Wine and cheese: two products or one association? A new method for assessing wine-cheese pairing

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Abstract

The aim of this study was to identify which attributes impacted the dynamic liking of cheese and wine individually as well as when consumed together. Three wines (a white one, *Pouilly Loché;* and two red ones *Maranges* and *Beaujolais*) and three cheeses (*Comté*, *Époisses*, *Chaource*) were individually evaluated by a group of 60 consumers using mono-intake Temporal Dominance of Sensations (TDS) with simultaneous hedonic ratings. The same data acquisition screen was used for all products showing a unique list of 14 descriptors (covering cheese and wine perception) and a hedonic scale for dynamical rating of liking. The dynamic hedonic data was associated to the TDS profiles obtaining Temporal Drivers of Liking (TDL). The nine wine-cheese associations were evaluated by multi-bite and multi-sip TDS, consumed in a free manner. Individually, *Chaource* had practically no TDL, in *Comté* mushroom flavor was a positive TDL, and in *Epoisses* salty was a negative TDL. All wines presented TDL, but negative were only present in the red ones: bitter, sour and astringent. In wines, the positive TDL were: fruity, spicy and woody. Dynamic perception changes had a bigger impact on liking in wine compared to cheese. For the associations, the negative TDL were only three and mostly wine related: sour (for 7/9 combinations), bitter (6/9) and astringent (5/9). Positive TDL were more varied (a total of 10 descriptors) and were related either to wine or cheese. As opposed to what was found in cheese alone, salty was a positive TDL in two of the combinations. It was observed that the dynamic sensory perception had a more important impact on liking in wine-cheese combinations than when consumed separately. This shows that TDS and TDL have a big potential in the study of food pairing which should be further exploited.

1. Introduction

Wine and cheese, are not only emblematic products of the French gastronomic culture, but also fundamental to the country's economy. Even though worldwide competition is strong, 17% of the world's wine production comes from France (OIV, 2014); wine exports represented, in 2015, 7.9 billions to the French economy (www.vinetsociete.fr). As for cheese, France is the third biggest producer worldwide, after USA and Germany (www.insee.fr). Other than this big market share, these two products have another thing in common: they are both obtained by a fermentation process. Fermentation was one of the earliest forms of food preservation, so this might be one of the reasons why they have long been consumed together, a natural match providing a safe source of complete protein along with a thirst-quenching liquid (King and Cliff, 2005).

After this long history side by side, numerous recommendations can be found in the gastronomic, culinary and popular literature on what makes a "good" or "bad" wine-cheese combination. However, in the scientific field of sensory evaluation and consumer science, few research papers can be found on wine and cheese pairing (Harrington and Hammond, 2005, King and Cliff, 2005, Harrington and Hammond, 2007, Bastian et al., 2009, Bastian et al., 2010, Harrington et al., 2010). Needless to say, food and beverage pairings are complex stimuli which can be challenging to rate in a consistent manner both by experts and naïve consumers (Paulsen et al., 2015). There can be a high variation among judges related to personal expectation or preference associated with the suitability of wine for a certain cheese (King and Cliff, 2005). Given the importance of these products from an economic and cultural point of view, and taking into account the immense variation of brands, elaboration procedures, taste, pricing, etc.; understanding how one can enhance, or not, the perception of the other and knowing what makes a "good" wine-cheese pair can be key for product marketing. But it is evident so far, that traditional evaluation methods are not enough to get this information.

The few sensory works which can be found explaining why one combination should be favored over another one (Nygren et al., 2003b, Nygren et al., 2003a, Nygren et al., 2002, Harrington et al., 2010, Harrington and Hammond, 2005, King and Cliff, 2005) present classic descriptive analysis methods (e.g. Quantitative Descriptive Analysis) which evaluate only one specific moment of the tasting (usually the final impression) giving a static global measurement. But it is known that sensory perception is a dynamic phenomenon, widely affected by mastication, volatile release, aftertaste and it requires a more complex methodology to better understand what consumers actually perceive.

Temporal Dominance of Sensation (TDS) (Pineau et al., 2009) is a temporal multi-dimensional sensory method which consists in presenting to the tasters a list of descriptors from which they can choose the one they consider dominant at every moment of tasting. "Dominant" is defined as the

sensation which triggers their attention at every given moment of the tasting. Using this dynamic technique, rather than a traditional profiling method, allows to find out how the dominant sensations perceived during wine-cheese consumption change in terms of duration (time in seconds during which the sensation is dominant) and/or sequentiality, widening the knowledge on the complete sensory experience.

It is also known that experts and consumers, especially in the wine sector, might not have the same opinion on a product (Hopfer and Heymann, 2014): that which might be relevant for experts might not be so for consumers. Working on wine TDS description, Brachet et al. (2014) found that consumers were as discriminant as experts, but that the obtained profiles of ones and the others were not the same, showing that what is dominant changes from consumers to experts. This revealed the importance of working directly with consumers. Moreover, it has been shown that TDS provides an intuitive response needing almost no training since no scaling is used and it can be effectively used by consumers (Schlich, 2013, Brachet et al., 2014, Thomas et al., 2015).

Another advantage of using consumers to evaluate the product is that TDS can be coupled with a hedonic response. This means that consumers describe what they perceive and rate their level of liking in the same session (Thomas et al., 2014, Thomas and Schlich, 2014). This can be done after every wine sip (Galmarini et al., 2016) or in simultaneous with the TDS evaluation. This makes it possible to associate hedonic temporal data and descriptive temporal data (TDS profiles), identifying temporal drivers of liking, that is to say, attributes which when cited as dominant lead to an increase or a decrease of liking (Thomas et al., 2015). This dynamic evaluation of liking drivers is definitely more in line with the normal way of eating, but it is seldom used due to the complexity of the obtained data.

Delarue and Blumenthal (2015) have lately pointed out that sensory evaluation should evolve towards more realistic experiments in regards to consumption episodes notably by taking into account more than one bite or sip of the product. In relation to this, TDS has also been used to evaluate successive intakes such as multi-bite or multi-sip working with consumers (Schlich et al., 2013, Galmarini et al., 2015). In a recent work (which was part of this same research project), Galmarini et al (2016) evaluated the impact of cheese on wine perception and liking over consecutive wine sips. Focusing only on wine description, it was found that cheese had either a positive or no impact on temporal wine perception and appreciation; but none of the cheeses had a negative impact on wine. However, no dynamic study on the pairing was done in this mentioned work.

