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

Mara V. Galmarini, Anne-Laure Loiseau, Doëtte Debreyer, Michel Visalli, and Pascal Schlich

Abstract: Even if wine and cheese have long been consumed together, there is little sensory evidence on how wine can influence the perception of cheese. In this work 4 cheeses were dynamically characterized in terms of dominant sensations without and with wine consumption in between intakes. The tasting protocol was based on multi-intake temporal dominance of sensations (TDS) coupled with hedonic rating. Frequent wine and cheese consumers ($n = 31$) evaluated 4 cheeses (*Epoisses*, *Chaource*, and 2 different *Comté*) over 3 consecutive bites. In the following sessions they performed the same task, but taking sips of wine (*rosé Riceys*, white *Burgundy*, red *Burgundy*, and red *Beaujolais*) between bites. All cheese–wine combinations were tasted over 4 sessions. TDS data were analyzed in terms of attribute duration of dominance by ANOVA, MANOVA, and canonical variate analysis. Results showed that wine consumption had an impact ($P < 0.1$) on dominance duration of attributes of cheeses, particularly on salty and some aromatic notes. But, as opposed to a previous work done by the same team, wine had no impact on the preference of cheese; this stayed constant under all the evaluating conditions.

Keywords: cheese perception, food pairing, multi-bite, temporal dominance of sensations, wine

Practical Application: This paper aims to validate an innovative protocol on dynamic sensory data acquisition in which consumers evaluate the impact of a beverage (wine) on a solid food (cheese). This protocol is complementary to a previous one presented in this journal, where the effect of cheese was tested on wine. Together they make up an interesting approach towards developing a new tool for the food sector to better understand the impact of one food product on another. This could lead to a better description of a whole meal, something which is still missing in sensory science.

Introduction

Wine and cheese is a classic gastronomic pair that is said to go together like birds of a feather, according to the popular knowledge. However, there is little scientific work in the area of sensory analysis to explain this. According to Harrington (2008), wine and cheese have 2 main things in common that help to create a natural match: both are obtained by a fermentation process, and both are living things that change substantially during the process of aging. However, there are still no hard-and-fast rules about pairing wine with cheese; much is based on personal preferences and recommendations.

In the area of sensory and consumer science, some works can be found on the description of ideal pairs, preference, or other sensory aspects of wine–cheese combinations (Harrington and Hammond 2005; King and Cliff 2005; Bastian and others 2009; Bastian and others 2010; Harrington and others 2010). But very few studies have focused on the effect of one product on the perception of the other, which could be the 1st step toward better understanding a combination.

Nygren and others (2002) were the 1st to study changes on the sensory descriptive profile of different white wines after the intake of blue mold cheese. Madrigal-Galan and Heymann (2006) did a similar work on the effect of cheese intake on red wines' sensory profile, working with a static protocol and a single wine sip after cheese intake. In both cases, the trained panels found mostly a wine character suppression more than enhancement. From the data of both works it could be concluded that the effect of cheese on wine did not seem to be enhancing its flavor.

Nygren and others (2003) also studied a reverse protocol: the effect of white wine on the perception of blue mold cheese, using a sequential tasting method. The trained panelists took some cheese, then expectorated it, then they took a sip of wine which they also expectorated and then again some cheese for which they evaluated its sensory profile. They found that most of the pronounced characteristics of the 2 studied blue mold cheeses (buttery, woolly and basement flavors, and sourness and saltiness), scored lower after the tasting of dry white wine. Authors stated that this was probably due to the changes in saliva composition, the fat content of the cheeses and the tasting technique; stressing the importance of the sensory method used to study this kind of changes.

Taking all these precedents into account, and given that sensory perception is a dynamic phenomenon, Galmarini and others (2016) proposed the use of a dynamic approach working with consumers instead of a trained panel, aiming at obtaining results

JFDS-2017-1081 Submitted 7/6/2017, Accepted 8/28/2017. *Authors Galmarini, Loiseau, Debreyer, Visalli, and Schlich are with Centre des Sciences du Goût et de l'Alimentation, CNRS, INRA, Univ. Bourgogne Franche-Comté, 9E Bvd Jeanne d'Arc, 21000, F-21000 Dijon, France. Author M.V. Galmarini is also a Member of CONICET, Buenos Aires, Argentina, Godoy Cruz 2290 (C1425FQB) Ciudad Autónoma de Buenos Aires, Argentina. Author M.V Galmarini is also with Facultad de Ingeniería y Ciencias Agrarias, Pontificia Univ. Católica Argentina, Buenos Aires, Argentina. Direct inquiries to author Galmarini (E-mail: mgalmarini@gmail.com).*

doi: 10.1111/1750-3841.13932

Journal of Food Science A Publication of the Institute of Food Technologists

Table 1–Evaluated cheese samples.

Sample name	Name of cheese[a]	Type of milk	Cheese classification	Age (wk)	H20 (g/100 g)	Lipids (g/100 g)	Sodium (mg/100 g)	Caproic acid	Butyric acid (mg/100 g)
Epoisses	*Epoisses*	Unpasteurized cow	Soft, smear-ripened	5	55.0	23.8	770	–	160
Chaource	*Chaource*	Thermally treated (72° 1 sec) cow	Soft, smear-ripened	2	56.0	22.0	792	0.5	680
ComtéA	*Comté*	Unpasteurized cow	Semi-hard	64	31.2	35.7	1350	4.4	19.7
ComtéB	*Comté*	Unpasteurized cow	Semi-hard	64	31.0	36.2	1290	1.9	6.7

[a]All cheeses have a protected origin designation (POD).

somewhat closer to real consumption. Because the effect of cheese on wine might build up along intakes, a multi-sip protocol was proposed based on the temporal dominance of sensations (TDS; Pineau and others 2009) paradigm.

TDS is a temporal multidimensional sensory method, which had already been used for dynamic sensory characterization of wine over 1 or multiple sips (Meillon and others 2009; Sokolowsky and others 2015; Vidal and others 2016; Galmarini and others 2017) and of cheese (Saint-Eve and others 2015; Thomas and others 2015; Meyners 2016). Galmarini and others (2016), showed that the duration of dominant sensations in wine changed after cheese intake.

Moreover, a TDS evaluation can be performed by consumers, given that the attributes are simple enough and well explained (Albert and others 2012; Schlich 2013; Castura and Li 2016), because no intensity is rated. Working with consumers allows obtaining a description directly from those that will buy the product (instead of specialists), and also gives 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). Collecting TDS data together with temporal liking (rather than doing it in 2 separate sessions) helps to better understand causality.

The aim of this work was to evaluate a reverse protocol in which the effect of wine on cheese perception was studied. A TDS multi-intake protocol performed by consumers was used to evaluate and better understand how consumers perceive cheese over consecutive bites as well as the effect of wine intake on consumers' cheese dynamic perception and appreciation.

