The Alchemy of Oak Add Ins

by Aurélia Rivier

Table of Contents

Oak Add Ins Study

1. Introduction

1.1. Acknowledgments

Nadalié would like to thank the winery participants of this experiment for helping in carrying on this project from beginning to the end. Thank you for accepting the project and supporting it until the end. The regular tastings and the 3 bottlings have been very time consuming and Nadalié is very thankful for the collaboration that they provided.
A special thank you for Eric Hervé, Phd from ETS laboratories for his support and time. The sharing of his knowledge in the interpretation of the data has made this study possible.
Thank you as well to Erin Miller, student from UC Davis, for her collaboration and for her statistical analysis. This part allows this study to put results in perspective.
Nadalié is happy to be able to present results that will hopefully result in the better understanding of these new products called Oak Add Ins.

1.2. The Purpose of this experiment

This study has been put together in order to evaluate and understand better the evolution of the oak impact on the wine over time and the change of aromas in the integration process.

This study was held in neutral barrels filled with different oak treatments. Based on the amount that was used per barrel, one can compare the flavours and quantity of extraction of each product. The comparison between toasting levels and different surface areas gives information that can be used to adjust your winemkaing technics. These results were also used by Nadalié to adjust recommended dosage rates.

1.3. Experiment process

This experiment started on May 16th, 2003. At that time, different types of French Oak Add Ins were added to 22 neutral (more than 3 year old) barrels. Two control barrels with no Oak Add Ins were included into this trial. They were filled with a Cabernet Sauvignon 2002 from Rutherford, Napa Valley that had seen no oak prior to this experiment.

During the first 4 months, the experiment was tasted every 3 weeks by two winemakers and Nadalié, then topped after each tasting.

Products and Quantities of the experiement

Products	Oak Type	Toasting	Amount/barrel	Equivalent in unit/1000 Gal
Control				
Chips	FO	MT	1.8 lbs	30 lbs
Chips	FO	HT	1.8 lbs	30 lbs
Cubes	FO	MT+	2 lbs	33 lbs
Cubes	FO	HT	2 lbs	33 lbs
Dominoes	FO	MT+	2.4 lbs	40 lbs
Dominoes	FO	HT	2.4 lbs	40 lbs
Blocks	FO	MT+	6 lbs	100 lbs
Oak chain	FO	MT+	45 pieces	For barrel only
Barrel inserts	FO	MT+	14 staves	For barrel only
Winewood	FO	MT+	7 staves	116 pieces

After 4 months of contact with the wine, one barrel per type of product was selected and bottled. Each wine was filtered, bottled and closed with a natural cork.

After the first bottling, those barrels were filled up with the wine from the second barrel that was holding the same type of product.

The same process of tasting and selection was reproduced after 8 months of treatment and again after 12 months. The last bottling was therefore made on May 18th, 2004.

1.4. Overview of oak aromas

There are many causes of variation in oak aromas and they interact to form a wide array of aroma profiles. The source of the oak itself is a substantial source of potential variation. In this experiment, we decided to compare all French Oak products. Geographic origin from the same type of oak can also influence the flavor of oak. However, most of Nadalié's French Oak used for Oak Add Ins comes from Centre France.

In a more detailed approach, study of oak composition has shown that growing conditions, age and genetic variation of individual trees can strongly affect wood structure and therefore extraction. Even a stave's position in a tree has been showing to influence its aroma composition.
Stave seasoning and drying are important. All Nadalié Oak Add Ins have been air dried in open air and natural humidity level for approximately 24 months. These conditions also have a great impact on flavor extraction.
Of course, the main impact of oak aroma compounds is the toasting level. The fire toasting used by Nadalié modifies the structure and chemical properties of the oak.
The first part of this study showing the chemical analysis of the oak demonstrates the impact of toasting on oak aroma.

Source : inspired by ETS Oak aroma analysis bulletin

2. Statistical analysis

This study used the SAS (Statistical Analysis System) Program to run a 2-way Analysis of Variance (ANOVA) on judges and wines for each attribute. It is a standard statistical model that can yield useful information on each attribute and the statistical significance of each wine. ANOVA models allow you to consider multiple variables at one time, expressing significance in terms of F-values compared to Pr values and Least Significant Differences (LSD). The higher the F-value, the more confidence you can have that there is a statistically significant difference. The LSD is the minimum difference acceptable in order to determine if two variables are statistically significantly different.