A good food-wine duo might be considered that in which no product dominates over the other (Nilsen & Öström, 2013); or that in which new sensations are created. By definition, a pair is something consisting of two parts joined together. In this way, evaluation of two products as a whole, almost in a simultaneous manner, is a natural step forward for describing perception of a food

pair. Following this hypothesis, it was the aim of the present work to identify which attributes impacted the dynamic liking of cheese and wine individually as well as when consumed together over several sips and bites. This would allow to have a real close look to what consumers perceive, and to better understand why they like - or dislike - a certain wine-cheese couple.

2. Materials and Methods

2.1 Samples

Three different cheeses (Table 1) and three different wines (Table 2) were used to in the present study. They were regional products which allowed working with the association of two products which shared *terroir*.

Table 1. Evaluated cheese samples

Name of cheese	Ageing time	Type of milk	Type of cheese (usual characterization)	H20 (g/100g)	Lipids (g/100g)	Proteins (g/100g)	Sodium (mg/100g)
Chaource **(Protected Origin Designation POD)**	2 weeks	Thermized cow	Soft-ripened Creamy, slightly crumbly	56.1	22.0	17.4	792
Époisses **(POD)**	5-6 weeks	Unpasteurized cow	Soft, smear-ripened Chewy, creamy and firm	55.0	23.8	16.5	770
Comté **(POD)**	14 months	Unpasteurized cow	Semi-hard Dense, firm, grainy	36.2	34.6	26.7	817

Table 2. Evaluated wine samples

Type of wine	Grapes	Year	Alcohol (vol%)	Reducing sugars (g/l)	Total acidity (gH_2SO_4/ l)	Tanins (mg/l)
Beaujolais **(red)**	*Gamay*	2014	12.20	0.07	3.92	1420
Maranges **(red)**	*Pinot noir*	2013	13.17	0.17	3.59	2046
Pouilly- Loché **(dry white)**	*Chardonnay*	2013	13.11	1.25	3.68	-

2.2 Consumer panel

The evaluation was carried out by 60 consumers from the city of Dijon, in the Burgundy region in France. They were recruited by means of an on-line questionnaire from a population registered in the *Chemosens Platform's PanelSens* database, declared to the relevant authority (*Commission Nationale Informatique et Libertés – CNIL – n° d'autorisation 1148039*). They were chosen based on their frequency of consumption of red and dry white wine (at least once every two

125 weeks) and of the cheeses *Epoisses*, *Comté* and *Chaource* (at least once every month). Moreover,
126 they were non-smokers and declared not to have any food allergies.
127 The final recruited group was composed of 45% males and 55% women, with a mean age of
128 44.5 years old (min 19 – max 68 years). They participated in five tasting sessions and were
129 economically gratified for their participation in the study.
130

131 *2.3 Tasting protocol and session organization*
132 The three wines and the three cheeses were evaluated in two different conditions: a)
133 Individually, in one single intake (mono-sip or mono-bite) and b) as part of a complete portion of a
134 wine-cheese combination, over multiple intakes (multi-intake). In both situations the task was based
135 on the same principle: a dynamic description using Temporal Dominance of Sensations coupled with
136 a simultaneous hedonic rating (TDS-L) (Schlich, 2015).
137 In every case, consumers swallowed the products, so one of the restrictive factors in the
138 experimental design was the amount of alcohol consumed per session. This was limited to only 12cl
139 of wine (≈ 15ml of alcohol per session). Also, since *Epoisses* and *Chaource* mature fast, tasting
140 sessions could not be much separated in time, in order to compare the evaluation of their different
141 combinations. Finally, the tasting was done in controlled conditions in sensory booths, so the
142 laboratory's facilities limited the amount of assessors to 30 per day. Taking all this into consideration,
143 the evaluation of the six products and the nine combinations took place over five one-hour long
144 sessions. In each session consumers tasted: one sample of cheese in mono-bite (6±0.5g), one sample
145 of wine in mono-sip (1cl) and two portions of wine-cheese combinations (5cl of wine and 30g of
146 cheese for each combination) which consumers could eat in as many intakes as they wanted,
147 beginning by one or the other product, alternating them more or less regularly in their own personal
148 manner. During the first session the tasting method and the attributes to be used were presented.
149 Details on the complete sensory method used are given in the subsections below.
150

151 *2.3.1 Familiarization with the method*
152 Based on previous experiments, 14 sensory attributes were chosen (Table 3) covering basic
153 tastes, textures and aromatic families. It should be noted that some of these aromatic families (e.g.:
154 fruity), could be used for the wines as well as for the cheeses. The definitions presented in Table 3
155 were given to consumers together with several examples.
156

157 **Table 3.** Definitions used to explain the attributes presented for the description of wines, cheeses
158 and their combinations.

Attribute	Definition
Sour/Pungent	Basic taste related to sour product such as lemon juice. The prickly sensation that can result from a very acid product.
Salty	Basic taste related to salt
Bitter	Basic taste related to bitter products such as endives or dark chocolate.
Sweet	Basic taste related to sucrose
Astringent	Sensation related to drying of mouth coating.
Sticky	Texture perceived when a product remains adhered to the teeth and mouth cavity
Fatty/ Creamy	Mellowness texture related to coating in the mouth cavity leaving a oily film
Fruity	Aroma related to all fruits; white, yellow and red fruits
Woody	Aroma related to wine aged in wooden barrels
Mushroom	Aroma related to forest, moss, old sock, etc.
Lactic	Aroma related to yogurt, milk, cream, fresh butter, etc.
Spicy/ Vanilla	Aroma related to all spices: pepper, nutmeg, cinnamon, minty, etc.
Animal	Aroma related to horse, leather, etc.
Toasted/ Roasted	Aroma related to toasted bread, coffee, chicory, etc.