Materials and Methods

Samples

The study was carried out using 4 commercial cheeses and 4 commercial wines which are described in Table 1 and 2, respectively. To better appreciate the effect of wine on cheese, cheeses from 3 different families were chosen: *Epoisses*, red bacteria smear-ripened; *Chaource*, white bacteria smear-ripened, and *Comté*, a firm cheese. To evaluate if smaller differences could be found between similar cheeses, 2 types of *Comté* were used. These had been previously evaluated by an expert panel who found them significantly different, especially in terms of the aromatic profiles. For descriptive purposes, basic chemical characterization provided by cheese manufacturers is presented in Table 1 and that of wines is presented in Table 2. Determination of alcohol, total acidity, and reducing sugars was done according to the Association of Analytical Chemists official methods international standards (method number 920.57, 964.08, and 920.64, respectively; AOAC 1984). Phenolic compounds were determined by spectrophotometry using the technique presented by Somers and Ziemelis (1985). The choice of wine for each of the categories (white, *rosé*, and red) was done by wine professionals from the *Bureau Interprofessionnel des Vins de Bourgogne* and the *Institut Français de la Vigne et du Vin* to ensure samples of good sensory quality. A wide spectrum of wines was covered, taking into consideration traditional wine–cheese associations.

Consumer panel

A total of 31 frequent cheese and wine consumers 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 – authorization no. 1148039). The group of 16 women and 15 men from the city of Dijon (Burgundy region, France), with a mean age of 52 y, were chosen based on their frequency of consumption of: *Epoisses*, *Comté*, and *Chaource* (at least once a month), red and dry white wine (at least once a fortnight), and they had to like *rosé* wine, even if consumption could be less frequent, because the intake of this type of wine is highly seasonal in France.

Table 2–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
Bourgogne (white)	*Chardonnay*	2012	12.87	3.33	1.76	–	7
Riceys (*rosé*)	*Pinot noir,* short maceration	2012	11.95	3.83	0.32	530	13
Beaujolais (red)	*Gamay*	2014	12.98	3.69	0.48	1806	49
Bourgogne (red)	*Pinot noir*	2012	13.07	2.77	0.16	2753	55

Table 3–Definitions and references of the attributes used in the cheeses' description.

Attribute	Definition	Presented reference	Descriptor for
Texture			
Firm	Describes the force required to cut through the sample with the teeth.	Cooked carrots	*Comté*
Melty	The property of melting easily in the mouth.	Milk chocolate	*Epoisses Chaource*
Sticky	Adherence of the cheese to the oral cavity.	Taffy	*Epoisses Chaource*
Creamy	Soft texture, smooth feeling which disappears after swallowing.	Mascarpone cheese	*Epoisses Chaource Comté*
Fatty	The perception of a fatty film in the mouth which can be perceived after product has been swallowed.	Olive oil	*Epoisses Chaource*
Gritty	The perception of small grains on the tongue, which can be crunchy or not.	Old *comté* cheese	*Comté*
Aroma and taste			
Sour	One of the basic tastes.	Citric acid solution (0.08%).	*Chaource Comté Époisses*
Bitter	One of the basic tastes.	Caffeine solution (0.05%).	*Chaource Comté Époisses*
Salty	One of the basic tastes	NaCl solution (0.2%).	*Chaource Comté Époisses*
Sharp	Tingling sensation.	Sparkling water.	*Chaource Comté Époisses*
Fruity	Related to the fruity smell of jam, or mature fruit.	Apricot jam.	*Chaource Comté*
Hazelnut / Dry fruits	Related to the smell of dry, roasted fruits.	Mix of crushed dry fruits	*Chaource Epoisses*
Caramel	Related to the smell of caramel.	Melted caramel.	*Comté*
Mushrooms	Related to the smell of mushrooms, earth, undergrowth.	Fresh mushrooms	*Chaource Epoisses*
Fresh lactic	Related to the smell of butter, cream.	Fresh cream.	*Chaource Comté*
Sour lactic	Related to the smell of curd, whey.	Solution of butyric acid (10%).	*Epoisses*
Vegetal	Related to the smell of cooked vegetables such as carrots, potatoes, celery, and so on.	Diluted vegetable soup.	*Comté*
Animal/Barn	Related to the smell of animals, livestock.	Meat broth and isovalerate solution (5%).	*Comté Epoisses*

As in Galmarini and others (2016), the number of assessors *n* was chosen as a compromise between recommendations given for TDS evaluations (Pineau and Schlich 2014), the minimum needed for an in-lab preference test (Stone and Sidel 2004) and the practical implications of the experiment. Even if the *n* can be small in comparison to a consumer test, it was not the aim of this study to do a population projection.

Sensory method

As previously stated, the sensory protocol used in this paper was adapted from Galmarini and others (2016) looking to evaluate impact of wine on cheese perception and liking.

The whole experiment took place over 6 1-h-long sessions, scheduled around noon. The 1st one had for aim to present the method and the attributes to be used. The 2nd session was devoted to cheese characterization in multiple intakes. The successive 4 sessions were used to perform the evaluation of cheese in multi-bites but drinking wine between each bite as a sort of palate cleanser (the same wine for all consumers with the 4 different cheeses in each session). In this way, the impact coming from successive consumption of cheese with wine was evaluated. Details of the tasting protocol over the different sessions are described in the subsections below.

Presentation of the method to consumers. During the 1st session, the descriptive vocabulary and the sensory method were presented to consumers. To assure that the provided attributes meant the same for all consumers, they were presented a list of descriptors for texture, taste, and aroma with their definitions and references (Table 3). The descriptors were provided by the cheese producers in agreement with the terms used by their internal panels. For the texture and taste attributes, references were tasted. For the flavor descriptors, references were sniffed and consumers were explained that they represented the different aromatic families, for example: for fruity, apricot jam was used as reference because it is close to the aromatic note that can be found in *Comté*, but they were instructed that if they perceived the aroma of another fruit they should choose this category. It should be noted that consumers were briefed on the descriptors and it was made sure that they agreed on the definition given, but they were not engaged in the generation of the list. Given the evident different characteristics of the cheeses, the final list of descriptors was not the same for all of them; only the 2 *Comté* (ComtéA and ComtéB) shared the list of descriptors. The final 12 attributes used for each cheese are presented in Table 3. It should be kept in mind that the aim of the study was not to compare the description of the cheeses but to evaluate the effect of the different wines on each cheese.

Consumers were explained the method defining dominant sensation as "the sensory attribute which catches the most your attention at a given moment" (Pineau and others 2009). Consumers evaluated 3 consecutive bites (3 cubes of 6 ± 0.5 g each) of a commercial *Comté* cheese as a training sample (not presented in Table 1) in individual sensory evaluation booths at 20 °C. Data were acquired by means of the TimeSens® software (INRA, CSGA, Dijon, France) as in all the subsequent sessions.

Cheese evaluation by multi-bite TDS and alternated hedonic test. The 4 cheeses presented in Table 1 were dynamically described by multi-bite TDS alternated with hedonic tests (Thomas and Schlich 2014; Galmarini and others 2016; Thomas and others 2016). Figure 1(A) shows a description of the tasting protocol along time.

