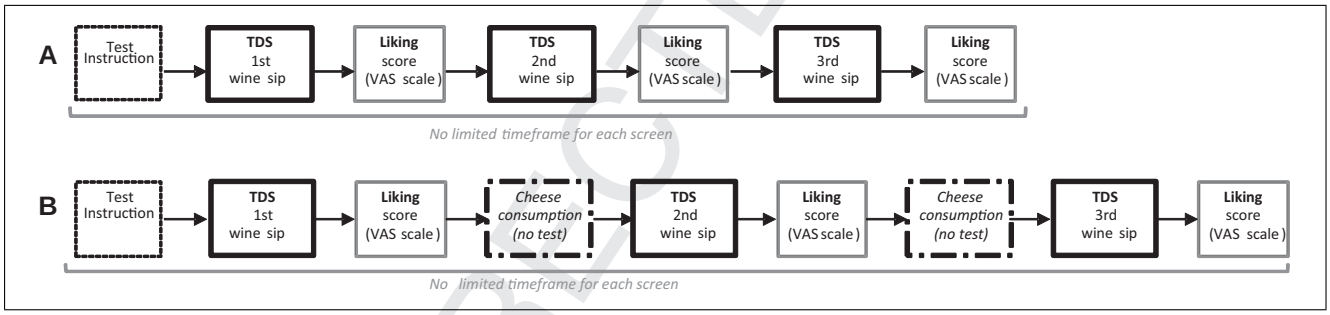

Figure 1–Description of the 2 wine evaluation processes across time. (A) Wine evaluation by multisip TDS and alternated hedonic test. (B) Wine evaluation by multisip TDS and alternated hedonic test after cheese consumption.

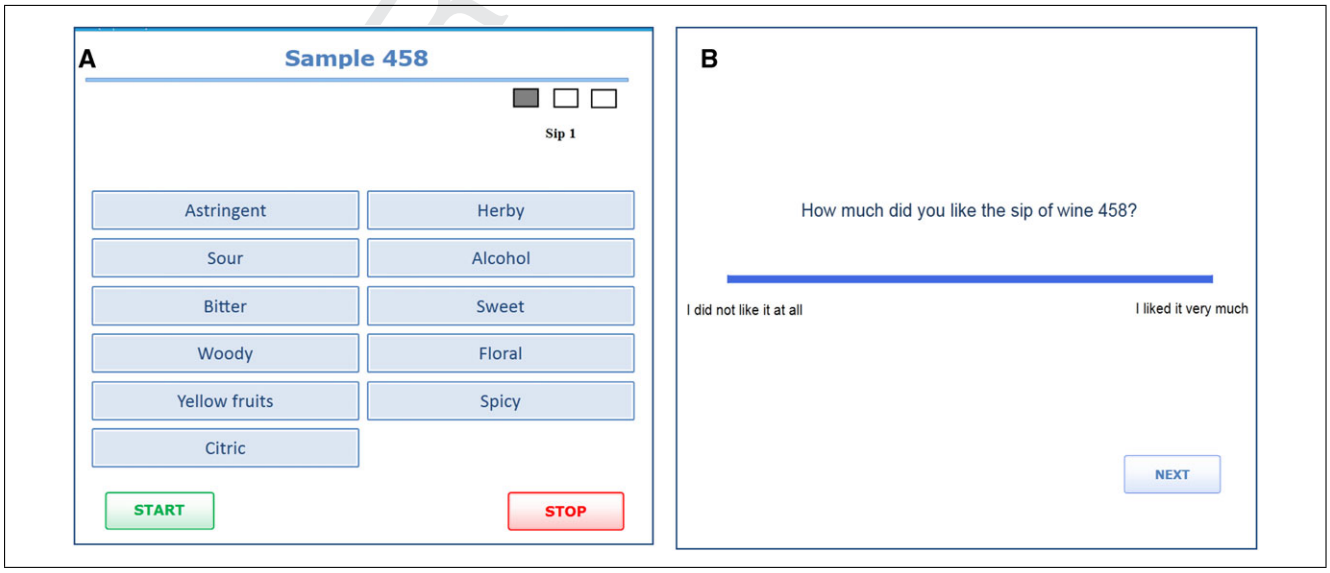

Figure 2–Screenshots used for data acquisition. (A) Temporal dominance of sensations (attributes in this figure are those which were presented for the wine *Sancerre*). (B) Hedonic test.

Wine samples (3cl) were presented in black wine glasses, coded with random 3-digit numbers in a monadic manner and following a Williams Latin square. The quantity served was sufficient for taking 3 sips (1 sip is approximately 1cl); however, the final actual amount ingested in each sip by each consumer was unknown. Wines were served 30 minutes before the tasting and stored at their usual serving temperature (18 °C for the red wines and 10 °C for the white wines). Participants were at no point informed on the type of wine they tasted. After each wine's complete evaluation, there was a 3-min long mandatory pause for mouth rinsing with water and bread. Drinking water between sips was not allowed. The 31 consumers evaluated the 4 wines over one 1-h long session,

