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# 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 (one white, *Pouilly Loché*; and two red, *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 were associated with the TDS profiles obtaining Temporal Drivers of Liking (TDL). Furthermore, the nine associations that resulted from combining each wine with each cheese were evaluated by multi-bite and multi-sip TDS. Individually, *Chaource* had practically no TDL; for *Comté*, mushroom flavor was a positive TDL, and in *Époisses*, salty was a negative TDL. As for wines, negative TDL were only found in the red wines: bitter, sour and astringent. Positive TDL for wines were: fruity, spicy and woody. Changes in the dynamic perception had a bigger impact on liking of wine compared to cheese. For the associations, the negative TDL were only three and mostly wine related: sour (for seven out of nine combinations), bitter (six out of nine) and astringent (five out of nine). 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. TDS and TDL have a big potential in the study of food pairing, which should be further exploited.

**Keywords:** temporal dominance of sensations; dynamic liking; consumers; wine-cheese pairing; sensory evaluation

## 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 [1]; wine exports represented, in 2015, 7.9 billion to the French economy (www.vinetsociete.fr). As for cheese, France is the third biggest producer worldwide, after the U.S. 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 [2].

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 [2–7]. Needless to say, food and beverage pairings are complex stimuli, which can be challenging to rate in a consistent manner both by experts and naive consumers [8]. There can be a high variation among judges related to personal expectation or preference associated with the suitability of wine for a certain cheese [2]. 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. However, it is evident so far that traditional evaluation methods are not enough to get this information.

The few sensory works that can be found explaining why one combination should be favored over another one [2,3,7,9–11] 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. However, it is known that sensory perception is a dynamic phenomenon, widely affected by mastication, volatile release and aftertaste, and it requires a more complex methodology to better understand what consumers actually perceive.

Temporal Dominance of Sensation (TDS) [12] is a temporal multi-dimensional sensory method that consists of 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 that triggers their attention at every given moment of the tasting. Using this dynamic technique, rather than a traditional profiling method, allows one 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 [13]: that which might be relevant for experts might not be so for consumers. Working on wine TDS description, Brachet et al. [14] found that consumers were as discriminant as experts, but that their obtained profiles 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 [14–16].

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 [17,18]. This can be done after every wine sip [19] or 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: attributes that, when cited as dominant, lead to an increase or a decrease of liking [16]. 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 [20] have lately pointed out that sensory evaluation should evolve towards more realistic experiments regarding 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 [21,22]. In a recent work (which was part of this same research project), Galmarini et al. [19] evaluated the impact of cheese on wine perception and liking over consecutive wine sips, as well as the impact of cheese on wine perception over consecutive bites [23]. 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 the aforementioned works.

A good food-wine duo might be considered that in which no product dominates over the other; 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 the 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 one to have a real close look at 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 that allowed working with the association of two products, which shared terroir.

### *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*, authorization number 1148039). They were chosen based on their frequency of consumption of red and dry white wine (at least once every two weeks) and of *Epoisses*, *Comté* and *Chaource* cheese (at least once every month). Moreover, they were non-smokers and declared not to have any food allergies.

The final recruited group was composed of 45% males and 55% women, with a mean age of 44.5 years old (min 19, max 68 years). They participated in five tasting sessions and were economically gratified for their participation in the study.

### *2.3. Tasting Protocol and Session Organization*

The three wines and the three cheeses were evaluated in two different conditions: (a) individually, in one single intake (mono-sip or mono-bite) and (b) as part of a complete portion of a wine-cheese combination, over multiple intakes (multi-intake). In both situations, the task was based on the same principle: a dynamic description using Temporal Dominance of Sensations coupled with a simultaneous hedonic rating (hereon mentioned as TDS-L) [24].