The alpha criterion chosen was = 0.05, a generally accepted criterion. In other words, it will be possible to have 95% confidence that there is a statistically significant difference in the wines or the judges if the Pr > F is less than 0.05. Therefore, with the large size of the panel, 42 judges, and the low alpha value, = 0.05, there is sufficient power in the statistical analysis to derive statistically viable information. The low alpha reduces the likelihood of Type I or Type II error, (rejecting the null hypothesis when it is true, or accepting the null hypothesis when it is false).

2.1. Analysis of significant results

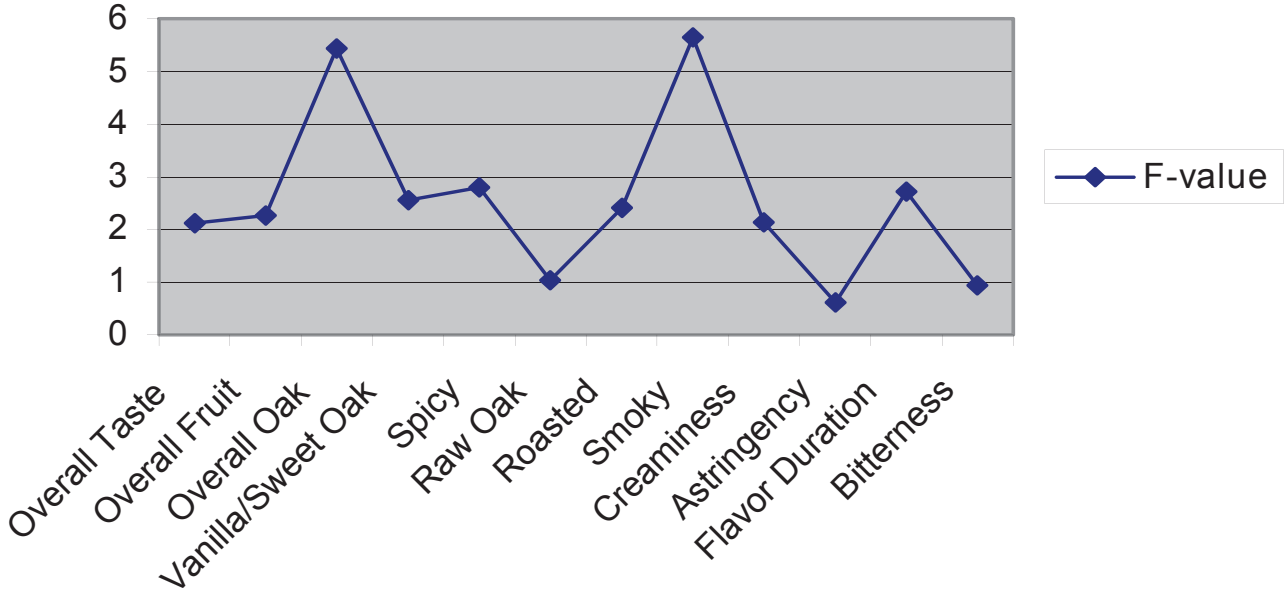
Table 1: Two-way Analysis of Variance for Perceived Red wine Attributes in 24 Wines Treated with Oak Add Ins including Means and Least Significant Differences, = 0.05, n = 42 judges.

	Degrees of Freedom	Sums of Squares	Mean	F Value	Pr>F and level of Significance	Least Significant Difference
Overall Oak	23	229.079	9.960	5.44	<.0001*	0.5796
Vanilla/ Sweet Oak	23	139.785	6.078	2.56	<.0001*	0.6604
Spicy	23	128.333	5.579	2.79	<.0001*	0.6056
Raw Oak	23	50.857	2.211	1.03	0.4203	0.6268
Roasted	23	108.514	4.718	2.41	0.0002*	0.599
Smoky	23	288.476	12.542	5.65	<.0001*	0.638
Creaminess	23	92.428	4.018	2.13	0.0016*	0.5885
Astringency	23	28.895	1.256	0.61	0.9238	0.6141
Overall Fruit	23	106.032	4.61	2.26	0.0007*	0.612
Overall Taste	23	115.095	5.004	2.12	0,0016*	0.6576
Bitterness	23	40.237	1.749	0.93	0.563	0.5886
Flavor Duration	23	98.792	4.295	2.72	<.0001*	0.5386
*** is significant at an alpha >0.05**						
Variables in orange are not significant						

