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Sensory characterisation of Cognac eaux-de-vie aged in barrels subjected to different toasting processes

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ABSTRACT

Toasting is a key step in the barrel-making process. It plays an important role in the breakdown of oak wood compounds and thus influences the chemical composition and organoleptic properties of wines and brandies. However, the effect of toasting on distilled spirit quality has not yet been extensively studied. The objective of this study was therefore to study the impact of toasting on cognac eaux-de-vie by characterising the eaux-de-vie sensorially after 12 months of ageing. Eight eaux-de-vie aged in barrels with 8 different toasts were studied. The 8 toasts represented 4 different temperatures (low, medium, medium plus and high) and two toasting lengths for each temperature (one so-called "normal" and the other "slow"). Sensory analysis was carried out on these eaux-de-vie through several tests. First, a sorting test showed the differences between the samples and then training was carried out on previously chosen descriptors in order to build a sensory profile and perform a ranking test. The study was realised for two alcohol levels: 60 % (*v/v*), which is the alcohol level of eaux-de-vie in barrels, and 40 % (*v/v*), which is the alcohol level of a commercial cognac. This approach demonstrated that barrel toasting generally leads to significant sensorial differences in eaux-de-vie during ageing. These differences are greater between a lightly and a highly toasted barrel. This study is a first step in the characterisation of cognac eaux-de-vie aged in barrels made with different toasts.

KEYWORDS: Cognac eau-de-vie, barrel toasting, sensory analysis, sorting task, ranking test, sensory profile

INTRODUCTION

For many years, wood has been used extensively in cooperage for the manufacture of barrels. Due to the unique mechanical properties of oak wood barrels in particular, their capacity to provide good thermal isolation (Vivas, 2002) - their structure is such that the casks will not leak - and their slight porosity which favours oxidation phenomena, they are more than just a container: they have become an essential tool for ageing wines and spirits. They allow the adjustment of the organoleptic quality and complexity of alcoholic beverages aged within them to take place (Caldeira *et al*., 2008; Fernández de Simón *et al*., 2014). Barrel ageing is therefore an integral part of the production of good-quality wines and spirits. Ageing in oak barrels is part of the specifications of the Cognac controlled designation of origin (AOC Cognac). This is a French spirit produced exclusively in the Nouvelle-Aquitaine region, and more precisely in the Cognac area, made from double-distilled white wines (Ugni blanc is the principal grape variety). A freshly distilled eau-de-vie has a high ethanol concentration, ranging from 70 to 72 % (*v/v*) for Cognac (Vivas *et al*., 2020), and is very rich in volatile compounds. It is the contact with the wood, which can last more than two years, that will enrich the spirits with phenolic compounds, such as phenolic aldehydes, phenolic acids, coumarins, lignans, phenylketones or even hydrolysable tannins (Canas, 2017). Oak wood affects colour, structure and organoleptic complexity, and the different steps in the barrel-making process, such as seasoning and toasting, will influence these quality attributes in both wines and spirits (Cadahía *et al*., 2003; Canas *et al*., 2007; De Rosso *et al*., 2009; Matricardi and Waterhouse, 1999). Barrel toasting is probably the most important step in barrel manufacturing, as it influences oak wood chemical composition, which is then likely to migrate into the wine and spirits during ageing, affecting their organoleptic properties. Oak toasting leads to wood compound thermodegradation, which in turn leads to the release of new volatile and non-volatile compounds (Cadahía *et al*., 2001, Cadahía *et al*., 2003; Chira *et al*., 2020; Jordão *et al*., 2006; Mosedale and Puech, 1998). The impact of toasting on the aromatic profile of Portuguese spirits in contact with wood and on whisky has been studied from a physico-chemical point of view (Caldeira *et al*., 2002; Caldeira *et al*., 2006). Snakkers *et al*. (2003) also conducted research into the influence of barrel toasting on Cognac eaux-de-vie using pilot barrels. Untoasted oak wood gave "vegetal" and "heavy" notes, whereas toasted wood gave higher-quality eaux-de-vie with "vanilla" notes. Sensory analyses are commonly performed on wines and spirits to characterise them or to study the organoleptic impact of compounds present in these matrices. In order to characterise wines and spirits in this way, the sensory profile is the most commonly used test. However, before building the sensory profile, it is important to assess the overall similarities or differences between the samples, for which a sorting task is performed. It is also necessary to train the panel on previously selected descriptors which will represent the sensory space of the studied samples, as well as on how to score using the descriptor intensity scale, and thereby create a sensory profile for the studied samples. Ranking tests can also be used to rank samples according to an overall criterion such as quality or typicality. However, from a sensory point of view, no studies have yet been conducted which focus on the influence of barrel toasting on Cognac eaux-de-vie. Therefore, the aim of our study was to perform a sensory characterisation of Cognac eaux-de-vie aged for 12 months in barrels which had been subjected to different toasting processes. This ageing duration was a limitation of the study; however, it should be noted that this initial preliminary study was performed for one year in order to determine the impacts of barrel toasting and with view to conducting further long-term studies which will align with the industrial practice of three years. In order to represent all the basic toasts found in cooperage, eight types were chosen.

To achieve our objectives, discriminative tests consisting of a free sorting task were carried out in a first step to show the differences between the samples, then a conventional sensory profile was defined by a descriptive method. To judge the quality of the eaux-de vie, a rank order test was used. All these tests are commonly used for the sensory analysis of wines or spirits (Lawless and Heymann, 2010; N. Martin and de Revel, 2000).

MATERIALS AND METHODS

1. Eaux-de-vie

Eight Cognac eaux-de-vie aged for 12 months in contact with barrels subjected to different toasts were studied. In all cases, the same young eau-de-vie from double-distilled Grande Champagne terroir (the grape variety was ugni blanc) from the 2020 vintage was placed in new barrels representing eight different toasting processes consisting of four different temperatures (Light, Medium, Medium plus and High) and two different durations (Normal and Slow). The different toasting processes are given in Table 1; the temperature which was recorded throughout each toasting process is given as integration of the area under the temperature curve over the entire toasting period note total °C/min. The barrels used were all 400 L, were made of French oak from two geographical origins, the Indre and the Dordogne, and were a mixture of medium and coarse grain. These barrels were in a cellar where the barrels were stacked vertically (with the bung hole on the top). The barrels are made like this in order respect the contact between the wood and the eau-de-vie and provide the same exchanges as when the barrel is horizontal. The eaux-de-vie have an alcohol content of 60 % (*v/v*) during ageing, but they are marketed at 40 % (*v/v*). For this reason, the sensory analyses were carried out at both alcohol levels. To bring the eaux-de-vie down to 40 % (*v/v*), osmosed water was used.