In every case, consumers swallowed the products, so one of the restrictive factors in the experimental design was the amount of alcohol consumed per session. This was limited to only 12 cL of wine (≈15 mL of alcohol per session). Furthermore, since *Époisses* and *Chaource* mature fast, tasting sessions could not be much separated in time, to compare the evaluation of their different combinations. Finally, the tasting was done in controlled conditions in sensory booths, so the laboratory's facilities limited the number of assessors to 30 per day. Taking all this into consideration, the evaluation of the six products and the nine combinations took place over five one-hour long sessions. Roughly, in each session, consumers tasted: one sample of cheese in mono-bite ($6 \pm 0.5$ g), one sample of wine in mono-sip (1 cL) and two portions of wine-cheese combinations (5 cL of wine and 30 g of cheese for each combination), which consumers could eat in as many intakes as they wanted, beginning by one or the other product, alternating them in their own personal manner. In the first session, warm-up products were used for the mono-intake evaluations and for the first combination (data not presented). In the second session, warm-up products were used only for the mono-intake evaluations, and two combinations were tested. Finally, in Sessions 3 to 5, the actual wine and cheeses were evaluated in mono-intake, as well as in combinations.

**Table 1.** Evaluated cheese samples.

| Name of Cheese | Ageing Time | Type of Milk | Type of Cheese (Usual Characterization) | $H_2O$(g/100 g) | Lipids (g/100 g) | Proteins (g/100 g) | Sodium (mg/100 g) |
|---|---|---|---|---|---|---|---|
| *Chaource* (POD) [1] | 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 |

[1] Protected Origin Designation.

**Table 2.** Evaluated wine samples.

| Type of Wine | Grapes | Year | Alcohol (vol%) | Reducing Sugars (g/L) | Total Acidity ($gH_2SO_4/L$) | Tannins (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 | - |

During the first session, the tasting method and the attributes to be used were presented. Details on the complete sensory method used are given in the subsections below.

#### 2.3.1. Familiarization with the Method

Based on previous experiments, 14 sensory attributes were chosen (Table 3) covering basic tastes, textures and aromatic families. It should be noted that some of these aromatic families (e.g., fruity) could be used for the wines, as well as for the cheeses. The definitions presented in Table 3 were given to consumers together with several examples. It should be noted that consumers were explained the attributes, but they did not participate in the generation of descriptors.

A short presentation was given to explain the tasting method. Consumers were instructed that a dominant sensation was the one that caught their attention at a given moment, not necessarily the most intense. Moreover, they were instructed that if no sensation was more important than another one, they could indicate it using a "nothing dominates" attribute, which was also present in the list to be used.

To conclude the training, a tasting was done on a commercial French cheese (*Comté*, Le Montarlier, Président) and commercial French wine (Macôn Villages, 2013), which were evaluated individually and then as a combination. The obtained data were only used to verify that consumers had understood the task (data not shown).

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

| Attribute | Definition |
|---|---|
| Sour/Pungent | Basic taste related to a 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 an 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. |

#### 2.3.2. Used Sensory Method

All data were acquired by means of the on-line software TimeSens 1.0 (INRA, Dijon, France) using a protocol based on TDS, with simultaneous evaluation of liking (TDS-L) [24]. For 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 was for the purpose of 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 1a,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 s to encourage re-notation. In addition, a reminder popped-up every 20 s 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. In this way, a blind tasting condition was guaranteed for the wines. As for the cheeses, even if they were not labeled, the type of cheese was somewhat evident for consumers, given their typical smell and aspect.

### *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 software TimeSens (INRA, Dijon, France) and R 3.0.3 [25].

#### 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 was standardized: the duration of each dominant attribute represents a percentage of the total time of the evaluation [26]. 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, 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 software TimeSens (INRA, Dijon, France) and R Core Team [25].