159
160
161 A short presentation was given to explain the tasting method. Consumers were instructed
162 that a dominant sensation was the one which caught their attention at a given moment, not
163 necessarily the most intense. Moreover, they were instructed that if no sensation was more
164 important than another one, they could indicate it using a "Nothing dominates" attribute which was
165 also present in the list to be used.
166 In order to conclude the training, the first tasting was done on a commercial French cheese
167 (*Comté, Le Montarlier, Président*) and commercial French wine (*Macôn Villages,* 2013) which were
168 evaluated individually and then as a combination. The obtained data was only used to verify that
169 consumers had understood the task (data not shown).
170

171 *2.3.2 Used sensory method*

172 All data was acquired by means of the on-line software TimeSens 1.0 (INRA, Dijon, France)
173 using a protocol based on TDS, with simultaneous evaluation of liking (TDS-L) (Schlich, 2015). For
174 each type of product(s) (wine, cheese and wine-cheese combinations) consumers had to indicate the

dominant sensation at each moment of the tasting and also give their level of liking all along the evaluation. This had for purpose obtaining the dynamic description and liking score(s) of the products when consumed alone to then better understand their role in the perception and appreciation of the combinations. Doing a descriptive and a hedonic task at the same time can be considered a controversial approach**.** However, we believe that when evaluating a combination of products, this protocol provided consumers the possibility of eating in a somewhat traditional manner, being able to state at every moment their liking (whether it changed or not) without being interrupted at fixed moments.

Consumers were instructed to click on the "START" button (Figure 1 a and b) and to place the sample in their mouth almost at the same time. Then, they could successively select the descriptors that most triggered their attention. Whether products were evaluated individually or as a combination, the same list of 14 attributes was available for the evaluation (Table 3). The descriptor order was randomized across consumers (Pineau et al., 2012) but each consumer had the same order for all evaluations. Consumers could select one attribute at a time and change as many times as they wanted whenever a new sensation became dominant. The clicked attribute stayed highlighted as dominant until the following one was selected.

At the same time, consumers were asked to rate their liking on a discrete 9-point hedonic scale in a dynamic way, as many times as they wanted. The given liking grade disappeared after 5 seconds to encourage re-notation. Also, a reminder popped-up every 20 seconds indicating consumers not to forget to give their appreciation (Figure 1b). However, re-notating was not mandatory. The evaluation ended by clicking on the "STOP" button; there was no pre-established time limit.

Products and combinations were coded with random three-digit numbers and were presented following a Williams Latin Square, by session. In every case, wine samples were presented in black wine glasses while cheese samples were presented in small plastic plates with a fork.

Figure 1 a and b – Screenshots of the method used for data acquisition. The same screen was presented for the mono-intake evaluation of wine, mono-intake evaluation of cheese and for the multiple intake evaluation of the combination.

2.4 Data analysis

2.4.1 Consumer behavior in relation to the sensory protocol

The performance of consumers on the TDS evaluation was analyzed in terms of the following parameters: number of different descriptors used (ND), total number of clicks done (NC), time before the first citation (TBFC) and duration of the evaluation (DE). As for the hedonic task the time before the first liking note (TBFL) and the total number of liking ratings given (NL) were evaluated.

For individual evaluation of products, the analysis was done according to the following ANOVA model:

Parameter = Product + Subject; subject being a random factor.

In the case of the combinations, wine and cheese were included as two different factors, while Subject and its interactions with wine and cheese were random factors.

Parameter = Wine + Cheese + Subject + Wine*Cheese + Wine*Subject + Cheese*Subject.

Analyses were done using the softwares TimeSens (INRA, Dijon, France) and R 3.0.3 (R Core Team, 2014).

2.4.2 Temporal characterization of products and combinations

Differences among products and combinations were evaluated in terms of the proportional duration of the dominant sensations. For this purpose, the total duration of the evaluations were standardized making the duration of each dominant attribute represents a percentage of the total time of the evaluation (Galmarini et al., 2017). Following standardization, ANOVA/MANOVA tests were carried out by descriptor according to the models:

(i) Duration = Subject + Product

For the individual wine and cheese evaluations, where duration represented the standardized duration of each recorded descriptor, product was either the wines or the cheeses and Subject was a random factor.

(ii) Duration = Subject + Wine + Cheese + Wine*Cheese + Subject* Wine + Subject* Cheese

For the evaluated combinations, where duration represented the standardized duration of each recorded descriptor and Subject and its interactions with wine and cheese were random effects.

In case of significant differences ($p<10\%$) a Fisher's Least Significant Difference test (LSD) was carried out.

Analyses were done using the softwares TimeSens (INRA, Dijon, France) and R Core Team (2014).

2.4.3 Temporal appreciation of products and their combination

Liking data was recorded in a dynamic way. For each panelist a series of liking scores was obtained; the amount of liking scores varied among products and assessors. For each wine, cheese and their combinations, an individual mean liking score weighted by its duration was calculated (see Figure 2). Differences among products in mono-intake and the effect of wine and cheese in the liking scores of the combinations were evaluated following the same model as described in 2.4.2(i) and 2.4.2(ii) respectively.

The relationship between the given liking score and a cited descriptor was obtained by calculating the Temporal Drivers of Liking (TDL), based on the concept of "Liking While Dominant" according to Thomas et al. (2015). Liking while dominant is the average rating given by a consumer to a product while a certain attribute was chosen as dominant.

3. Results and discussion

3.1 Consumer behavior in relation to the sensory protocol

Table 4 shows the mean values for the parameters: time before the first citation (TBFC), number of different attributes used (ND) and total number of clicks done (NC) for the TDS description as well as time before the first liking note (TBFL) and the total number of liking score given (NL) together with the duration of the complete evaluation (DE) for the products tasted in mono-intake. The F-value corresponds to the ANOVA done taking into account all six products, in order to explore differences between the way consumers evaluated the wines and the cheeses.

TBFC was bigger for wines in comparison to cheeses, showing that consumers took more time to choose a given attribute for the wine than for the cheese. The ND was also higher for cheeses, with a mean of 4.4 as opposed to 3.7 for the three wines. In terms of NC, *Chaource* and *Comté* had significantly more clicks than *Pouilly Loché* and *Maranges*. However, there was no significant difference between *Beaujolais* and *Epoisses*, showing that a wine and a cheese can have, in average, the same amount of clicks along the tasting.