The TDS evaluation began by the assessors clicking on the "START" button and placing the cheese in their mouth. 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 cheese was chewed

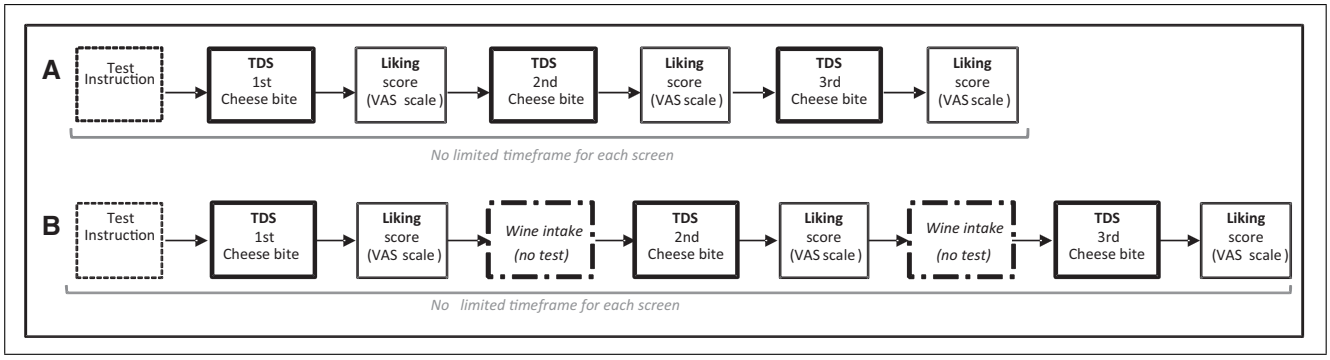

Figure 1–Description of the 2 wine evaluation processes across time. (A) Cheese evaluation by multi-bite TDS and alternated hedonic test. (B) Cheese evaluation by multi-bite TDS and alternated hedonic test after wine consumption.

at their own individual pace and was swallowed whenever they felt like it and the evaluation went on until no sensation was perceived as dominant and they clicked on the "STOP" button. There was no preestablished time limit for the evaluation. Attribute order within the list was randomized across the panel (Pineau and others 2012), but each consumer had the same order for the 3 consecutive bites. After the TDS evaluation consumers were asked to rate their liking on a continuous scale. The same steps (TDS + hedonic rating) were followed for the 2nd and 3rd cheese bite. In this way, 3rd TDS profiles and 3 hedonic ratings were obtained by cheese.

Epoisses and *Chaource* were presented in slices of 18 ± 1 g on small plastic dishes and were instructed to be eaten (with a fork) from the point to the bottom in 3 different bites (approximately 6 g by bite). *Comté* cheeses were cut into cubes (sides of approximately 12 mm long each, 6 ± 0.5 g final weight) and were presented in close plastic containers. Consumers were instructed to introduce the whole cube in their mouth and chew it, but not to nibble it. All samples had random 3-digit codes; and were presented in a monadic manner and following a Williams Latin square. Cheeses were cut 30 min before the tasting and stored at control temperatures until the moment of tasting (16 °C for *Comté* and 4 °C for *Epoisses* and *Chaource*).

Participants were informed on the type of cheese they tasted, based on what was evident for them, but had no further information. After each cheese's complete evaluation, there was a 3-min-long mandatory pause for mouth rinsing with water and bread. Drinking water between bites of a same cheese was not allowed. The 31 consumers evaluated the 4 cheeses over one 1-h-long session.

Cheese evaluation by multi-bite TDS and alternated hedonic test after wine consumption. Figure 1B shows the global process of cheese description for this 2nd stage of the experiment. Consumers performed the same evaluation in multi-bite but they had to drink a sip of wine between bites. Consumers were presented the cheeses in the same way as in the previous session (cubes or slices) but this time they were also given 2 cl of wine in a black glass (see Table 2 for wine description). They were instructed that the amount of wine was sufficient for taking 2 sips (1sip ≈ 1cl), but the size of each sip was not controlled. There was no time limit for wine drinking and they were asked to eat the 2nd and 3rd bite of cheese as soon as they had swallowed the wine to better perceive the impact of 1 product on the other.

During each session, the 4 cheeses were evaluated in combination with 1 wine; the wine was the same for all consumers. Cheeses were presented in a monadic order following a Williams Latin Square and consumers did not taste them in the same order over sessions. Consumers had no information whatsoever on the type of wine they were tasting. The 16 combinations were evaluated after 4 sessions over 2 wk. All samples (wine and cheese) were always swallowed. Attribute order was also randomized across the panel and there was a 3-min mandatory break after each combination for mouth rinsing with bread and water.

Data analysis

Data analysis followed the same structure as that presented in Galmarini and others (2016).

Cheese perception by multi-bite TDS. Differences among bites were evaluated by cheese in terms of total duration of the evaluation, different citations, and duration of dominance by attribute following the ANOVA/MANOVA model: Duration = Subject + Bite (Galmarini and others 2016; Galmarini and others 2017).

Multi-bite TDS profiles were represented by TDS bandplots by descriptor for visual inspection and comparison of sequentiality of dominant sensations over bites. These bandplots were chosen over traditional TDS curves, for the purpose of clarity, given the amount of representations (Galmarini and others 2017). 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.

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

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

Duration = Subject + Cheese tasting condition, where the cheese tasting condition (CTC) represents each cheese evaluated after no wine, *red Beaujolais, red Burgundy, white*, and *rosé*. Subject was always considered as a random effect.

To see the effect of wine, bite 2 and bite 3 were compared over sessions without and with wine intake. Moreover, because cheese after no wine and cheese after wine were evaluated in 2 different sessions, differences could also be due to a session effect or a slight maturation of the cheese. It could be hypothesized that if differences in CTC for bite 1 < differences in CTC for bite 2 < differences in CTC for bite 3; then these could be explained by the impact of wine and not by inconsistency over sessions.

Differences on duration of dominance were graphically represented (by cheese) by a canonical variate analysis. Only attributes

Table 4–Mean values by bite for duration of the evaluation and distinct citations together with MANOVA results for attribute duration of dominance comparison by cheese.

	Bite 1	Bite 2	Bite 3	*F*-value
Epoisses				
Mean duration of the evaluation (s)	47a	48ab	54b	3.85*
Mean distinct citations (*n*)	5.6	5.4	5.4	0.5
All attributes duration of dominance (*F*-MANOVA)				1.743*
Sticky	2.6a	4.3a	8.5b	8.35*
Chaource				
Mean duration of the evaluation (s)	41	40	43	0.81
Mean distinct citations	4.9	4.7	4.7	0.23
All attributes duration of dominance (*F*-MANOVA)				0.513
ComtéA				
Mean duration of the evaluation (s)	56	56	57	0.08
Mean distinct citations	5.7	5.3	5.6	1.21
All attributes duration of dominance (*F*-MANOVA)				0.879
ComtéB				
Mean duration of the evaluation (s)	56	54	56	0.62
Mean distinct citations	5.1	4.9	4.8	1.09
All attributes duration of dominance (*F*-MANOVA)				0.593

Two bite means with the same letter are not significantly different (LSD test, $P = 0.05$).
*$P < 0.05$.

with a total duration longer than 5% of the mean total duration of the bite (at panel level) were taken into consideration for the analysis.