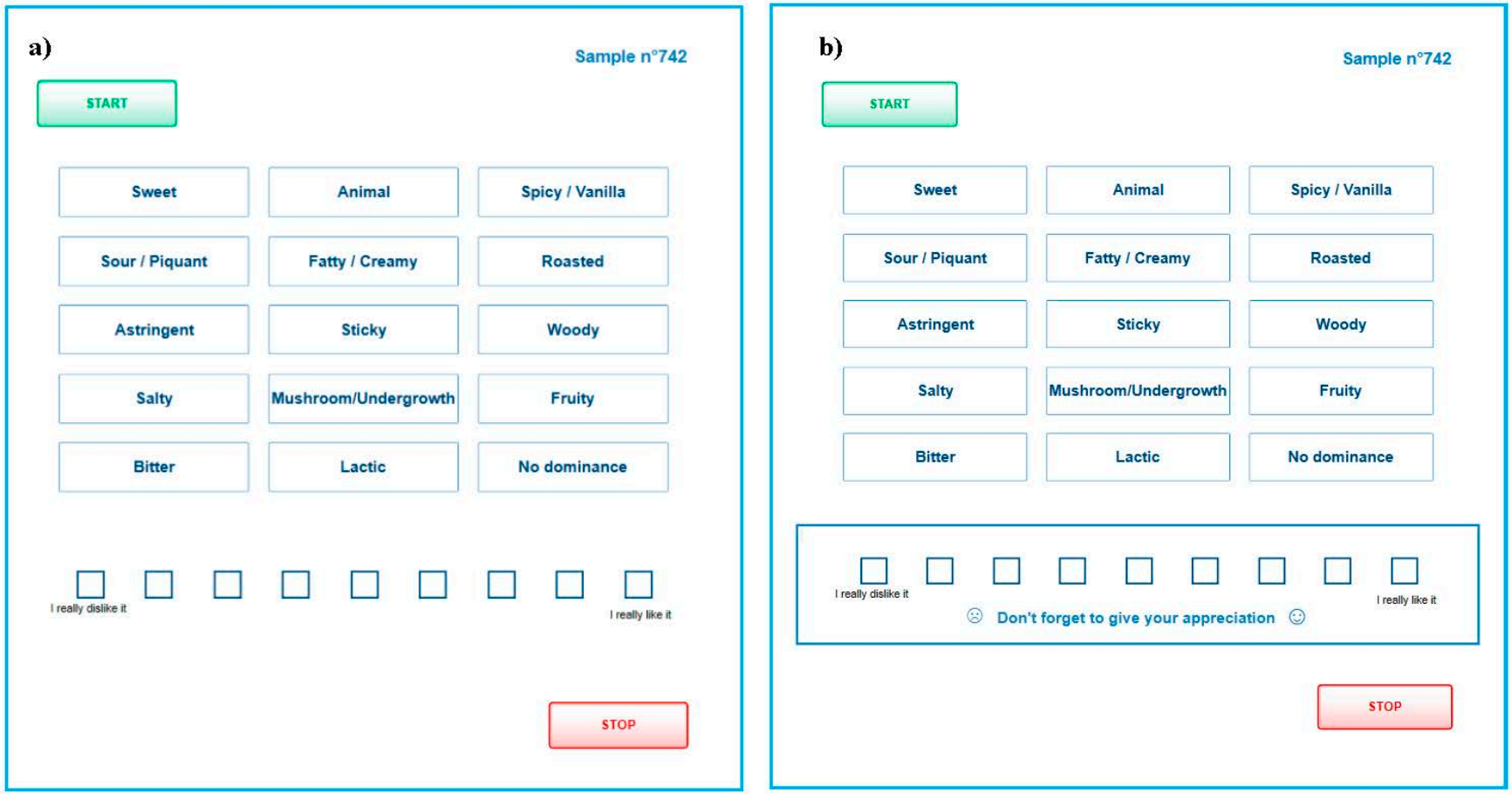


**Figure 1.** (**a**,**b**) Screenshots of the method used for data acquisition. The same screen was presented for the mono-intake evaluation of wine, mono-intake evaluation of cheese and for the multiple intake evaluation of the combination.

#### 2.4.3. Temporal Appreciation of Products and Their Combination

Liking data were recorded in a dynamic way. For each panelist, a series of liking scores was obtained; the number 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. 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 Section 2.4.2 (i) and (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. [16]. 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: TBFC, ND and NC for the TDS description, as well as TBFL and NL together with DE for the products tasted in mono-intake. The F-value corresponds to the ANOVA done considering all six products, in order to explore differences between the way consumers evaluated the wines and cheeses.