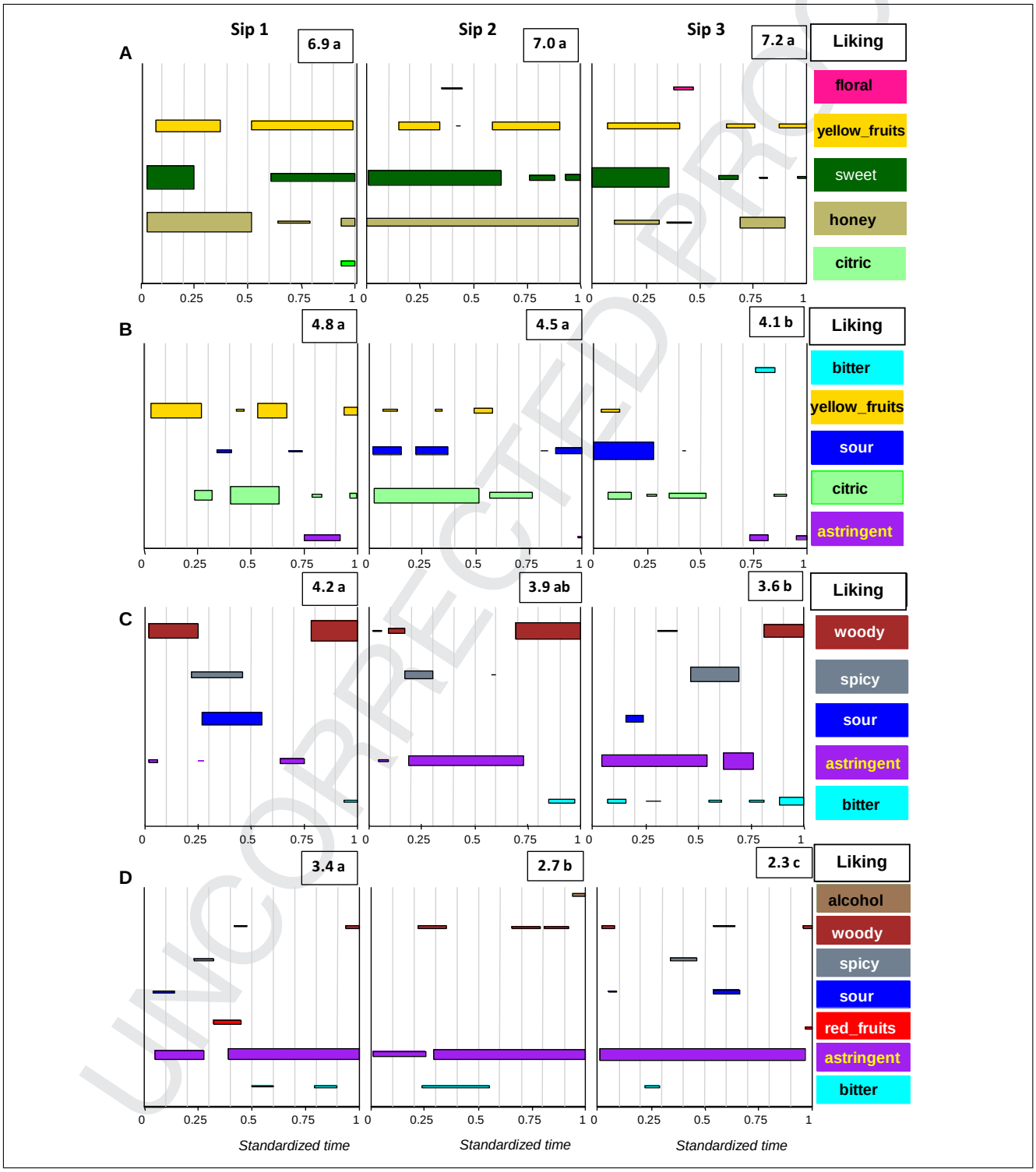

Figure 3–Bandplot by descriptor for each of the evaluated wines as follows: (A) *Pacherenc*, (B) *Sancerre*, (C) *Bourgogne*, (D) *Madiran*. The x-axis of each graph represents standardized time between 0 and 1. Different letters on liking scores represent significant differences among sips for each wine according to LSD test.

Table 4–Significant differences among sips, by wine, in terms of total sip duration and duration of dominance (both in seconds).

	F-sip	Sip 1	Sip 2	Sip 3
SANCERRE				
Total duration	2.65 (.)	33.9 ± 15.4 ab	31.8 ± 13.2 b	34.9 ± 13.4 a
Sour	2.59 (.)	4.6 b	4.8 ab	6.6 a
Sweetness	2.63 (.)	2.1 a	1.0 ab	0.5 b
Yellow_fruits	3.11*	6.4 a	4.3 b	5.3 ab
MADIRAN				
Total duration	7.29***	38.2 ± 15.7 a	34.0 ± 14.7 b	32.6 ± 16.8 b

Significance levels: (.)10%, *5%, ***0.1%.
Different letters indicate significant differences according to an LSD test.

meaning they had 12 sips of wine along 1 h. Evaluation was performed in individual sensory booths at 20 °C and data were acquired by means of the TimeSens® software (INRA, CSGA, Dijon, France).

Since the wine was swallowed, the 3 sips per wine sample were established in order to limit alcohol consumption (12cl of wine is approximately 15mL of alcohol per session). As a precaution, a breath alcohol test was carried out before and after the tasting sessions. Consumers had to have 0.00 g/L of ethanol in order to participate in the test and at the end of the sessions, values were always below 0.2 g/L. Taking into consideration this precaution and the fact that the samples used were commercial wines, no further ethical approval was demanded for the experiment.