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

Effect of wine intake on hedonic rating of cheese. Preference was analyzed for every cheese without and with wine intake in-between bites. Because successive liking scores are correlated, an autoregressive heterogeneous structure of covariance was used according to the model:

$$\text{Liking} = \text{Subject} + \text{CTC} + \text{Bite} + 3 \text{ interactions of first order;}$$

where Bite 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

Multi-bite cheese evaluation. The multi-bite effect was evaluated, by product, in terms of the duration of the evaluation, the distinct citations, and the duration of dominance of the attributes (for the purpose of brevity, only significant attributes are presented). Results are presented in Table 4.

The number of different attributes cited did not change significantly from bite to bite in any cheese, showing that the amount of different words chosen from the list depended on the product and not on the repeated exposure to the product.

For the mean duration of the evaluation from bite to bite there were only differences for *Epoisses* ($P < 0.05$): the evaluation of the 3rd bite was longer than in the 1st one.

The duration of dominance of the different attributes was compared among bites to evaluate possible cumulative sensations or changes in perception resulting from the multiple intake. For 3 out of the 4 cheeses, there was no bite effect for any of the attributes, which also resulted in no global differences by MANOVA. Only in *Epoisses* there were differences among bites due to an increase in the duration of dominance of sticky (Table 4; ANOVA results by attribute not shown for *Chaource, ComtéA*, and *ComtéB* since they were not significant).

This lack of bite effect might seem strange, because it is known that the amount of consumed sample might have an impact on perception. Working with custard desserts, Prinz and De Wijk (2007) found that the amount of the intake had an impact on the perceived intensity of temperature, creamy, astringent, melting and airy mouthfeels, and rough and fatty after-feel. These results might seem opposed to the lack of changes in the dominant sensations here observed from bite to bite. However, it should be taken into consideration that sensations might become more intense after the 3rd bite, but because TDS gives no quantification, this cannot be proven. Using TDS coupled with simultaneous hedonic evaluation (S-TDL), Thomas and others (2017) carried out a study on *Gouda* cheese were consumers evaluated 3 consecutive bits of cheese. Using 667 consumers over 6 countries, these authors found similar results to those of this study: no bite effect on the duration of dominance of the attributes. More recently, Antúnez and others (2017) did not find a bite effect when describing bread by CATA method, another descriptive not quantitative method.

In addition to the duration of dominance, the sequentiality of dominant sensations was analyzed. This is presented on the TDS bandplots by descriptor for each bite of the 4 cheeses are presented in Figure 2(A–D), together with the mean liking scores for each bite.

In *Epoisses* (Figure 2A), a total of 8 descriptors reached significant dominance rates over the 3 bites, but for some (mainly animal and sour lactic) this was for a very short period of time. The beginning of the bite was characterized by sticky, creamy and, with a smaller dominance rate, melty. Sticky persisted until the end of the bite in the 3rd bite. Salty was dominant almost during the whole bite. There was also some bitterness (probably as a consequence of proteolysis (Habibi-Najafi and others 1996)), perceived in every bite. As for the aromas, in the 1st bite sour lactic was dominant at the end of the bite, although animal reached significance at the end of the 3rd bite. It should be pointed out that, their duration

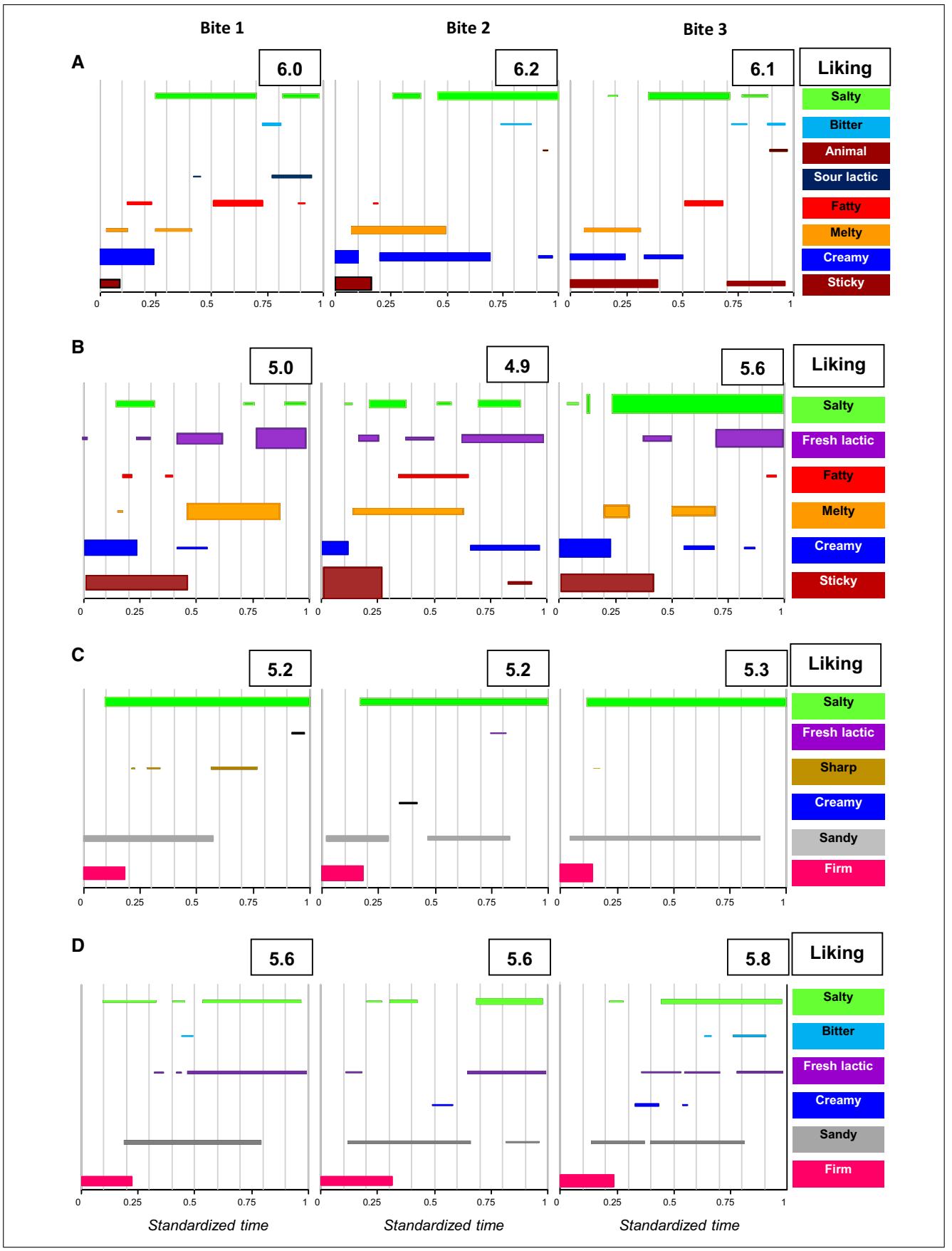

Figure 2–Bandplot by descriptor for each of the evaluated cheeses as follows: (A) *Epoisses*, (B) *Chaource*, (C) Comte A, (D) Comte B. The *x*-axis of each graph represents standardized time between 0 and 1.