**Table 4.** Mean values for: Time Before the First Citation (TBFC), Number of Descriptors used (ND), total Number of Clicks used (NC), Time Before the First Liking rating (TBFL), proportion of TBFL in relation to the total Duration of the Evaluation (TBFL/DE), the number of ratings given for the hedonic test (Number of Liking ratings (NL)) and total Duration of the Evaluation (DE) for wines and cheeses evaluated in mono-intake TDS-L.

| Product | TDS | | | Hedonic | | | |
|---|---|---|---|---|---|---|---|
| | TBFC (s) | ND | NC | TBFL (s) | TBFL/DE | NL | DE (s) |
| 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 Loché.* | 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 |

Significance levels: ** 1%, *** 0.1%. Different letters indicate significant differences according to an LSD test.

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, on average, the same number 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. To have a more accurate description of consumers' behavior towards product rating, the TBFL was compared to the DE (proportion TBFL/DE), showing at which moment of the tasting consumers gave their liking. For *Chaource*, *Comté* and *Beaujolais*, the first liking score was given before the first half of the tasting. For the other three products, consumers gave the first liking score in the second part of the tasting, even after 67% of the tasting time has passed in the case of *Pouilly Loché.*

It was also found that consumers clicked on the liking scale more than once for every product (mean NC $\geq$ 2.5), therefore validating the fact that giving several liking scores was possible even when

evaluating one intake. For NC, cheeses and wines did not result in two separate clear groups as in the case ND (TDS description). This shows that the number of clicks on the liking scale was independent of the product type and directly related to the individual characteristics of each product. *Comté* cheese recorded the most number of liking clicks, while *Maranges* was the one with the fewest. However, it should be noted that a change in the number of clicks is not the same as having changes in the dynamics of liking; this will be analyzed in Section 3.3.

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

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

**Table 5.** Mean values for: TBFC, ND, NC, TBFL, NL and total DE for wine-cheese combinations evaluated in multiple-intake TDS-L.

| Wine-Cheese Combination | | TDS | | | Hedonic | | | |
|---|---|---|---|---|---|---|---|---|
| | | TBFC (s) | ND | NC | TBFL (s) | TBFL/DE | NL | DE (s) |
| 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-VinxFromage | | 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 Loché* | 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 Loché* | 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 Loché* | 7.4 | 9 a | 33 b | 37.2 ab | 0.15 | 12 | 243 a |

Significance levels: * 5%, ** 1%, *** 0.1%. Different letters indicate significant differences according to an LSD test.

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

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

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

### *3.2. Temporal Perception of Wines and Cheeses Individually and Combined*

#### 3.2.1. Individual Wine and Cheese Description

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

The tested products had different temporal profiles, which are also evident in Figure 2a (wines) and b (cheeses). *Pouilly Loché* 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 Loché* as astringent for 6% of the time of the tasting was quite surprising. Previous work done by Brachet et al. [14] 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 [27]. 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 fruitiest; and *Époisses* was the one with the longest duration for sticky. Salty had an important duration in all cheeses, but it was not discriminant among samples.