For the hedonic test, TBFL did not result in a clear grouping of the products, probably related to a higher inter-Subject variation. In order to have a more accurate description of consumers' behavior towards product rating, the TBFL was compared to the DE, showing at which moment of the tasting consumers gave their liking. It could be observed that for

294 *Chaource, Comté* and *Beaujolais*, the first liking score was given before the first half of the
295 tasting. For the other three products, consumers gave the first liking score in the second part
296 of the tasting, even after 67% of the tasting time has passed in the case of *Pouilly L.*

297 Moreover, it was found that consumers clicked on the liking scale more than once for
298 every product (mean NC≥2.5), therefore validating the fact that giving several liking scores was
299 possible even when evaluating one intake. For NC, cheeses and wines did not result in two
300 separate clear groups as in the case ND (TDS description). This shows that the number of clicks
301 on the liking scale was independent of the product type and directly related to the individual
302 characteristics of each product. *Comté* cheese recorded the most number of liking clicks while
303 *Maranges* was the one with the fewest. However, it should be noted that a change in the
304 number of clicks is not the same as having changes in the dynamics of liking; this will be
305 analyzed in section 3.3.

306 Finally, there were differences in terms of the duration of the evaluation. The
307 evaluation of *Comté* cheese lasted the longest while the one for *Pouilly Loché* was the shortest.
308 However, there was no grouping of cheese vs. wines, showing that the duration of the
309 evaluation was determined by the product itself and not by the product category.

310

311 **Table 4** – Mean values for: Time before the first citation (TBFC), number of descriptors used
312 (ND), total number of clicks used (NC), time before the first liking rating (TBFL), number of
313 ratings given for the hedonic test (NL) and total duration of the evaluation (DE) for wines and
314 cheeses evaluated in mono-intake TDS-L.

	TDS			Hedonic			
	TBFC (sec)	**ND**	**NC**	**TBFL (sec)**	**TBFL / DE**	**NL**	**DE (sec)**
F-value	7.02***	8.5***	8.05***	5.11***		4.44***	2.73**
Chaource	6.5 a	4.2 a	7.6 a	17.0 d	0.35	3.2 ab	42.8 bc
Époisses	5.4 a	4.5 a	7.2 ab	24.1 ab	0.52	2.7 cd	45.5 ab
Comté	6.2 a	4.5 a	7.9 a	19.6 cd	0.46	3.3 a	47.8 a
Beaujolais	8.2 b	3.7 b	6.2 bc	21.2 bc	0.47	3.1 abc	44.7 abc
Pouilly L.	9.0 b	3.8 b	5.8 c	27.8 abc	0.67	2.8 bcd	41.5 c
Maranges	8.7 b	3.6 b	5.6 c	25.2 a	0.59	2.5 d	42.3 bc

315
316 Significance levels: **1%, ***0.1%.
317 Different letters indicate significant differences according to a LSD test.

318

319 The same type of analysis was done for the evaluation of the wine-cheese
320 combinations with multi-intake TDS-L. Results are presented in Table 5, together with the
321 effect of wine, cheese and their interaction.

322 For the TDS evaluation, no significant effect of wine or cheese was observed for TBFC
323 and nine attributes were used in average, from a list of 15. As for the NC, the combination
324 *Comté-Maranges* received the least number of clicks, maybe due to the fact that it was the
325 first evaluated combination.

326 For the hedonic task, between 10 and 12 liking scores were registered, showing that
327 consumers were able to perform the TDS task simultaneously to the TDS description.

328 Finally, evaluations lasted 3.8 min in average and there was a cheese effect on the DE;
329 combinations with *Chaource* were evaluated faster.

330

331

332 **Table 5** – Mean values for: Time before the first citation (TBFC), number of descriptors used
333 (ND), total number of clicks used (NC), time before the first liking rating (TBFL), number of
334 ratings given for the hedonic test (NL) and total duration of the evaluation (D) for wine -cheese
335 combinations evaluated in multiple-intake TDS-L.

		TDS			Hedonic			
		TBFC (sec)	**ND**	**NC**	**TBFL (sec)**	**TBFL/DE**	**NL**	**DE (sec)**
F – Vin		2.8	1.18	5.6**	3.5*		5.3**	0.50
F - Fromage		2.7	0.14	1.1	5.1**		0.4	9.4***
F – Vin*Fromage		1.3	4.4**	3.8**	1.8		2.5*	1.6
Chaource	**Beaujolais**	6.2	9 a	32 ab	28.6 a	0.13	12	214 ab
Chaource	**Maranges**	7.0	9 a	30 ab	34.1 ab	0.16	11	219 ab
Chaource	**Pouilly**	6.5	9 a	31 ab	27.5 a	0.13	11	204 b
Comté	**Beaujolais**	7.8	9 a	33 b	33.6 ab	0.14	12	238 a
Comté	**Maranges**	10.6	8 b	26 a	50.1 b	0.21	10	228 abc
Comté	**Pouilly**	7.2	9 a	34 b	33.1 ab	0.14	12	237 a
Époisses	**Beaujolais**	7.0	9 a	33 b	45.0 ab	0.19	10	241 a
Époisses	**Maranges**	7.6	9 a	32 b	41.2 ab	0.18	10	233 ab
Époisses	**Pouilly**	7.4	9 a	33 b	37.2 ab	0.15	12	243 a

336 Significance levels: *5%, **1%, ***0.1%.
337 Different letters indicate significant differences according to a LSD test.
338

3.2 Temporal perception of wines and cheeses individually and combined

3.2.1 Individual wine and cheese description

Figure 2 a and b present the percentage duration of dominance of the attributes used to describe the wines (a) and the cheeses (b). As it was expected, certain attributes were used mainly for cheese description (e.g. lactic, fatty/creamy, sticky) while others were used for the wine (e.g. astringent, sweet). However, fruity for example, was used to describe both, and it was a discriminant attribute for wines and cheeses.

The tested products had different temporal profiles which are also evident in Figure 2a (wines) and b (cheeses). *Pouilly L* was characterized by the duration of dominance of fruity and sweet, *Maranges* was the wine with the longest duration of dominance of astringent and the least duration of sweet; and *Beaujolais* had the longest duration of dominance of bitter taste. These results are in-line with the chemical composition of the wines (Table 2). The Maranges had the highest level of tannins and was perceived as the most astringent, while the tannins present in the Beaujolais, together with the almost non-existent reducing sugars, resulted in the perception of the wine as bitter. At the same time, the fact that consumers would perceive the *Pouilly Loche* as astringent during 6% of the time of the tasting was quite surprising. Previous work done by Brachet et al (2014) showed that consumers referred more to the term astringent when describing wines in comparison to a trained panel. It could be possible that some of the consumers could mix-up sourness with astringency (Lee and Lawless, 1991). All three wines were characterized by sour/pungent but this attribute was not discriminant among them.