Wine evaluation by multisip TDS and alternated hedonic test after cheese consumption. Figure 1B shows the global process of wine description for this 2nd tasting protocol. As it can be observed, consumers performed the same type of wine evaluation as before (2.3.2, Figure 1A). But, this time, they had to eat a portion of cheese (6 ± 0.5 g, see Table 2 for cheese description) between sips. *Comté* and *Crottin de Chavignol* were served in 2 cubes, *Roquefort* was served on 2 spoons, and *Epoisses* was presented as a small slice which had to be eaten in 2 separate bites. There was no time limit for eating the piece of cheese, but consumers were instructed to take the 2nd and 3rd sip of wine as soon as they had swallowed the cheese. It was the purpose of this instruction to minimize the time between cheese swallowing and wine tasting in order to better perceive the impact of cheese flavor on wine description and liking.

Assessors evaluated the 4 wines after the intake of the 4 cheeses, resulting in 16 combinations, across 4 sessions over 2 wk. During each session, the 4 different wines were evaluated with the same cheese, to avoid changes due to cheese maturation over sessions. For example, in one session all consumers tasted: *Madiran+Comté, Pacherenc+Comté, Bourgogne+Comté and Sancerre+Comté*. The following session was the same but with *Epoisses* and so on.

As in the previous section, attribute order was randomized across the panel. Each consumer had the same order for the 3 consecutive sips, but they did not have the same order for every wine. There was a 3-min mandatory break between different wines for mouth rinsing with bread and water. Wines were presented in black wine glasses, consumers had no information on the tasted wines, and the 3 sips were taken from the same glass. The evaluation was performed in individual sensory booths at 20 °C and data were acquired by means of the TimeSens® software (INRA, CSGA, Dijon, France).

Data analysis

Wine perception by multisip TDS. Differences among sips were evaluated by wine in terms of total sip duration and duration of dominance by attribute. Duration of dominance was obtained,

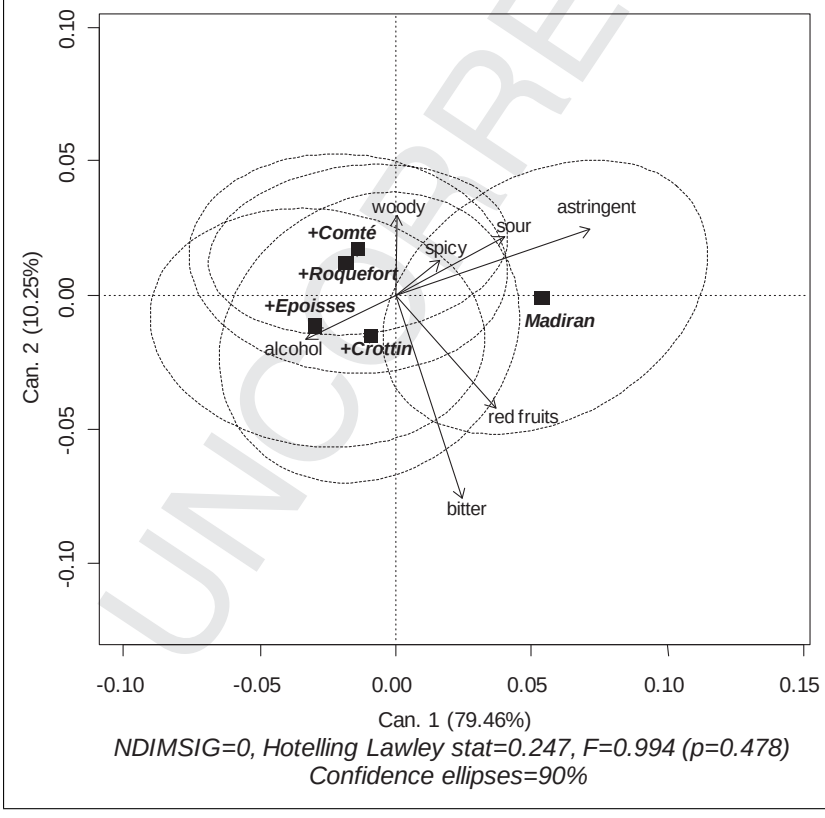

Figure 4–Canonical variate analysis of the durations of dominance of descriptors for sip 1 of *Madiran* wine evaluated over the different sessions where: no cheese was consumed (*Madiran*), *Comté* (+*Comté*), *Roquefort* (+*Roquefort*), *Epoisses* (+*Epoisses*) or *Crottin de Chavignol* (+*Crottin*) were eaten after the 1st sip.

Table 5–Significant differences on the 3rd sip, by wine, in terms of total sip duration and duration of dominance (both in seconds).