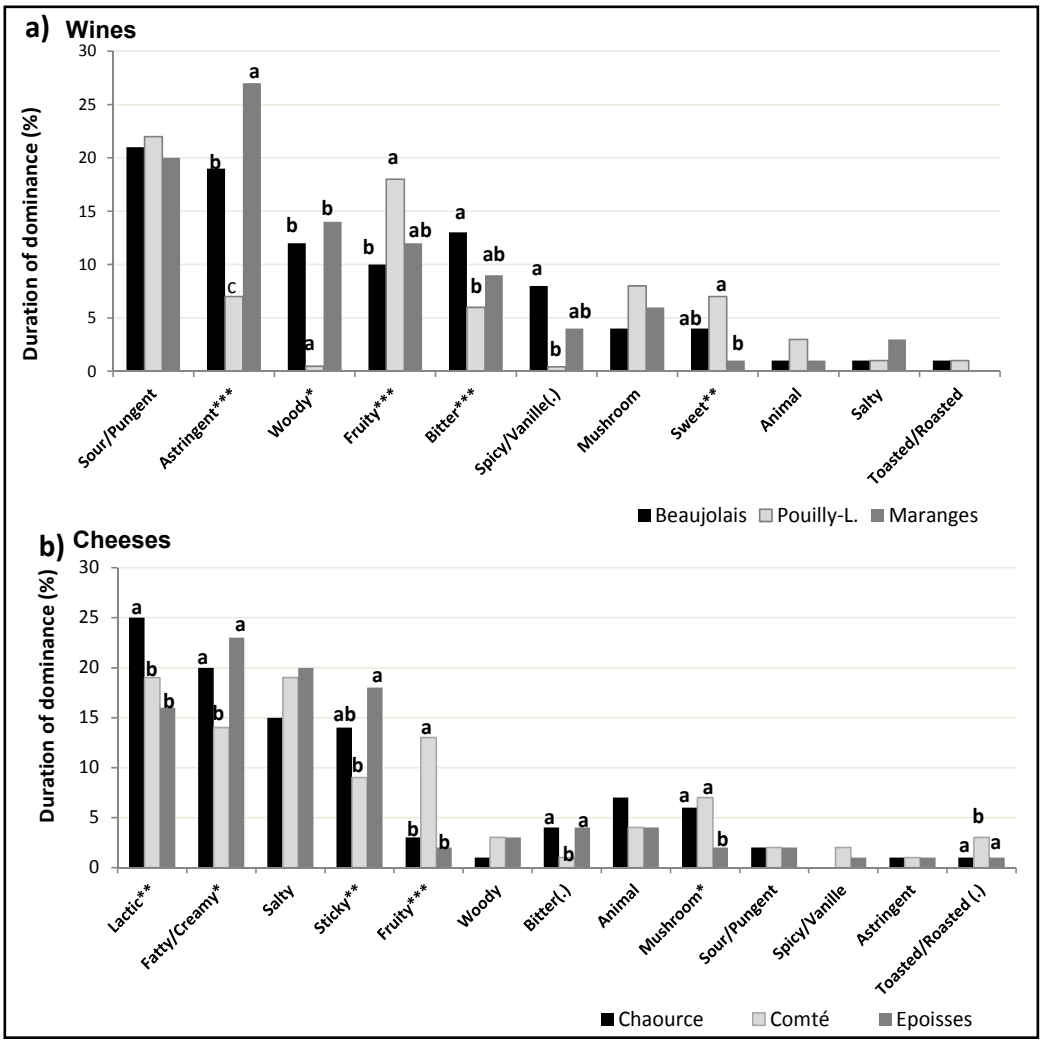


**Figure 2.** (**a**,**b**) Description of wine and cheeses in terms of duration of dominance (% of total standardized duration) of the different attributes. Significance levels: (.) 10%, * 5%, ** 1%, *** 0.1%. Different letters indicate significant differences according to a LSD test.

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

### 3.2.2. Evaluation of Wine and Cheese Combinations

The standardized durations of dominance for these descriptors for each wine-cheese combination are presented in Figure 3.