2. Sensory analysis

2.1. General conditions

The samples were evaluated at room temperature (20 °C) in covered black ISO glasses containing 12 mL of liquid

TABLE 1. Description of the types of toast studied.

Toast	Notation	Sum °C min
Light toast normal	LTN	3560
Light toast slow	LTS	5036
Medium toast normal	MTN	4566
Medium toast slow	MTS	5134
Medium toast plus normal	MT+N	5088
Medium toast plus slow	MT+S	6015
High toast normal	HTN	6892
High toast slow	HTS	7320

and coded with random three-digit numbers. Sessions were conducted at individual tasting stations.

2.2. Panel

The panel comprised the members of the tasting committee of the Courvoisier Cognac Company. Fourteen professionals (6 women and 8 men) aged between 27 and 63 years old (median age: 46.5 years old) tasted the cognac eaux-de-vie. They were selected for their availability and their interest and skills in tasting eaux-de-vie, all carrying out daily eaux-de-vie tasting on a professional basis. In addition, they have all been officially trained in tasting Cognac eaux-de-vie by an approved training organisation called ORECO and therefore have the same level of sensory expertise. The participants were not given any information about the study prior to it, and they therefore did not know which type of eau-de-vie they would be evaluating. All the panellists provided written consent to perform the tasting.

2.3. Free sorting task

Each panellist participated in four 45-min sessions. First, the panel was asked to smell 8 eaux-de-vie in random order. Then they were asked to group the samples according to their similarities, forming at least two groups. They were asked to smell the samples as many times as they wished, and in any order they wanted (Campo *et al*., 2008). They were not asked to explain their choice regarding the groups formed. After the olfactory session, a second session of the sorting task related to gustatory and retronasal perception was carried out. These two exercises were performed on samples at 60 % (*v/v)* and 40 % (*v/v*) which were subject to four sorting sessions.

2.4. Descriptive testing: Conventional sensory profile

Descriptive testing was performed with a sensory profile (NF ISO 13299:2016) in three steps: i) a free descriptor generation was performed (NF ISO 11035:1994) to best characterise the sensory space of the samples, ii) the panel received training on the generated descriptors (NF ISO 8586:2012) and the scale used (NF ISO 4121:2003), and iii) the eaux-de-vie was evaluated. All the tasting sessions took place over a period of one and a half months.

2.4.1. Free descriptor generation

A free descriptor generation was held in a single 1-hour session on the eight eaux-de-vie with an alcohol level of 60 % (*v/v*). The panel was asked to taste all the eaux-de vie samples from an othonasal, gustatory and retronasal point of view in a specific pre-determined order. Each panellist could smell and taste the samples several times, and was asked to generate a list of 10 descriptors to differentiate between each of the eaux-de-vies. The panel members were also asked to provide at least 4 taste descriptors out of the 10 descriptors. At the end of the session, a discussion took place between the members of the panel in order to choose the descriptors to be used for the rest of the study; as a result, of the 140 generated descriptors, twelve were retained.

2.4.2. Training testing method

References were defined for the twelve generated descriptors. Chemical compounds were used as references when common descriptors were involved. When it was difficult to associate a descriptor with a compound, macerates were made, such as for "tobacco" notes for example, with cigars being placed in a 60 % hydroalcoholic solution and agitated for 48 h. Table 2 shows the references used for each descriptor, as well as the concentration used. The concentrations reported in the table correspond to the highest concentration presented during the training sessions, so that everyone could memorise the different descriptors.

The panel was trained (NF ISO 8586:2012) on the 12 descriptors of the study and on use of the scale (NF ISO 4121:2003). The training sessions were based on those described in Pelonnier-Magimel *et al*. (2020), but Session 3 on intensity assessment was repeated in order to familiarise the panel with the use of the continuous scale. Panel training was conducted in six 1-hour sessions spread over three weeks.

2.4.3. Eaux-de-vie evaluation

2.4.3.1. Sensory profile

The 16 samples (8 eaux-de-vie for each alcohol level) were divided into two sessions, with 8 samples at 60 % alcohol level (*v/v*) in the first session and 8 eaux-de-vie at 40 % (*v/v*) in the second. The samples were presented simultaneously

TABLE 2. List of terms used for descriptive measures and reference standards presented during the training period.

Descriptors	Composition for recognition session	Model solution for intensity session
Vanilla	Vanillin (Sigma Aldrich)	0.4 g/L in hydroalcoholic solution (60 % *v/v*)
Dry wood	Untoasted wood chips (Nadalié OAK ADD INS)	Untoasted wood chips (100 g/L) in hydroalcoholic solution (60 % *v/v*)
Green wood	Stave sawdust being dried (Courvoisier wood yard)	Stave sawdust being dried (100 g/L) in hydroalcoholic solution (60 % *v/v*)
Brioche	sliced brioche, original recette (from the bakery 'La Fournée dorée')	A piece of gâche in black glass covered with aluminum foil
Leather	"p-cresol" (Sigma Aldrich)	5 mg/L in hydroalcoholic solution (60 % *v/v*)
Toasted	Furfurylthiol (Sigma Aldrich)	0.75 µg/L in hydroalcoholic solution (60 % *v/v*)
Tobacco	Cigars (Neos Country)	1.5 cigars in 1L of hydroalcoholic solution (60 % *v/v*)
Freshness	Hydroalcoholic solution frozen	hydroalcoholic solution (60 % *v/v*) placed in freezer, fridge and room temperature
Astringency	Aluminum sulfate (Fischer Scientific)	0.5 g/L in hydroalcoholic solution (60 % *v/v*)
Bitterness	Quinine sulfate (Merck)	20 mg/L in hydroalcoholic solution (60 % *v/v*)
Sweetness	1/3 Glucose / 2/3 Fructose (Sigma Aldrich)	10 g/L in hydroalcoholic solution (60 % *v/v*)
Heat	Grain alcohol (96.1 % *v/v)*	Grain alcohol (96.1 % *v/v*) diluted with osmosis water