	F- prod	+ no cheese	+ *Comté*	+ *Crottin*	+ *Époisses*	+ *Roquefort*
PACHERENC						
Total duration	3.22*	35.0 ± 16.6 a	28.9 ± 12.9 b	31.3 ± 16.0 b	29.7 ± 12.8 b	31.0 ± 15.3 b
Alcohol	2.91*	1.48 b	3.37 a	2.54 ab	1.47 b	1.43 b
Bitter	2.26(.)	0.67 b	0.65 b	1.06 b	1.33 ab	3.21 a
Citric	2.63*	2.36 ab	1.49 b	1.63 b	3.07 a	0.98 b
Sour	2.04(.)	1.64 ab	0.90 b	1.81 ab	1.03 b	2.93 a
Overall (MANOVA)	1.776**					
SANCERRE						
Total duration	3.31*	34.9 ± 13.4 a	28.7 ± 11.8 b	32.2 ± 13.5 ab	30.3 ± 16.8b	31.0 ± 15.4b
Astringent	3.18*	3.25 a	0.75 c	2.77 ab	1.43 bc	2.13 abc
Citric	2.16(.)	7.43 a	6.47 ab	6.5 ab	4.35 b	4.34 b
Overall (MANOVA)	1.44*					
BOURGOGNE						
Total duration	4.58**	34.5 ± 16.2 a	29.3 ± 12.9 bc	31.8 ± 14.3 ab	28.1 ± 14.0 bc	26.3 ± 13.5 c
Astringent	4.65**	5.98 a	4.22 b	3.64 b	2.83 b	2.63 b
Red fruits	2.51*	2.61 b	4.56 ab	5	4.38 ab	2.54 b
Overall (MANOVA)	1.75**					
MADIRAN						
Total duration	1.07	32.6 ± 16.8	29.1 ± 12.0	29.7 ± 14.4	29.5 ± 14.4	27.9 ± 12.7
Astringent	8.10***	10.03 a	4.38 b	4.36 b	4.23 b	5.88 b
Red fruits	2.08(.)	2.34 b	3.86 ab	4.98 a	4.45 a	3.28 ab
Sour	2.94*	3.72 a	2.3 ab	2.18 b	1.15 b	2.55 ab
Overall (MANOVA)	2.544***					

Significance levels: (.)10%, *5%, ***0.1%.
Different letters indicate significant differences according to an LSD test.

at individual level, by adding all the time periods during which an attribute was dominant, regardless of the moment of perception. Differences among sips were tested for each wine, according to the following analysis of variance (ANOVA)/multivariate analysis of variance (MANOVA) model:

Duration = Subject + Sip; where Duration represents the total duration (in seconds) of each recorded attribute and Subject was a random effect (Galmarini and others, in press) .

MANOVAs of the sips were represented by canonical variate analysis (CVA; Noble and others, 1984, Peltier and others, 2015).

TDS data for each wine sip were represented by TDS bandplots by descriptor for visual inspection and to facilitate comparison of sequentiality of dominant sensations. Time was standardized between 0 (START) and 1 (STOP) and the height of each bar was proportional to the highest dominance rate in each intake (Galmarini and others, in press).

All analyses were done using TimeSens® software (INRA, CSGA, Dijon, France).

Effect of cheese intake on wine perception. The impact of cheese on wine perception was evaluated by comparing TDS results by sip with and without previous cheese consumption. This was done in terms of duration of dominance of attributes according to the following ANOVA/MANOVA model by wine and sip:

Duration = Subject + Wine tasting condition; where the wine tasting condition represents each wine evaluated after no cheese, *Comté, Crottin de Chavignol, Eppoises,* and *Roquefort*. Subject was again considered as a random effect.

Since each wine tasting condition occurred over different sessions, differences could also be due to a session effect. In order to rule this out, an analysis of sip 1 was used to evaluate consumers' agreement over sessions.

In order to see the effect of cheese intake, sip 2 and sip 3 were compared over sessions without and with cheese intake. For the sake of brevity, only comparisons of sip 3 will be presented in the results section.

Differences on duration of dominance were graphically represented (for each wine) by a CVA. Only attributes with a total duration bigger than 5% of the mean total duration of the sip (at panel level) were taken into consideration.

Analyses were done using TimeSens® software (INRA, CSGA, Dijon, France).

Effect of cheese intake on hedonic rating of wine. The effect on preference was explored for every wine without and with cheese intake in-between sips. Because successive liking scores are correlated, an autoregressive heterogeneous (ARH) structure of covariance was used according to the model:

$$Liking = Subject + Wine\ tasting\ condition + Sip + 3\ interactions\ of\ first\ order,$$

where Sip was considered as a repeated measurement and Subject as a random effect. Proc Mixed from SAS® software (SAS Inst. Inc., Cary, N.C., U.S.A.) was used with a differences least squares means test.

Results and Discussion

Multisip wine evaluation

Changes in wine perception over multiple intakes were analyzed in terms of total duration of dominance sensations, sequentiality of dominant sensations and in terms of liking. Results are presented and discussed following that structure.

Differences on the total duration of the sip were analyzed to detect a possible evolution of the evaluation along intakes, since there was no pre-established time limit for performing the TDS evaluation. Results are presented in Table 4. Only *Sancerre* and *Madiran* showed significant differences for total duration over sips. In *Sancerre*, sip 3 was longer than sip 2 ($P < 0.1$) while for *Madiran* the 1st sip was significantly longer than the other 2 ($P < 0.001$). For the other 2 wines, there was no significant difference in the duration of the evaluation among the 3 sips (mean and standard

error over the 3 sips 34.1±16.1 s for *Pacherenc* and 34.4±16.0 s for *Bourgogne*). Therefore, the time devoted to each sip was not the same for all the products. From a methodological point of view, this shows the merit of not having a pre-established time limit for the tasting of this type of products.

In terms of duration of dominance, only significant ($P < 0.1$) results are presented in Table 4 for the purpose of brevity. The wine which showed differences among sips was the *Sancerre.* There were differences for sour ($P < 0.1$), sweet ($P < 0.1$) and yellow fruits ($P < 0.05$). The dominance duration of sweetness decreased from sip to sip while for sourness it increased. Sourness was an important descriptor in terms of duration of dominance while sweetness was dominant for a very short time. For *Bourgogne, Pacherenc* and *Madiran* no significant changes were observed for descriptors in terms of duration of dominance over sips.