Table 5–Significant differences on the third bite, by cheese, in terms of total duration and duration of dominance (both in seconds).

	F-prod	[a]No wine	[a]White	[a]Rosé	[a]Red burgundy	[a]Red Beaujolais
Epoisses						
Total duration	2.76*	53.6a	41.7b	47.0ab	41.6b	46.0ab
Creamy	3.40*	8.0a	7.6a	4.9b	4.5b	4.6b
Salty	2.94*	9.8a	5.1b	7.3ab	6.2ab	6.2ab
Mushroom	2.94*	0.2b	2.4ab	0.8ab	1.9ab	2.9a
Animal	2.57*	2.6ab	1.4b	4.3ab	3.0ab	5.0a
Overall (MANOVA[a])	1.909**					
Chaource						
Total duration	5.31**	42.7a	34.8b	36.6b	34.8b	39.7ab
Fresh lactic	2.81*	7.1a	5.9a	2.9b	5.5a	3.3b
Fruity	2.46*	0.5b	1.2a	0.1b	0.0b	0.1b
Overall (MANOVA[a])	1.652*					
Comté A						
Total duration	2.59*	57.1a	48.9b	49.5ab	51.7ab	51.0ab
Salty	4.67**	15.6a	8.5b	9.4b	7.8b	8.6b
Animal	3.07*	2.3ab	1.4b	2.3ab	3.0ab	5.3a
Overall (MANOVA[a])	1.653*					
Comté B						
Total duration	3.55**	53.6a	46.0b	47.5ab	46.9ab	51.7ab
Salty	3.36**	8.3ab	5.3b	7.6ab	5.7b	11.9a
Overall (MANOVA[a])	1.442*					

Significance levels: (.)10%, *5%, ***0.1%.
Different letters indicate significant differences according to a LSD test.
[a]Calculated taking into account all attributes, even those with a duration shorter than 5%.

of dominance as well as their dominance rate, were very small in comparison to the other attributes. This was the most liked of all the evaluated cheeses, and there were no significant changes on the mean liking scores from bite to bite.

Chaource (Figure 2B) was the cheese with the somewhat richest profile. Six attributes achieved significant dominance rates, 4 of them being texture descriptors. In agreement with what was previously stated, it can be observed that the 3 bites had a very similar dynamic profile, with a high dominance rate of creamy and sticky at the beginning, a melty middle and dominance of fresh lactic at the end of the bite. This dominance of fresh lactic might be due to the high content of butyric acid (Table 1). The dominance rate of salty increased for the 3rd bite. Fatty also reached significant levels, but had smaller dominance rates. Liking for this cheese increased slightly (but not significantly, *P*–value approximately 0.1) for the 3rd bite.

ComtéA (Figure 2C) had a very plain profile, which was almost identical over the 3 bites. It was described as firm at the beginning of the bite, with a high dominance rate, and then as sandy and salty. Even if consumers were provided with aromatic descriptors (as recommended by *comté* producers) only fresh lactic reached dominance at the end of the 1st and 2nd bite. The mean liking score for this cheese also remained constant over the bites.

Finally, *ComtéB* (Figure 2D) had a somewhat more complex profile. Firm, sandy and salty were dominant as in the previous cheese, but the dominance rate of salty was smaller in this one. This is in relation to the lower sodium content of this *comté* in comparison to the other one (Table 1). The fresh lactic aroma was significantly dominant for the 2nd half of each bite. The last bite was characterized by a certain bitterness which achieved dominance at the end. The mean liking score given for this cheese was a little higher than for *ComteA*, and as for every other of the tasted samples, it did not change over bites.

The evaluated cheeses had different temporal profiles. They were mostly characterized by texture and taste attributes, whereas aromas were not the main dominant characteristics. It could be argued that this was due to a lack of training of the used panel. However, Bemfeito and others (2016) had similar results when describing *Minas Gerais* cheese by TDS. In their work, the authors used a trained panel and evaluated texture and flavor in different sessions. Their results showed that texture was more important for describing cheese, then salty and bitter whereas aromatic descriptors reached very low dominance rates. Moreover, it is interesting to point out that there was almost no bite effect, either on liking or on description. Similar results were found on liking by Thomas and others (2017) on *Gouda* cheese. They found that liking did not evolve throughout the 3 evaluated bites. Similar nonsignificant bite effect on liking of a solid food product was recently found by Antúnez and others (2017) working with bread. It should be noted that this is quite different to what was observed on the multiple intake evaluation of liquid food products such as juice (Zorn and others 2014), wines (Galmarini and others 2016; Galmarini and others 2017), or new beverages (Rocha-Parra and others 2016), where the sip effect was usually significant, especially in the cases when liking was also evaluated. However, there is still little literature on multi-bite effect on liking.

Effect of wine on cheese perception and hedonic rating. The effect of wine on cheese perception was evaluated in the same manner as in Galmarini and others (2016): comparing the obtained durations of dominance by attribute in each product without and with previous wine intake. Results for bite 1 were compared to assure that the observed differences were due to wine intake and not to a session effect, because "no wine" and the 4 "with wine" CTC were evaluated in 2 separate sessions.

MANOVAs showed no significant differences for the attribute duration of dominance for the 1st bite. The following *F*-values (and *P*-values) were obtained: *Epoisses*, 1.328 ($P = 0.082$); *Chaource*, 1.220 ($P = 0.164$); *ComtéA*, 1.126 ($P = 0.274$), and *ComtéB*, 1.163 ($P = 0.226$). So, differences ($P < 0.05$) found for the 2nd and 3rd bite, would for sure be due to the wine effect and not to inconsistency over sessions. This also showed (as found in previous works [Brachet and others 2014; Galmarini and others 2016]) that 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 consistencies.