* The concentrations used met exposure recommendations.

in a Latin-square arrangement. For the olfactory evaluation, the descriptors were smelt one by one so that the panellist could compare the eaux-de-vie with each other for each descriptor. The 8 olfactory descriptors were smelt in random order so as not to create any bias by possible sensory fatigue. For the taste evaluation, the members of the panel received 8 eaux-de-vie samples in random order, rating each in terms of intensity of the four taste descriptors This avoided excessive sensory fatigue, which is likely to occur with such high alcohol content. A continuous ten-centimetre scale from "not intense" to "very intense" was used to rate the intensity of each descriptor (NF ISO 4121: 2003).

2.4.3.2. Ranking test

A final session consisting of a ranking test (ISO 8587: 2006/AMD 1:2013) was carried out to rank the eaux-de-vie from the lowest to the highest quality. In this session, the 8 eaux-de-vie at both alcohol levels were smelt and tasted (total of 16 samples), with a 15-minute gap between the two groups of samples. The panel was asked to rank the eaux-de-vie from lowest to highest olfactory, gustatory and overall quality in that order. The panel followed the instructions for the order of smelling and tasting of the samples, which was random for all panellists (ISO 8587: 2006/AMD 1:2013).

3. Statistical treatment

For the free sorting task, multidimensional scaling (MDS) and hierarchical clustering were used. In order to carry out the MDS analysis, a proximity matrix was made from a contingency table, allowing the Euclidean distances between the eaux-de vie samples to be obtained. Hierarchical clustering was used to obtain a dendogram that defined the formed groups of eaux-de-vie according to their similarities.

For the descriptors that were generated freely, a citation frequency was calculated. To study the consensus between panellists during the training sessions and sensory profile, principal component analysis (PCA) was performed, completed by two-way ANOVAs (panellist and sample) or a two-way Friedman non-parametric test with a Nemenyi test as post-hoc. To analyse the eaux-de-vie during the sensory profile, ANOVA was used to analyse the toasting duration-temperature interaction, then parametric (one-way ANOVA with a post-hoc Duncan test) and non-parametric (Kruskal Wallis and Pairwise-Wilcox as post-hoc) tests were used to determine the effects of overall toast, toasting temperature and toasting duration. Finally, the Friedman test was applied for the ranking. Each panellist attributed a value

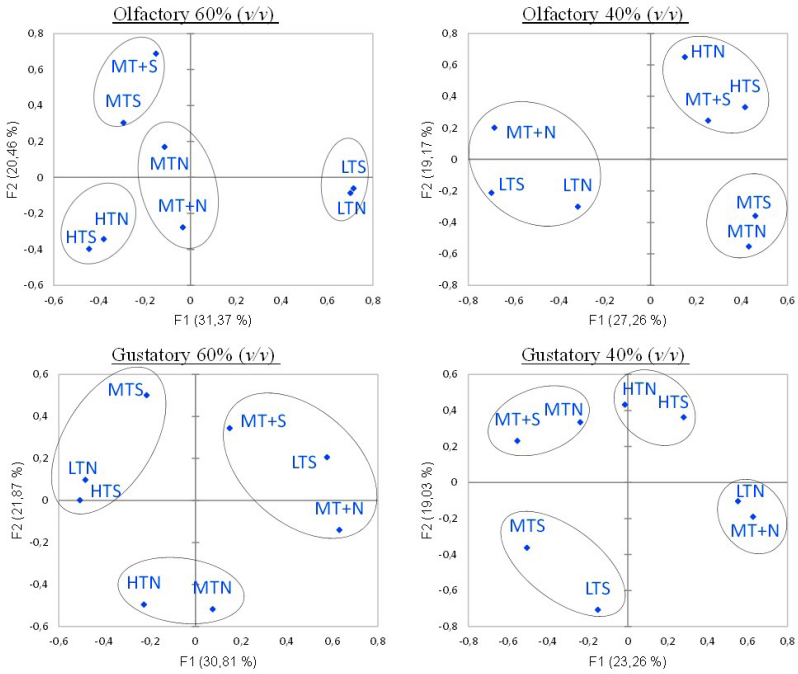


FIGURE 1. MDS plane obtained from the olfactory sorting tasks and the gustatory sorting tasks. The ellipses include the eaux-de-vie belonging to the same cluster according to the HCA.

of between 1 and 8 to each sample (1 for samples designated as the lowest quality and 8 for the highest). The sum of the ranks was obtained for each sample, and the χ^2 table was used to determine the test significance.

All statistical treatments, except multidimensional scaling (MDS) and hierarchical clustering, were performed using Rstudio software (Rstudio Inc., Boston, USA, 2018). The XLSTAT software (Addinsoft, Paris, France, 2018) was used for MDS and hierarchical clustering. All statistical treatments were performed using Rstudio software (Rstudio Inc., Boston, USA, 2018).