Evaluation in terms of duration of dominance allows a statistical comparison by descriptors; however, the sequentiality of the dominant sensations at panel level is not represented. In a complementary way, TDS curves (Pineau and others 2009) or bandplots by descriptors (Galmarini and others, in press) enable the representation of sequences of dominant sensations, together with the dominance rate of each descriptor at panel level. For the purpose of clarity in the comparison of multiple sips, the TDS profile of each wine is presented by means of bandplots by descriptors in Figure 3A to D in order to visualize the sequentiality of sensations sip to sip (by wine) together with the agreement among panelists

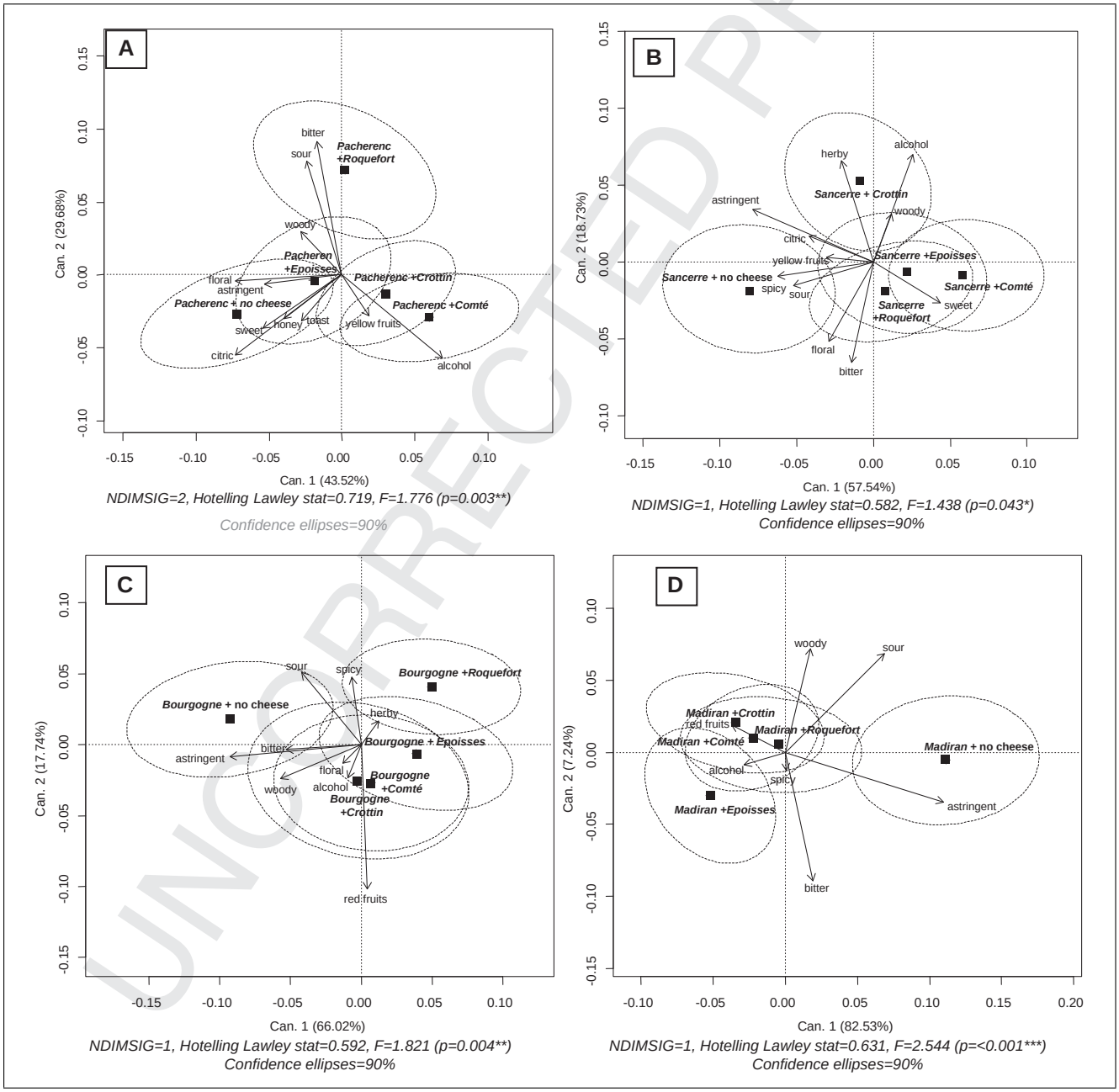

Figure 5–(A, B, C, D). Canonical variate analysis for the 3rd sip of each wine evaluated over the different sessions after no cheese, *Comté*, *Roquefort*, *Epoisses*, and *Crottin de Chavignol* (referred to as *Crottin* in the figure for the purpose of brevity).

(dominance rate). A bandplot by attribute is a 2-dimension graph with the *x*-axis showing time (here standardized between 0 and 1) and the *y*-axis showing the descriptors. The height of the bars is proportional to the dominance rates, giving an idea of the order of importance of attributes for the panel. To sum up all the information on the wines in one figure, the mean hedonic rating of each wine sip and the results of the differences of least squares means comparisons are also presented.

Pacherenc, a wine with a high concentration of sugars (Table 1), revealed a simple profile without an important sequentiality of dominant sensations (Figure 3A). Sweetness, yellow fruits, and honey were dominant almost all along the intake of each sip, changing in terms of dominance rate. The sugar content in this wine was 8.5 times above the average threshold level for sweetness in wines (Amerine 1983). Given that sweet is an easily identifiable taste it is not strange that this descriptor was dominant at the panel level over the 3 sips. Liking was also high and stable over the 3 sips.