Chaource cheese had the longest duration of lactic aroma; *Comté* was the least creamy and the most fruity and *Epoisses* was the one with the longest duration for sticky. Salty had an important duration in all cheeses but it was not discriminant among samples.

This individual characterization of the products was important to know how they can change when ingested in combination.

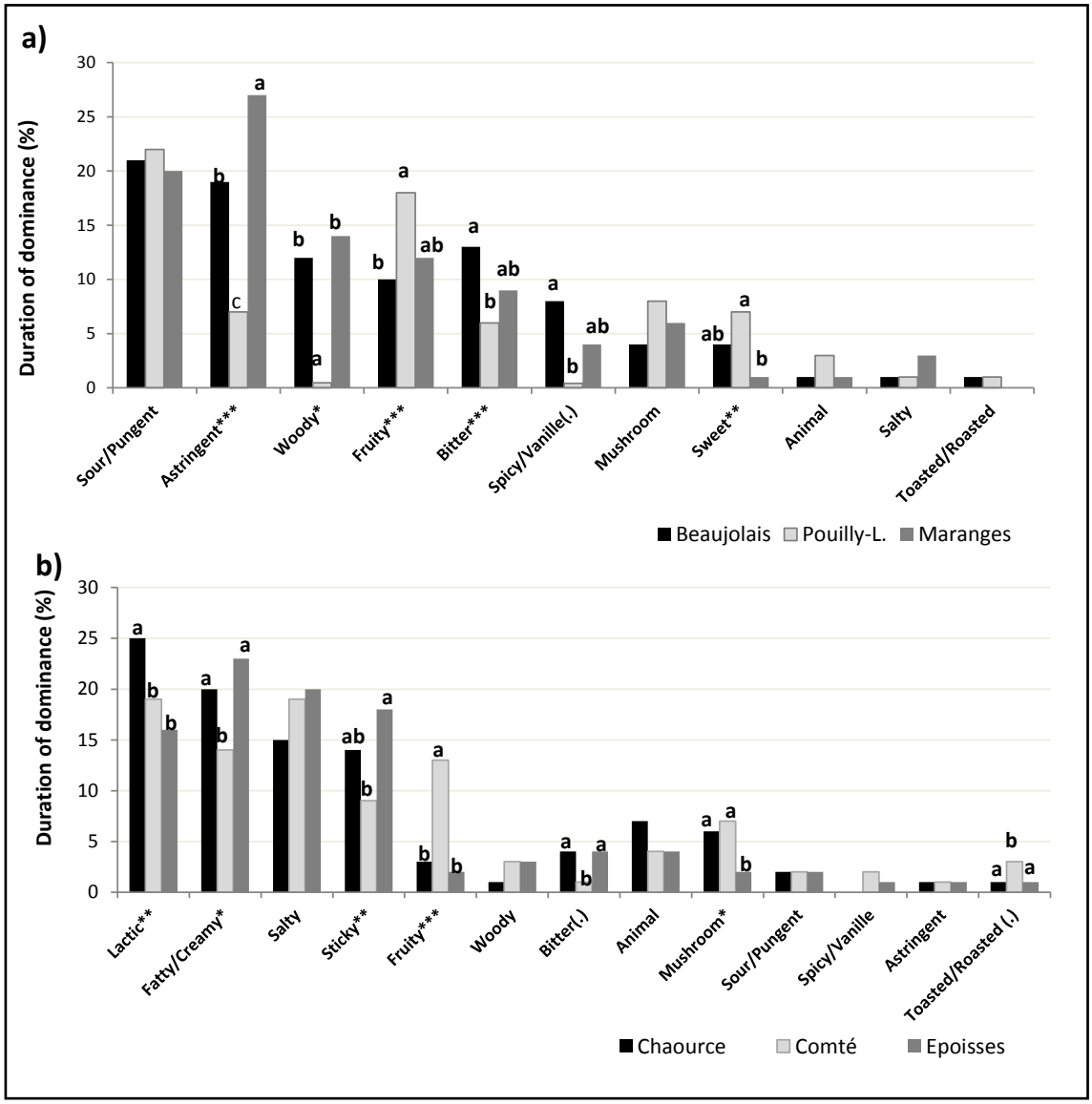

Figure 2 a and b. Description of wine and cheeses in terms of duration of dominance (% of total standardized duration) of the different attributes.

Significance levels: (.)10%, *5%, **1%, ***0.1%.

Different letters indicate significant differences according to a LSD test.

3.2.2 Evaluation of wine and cheese combinations

As mentioned in the materials and methods section, the effect of cheese on wine and vice-versa was analyzed by evaluating changes in duration of dominance by descriptor with an ANOVA were cheese and wine were the fixed factors. In this way, significant differences ($p<0.1$) were found for nine descriptors of the 14 used to describe the combinations. The