RESULTS AND DISCUSSION

1. Free sorting task

Figure 1 shows four MDS maps representing the similarity matrix obtained from the sensory sorting task in the olfactory and gustatory sessions for both alcohol levels (60 % and 40 % (*v/v*). According to the hierarchical cluster analysis (HCA), the panellists recognised three to four main groups of eaux-de-vie. The results of the olfactory sorting task show that similar groups formed, whether at 60 % (*v/v*) or 40 % (*v/v*). At 60 % (*v/v*), the two high toasts HTN and HTS formed a single group and were perfectly distinct from the light toasts LTN and LTS, which formed a group as well. Differences were found between these toasts and the medium toasts, as the latter were also classified into two different groups. Similarities were found between the medium toast (MT and MT+) samples with the same toasting duration, because differences were observed between the medium slow (S) toast and medium normal (N) toast. In contrast, no olfactory dissimilarity seems to have been found between the eaux-de-vies aged in medium and medium plus toasted barrels. The results at 40 % (*v/v*) were similar: differences were found between the two light toasts and the two high toasts, which were classified into different groups. However, one difference was that the samples of the two medium toasts were also classified in a different group, while the medium plus toasts were dissimilar. The MT+N toast would appear to be similar in olfactory terms to the light toast samples, and the MT+S toast to the high toasts. As far as the gustatory aspect is concerned, differences between the different barrel toasts were less pronounced, except for the high toasts which formed a group at 40 % (*v/v*) and differed from the other types of toasting. These results show that aged Cognac eaux-de-vie can be distinguished by type of toasting of their barrel. Indeed, from an olfactory point of view, light and high toasting of barrels would result in different eaux-de-vie, which are also more or less well differentiated from eaux-de-vie aged in barrels that have undergone medium or medium plus toasting. In terms of taste, the alcohol content seems to influence the differences found between the eaux-de-vie, and the differentiation according to the type of toasting is less marked. However, it would seem that high toasting results in different taste characteristics in these 40 % (*v/v*) eaux-de-vie. The next step in the study was to characterise these eaux-de-vie at both alcohol levels, since differences were found in both cases.

2. Descriptor selection and training

In order to describe the sensory space of the eaux-de-vie being studied, each panellist generated a list of ten descriptors. All the terms were listed, and the number of times the same descriptor was cited was counted. Terms that were hedonic, redundant, undefinable, or referred to the intensity

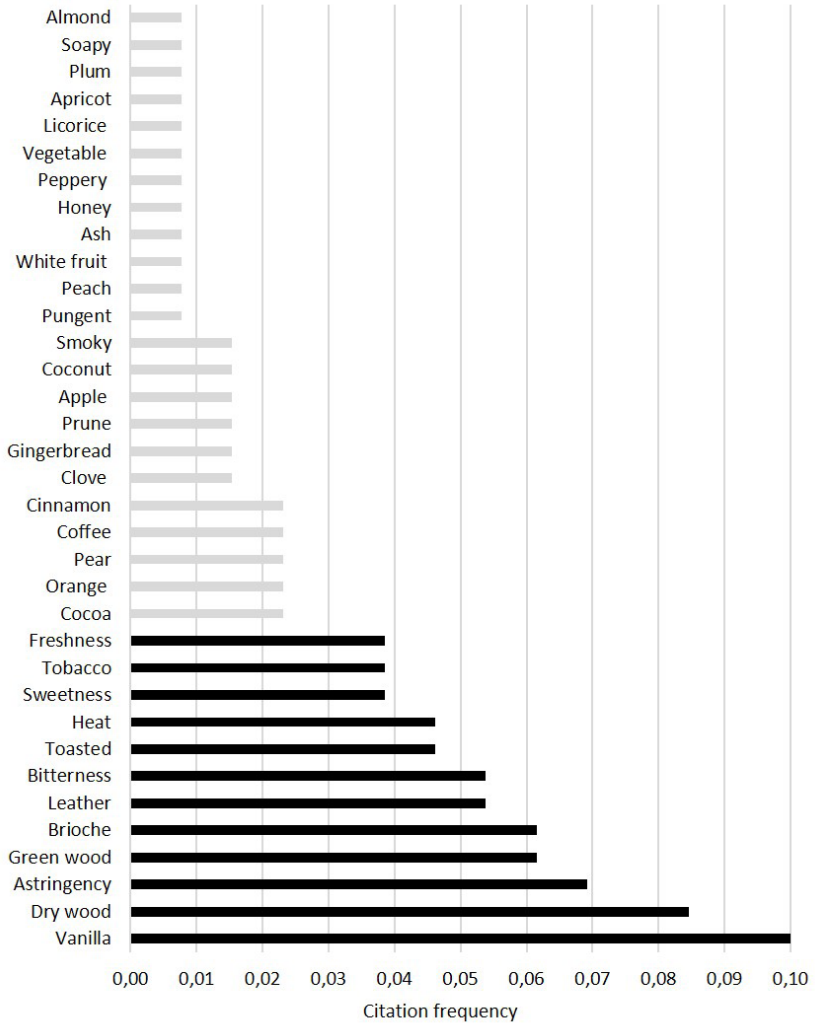


FIGURE 2. Eaux-de-vie descriptor citation frequency.

of a descriptor were eliminated. Out of the 140 descriptors listed for 14 panellists, ten were eliminated for the reasons mentioned above. For the remaining 130 descriptors, the frequency of citation was calculated. A descriptor cited 4.66 times or more was considered relevant. This value corresponds to a descriptor cited by at least 1/3 of the panel, giving a citation frequency value of 0.04 (Pelonnier-Magimel *et al*., 2020). The results of the citation frequencies for the descriptors generated by the panel are shown in Figure 2. As a result, 12 terms were considered to discriminate between the samples: 8 olfactory descriptors, including the terms "vanilla", "dry wood", "green wood", "brioche", "leather", "toasted", "tobacco" and "freshness"; and 4 gustatory descriptors including "astringency", "bitterness", "heat" and "sweetness".

A discussion with the judges on the list of descriptors helped to define the different terms and agree on their relevance. "Vanilla" was described as vanillin, and "brioche" was chosen to represent the brioche and pastry aspect of an eau-de-vie. "Leather" was associated to the leathery smell of a belt, but not with animal leather or horsehide which are characteristic of the ethylphenols often found in wine. Two types of wood were described: "dry wood" and "green wood". For the panel, "dry wood" represented untoasted wood, while "green wood" is more like a defect, characterized by the plant-like aspect of wet wood, which smells like a plank. The "heat" descriptor was considered by some to be due to the burning sensation of alcohol. However, a discussion among the whole panel revealed that different intensities of this descriptor were perceived in samples of the same alcohol level. It was therefore decided to keep this descriptor, which can vary in intensity due to perceptual interactions.

It was also through discussion with the panel that the references associated with the descriptors were chosen. For descriptors associated with commercial molecules, chemical reference standards were used. For "vanilla", vanillin, for "leather", *p*-cresol and for "toasted", furfurylthiol. *p*-crésol was chosen because in low concentrations it does not have the animal leather smell that can be found with ethylphenols, but corresponds more to the leathery smell found in brandies. As there was no reference for the thresholds of the chemical compounds in an alcoholic solution at 60 % (*v/v*), it was necessary to start from the values already found in a hydroalcoholic wine solution and adapt them.