For *Sancerre* (Figure 3B), the 1st sip was characterized by the dominance of yellow fruits at the beginning, followed by citric, a certain dominance of sour in the middle of the sip and a slightly astringent and aromatic finish. The 2nd sip was perceived with a more sour attack and finish, while citric was dominant during almost the whole sip. In the 3rd sip, dominance of sourness was more present at the beginning while at the end some bitterness was dominant together with astringency. Regardless of changes in duration of dominance (Table 4), sweetness did not achieve significance at panel levels. As a dry white wine it was expected to have a certain sour/sweet balance (Zamora and others 2006). The duration of dominance of sourness increased over sips while sweetness was not dominant at the panel level and its total duration decreased over sips (Table 4). So even if sour/sweet balanced was not measured, results showed that sips after sip sourness caught more the consumers' attention. This evolution was accompanied by a decrease in liking.

Red wines were described by the same attributes, but their TDS profiles were quite different. *Bourgogne* (Figure 3C) was described by a woody attack, followed by the dominance of spicy and sour, ending mostly on a woody note with a little bitterness and astringency. Dominance of astringency and bitterness seemed to increase over sips at panel level, while there was always a dominance of spicy and woody. In terms of hedonic ratings, the wine was not highly liked in the 1st sip and this slowly decreased over sips.

The TDS profile for *Madiran* was different and more plain (Figure 3D). Astringency was the dominant attribute all along the sip for the 3 sips. Even though several other attributes reached significance at different moments (bitter, red fruits, sour, spicy, woody, alcohol), their dominance rates were very small compared to astringency. This was probably related to its high levels of tannins (Table 1). Colonna and others (2004) showed that astringency of red wines has a carry-over effect which builds up over multiple sips. It could have been expected to have differences in astringency over sips, but TDS is a qualitative—not quantitative—technique. So results showed that the astringency of the wine caught the attention of consumers on the 1st, 2nd, and 3rd sip but we cannot know if its intensity increased over the sips. This wine was the least liked by consumers and liking decreased markedly from sip to sip.

The 4 evaluated wines presented different temporal profiles within and between sips together with distinguished differences in liking, providing a wide product range to evaluate the effect of cheese.

Effect of cheese on wine perception and hedonic rating. As presented in data analysis section, the effect of cheese on wine was evaluated by comparing the durations of dominance obtained sip to sip without and with previous cheese ingestion. In order to assure that the observed differences were due to cheese intake and not to a session effect, results for sip 1 over the 5 sessions (no cheese, *Comté, Crottin de Chavignol, Epoisses* and *Roquefort* sessions) were compared for each wine. It should be pointed out that at each session wines had a different code.

MANOVAs showed no significant differences in terms of attribute duration of dominance in any of the wines. The following *F values* (and *P* values) were obtained: *Pacherenc*, 1.002 ($P = 0.466$); *Sancerre*, 0.894 ($P = 0.656$); *Bourgogne*, 1.064 ($P = 0.374$); and *Madiran*, 0.994 ($P = 0.478$). As an example, results for *Madiran* are represented in a CVA in Figure 4. As it can be observed, all sips are superimposed showing no differences in terms of attribute's duration of dominance over sessions. We conclude that differences found over the 3rd sip are certainly due to cheese intake and not to a session effect or lack of consistency. This also showed that a group of consumers can give consistent TDS results over sessions in terms of duration of dominance; even if this is only a subset of possible types of TDS consistency.

The effect of cheese on the total duration of the sip and on the dominance duration of each attribute for the different wines is presented in Table 5 (only significant differences are presented). When cheese had an effect, it was reducing wine's persistence. For *Pacherenc* the total duration of the sip was reduced in the same way ($P < 0.05$) after the consumption of all of the presented cheeses. For *Sancerre* and *Bourgogne* the sip evaluation was shorter ($P < 0.05$) after eating *Comté, Epoisses* and *Roquefort*; no differences were observed after *Crottin de Chavignol*. No changes were observed for *Madiran*.

Cheeses also had different impact on the duration of dominance of different attributes. It should be noted that, even if only results for sip 3 are presented, results for sip2 showed the same tendency.

In *Pacherec, Comté* significantly ($P < 0.05$) increased the duration of dominance of alcoholic sensation (in comparison to no cheese intake) and *Roquefort* increased the duration of bitter (almost nonexistent without cheese intake). The citric aroma was increased after *Epoisses* in comparison to *Comté, Crottin the Chavignol,* and *Roquefort*. However, those attributes with the longest duration (sweet, yellow fruits, honey) did not change significantly after eating cheese. MANOVA results showed global differences among the 5 different cases represented by a CVA in Figure 5A. Overall, *Roquefort* cheese made consumers perceive wine as bitter and sour at a certain point of the tasting, adding new information on the temporality of perception of the wine. This cheese had a different impact from the other cheeses which could be a consequence of the sensory contrast between the 2 products, as stated by Harrington and Hammond (2005) who evaluated wine–cheese pairing.

Pacherenc was highly liked in all tasting conditions (Figure 3 and 6A**)**. The mixed model used showed that sip, wine tasting condition and the interaction sip*wine tasting condition were not significant. However, it should be pointed out again that 31 consumers is a small number, so all hedonic results are presented as tendencies which in this case did not reflect the changes in perception.