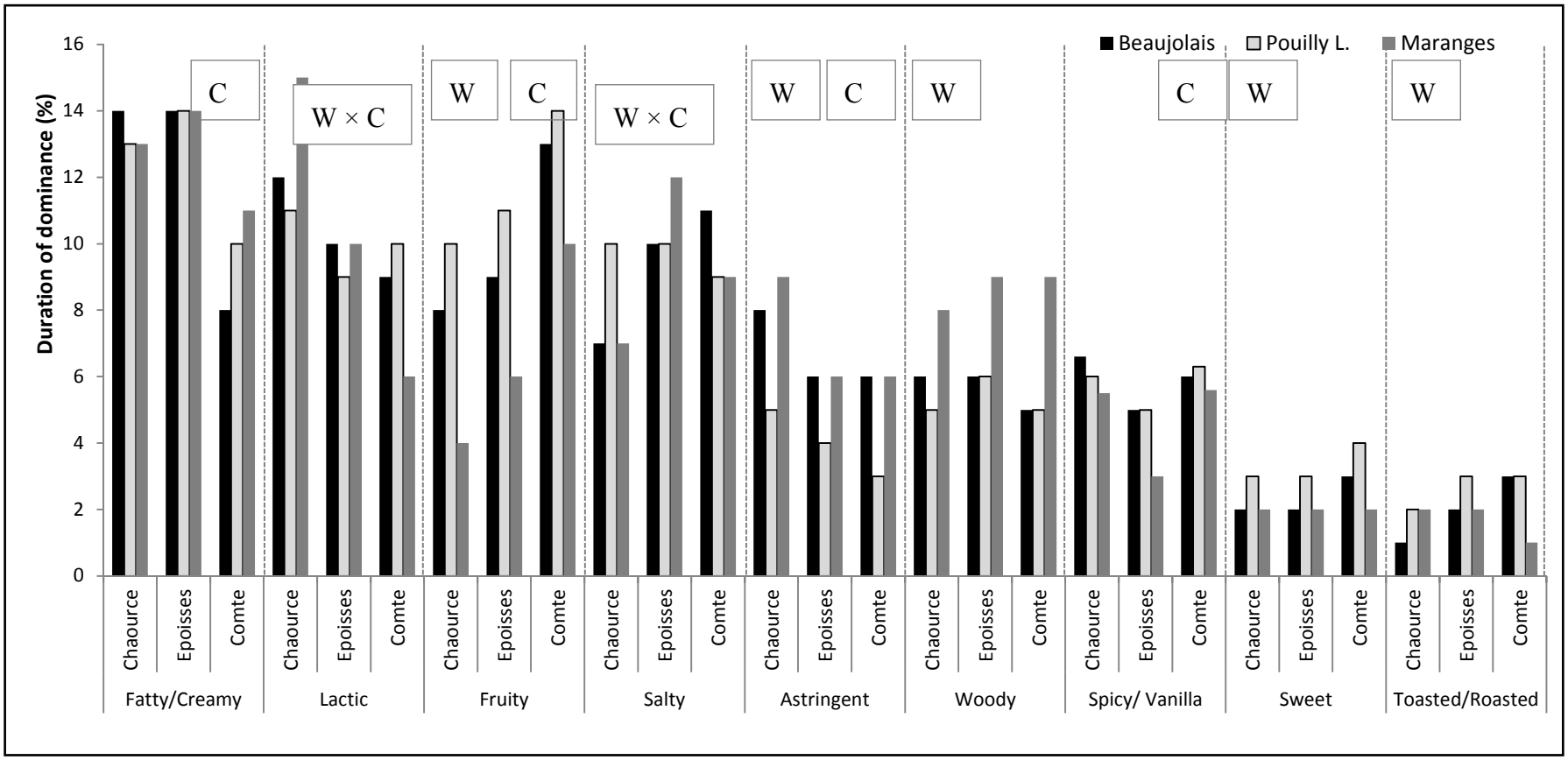


**Figure 3.** Standardized duration of dominance (%) by descriptor by combination. W = significant wine effect ($p < 0.1$); C = significant cheese effect ($p < 0.1$); W × C = significant interaction ($p < 0.1$).

A wine by cheese interaction ($p < 0.1$) was found for salty and lactic. A significant cheese effect was obtained for creamy, fruity and spicy/vanilla; a wine effect was found for astringent, sweet, fruity, woody and toasted/roasted.

There was no difference among cheeses for the duration of dominance of salty (Figure 2b), but when evaluated as wine-cheese pairs, the duration of salty as dominant changed a lot according to the wine that accompanied the cheese. The longest duration of dominance for salty was found in *Epoisses-Maranges* and the shortest duration in *Chaource-Maranges*, while it stayed almost the same for all cheeses when eaten together with *Pouilly Loché*. Another interesting interaction was observed with lactic. In the combinations with *Maranges*, its perception changed drastically from one cheese to another, but this was more moderate in the *Beaujolais* and *Pouilly Loché*. associations (Figure 3). This interaction was probably the result of synergistic and antagonistic interactions between the volatile compounds in the different cheeses and wines. This kind of behavior has been previously studied in food pairing interactions [28] with a conjoint approach using qualitative (organic volatile analysis and descriptive sensory analysis) and quantitative (comparable semi quantitative organic volatile analysis and affective sensory tests) methods of analysis in an attempt to elucidate the success or failure of selected food pairings. It would be interesting to have studies done using a similar approach, but on wine-cheese pairs.