379 standardized durations of dominance for these descriptors for each wine-cheese combination
380 are presented in Figure 3.
381 A wine by cheese interaction ($p<0.1$) was found for salty and lactic. A significant cheese
382 effect was obtained for: creamy, fruity and spicy/vanilla; a wine effect was found for
383 astringent, sweet, fruity, woody, toasted/roasted.
384 It should be noted that there was no difference among cheeses for the duration of dominance
385 of salty (Figure 2b). But, when evaluated as wine-cheese pairs, the duration of salty as
386 dominant changed a lot according to the wine that accompanied the cheese. The longest
387 duration of dominance for salty was found in *Epoisses-Maranges* and the shortest duration in
388 *Chaource-Maranges*, while it stayed almost the same for all cheeses when eaten together with
389 *Pouilly L*. Another interesting interaction was observed with lactic. In the combinations with
390 *Maranges*, its perception changed drastically from one cheese to another, but this was more
391 moderate in the *Beaujolais* and *Pouilly L*. associations (Figure 3). This interaction is probably
392 the result of synergistic and antagonistic interactions between the volatile compounds in the
393 different cheeses and wines. This kind of behavior has been previously studied in food pairing
394 interactions (Traynor et al., 2013) with a conjoint approach using qualitative (organic volatile
395 analysis and descriptive sensory analysis) and quantitative (comparable semi quantitative
396 organic volatile analysis and affective sensory tests) methods of analysis in an attempt to
397 elucidate the success or failure of selected food pairings. It would be interesting to have
398 studies done using a similar approach but on wine-cheese pairs.
399 In the same way as for salty, the descriptor spicy was not significant when describing
400 the cheeses on their own; but in the combinations there was a cheese effect making the
401 perception of this aroma last as dominant for a longer period of time when eating *Chaource* or
402 *Comté*, regardless of the wine. Fatty/creamy also showed a cheese effect, but in this case it
403 could be interpreted as a reflection of what was found in the evaluation of the cheeses;
404 combinations with *Comté* were less fatty/creamy.
405 Changes in the perception of fruity were related to the cheese and the wine. There
406 was a somewhat additive effect given by *Comté* (the fruitiest cheese) and *Pouilly L.* (the
407 fruitiest wine).
408 The dominance duration of astringency, was longer in the red wine combinations (as
409 expected). Nonetheless its dominance duration was reduced more in the combination with
410 *Comté* and *Epoisses* than with *Chaource*. The effect of sweetness followed the same pattern: in
411 those combinations with white wine sweetness was dominant for a longer period. When
412 evaluating the wine alone, it was observed that both *Maranges* and *Beaujolais* had a woody
413 character (Figure 2a). However, in the associations, there was a distinct difference in the

duration of dominance of this attribute, being the associations with *Beaujolais*, less woody (and as woody as those with *Pouilly L.)* than those with *Maranges* wine. In a previous work Galmarini et al (2016) had found that after eating *Roquefort* and *Epoisses* duration of dominance of astringency in red *Bourgogne* was reduced. A similar effect was found for *Madiran* (*P* value of MANOVA <0.001) where duration of astringency and sourness was reduced after eating *Crottin de Chavignol, Epoisses, Comté* and *Roquefort*.

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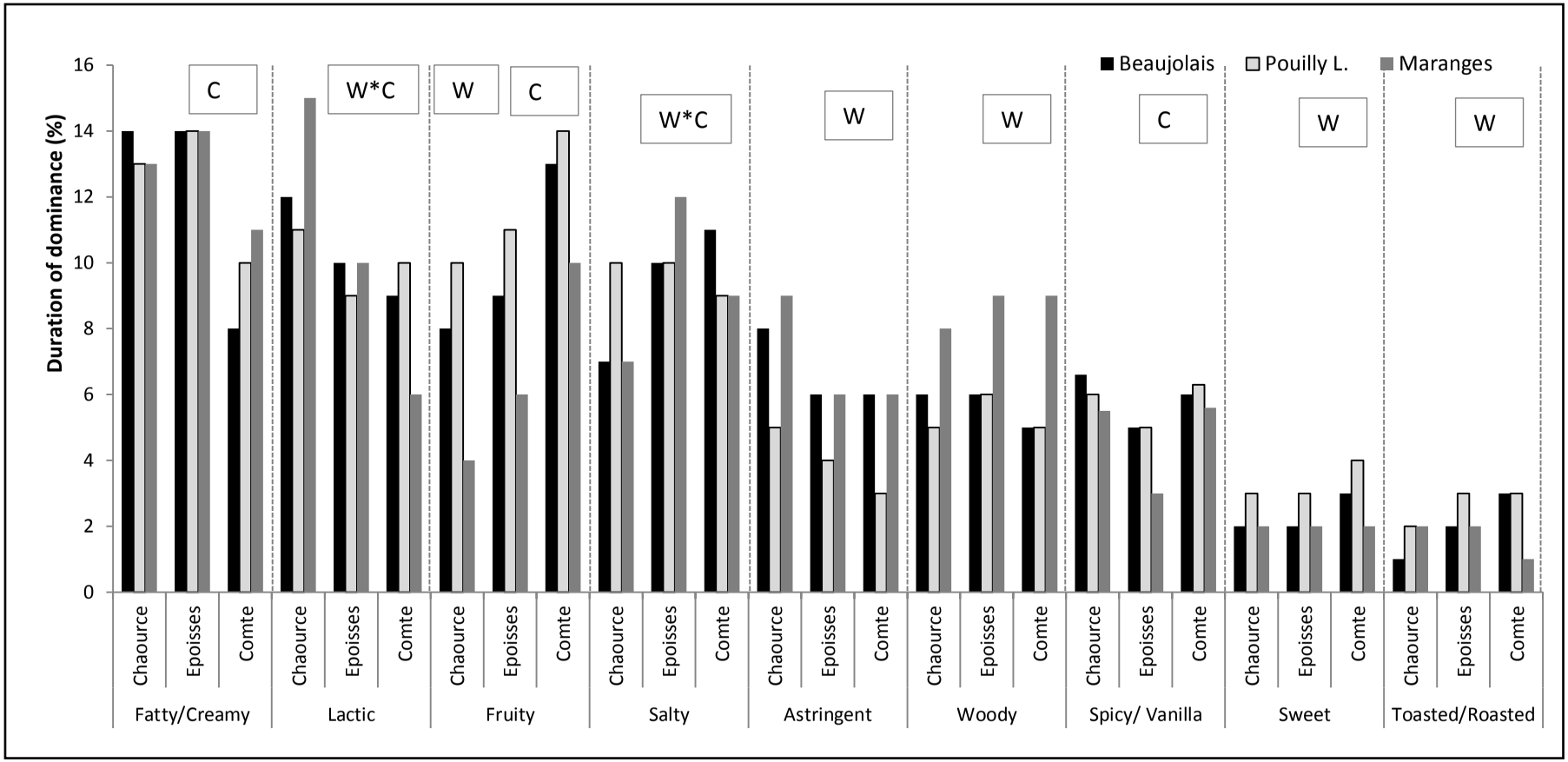

Figure 3. Standardized duration of dominance (%) by descriptor by combination.
W= significant ($p<0.1$) wine effect
C= significant ($p<0.1$) cheese effect
W*C=significant ($p<0.1$) interaction

3.3 Temporal appreciation of wines and cheeses individually and combined

Figure 4 presents the weighted mean liking scores for the wines and the cheeses when evaluated individually. Among the wines, white wine was more liked than the two red wines. The cheeses had higher mean values than wines, but they were all three equally liked. This was probably due to the fact that wines were evaluated blindly; black glasses were provided and no previous information on the type of wine was given. On the other hand, the type of cheese to be tested was evident for consumers. It is known that information, whether it is on the price (Almenberg and Dreber, 2011) on the label (Combris et al., 2006) or the product category, can influence ratings given by consumers. This is particularly so in the case of wine tasting which is a multi-sensory experience (Spence et al., 2014). This could explain why the wines on their own had lower ratings than cheeses on their own. It would be interesting to repeat the experience but providing consumers information on at least the kind of product they taste (dry white wine, aged red wine, etc.).