In *Sancerre* only 2 descriptors changed significantly after eating cheese: citric and astringent. Citric was an important attribute in terms of duration for this wine and its duration was significantly

reduced by *Roquefort* and *Epoisses*. Nygren and others (2002) studied flavor changes in white dry wine after tasting *Roquefort* cheese and found that the intensity of citrus flavor in *Sancerre* wine (*Les belles dames,* 1997) decreased significantly after consuming *Roquefort* (*Roquefort Société*). Even if the present tasting method measures duration of dominance and not intensity, results show an interesting coherence. Astringency duration was reduced by cheese intake: it was significantly different from no cheese after *Epoisses* and *Comté*. Figure 5B shows that *Crottin de Chavignol*—which shared *terroir* with *Sancerre*—changed the global perception of *Sancerre* in a different way than the others.

The interaction sip*wine tasting condition for the liking ratings was significant ($P = 0.0015$) showing that wine liking did not evolve in the same way under each tasting condition. Eating *Comté* increased significantly the liking of wine when compared to no cheese (Figure 6B), a condition under which liking decreased slightly over the consecutive sips.

In red *Bourgogne,* changes were observed on astringency and on red fruits. Especially *Roquefort* and *Epoisses* reduced astringency's dominance duration. Without cheese intake, dominance duration of red fruits was short and not cited at the same time for all consumers and was therefore absent on the bandplot (Figure 3C). Cheese intake had a positive impact increasing its duration, being this especially significant after *Crottin de Chavignol*. This can be observed on the CVA in Figure 5C which shows that the perception of this wine changed after eating *Roquefort* reducing the duration of dominance of astringency while *Comté* mostly increased the duration of red fruits and sweet. There were also changes in liking (Figure 6C), where sip*wine tasting condition and sip were significant (P values = 0.024 and 0.006, respectively). Wine liking decreased along sips without cheese intake while it increased after cheese intake.

The most significant impact of cheese on wine perception was found for *Madiran* (P value of MANOVA <0.001). Its dominance duration of astringency and sourness was reduced while for red fruits it increased (Table 5). Figure 5D shows how cheese reduced the duration of dominance of astringent and sour and increased that of aromatic descriptors. All cheeses increased liking of *Madiran* (Figure 6D). A highly significant sip*wine tasting condition interaction (P value <0.0001) showed that the dynamic of liking changed drastically between with and without cheese intake. Even though, as previously stated, the number of consumers was not big enough to be considered as a consumer test, this level of significance shows an important effect of cheese on wine liking.

Astringency is a complex tactile sensation produced by binding polyphenols with saliva proteins which later precipitate (Goldner and Zamora 2010). Studies on the perception of astringency in red wine have shown a link between salivation flow and astringency intensity rating (Ishikawa and Noble 1995) where astringency was rated more intensely and longer (by time-intensity evaluations) by low-flow subjects, suggesting that the difference is a function of salivary flow status. Nayak and Carpenter (2008) showed that assessors rated black tea as less astringent after chewing than after drinking water, because their volume of saliva was above resting