In the same way as for salty, the descriptor spicy was not significant when describing the cheeses on their own; but in the combinations, there was a cheese effect making the perception of this aroma last as dominant for a longer period of time when eating *Chaource* or *Comté*, regardless of the wine. Fatty/creamy also showed a cheese effect, but in this case, it could be interpreted as a reflection of what was found in the evaluation of the cheeses; combinations with *Comté* were less fatty/creamy.

Changes in the perception of fruity were related to the cheese and the wine. There was a somewhat additive effect given by *Comté* (the fruitiest cheese) and *Pouilly Loché* (the fruitiest wine).

The dominance duration of astringency was longer in the red wine combinations (as expected). Nonetheless, its dominance duration was reduced more in the combination with *Comté* and *Époisses* than with *Chaource*. The effect of sweetness followed the same pattern: in those combinations with white wine, sweetness was dominant for a longer period. When evaluating the wine alone, it was observed that both *Maranges* and *Beaujolais* had a woody 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 Loché*) than those with *Maranges* wine. In a previous work, Galmarini et al. [19] had found that the duration of dominance of astringent was reduced in red *Bourgogne* after eating *Roquefort* and *Époisses* and in *Madiran* ($p$-value of MANOVA < 0.001) after eating *Crottin de Chavignol*, *Epoisses*, *Comté* and *Roquefort*.

### *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 [29], on the label [30] 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 [31]. 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.).

For the combinations, the wine, cheese and wine × cheese effect were 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 5), 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 [2] who showed, using a static "ideal pair" scale that white wines had mean scores closer to ideal than the red wines. The 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 reflect consumers' preferences. However, these scientific findings would be opposed to those presented by Bastian et al. [5], 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 that 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 a certain product or combination more at a given moment of the tasting.

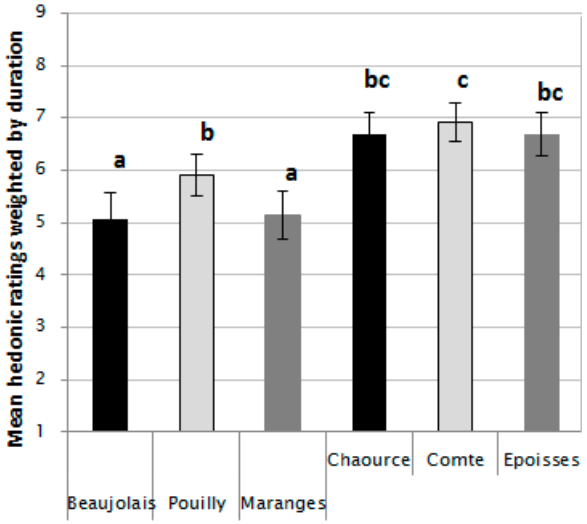


**Figure 4.** Weighted mean liking scores given to the products when tasted on their own in mono-intake. Different letters represent significant differences ($p < 0.05$) according to LSD test.