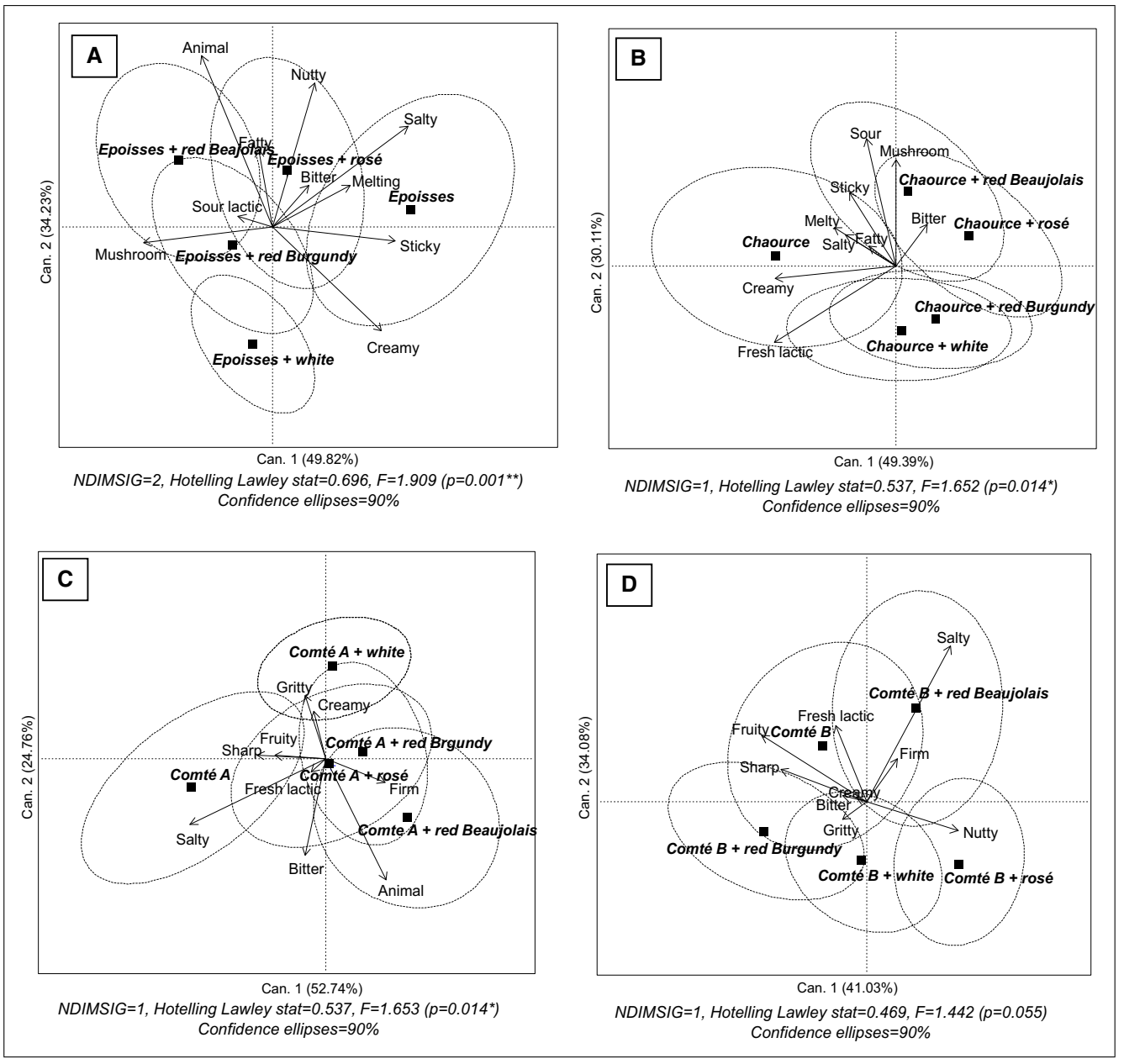

Figure 3–(A–D) Canonical variate analysis for the third bite of each cheese evaluated over the different sessions after no wine, white, *rosé*, red Burgundy, and red Beaujolais.

The effect of wine on the evaluation of the cheese (total duration of the bite and duration of dominant sensations) is presented in Table 5 (only significant differences are presented for brevity).

It can be observed that the duration of the evaluation was not changed or reduced after drinking wine. White wine reduced the duration of the evaluation significantly ($P < 0.05$; between 7.6 and 11.9 s) for the 4 cheeses. Red Burgundy wine significantly reduced the duration of the evaluation of *Epoisses* and *Chaource*, whereas *Rosé* only reduced that of *Chaource*. Red Beaujolais wine had no significant impact on the duration of the evaluation. It should be noted that, even if only results for bite 3 are presented, results for bite 2 showed the same tendency. This reduction in evaluation time could be related to the facilitation of bolus formation due to the alternation of solid and liquid (Nogueira 2015). Also, when evaluating the effect of cheese on wine, Galmarini and others (2016) found that the duration of the evaluation of a wine was shorter after eating a piece of cheese. This would be showing that alternating these 2 products would be reducing the duration of the perception.

Epoisses was the cheese that changed the most after wine intake. This was evidenced by the highest *F*-value for the MANOVA (1.909; P value $= 0.001$) and is graphically clear in Figure 3A. Perception of this cheese changed the most after white wine intake (reduction of duration of salty) and *Beaujolais* (reduction of duration of creamy and increase in duration of aromas).

Impact of wine on *Chaource* was characterized by a MANOVA *F*-value of 1.652 ($P = 0.014$, Table 5 and Figure 3B). Surprisingly, perception of *Chaource* after red and white Burgundy were grouped together whereas descriptions after *Rosé* and *Beaujolais* were also similar; but these were characterized by bitter and mushroom (Figure 3B).