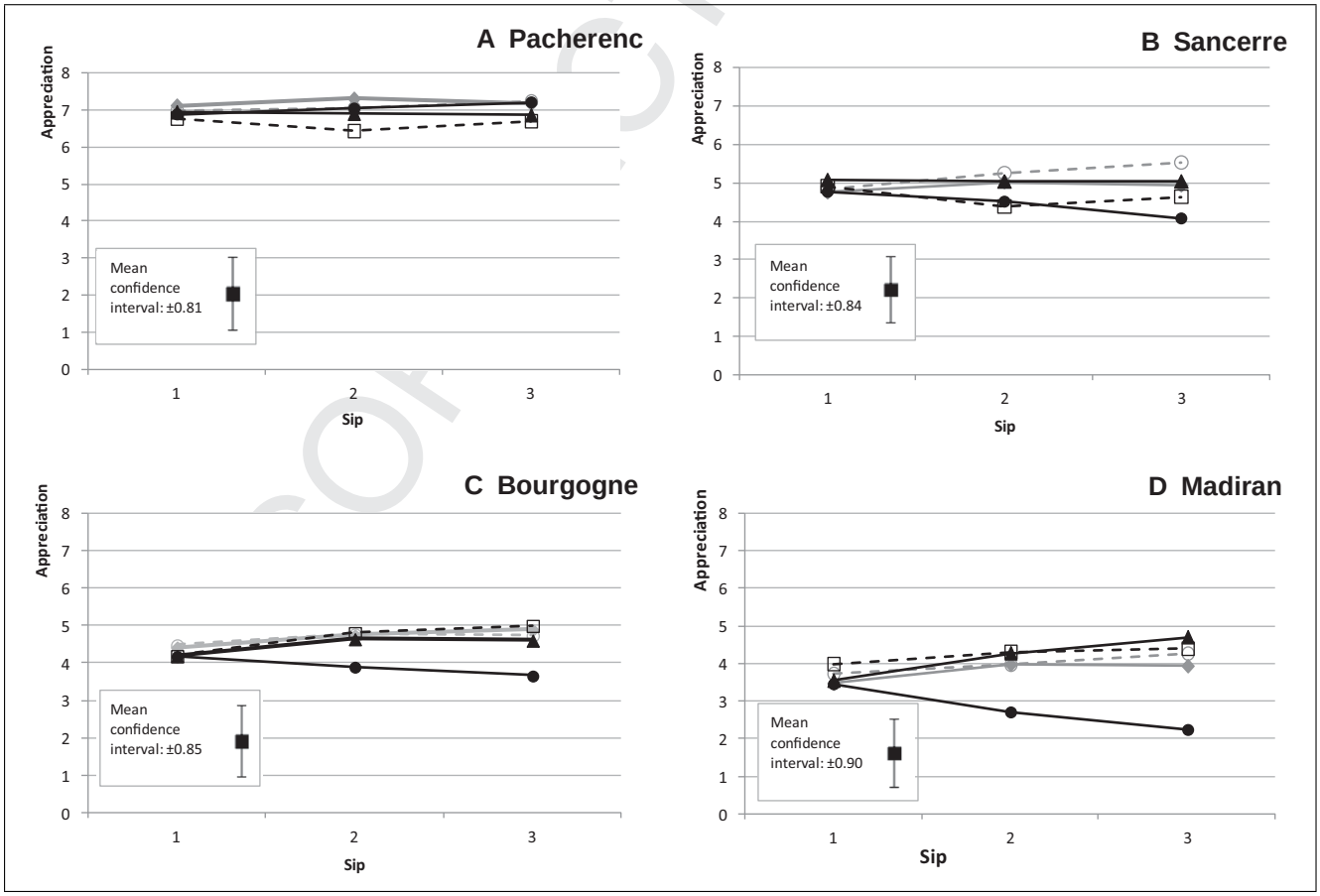

Figure 6–(A, B, C, D). Mean hedonic ratings for wines over the 3 consecutive sips (—●— No cheese) and mean hedonic ratings for wines before (Sip 1) and after (Sips 2 and 3) eating: -●- *Comté* —◆—, *Crottin de Chavignol*, —▲— *Epoisses*, -■- *Roquefort*.

levels. This could be one possible explanation to why the astringent sensation was dominant for a significantly shorter period of time after eating cheese, regardless of the type of cheese. Other than salivation, fat present in the cheese can have a mouth-coating effect (Nygren and others 2002) increasing lubrication and decreasing the perception of astringency.

Assessors noticed the astringency of the red wines less, whereas the aromatic notes caught their attention. Madrigal-Galan and Heymann (2006) and Nygren and others (2002) found that cheese intake translated into a reduction of wine character since cheese (generally) decreased the perceived intensity of sourness and many flavor attributes. In the present case, red fruit aroma became dominant for a longer period of time after cheese intake, adding some complementary information which could not be assessed by traditional profiling.

Traditionally, sensory and hedonic responses are collected from a trained panel and consumers separately, or from consumers but on different sessions. Getting this information from consumers in the same evaluation could be considered a controversial practice, especially if a descriptive task is done before the hedonic evaluation. When consumers were asked to rate their liking after doing an analytical task, Prescott and others (2011) found that liking rates decreased. However, this halo effect was the same whether consumers were focused on positive or negative attributes.

Coupling overall liking with a temporal descriptive technique is a very recent practice. Oliveira and others (2015) were the 1st to ask consumers to rate their overall liking after completing a TCATA evaluation on probiotic chocolate-flavored milk. More recently, Thomas and others (2016) coupled TDS to a hedonic task over successive sips of an oral nutritional supplement. According to these authors, TDS cannot be really considered as a classic analytic sensory method since it is an instinctive, global task in which consumers are asked to select the attribute(s) associated to the sensation catching their attention at a given time. We agree with this point of view, and we believe it would be interesting to develop future research on the impact of TDS evaluation on liking. In the present work, ratings where compared from sip to sip with or without cheese. The importance of the analysis is in relative, not absolute, terms. All the hedonic ratings were given under the same conditions and were at no point compared to external rating values. Therefore, we believe that the protocol is adequate to see if the liking of a given wine increases, stays the same or is reduced by the previous intake of a cheese, regardless of the value of the rating itself. Taking this into consideration, it was observed that cheeses either increased or had no impact on wine liking (Figure 6).

Conclusions

Wine dynamic characterization and perceived changes along consumption were obtained by multi-intake TDS. Analyzing data in terms of duration of dominance gave new information on how wine perception evolved over sips, showing that not in all cases duration of dominance changed significantly from sip to sip.

Cheese intake in-between wine sips changed the dynamic characterization of wines. In both red wines, the 4 cheeses decreased the duration of dominance of astringency and increased that of red fruits aroma. In the sweet white, the duration of dominance of sweetness (the main descriptive attribute) was not changed by cheese intake. In the white dry wine, cheeses had an impact on the main aroma (citric).

None of the 4 cheeses included in this study had a negative impact on wine liking. Liking of wine was either improved, or remained the same after cheese intake; however, hedonic results should be validated with a bigger group of consumers. It would also be interesting to carry out a similar protocol with 2 separate groups to compare liking scores with and without TDS evaluation.

Multisip TDS is a promising technique which should continue to be studied in relation to the evaluation of a whole portion of food or beverage. Moreover, the consumption of different products in-between sips (or bites) could be a starting point toward the development of food-pairing evaluation techniques.

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Author Contributions

Mara V. Galmarini designed the study, carried out the experiment, interpreted the results, and drafted the manuscript. Anne-Laure Loiseau participated in data collection and experimental design. Michel Visalli did most of the statistical tests. Pascal Schlich designed the study and the different statistical models. All authors collaborated in the writing of the manuscript and interpretation of results.

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