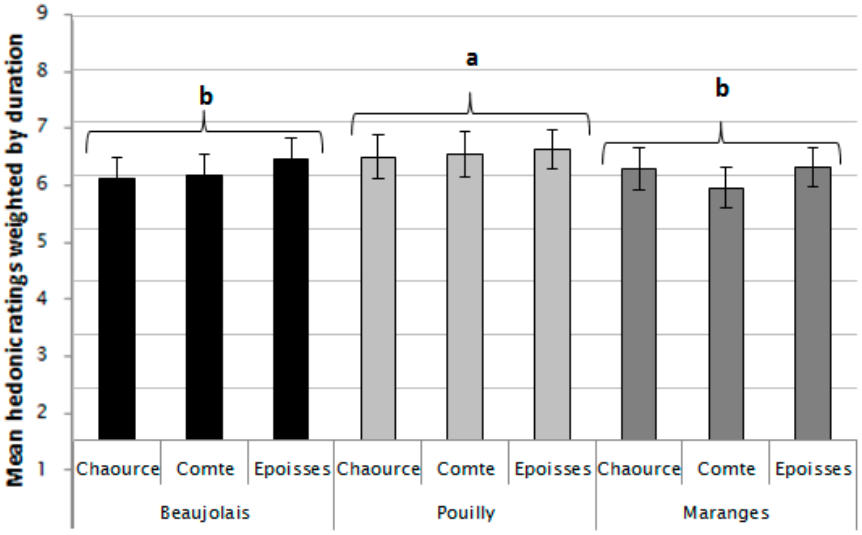


**Figure 5.** Weighted mean liking scores given to the combinations of wine and cheese evaluated over multiple intakes. Different letters represent significant differences ($p < 0.05$) according to LSD test.

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 *Époisses*, 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 by 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 by 0.2 when citing mushroom; *Chaource:* only 8% increased their liking by 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 all 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* (Figure 2a), it was not considered a negative driver of liking in this wine, but it decreased 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*, in two with *Beaujolais* and only in 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. Therefore, probably, a good combination would be that in which the perception of these three attributes is reduced. Sourness also made liking scores decrease, in seven out of the nine combinations with an even higher agreement among consumers, but the reduction in the scores was smaller. Finally, the third negative TDL was astringency, which reduced the scores in four red wine combinations and surprisingly in the *Pouilly Loché-Comté* combination, where 48% of the consumers reduced their score by 0.34.

Opposite to that, positive TDL were more varied (a total of 10 descriptors) and were related either to wine or cheese. Furthermore, one negative driver of liking in cheese description became a positive one when evaluating the combinations: salty. In *Maranges-Comté* and *Maranges-Époisses*, consumers (65% and 83% respectively) increased their liking scores when this attribute was perceived. Actually, *Maranges-Époisses* was the combination in which salty lasted as dominant for the longest period of time. Therefore, 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. Furthermore, sticky and lactic were positive TDL for this combination.

The most liked combination was *Époisses-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 by 0.2, while the liking increased by 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 an increase in the liking score.

**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)** | | | | | | | | | | | | | | | | | |
| | *Chaource* | 6.7 | | | | | | | | | | | | | | 8 (0.29) | |
| | *Comté* | 6.9 | | | | | | | | | 33 (0.20) | | | | | | |
| | *Époisses* | 6.7 | | | | | | 78 (−0.18) | | | | | | | | | |
| *Beaujolais* | | 5.1 | | | 57 (−0.11) | 75 (−0.12) | 42 (−0.11) | | | | | | 47 (0.17) | | | | |
| *Pouilly Loché* | | 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* | *Époisses* | 6.3 | | | 60 (−0.39) | 73 (−0.46) | | | 27 (0.42) | | | 43(0.52) | | | 82 (0.40) | | |
| *Pouilly Loché* | *Chaource* | 6.4 | | | | 78 (−0.24) | | | | | | | | | | | |
| *Pouilly Loché* | *Comte* | 6.4 | | | 48 (−0.34) | | 55 (−0.45) | | | | 53 (0.31) | | | | 77 (0.19) | | |
| *Pouilly Loché* | *Époisses* | 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* | *Époisses* | 6.2 | 82 (0.17) | | 65 (−0.41) | 75 (−0.35) | 61 (−0.35) | 83 (0.15) | | | | | | | 87 (0.19) | | 10(0.51) |

## 4. 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, revealing 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 establishing 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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**Author Contributions:** Mara V. Galmarini designed the study, carried out the experiment, interpreted the results and drafted the manuscript. Anne-Laure Loiseau and Lucie Dufau 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 the interpretation of the results.

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