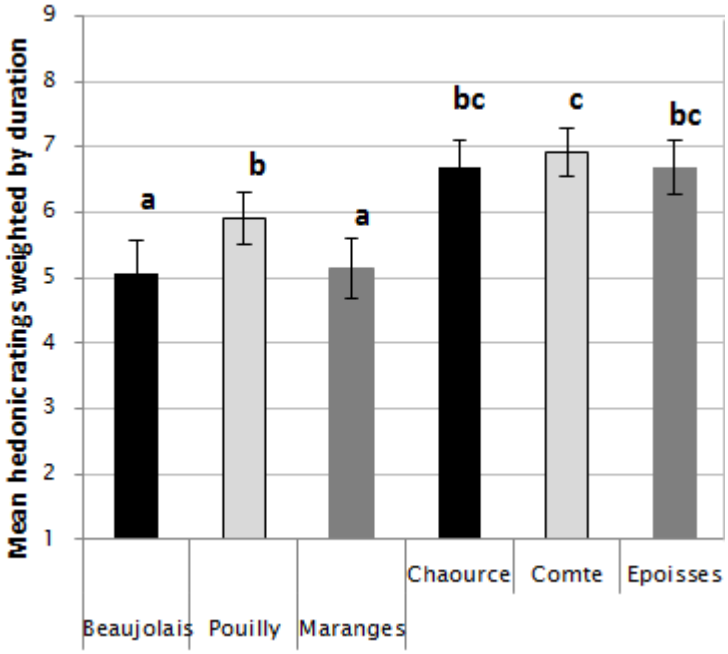

Figure 4. Weighted mean liking scores given to the products when tasted on their own in mono-intake.

For the combinations, the wine, cheese and wine*cheese effect was studied (section 2.4.3). No significant effect was found for the wine*cheese interaction ($F=0.90$, p-value=0.4639) nor for cheese ($F=1.74$, p-value=0.1793); but a significant wine effect was observed ($F=7.92$, $p<0.001$). This meant that the combinations with white wine had higher weighted mean liking than the

combinations with *Beaujolais* or *Maranges* (Figure 6), regardless of the accompanying cheese. In this way, white wine would be a more suitable fit for an assorted plate of cheeses. This is in agreement with previous work done by King and Cliff (2005) who showed, using a static "ideal pair" scale, that white wines had mean scores closer to ideal than the red wines. Authors stated that white wines (*Sauvignon Blanc Chardonnay, Pinot Gris, Gewurztraminer* and *Riesling*) were easier to pair with a broader range of cheeses. It should be noted that in their work, the evaluation was carried out by wine and cheese experts, while our results show reflect consumers' preferences. However, these scientific findings would be opposed to those presented by Bastian et al (2009), who in their study found that overall, red table wines were a better accompaniment to cheeses than white wines. This contradiction must be showing that, in fact, it might be quite difficult to stablish a rule of thumb which generalizes in terms of "red vs. white" and that we need to consider narrowing the specter of products before concluding; needing to take a deeper look into what is liked and disliked. In this way, temporal drivers of liking might be a good tool to better understand what makes consumers like more a certain product or combination at a given moment of the tasting.

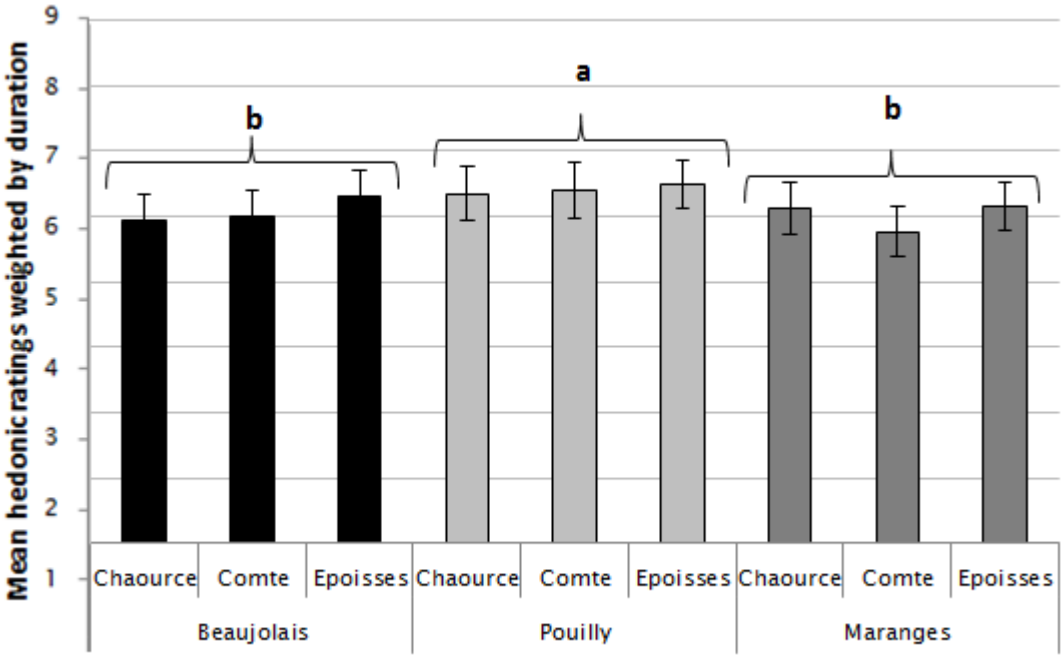

Figure 5. Weighted mean liking scores given to the combinations of wine and cheese evaluated over multiple intakes.