For the odorous compounds to be perceived at 60 % (*v/v*) it was necessary to multiply the threshold by 100 or 1000. Previous studies on red wine have described the preparation of astringent and bitter solutions (Chira *et al*., 2011). For astringency, aluminium sulphate was used, and for bitterness quinine sulphate. References for the other descriptors were made from macerates in a hydroalcoholic solution of eau-de-vie 60 % (*v/v*) (Table 1).

Training was mainly carried out for 60 % (*v/v*) eaux-de-vie samples, as this was considered more complicated than training for 40 % *(v/v*) samples; it was thought that the panel would do better in the different sessions if they had been trained for the higher alcohol level. The training worked well, because in the 60 % (*v/v*) test profile, each sample of eau-de-vie was tasted twice, and the panel gave the same score for all descriptors. In addition, a consensus was reached by the members of the panel regarding the different descriptors, except in the case of "brioche". However, the descriptors "dry wood" and "green wood" were scored in the same way for the different samples. After discussion with the members of the panel, it turned out that differentiating between the two descriptors was too complicated, as the two wood macerates did not allow a distinction to be made. The "green wood" descriptor was therefore removed from the list of descriptors, as panel agreed that the "dry wood" descriptor was more important. The reference associated with the "brioche" descriptor was found to be a poor choice. Maltol as a chemical compound had been tested at different concentrations in order to find this "brioche" smell, but even at very low concentrations, there was a strong note of caramel which did not produce a close enough resemblance to the "brioche" note. In the absence of a chemical molecule that would give the brioche character found in an eau-de-vie, the members of the panel were trained on this descriptor using a piece of brioche wrapped in aluminium foil at the bottom of black glasses. Intensity tests for this descriptor could not be carried out.

3. Impact of barrel toasting on eaux-de-vie perception

3.1. Sensory profile

The sensory profiles were carried out on eaux-de-vie that had been aged for one year in barrels subjected to different toasting processes. They were carried out on samples with two alcohol levels, 60 % (*v/v*) and 40 % (*v/v*). The sensory profile on 60 % (*v/v*) samplers did not give conclusive results, unlike that on 40 % (*v/v*) samples. A consensus was not reached by the panel regarding the PCAs at the higher alcohol level of 60 % (*v/v*); for example, for the "sweetness" descriptor at 60 % (*v/v*), seven panellists were in the positive part of the first axis of Figure 3 and six in the negative part. In addition, several of the panellists in the negative part of dimension 1 showed a high contribution, indicating that they influenced the consensus negatively compared to the other panellists. In contrast, at 40 % (*v/v*), nine panellists were in the positive part of axis one, the majority of them contributing strongly to the rating of the "sweetness" descriptor, while only four were in the negative part, with only one contributing negatively to the rating of the descriptor. The other three panellists did not contribute, as they may not have used the scale in its entirety, which could prevent significant differences being found between the samples.

Only 13 panellists were represented on the PCAs instead of 14, as the panel member with the highest negative impact was removed for the entire treatment for both 40 % (*v/v*) and 60 % (*v/v*) samples. Although the removal of this panellist from the treatment did not improve consensus within the panel, he gave an opposite score for a descriptor to that of the majority of the panel. His strong negative impact helped to reduce the marked differences between the samples.

The fact that the sensory profile of 60 % (*v/v*) samples did not give conclusive results regarding the characterisation of the eaux-de-vie, due to the lack of consensus among the panel members, may be due to sensory fatigue arising from

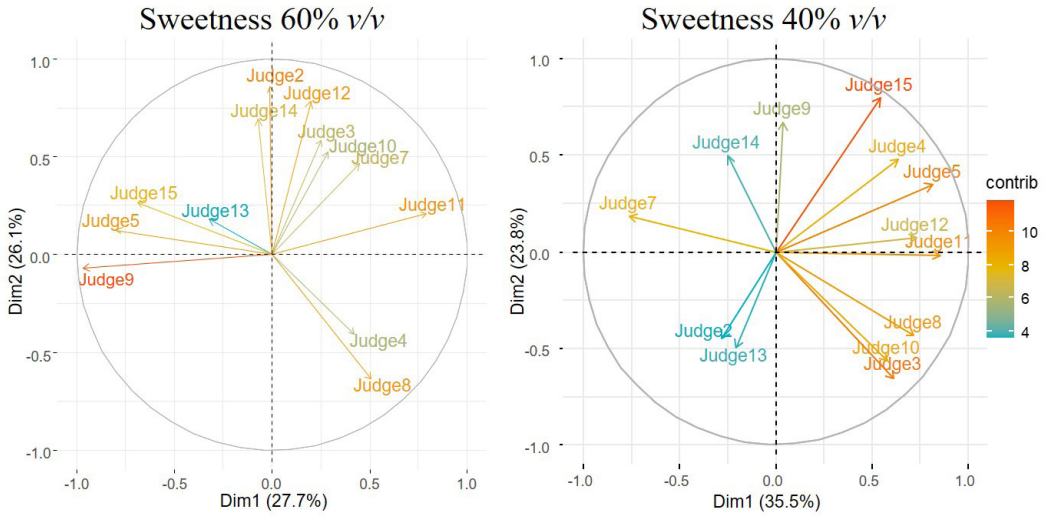


FIGURE 3. Example of PCA correlation circles for sweetness at 60 % *v/v* and 40 % *v/v* with respectively no consensus and consensus between judges in the final sensory profile.

the high alcohol content. However, in the 60 % (*v/v*) test profile (the last training session) showed that a consensus was reached on the different descriptors among the panellists, unlike in the final profile. This could be explained by the fact that during training, the descriptors added in the eaux-de-vie were in high concentrations, and therefore they were easily recognised.