A two-way ANOVA was conducted on the 12 descriptive analysis attributes in order to determine statistical significance according to the 42 judges and the 24 wines. The degrees of freedom (n-1) for wines are 23. The sum of squares variance, the variation within the wines for each attribute is given in column 3 of the above table. The mean is the mean variance between the wines, as shown in column 4 of the above table. The sum of squares and the means for each attribute are used to find the F-value. The Pr > F values in column 6 of the above table in relation to = 0.05 is used in order to determine the significance of the data. The LSD values in the last column describe the minimum difference between the statistically significant wines according to each attribute. Based on the = 0.05, it is prudent to reject the null hypothesis and determine there is a statistically significant difference in the wines based on specific attributes. In the table the statistically significant attributes, (those with Pr values less than 0.05), are shown in black, while the insignificant attributes are in red. The study found in all cases, the judges to be statistically significantly different, which indicates the study should have had replications in order to ensure the judges were using the scale in the same manner throughout the tasting. The judges may have been using the 1-9 scale differently within their tasting and across the tasting panels.

2.2. F-value of all wines

Figure 1: Red Wine F-values based on 12 Red wine attributes, n= 42 judges, α = 0.05.



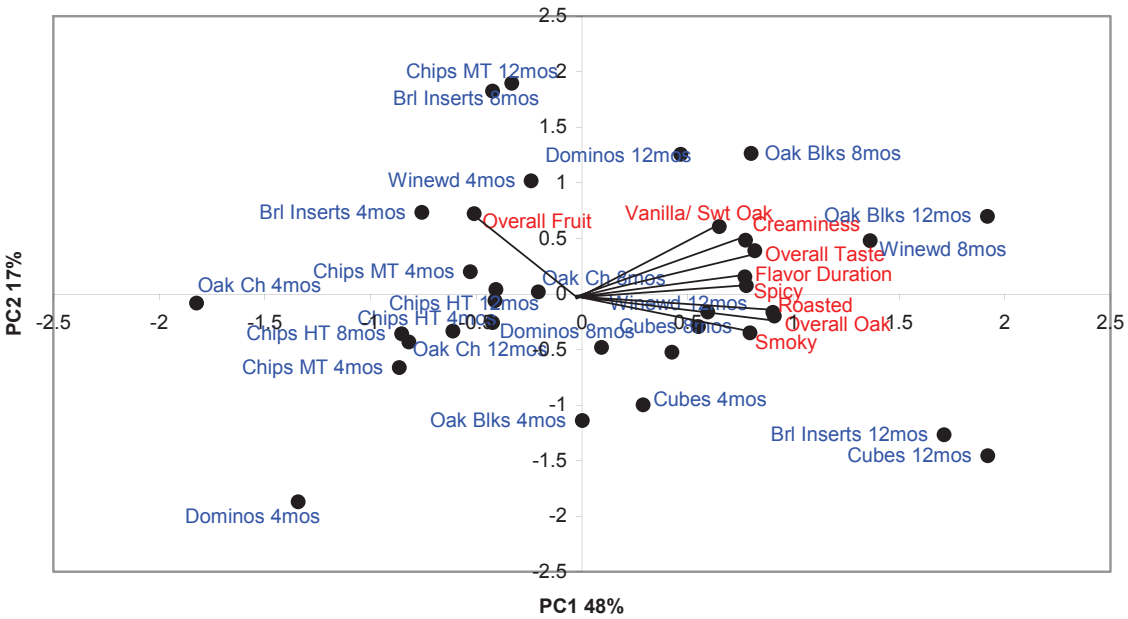
The F-values are graphed here in order to clearly demonstrate the relationship between the high F-value or F-ratio and the statistically significant attributes. The F-ratio is the ratio of the mean squared deviation over the mean-squared error. In this

summary of the F-ratios it is obvious that Overall Oak and Smoky have the highest F-ratios, while Raw Oak, Astringency and Bitterness have the lowest F-ratios. This is indicative of the higher confidence in the variances of the wines according to the Overall Oak and Smoky attributes, and a lower confidence in the variances according to the Raw Oak, Astringency, and Bitterness attributes based on α = 0.05. The judges had a more difficult time discerning between Raw Oak, Astringency, and Bitterness than they did between all the rest of the attributes. The judges were easily able to distinguish the Overall Oak and Smoky attributes from all the other attributes.

2.3. Principal Component Analysis

The PCA was run in two parts, with three PC's such that 75% of the variance in the data could be explained. One standard deviation was applied to normalize the data. Variance is defined as the mean difference of each score from the mean. The attributes, (in red) fall on the graph such that any direct correlation between attributes (two attributes close to each other) and the dissimilarity (attributes at opposing ends of a vector) can be explained according to the wines.