Table 6 shows that, when evaluated individually, less drivers of liking were found for the cheeses than for the wines. The most outstanding finding for the cheeses was that in *Epoisses*, salty was a negative driver of liking for 78% of the panel. This meant that when this descriptor was cited, the given score was reduced in 0.18. For the other two cheeses, positive drivers of liking were found, but they were relevant for a smaller proportion of the panel (*Comté:* 30% increased their liking in 0.2 when citing mushroom; *Chaource:* only 8% increased their liking in 0.29 while citing Toasted). This negative perception of salty could be related to expectations regarding the cheese category and not towards the attribute in itself, since al cheeses seem to have the same duration of dominance for this attribute (Figure 2b).

For the wines, it was observed that astringent, bitter and sour were negative temporal drivers of liking and were found only in the red wines. It should be noted that, even if astringency was a highly dominant attribute when describing *Maranges* (Figue 2a), it was not considered a negative driver of liking in this wine, but it made decrease the liking score in the *Beaujolais*.

When looking at the combinations it was observed that the negative TDL were only three and mostly wine related: sour, bitter and astringent. Perception of bitterness made consumers reduce their liking scores in all combinations with *Maranges*, two with *Beaujolais* and only one with *Pouilly Loché* (with *Comté*). The interesting thing is that in every case, this impact was cited by more than half the panel and ratings were reduced up to 0.47; showing consensus on this dislike. So probably what would be driving a good combination is that in which the perception of these three attributes is reduced. Sourness also made liking scores decrease, in 7 out of the 9 combinations with an even higher agreement of the panel; but the reduction in the scores was smaller. Finally, the third negative TDL was astringency, which reduced the scores in 4 red wine combinations and surprisingly in the *Pouilly Loché-Comté* combination where 48% of the consumers reduced their score in 0.34.

Opposite to that, positive TDL were more varied (a total of 10 descriptors) and were related either to wine or cheese. Also, one negative driver of liking in cheese description became a positive one when evaluating the combinations: salty. In *Maranges-Comté* and *Maranges-Epoisses*, consumers (65 and 83% respectively) increased their liking scores when this attribute was perceived. Actually, *Maranges-Epoisses* was the combination in which salty lasted as dominant for the longest period of time. So this might be showing that consumers like to perceive the salty taste and the characteristics of the cheese and not for them to be "blurred" by the wine; so a liked combination would be that in which both the wine and the cheese can be perceived. Also sticky and lactic were positive TDL for this combination.

The most liked combination was *Epoisses-Pouilly Loché* which had no negative drivers of liking and had fatty and sweet as positive drivers of liking. The moment fatty was cited as dominant, 95% of the consumers increased their liking score in 0.2 while the liking increased in 0.3 for 43% of the panel when choosing sweet.

It is important to point out that, in the combinations, negative drivers of liking were only three, out of the 14 presented descriptors, and they were repeated in several combinations. However, the positive drivers of liking varied more from combination to combination, having a total of 10 attributes (including “nothing dominates”) which could explain a rising in the liking score.

513 Table 6. Mean liking scores and Temporal Drivers of Liking for cheeses, wines and combinations.

Wine	Cheese	Mean liking	Sticky	Fatty/ Creamy	Astringent	Sour/ Pungent	Bitter	Salty	Sweet	Fruity	Mushroom	Animal	Woody	Spicy/ Vanilla	Lactic	Toasted	Nothing dominates
			% of the panel having cited the descriptor as dominant (average of individual Centered Liking While Dominant scores (CLWD))*														
	Chaource	6.7														8 (0.29)	
	Comté	6.9									33 (0.20)						
	Epoisses	6.7						78 (-0.18)									
Beaujolais		5.1			57 (-0.11)	75 (-0.12)	42 (-0.11)						47 (0.17)				
Pouilly		5.9								55 (0.16)				32 (0.16)			
Maranges		5.1				70 (-0.13)	42 (-0.22)			42 (0.25)							
Beaujolais	*Chaource*	6.0			68 (-0.31)	75 (-0.22)	52 (-0.27)			65 (0.18)					93 (0.34)	30 (0.37)	
Beaujolais	*Comte*	6.0				80 (-0.28)	62 (-0.43)			78 (0.31)							
Beaujolais	*Epoisses*	6.3			60 (-0.39)	73 (-0.46)			27 (0.42)			43(0.52)			82 (0.40)		
Pouilly	*Chaource*	6.4				78 (-0.24)											
Pouilly	*Comte*	6.4			48 (-0.34)		55 (-0.45)				53 (0.31)				77 (0.19)		
Pouilly	*Epoisses*	6.5		95 (0.18)					43 (0.29)		60 (0.30)						
Maranges	*Chaource*	6.1				83 (-0.24)	67 (-0.36)		20 (0.27)						93 (0.20)	28 (0.20)	
Maranges	*Comte*	5.8			62 (-0.54)	83 (-0.25)	58 (-0.47)	65 (0.16)		73 (0.44)							
Maranges	*Epoisses*	6.2	82 (0.17)		65 (-0.41)	75 (-0.35)	61 (-0.35)	83 (0.15)							87 (0.19)		10(0.51)

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Conclusions

From a methodological point of view, this experiment showed that dynamic descriptive and hedonic data could be obtained on a full combined portion of wine and cheese.

Wine-cheese interactions were found when describing the combinations, which reminds us that the perception of a combination of products is not the result of an additive or subtracting effect which can be predicted based on their individual perception, but that they are complex associations that need to be deeply studied. This is one of the reasons why stablishing a rule of thumb can be difficult and sometimes even contradictory.

There was a wine effect on the liking of the combinations, showing that in the present case, white wine was a better companion for the evaluated cheeses than the red wines. This liking was explained by a reduced duration of astringency or bitterness as dominant.

Another finding of the present work was that astringency, bitterness and sourness in wine and in these wine-cheese combinations, were perceived as negative drivers of liking by consumers. This is important information to be considered not only when pairing wine with cheeses (and other foods probably) but also when communicating the products' characteristics to consumers.

The innovative method used in the present work opens a whole new field in the evaluation of wine pairing. This could be used not only with cheese, but also pairing wine (or beer) with complete dishes. This would enable a better communication on wine sensory characteristics and usage, and could become a great tool for wine marketing.

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