Regarding the results of the sensory profile on 40 % (*v/v*) eaux-de-vie consensus was reached by the panel on seven of the eleven descriptors: "leather", "freshness", "tobacco", "toasted", "dry wood", "sweetness" and "heat". No consensus was reached for the "astringency", "bitterness", "brioche" and "vanilla" descriptors. Training on these descriptors was complicated. Reaching a consensus about these descriptors has been more difficult. Moreover, eau-de-vie astringency is much less marked than that commonly found in a red wine. Ethanol decreases the sensation of astringency via its intervention in hydrophobic interactions between proteins and tannins (Fontoin *et al*., 2008; Gawel, 1998). Bitterness is a complex descriptor, as sensitivity varies widely from one person to another (Roudnitzky *et al*., 2015). Some people are very sensitive to it, while others do not perceive it at all, especially those used to drink a lot of coffee and other bitter drinks. In addition, a high alcohol content can itself cause a bitter taste (Fischer and Noble, 1994; Martin and Pangborn, 1970); it was therefore difficult for the panel to rate this descriptor. A study by Cretin *et al*. (2018) has also showed that ethanol is involved indirectly in the perceived bitterness of white wine. As for the "brioche" and "vanilla" olfactory descriptors, because the young eaux-de-vie spent only one year in oak barrels, it follows that these descriptors should be more difficult to detect than the other olfactory descriptors.

In order to study the impact of barrel toast on eaux-de-vie, the seven consensus descriptors were used. First, the ANOVA of the duration~temperature interaction was carried out for each of the seven consequential descriptors. If the interaction was significant (p-value < 0.05) then the toasting duration and temperature factors could not be treated independently of each other. On the other hand, if the p-value of the interaction was not significant, then the two factors could be treated independently. Of the seven descriptors, "heat" was the only one to show significant interaction, thus toasting temperature and duration could not be treated independently. As a result, the MTS and MT+N toasts were significantly different from the MT+S, HTN and HTS toasts. The LTN, LTS and MTN toasts showed no significant differences. It seems that the "heat" descriptor was more intense for the high than the medium toasts (Figure 4 A). For the duration of toasting, only the descriptor "freshness" was significantly affected by duration. Normal toasting (N) of the barrel produced a more intense freshness than slower toasting (S) (Figure 4 B).

In general, toasting temperature had a greater impact than temperature duration. Out of the seven consensus descriptors, five were significantly impacted by the toasting temperature of the barrel: "dry wood", "leather", "tobacco", "toasted" and "sweetness" (Figure 5). Toasting temperature was therefore the main factor to discriminate and characterise the different eaux-de-vie. The eaux-de-vie aged in highly toasted barrels were significantly more intense in terms of "dry wood", "leather", "tobacco" and "toasted" notes compared to the eaux-de-vie in lightly toasted barrels. They were also significantly more intense in "dry wood" and "tobacco" notes than the eaux-de-vie in medium and medium+ toasted barrels. However, the opposite was true for the "sweetness" descriptor: an eau-de-vie aged in a lightly toasted barrel was characterised with a higher "sweetness" intensity than the eaux-de-vie aged in medium plus and highly toasted barrels.

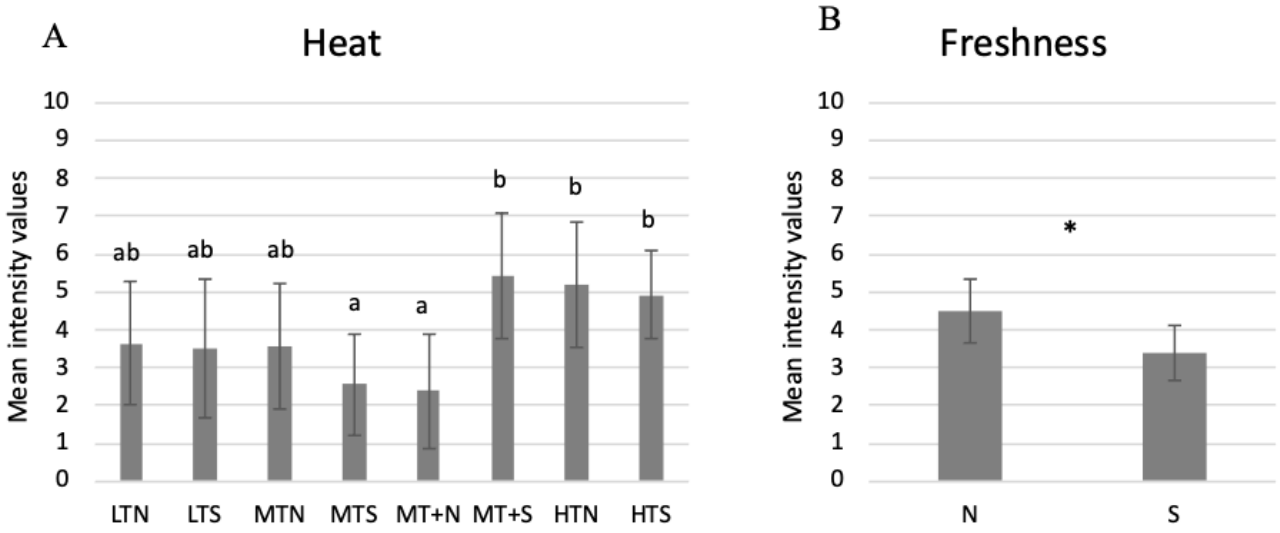


FIGURE 4. "Heat" descriptor intensity in eaux-de-vie at 40 % (*v/v*) with different barrel toasts (A) and "Freshness" intensity in eaux-de-vie at 40 % (*v/v*) with different barrel toasting durations (B). Error bar represents the confidence interval with a threshold of 0.05.