Figure 2: Principal Component Analysis explaining 65% of the variance of 12 Red Wine Attributes in 24 Oak AddIn Wines with n = 42 judges, alpha = 0.05.



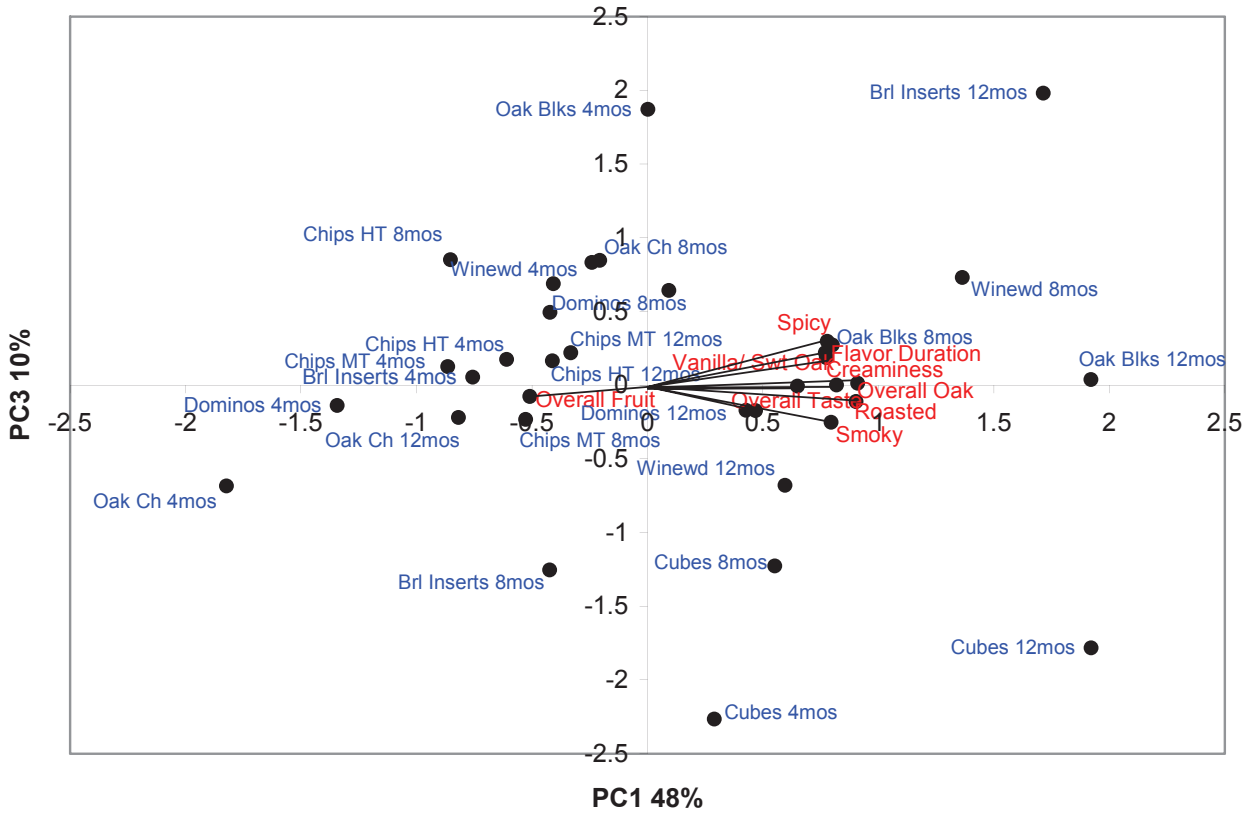
This PCA presents approximately 48% of the variation in the data set. The first PC (PC1) explains 48% of the variance, while the second PC (PC2) explains an additional 17% of the variance. The attributes tend to fall in the first and fourth quadrants of the graph indicating PC1 was able to explain a large amount of the positive variance in most of the attributes. The attributes have a strongly positive correlation to the wines treated with Dominoes 12mos, Oak Blocks 8mos, Oak Blocks 12mos, Winewood 8mos, Winewood 12mos, Cubes 8mos, Cubes 4mos, Cubes

12mos, and Barrel Inserts 12mos Oak Add Ins. The only attributes explained with negative variance in PC1 are the Overall Fruit and Bitterness attributes, which are strongly correlated to Winewood 4mos, Barrel Inserts 8mos, Chips Medium Toast 12mos, Barrel Inserts 4mos, Chips Medium Toast 4mos, and Oak Chain 8mos Oak Add In Treatments. The opposite end of the vector indicates wines treated with Cubes for 4, 8, and 12 months are very negatively correlated to the Overall Fruit and Bitter attributes.