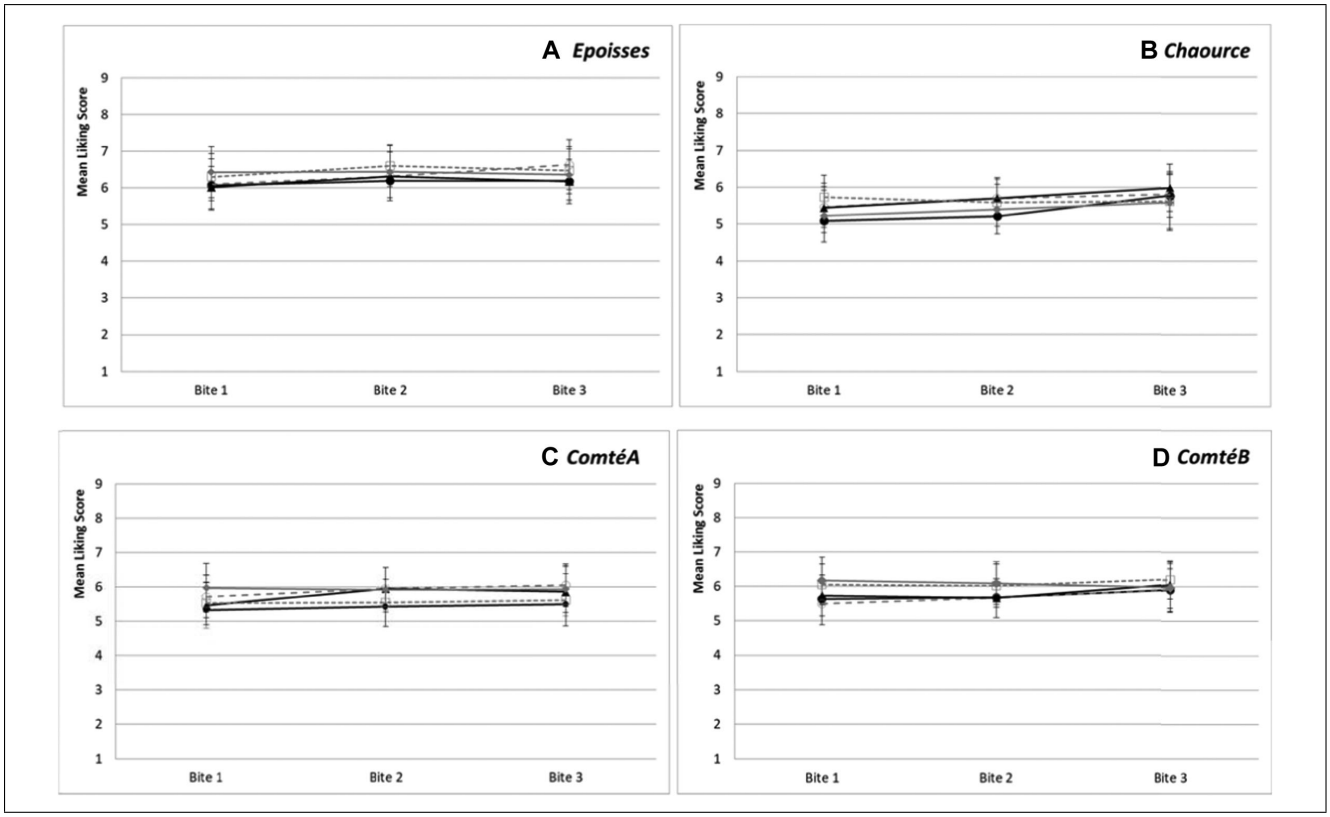

Figure 4–(A–D). Mean hedonic ratings for cheeses over the 3 consecutive bites: No wine, white, rosé, red Burgundy, and red Beaujolais.

Of the 2 *Comtés, ComtéA* was the 1 with the longest duration of dominance of salty, and this was significantly reduced ($P < 0.01$) after the intake of the 4 types of wine. Moreover, the animal note lasted the shortest with the white wine and the longest after the red *Beaujolais*; this might be why perception after these 2 wines are the most different ones, as seen on Figure 3C.

On *ComtéB*, duration of salty was also changed by wine intake, but it was not the same for the 4 wines. After drinking *Beaujolais*, its duration was longer than with no wine; but after white and red Burgundy its duration was reduced. However, when looking at the global changes in Figure 3D, the MANOVA *F*-value could be significant only at a 10% level. This cheese was the least impacted by wine intake, when comparing all the CTC.

Finally, Figure 4A to D presents mean liking scores (and confidence intervals) of the 4 cheeses over the 3 bites without and with wine intake in-between sips. It can be observed that there was no bite nor CTC effect. Surprisingly, wine had an impact on perception, but no effect on liking. This is quite a different outcome than that observed by Galmarini and others (2016) in which cheese altered the perception of wine and had an important influence on wine liking scores, particularly improving the liking of the wines which were not well rated over multiple sips without cheese intake.

These differences on the influence of one product on the other (wine on cheese compared with cheese on wine), found in these 2 correlative works, could be due to different reasons. For starters, the cheese tasting was not blind, contrary to that of wine (Galmarini and others 2016). So, in addition to the physiological perceived changes (for example, reduction of astringency), tasting wine in blind conditions could result in a lack of confidence on the given liking score. As a result, consumers could be transferring their liking of the cheese onto the wine, therefore changing significantly the liking given to the wine. In this work, consumers were probably more confident on their preference on cheese because the tasted product was more evident and therefore kept the same liking score. Moreover, because they were not sure of which wine they were taking with the cheese, this transfer phenomenon was less likely to happen.

Another explanation for the smaller effect of wine on cheese (the inverse was found in our previous work) could be the fact that a liquid has a smaller impact on a solid, than the other way around. Cheese (solid and semi-solid) follows a different oral processing than wine, which includes: chewing for reducing of particles while liberating volatiles, and generating bolus to be swallowed. Even if a dynamic evaluation as TDS can capture perception all along this process, the impact of wine on perception and specially in appreciation might be cushioned by this process. Probably more than 3 bites would be needed to see a bigger effect, or trying the consumption of both products at the same time.

Moreover, even if the task was considered as simple by consumers and they all agreed on the used descriptors, having texture, flavor, and aroma descriptors might have increased the complexity of the task and therefore reduced discrimination among CTC. This should be tested in the future, maybe using one sensory category at the time.

Conclusions

The temporal profiles based on dominant sensations were obtained for the 4 cheeses. It was found that, as opposed to wine, 3

cheese intakes (and 2 sips of wine) were not sufficient to provoke a change of cheese perception over intakes.

Moreover, it was observed that the intake of wine in-between bites of cheese had a small impact on their dynamic perception which changed for each combination. Two cheeses of the same family (*ComtéA* and *ComtéB*) were differently changed by the wines used in this experiment (for example, duration of dominance of salty was significantly increased by red *Beaujolais* in 1 while it was reduced on the other). This proofs the difficulty of elaborating a rule-of-thumb to explain wine-cheese interactions. Nonetheless, it was remarkable that the impact of wine on cheese perception did not translate in changes in liking. None of the wines had either a positive or negative effect on cheese liking. There were no significant differences on liking ratings of cheese among intakes and with or without wine.

The comparison of the results to a previous experiment where the impact of cheese on wine perception was studied, showed that cheeses changed less from wine to wine than wines did from cheese to cheese. This would be revealing that the choice of wine would be more important when pairing cheese and wine, because it is wine perception which is more likely to be changed. It would be interesting to validate this theory with further studies evaluating not the impact of 1 product on the other, but the perception of the wine-cheese combination as a whole.

Acknowledgments

Mara V. Galmarini received the support of the EU in the framework of the Marie-Curie FP7 COFUND People Programme, through the award of an AgreenSkills fellowship under grant agreement no. 267196. This research was partly financed by the Burgundy Council, project PARI 2014 - VIGNE et VIN No. 29000857 together with the collaboration of the following partners: Comité Interprofessionnel de Gestion du Comté (CIGC), Centre Technique des Fromages Comtois (CTFC), Syndicat de défense de l'Epoisses, Syndicat du Crottin de Chavignol, Institut Français de la Vigne et du Vin (IFV) – SICAREX, Bureau Interprofessionnel des Vins de Bourgogne (BIVB).

Authors' Contributions

Mara V. Galmarini designed the study, carried out the experiment, interpreted the results, and drafted the manuscript.

Anne-Laure Loiseau and Doëtte Debreyer 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.

References

Albert A, Salvador A, Schlich P, Fiszman S. 2012. Comparison between temporal dominance of sensations (TDS) and key-attribute sensory profiling for evaluating solid food with contrasting textural layers: fish sticks. Food Qua Prefer 24:111–18.

Antúnez L, Giménez A, Alcaire F, Vidal L, Ares G. 2017. Consumer perception of salt-reduced breads: comparison of single and 2-bites evaluation. Food Res Intl 100:254–59.

AOAC 1984. Official methods of analysis of AOAC International Gaithersburg, MD, USA.