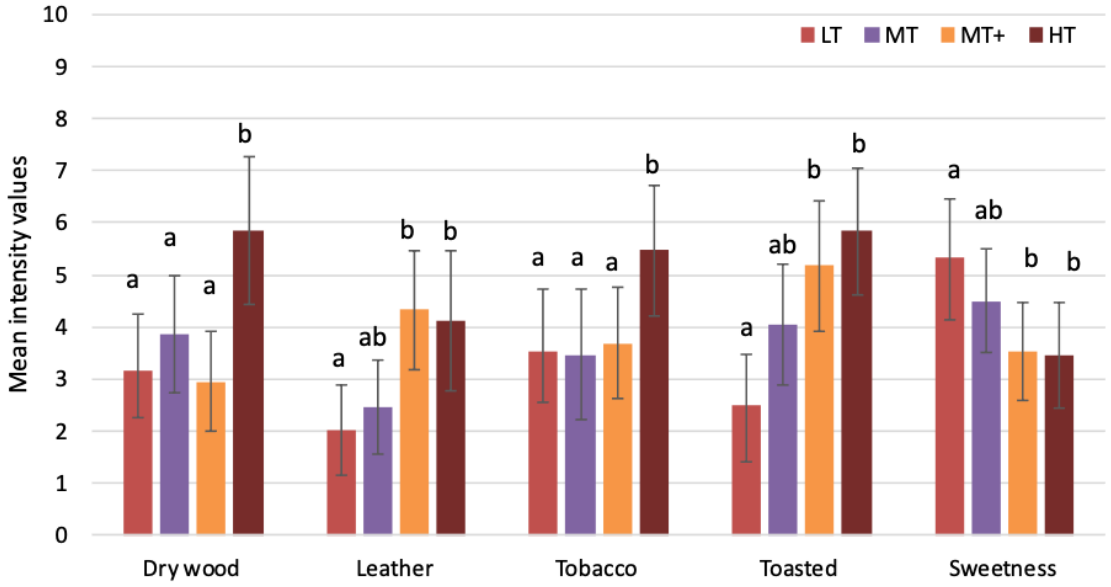


FIGURE 5. Descriptor intensity in eaux-de-vie at 40 % (*v/v*) with different barrel toasting temperatures (LT: Light toast, MT: Medium toast, MT+: Medium toast +, and HT: High toast). Error bar represents the confidence interval with a threshold of 0.05.

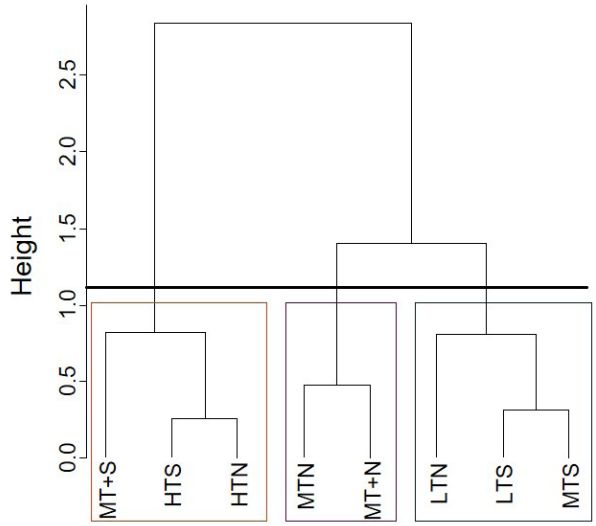


FIGURE 6. Clustering of eaux-de-vie based on the consensus descriptors for the eight products.

Normally, the more intense the toast, the more the taste of sweetness increases (Chira and Teissedre, 2013). Under the conditions of this experiment, "heat" notes were perceived more intensely in eaux-de-vie from highly toasted barrels, suggesting that this sensation of heating could influence the perception of sweetness. Studies have shown that high alcohol levels contribute to the sensation of "heating" or "hotness" (Gawel *et al*., 2007; Jones *et al*., 2008; King *et al*., 2013) and alter the perception of sweetness (Zamora *et al*., 2006). It is therefore possible for eaux-de-vie in highly toasted barrels to give off an intense "heat" sensation, thereby reducing the perception of sweetness. Thus, a higher intensity of the "sweetness" descriptor was perceived in eaux-de-vie aged in light-toast barrels.

Clustering was performed to classify the eaux-de-vie according to their sensorial proximity. Figure 6 shows that three groups of eaux-de-vie were formed, making it possible to distinguish between the eaux-de-vie aged in casks depending on their toast. The sensory profile made it possible to characterise the eaux-de-vie and confirm the results obtained during the sorting task. The eaux-de-vie aged in high toast barrels are part of the same sensory space as those aged in a MT+S barrel. This group had already been formed during the olfactory sorting test at the same alcohol level (40 % *v/v*). In contrast, a second group consisted of eaux-de-vie aged in lightly toasted barrels, as well as eau-de-vie in MTS barrels. Finally, the third group was made up of eaux-de-vie aged in barrels with two medium toasts, MTN

TABLE 3. Ranking of perceived quality in eaux-de-vie after 12 months of ageing in barrels subjected to different toasts.

Test	Eaux-de-vie and sum of ranks								F[a]	Results[b]
	HTS	HTN	MT+S	LTS	MT+N	MTS	MTN	LTN		
Olfactory	87	78	71	66	64	57	53	28	26.6	Significant at 0.1 %
	a	ab	ab	ab	ab	b	c	c		
Gustatory	63	85	75	72	73	58	37	41	23.7	Significant at 0.5 %
	ab	a	a	a	a	ab	b	b		
Global	81	76	73	72	67	59	42	34	23.6	Significant at 0.5 %
	a	a	a	a	ab	bc	bc	c		

[a] F was calculated as described in ISO 8587: 2006 for the Friedman test. $F = (12 \times \Sigma p^{i=1} R_i^2) / (j \times p \times (p + 1)) - 3 \times j \times (p + 1)$ where j represents the number of judges, p represents the number of products and R_i represents the sum of the ranks for the modality i.
[b] With eight products, the test was significant at 0.5 % when F > 21.9 and at 0.1 % when F > 26.1.

and MT+N. As there are no previous studies on the impact of toasting on cognac eaux-de-vie from a sensory point of view, these results cannot be compared with other studies.

3.2. Ranking test

Once the eaux-de-vie had undergone sensory characterisation, a ranking test was carried out in order to classify them according to each of their olfactory, gustatory and overall quality, and thus determine the impact of the choice of barrel toast on cognac eau-de-vie quality. This test was performed for both alcohol contents, 60 % (*v/v*) and 40 % (*v/v*).

Each taster assigned 1 point to the lowest-quality eau-de-vie and 8 points to the highest. The sum of the ranks was calculated for each modality for each ranking. The statistical analysis showed no significant results at 60 % (*v/v*) for the olfactory, gustatory or even overall quality. Not enough real differences were found between the eaux-de-vie to classify them by quality. This result is consistent with those for the sensory profile, in which no consensus was reached by the judges when tasting the 60 % (*v/v*) eaux-de-vie samples. Regarding the results related to the 40 % (*v/v*) alcohol level, the statistical analysis was significant at 0.1 % when classifying the eaux-de-vie according to quality from an olfactory point of view (Table 3); this means that the tasters were able to distinguish different eaux-de-vie qualities depending on the barrel toast. Moreover, the highest sum of ranks was observed for the eaux-de-vie aged with HTS and HTN barrels, followed by MT+S, LTS, MT+N barrels, and then the MTS, MTN and LTN barrels. These results are in agreement with those of the olfactory sorting task and of the sensory profile, as eaux-de-vie samples from HTN, HTS and MT+S were of the highest quality. The results differ slightly for the light and medium toasts, as MTN and LTN are in the same group, which was not the case in the previous tests. Nevertheless, it is possible for two samples to be different but of equal quality. Furthermore, even though the ranking test shows significant results at the 0.1 % level, it does not allow a clear differentiation between the different eaux-de-vie (see letters showing the differences in Table 3). The overall ranking test shows the same results as the olfactory test, as the sum of ranks classifies the eaux-de-

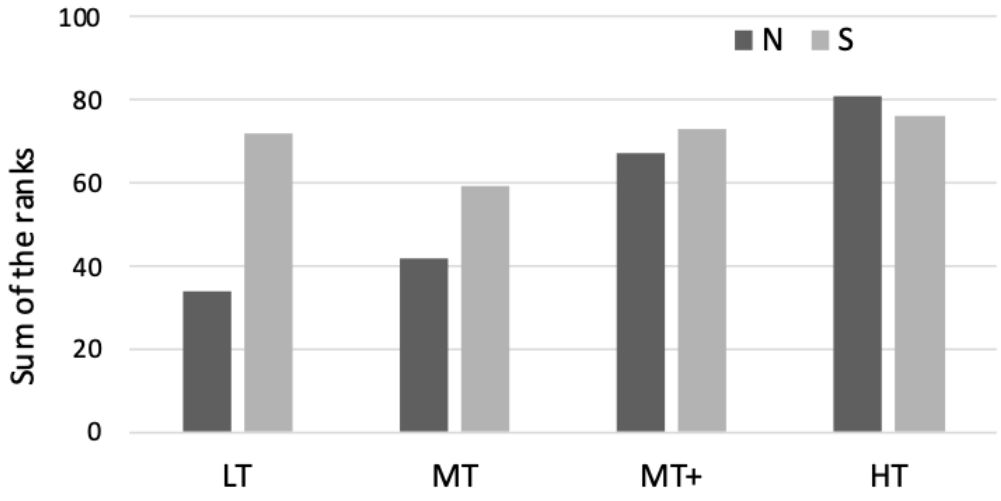


FIGURE 7. Results of the overall ranking of the 40 % (*v/v*) eaux-de-vie according to the toasting duration (Normal or Slow) for each barrel toasting temperature (LT, MT, MT+ and HT).

vie in the same way. The only difference is the significance level of 0.5 %. Similarly, the eaux-de-vie are not clearly differentiated as four samples are in the "a" group, one in the "ab" group, two in the "bc" group and one in the "c" group. The gustatory ranking also shows a significant difference of 0.5 % between the products (Table 3), but the ranking differs. Unlike the results of the taste sorting task and the sensory profile, the two high toasts showed a very different rank sum and did not differ from one of the weak LTS barrel toasts. The eau-de-vie aged in the HTN barrel had the highest rank sum, but did not differ from the eaux-de-vie corresponding to the HTS, MT+S, LTS MT+N and MTS barrels. On the other hand, the MTN and LTN toasts appear to cause a significant reduction in quality in the associated eaux-de-vie.

Figure 7 shows the results of the overall ranking test for the 40 % (*v/v*) eaux-de-vie. The sum of the ranks was plotted for each toasting duration against the toasting temperature of the barrel. It seems that for a slow barrel toast, the eaux-de-vie are not sorted qualitatively according to the toasting temperature, as the light toast gives higher quality than the medium toast, but to a lesser extent than the MT+ and HT toasts. On the other hand, it is interesting to note that for a normal toasting duration, the eaux-de-vie are sorted from the lowest to highest quality according to the toasting temperature, which goes from light to high in ascending order. It would therefore be possible to differentiate eaux-de-vie according to the toasting temperature for the same barrel toasting duration. Light toasting temperatures showed the lowest quality and high toasting temperatures the best quality.

CONCLUSIONS

The objective of this study was to compare and sensorially characterise Cognac eaux-de-vie aged in barrels subjected to different toasts. It showed the difficulty in tasting at a high alcohol level, as even with training, it was too difficult to study eaux-de-vie sensorially at the alcohol level found during ageing (60 % *v/v*). On the other hand, the generation of descriptors from adapted references in order to characterise the samples, as well as the training of the panel were essential and enabled results to be obtained from the various sensory tests on eaux-de-vie with the commercial cognac alcohol level (40 % *v/v*).

The results showed that the eaux-de-vie are strongly impacted by the toast of the barrel during the first year of ageing and it is possible to distinguish between them according to the toast used. Light barrel toasting results in significantly different eaux-de-vie from those aged in high-toast barrels. The latter tends to result in high-quality eaux-de-vie. This study is a first step in the characterisation of cognac eaux-de-vie aged in barrels made with different toasts and can lead to practical recommendations in order to obtain the ideal toast temperatures that give the best olfactory and gustatory profiles in eaux-de-vie. However, it would be interesting to complete this study with a longer ageing period such as 3 years, which would correspond to the minimum ageing period for the Cognac eau-de-vie appellation. A new generation of descriptors should be developed in order to compare the terms generated at 1 year and 3 years of ageing, and the training of panellists should be adapted to advanced products. In addition, a generation of descriptors at both alcohol levels might be useful for perceiving odours that may have been hidden by the 60 % alcohol. Given the substantial difficulties encountered when tasting the eaux-de-vie because of their high alcohol content, longer training sessions with other natural references would need to be carried out in the future to gain a more in-depth understanding of the organoleptic impact of toasting on Cognac eaux-de-vie.

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