Bastian SEP, Collins C, Johnson TE. 2010. Understanding consumer preferences for Shiraz wine and Cheddar cheese pairings. Food Qual Prefer 21:668–78.

Bastian SEP, Payne CM, Perrenoud B, Joscelyne VL, Johnson TE. 2009. Comparisons between Australian consumers' and industry experts' perceptions of ideal wine and cheese combinations. Aus J Grape and Wine Res 15:175–84.

Bemfeito RM, Rodrigues JF, Silva JGE, Abreu LR. 2016. Temporal dominance of sensations sensory profile and drivers of liking of artisanal Minas cheese produced in the region of Serra da Canastra, Brazil. J Dairy Sci 99:7886–97.

Brachet S, Galmarini M, Chatelet B, Loiseau A-L, Cordelle S, Lempereur V, Schlich P. 2014. Evaluation de la Dominance Temporelle des Sensations de vins rouges de Bourgogne et du Beaujolais par un panel d'experts et de consommateurs. Proceedings of the 37th World Congress of Vine and Wine and 12th General Assembly of the OIV. EDP Sciences, 06006, Mandoza, Argentina.

Castura JC, Li M. 2016. Using TDS dyads and other dominance sequences to characterize products and investigate liking changes. Food Qual Prefer 47 Part A:109–21.

Galmarini MV, Loiseau A-L, Visalli M, Schlich P. 2016. Use of multi-intake temporal dominance of sensations (TDS) to evaluate the influence of cheese on wine perception. J Food Sci 81:S2566–77.

Galmarini MV, Visalli M, Schlich P. 2017. Advances in representation and analysis of mono and multi-intake Temporal Dominance of Sensations data. Food Qual Prefer 56 Part B: 247–55.

Habibi-Najafi MB, Lee BH, LAW B. 1996. Bitterness in cheese: a review. Critic Rev Food Sci Nutr 36:397–411.

Harrington RJ. 2008. Food and wine pairing. A sensory experience. USA: John Wiley and sons, Inc.

Harrington RJ, Hammond R. 2005. The direct effects of wine and cheese characteristics on perceived match. J Foodservice Business Res 8:37–54.

Harrington RJ, Mccarthy M, Gozzi M. 2010. Perceived match of wine and cheese and the impact of additional food elements: a preliminary study. J Foodservice Business Res 13 311–30.

King M, Cliff M. 2005. Evaluation of ideal wine and cheese pairs using a deviation-from-ideal scale with food and wine experts. J Food Qual 28:245–56.

Madrigal-Galan B, Heymann H. 2006. Sensory effects of consuming cheese prior to evaluating red wine flavor. Am J Enol Viticult 57:12–22.

Meillon S, Urbano C, Schlich P. 2009. Contribution of the Temporal Dominance of Sensations (TDS) method to the sensory description of subtle differences in partially dealcoholized red wines. Food Qual Prefer 20:490–99.

Meyners M. 2016. Temporal liking and CATA analysis of TDS data on flavored fresh cheese. Food Qual Prefer 47 Part A:101–8.

Nogueira D. 2015. Presbyphagia. In: Mankekar G, editor Swallowing – physiology, disorders, diagnosis and therapy. India: Springer.

Nygren IT, Gustafsson I-B, Johansson L. 2003. Perceived flavor changes in blue mould cheese after tasting white wine. Food Serv Technol 3:143–50.

Nygren IT, Gustafsson IB, Johansson L. 2002. Perceived flavor changes in white wine after tasting blue mould cheese. Food Serv Technol 2:163–71.

Oliveira D, Antúnez L, Giménez A, Castura JC, Deliza R, Ares G. 2015. Sugar reduction in probiotic chocolate-flavored milk: impact on dynamic sensory profile and liking. Food Res Int 75:148–56.

Pineau N, DE Bouillé AG, Lepage M, Lenfant F, Schlich P, Martin N, Rytz A. 2012. Temporal dominance of sensations: what is a good attribute list? Food Qual Prefer 26:159–65.

Pineau N, Schlich P. 2014. Temporal dominance of sensations (TDS) as a sensory profiling technique. Rapid sensory profiling techniques: applications in new product development and consumer research. Cambridge, UK: Woodhead Publishing, Elsevier. p 269.

Pineau N, Schlich P, Cordelle S, Mathonnière C, Issanchou S, Imbert A, Rogeaux M, Etiévant P, Köster E. 2009. Temporal dominance of sensations: construction of the TDS curves and comparison with time–intensity. Food Qual Prefer 20:450–55.

Prinz JF, De Wijk RA. 2007. Effects of bite size on the sensory properties of vanilla custard desserts. J Sensor Stud 22:273–80.

Rocha-Parra D, García-Burgos D, Munsch S, Chirife J, Zamora MC. 2016. Application of hedonic dynamics using multiple-sip temporal-liking and facial expression for evaluation of a new beverage. Food Qual Prefer 52:153–59.

Saint-Eve A, Panouillé M, Capitaine C, Déléris I, Souchon I. 2015. Dynamic aspects of texture perception during cheese consumption and relationship with bolus properties. Food Hydrocol 46:144–52.

Schlich P. 2013. TDS with untrained consumers in lab and at home. Proceedings of the 10th Pangborn Sensory Science Symposium, Rio de Janeiro, Brazil.

Sokolowsky M, Rosenberger A, Fischer U. 2015. Sensory impact of skin contact on white wines characterized by descriptive analysis, time–intensity analysis, and temporal dominance of sensations analysis. Food Qual Prefer 39:285–97.

Somers TC, Ziemelis G. 1985. Spectral evaluation of total phenolic components in vitis vinifera: grapes and wines. J Sci Food Agric 36:1275–84.

Stone H, Sidel JL. 2004. Affective testing. Sensory evaluation practices. 3rd ed. London: Academic Press.

Thomas A, Chambault M, Dreyfuss L, Gilbert C, Hegyi A, Henneberg S, Knippertz A, Kostyra E, Kremer S, Silva A. 2017. Measuring temporal liking simultaneously to Temporal Dominance of Sensations in several intakes. An application to Gouda cheeses in 6 Europeans countries. Food Res Int 99:426–34.

Thomas A, Schlich P. 2014. From temporality of sensations to dynamic of liking. Chicago, Ill.: Sensometrics.

Thomas A, Van Der Stelt AJ, Prokop J, Lawlor JB, Schlich P. 2016. Alternating temporal dominance of sensations and liking scales during the intake of a full portion of an oral nutritional supplement. Food Qual Prefer 53:159–67.

Thomas A, Visalli M, Cordelle S, Schlich P. 2015. Temporal drivers of liking. Food Qual Prefer 40 Part B:365–75.

Vidal L, Antúnez L, Giménez A, Medina K, Boido E, Ares G. 2016. Dynamic characterization of red wine astringency: case study with Uruguayan Tannat wines. Food Res Int 82:128–35.

Zorn S, Alcaire F, Vidal L, Giménez A, Ares G. 2014. Application of multiple-sip temporal dominance of sensations to the evaluation of sweeteners. Food Qual Prefer 36:135–43.