The attributes accompanied by a wine in the same proximity are statistically significantly correlated to each other. Wines treated with Oak Blocks for 8mos and 12mos, Winewood for 8mos, and Dominoes for 12mos are strongly perceived as having a high Creaminess, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy attributes. The length of the vectors indicates the perceived intensity of the attributes; Creaminess, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy are attributes with similar intensities. The opposite side of the Creaminess, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy vectors, which would end in the second quadrant, are wines treated with Chips Heavy Toast for 4, 8, and 12mos, Dominoes for 8mos, Oak Chain for 12mos, Chips Medium Toast for 4mos, and Dominoes for 4mos. This indicates these wines are perceived to have very little Creaminess, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy attributes. The proximity of one attribute to another also speaks to its correlation. Overall Oak and Roasted are almost overlapping, which indicates that their perceived intensities were very similar. Bitterness and Astringency are not near each other, which is surprising as the two are often times confused in tastings. The outlier Dominoes 4mos, is very negatively correlated to the Creaminess, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy attributes, while the outliers: Barrel Inserts 12mos, and Cubes 12mos are significant of the extreme dissimilarity to the attributes Overall Fruit and Bitterness.

It is possible to see the correlation between wine treatments and the Red wine attributes scored. One trend found indicates the Cube treatments are seldom described as having high Overall Fruit or Bitterness, but tend to be described as having high Astringent, Smoky, Overall Oak, Raw Oak and Roasted attributes. The Chips Heavy Toast Treatments are described as having more Overall Fruit and Bitter characters than having Creamy, Vanilla/Sweet oak, Overall Taste, Flavor Duration, and Spicy attributes. There is a greater amount of variation along the x-axis than along the y-axis as 48% and 17% of the variances are explained respectively.

Figure 3: Principal Component Analysis of Oak Add-ins for 12 Red Wine Attributes with n = 42 judges, alpha = 0.05.



This PCA explains a total of 58% of the variance in the data. PC1 explains 48% of the variance in the data, while PC3 explains another 10% of the variance. When two wines or two attributes are in close proximity to each other, as in the case of the Flavor Duration and Vanilla/Sweet Oak, and Spicy attributes, these variables are so similar, strongly correlated, that they fall into the same vector space. The attributes Overall Oak, Overall Taste and Creaminess are along very similar vectors but Overall Taste and Creaminess are shorter than the vector for Overall Oak, which indicates they are less intense attributes. An attribute along its vector, with a wine next to it, as in Spicy and Oak Blocks 8mos, signifies the attribute is statistically significantly correlated to that wine. This is as in the case of the Domino 12mos treatment and the Raw Oak attribute in the 4th quadrant.

Wines in the complete linearly opposite direction, as in wines treated with Cubes for 4, 8, and 12mos are very low in perceived Bitterness character. Thus, it is possible to look at the entire vector space and find which wines are correlated to which attributes. The wine treated with Chips Medium Toast for 8mos is highly correlated to the Overall Fruit attribute. While, wines treated with Oak Blocks for 8mos, Winewood for 8mos and Oak Blocks for 12moa are lower in perceived Overall Fruit and higher in perceived spicy and vanilla/sweet oak characters. Wines treated with Winewood 4mos, and Oak Chains for 8mos are overlapping such that it would explain the similarity for these two wines.

Again, most of the attributes are positively explained by PC1 with 48% of the variance accounting for these attributes. There is a greater amount of variation in attributes and wines found along the x-axis than in attributes and wines found along the y-axis as PC1 (x-axis) accounts for a greater amount of the variance than PC3 (y-axis).

Attributes such as Astringency, Creaminess, Spicy, Favor Duration, and Vanilla/Sweet Oak are negatively correlated to Barrel Inserts 8mos, Oak Chain 4 and 12mos, Chips Medium Toast 8mos, and Dominoes 4mos, but strongly correlated to wines treated with Barrel Inserts 12mos, Winewood 8mos, and Oak Blocks 8 and 12mos. Wines treated with Chips Heavy Toast 4, 8, and 12mos, Chips Medium Toast 4 and 12mos, Barrel Inserts 4mos, Dominoes 8mos, Winewood 4mos, Oak Chain 8mos, and Oak Blocks 4mos are strongly correlated to the Astringency attributes, but negatively correlated to the Overall Oak, Overall Taste, Raw Oak, Roasted and Smoky attributes.

The Cube Oak Add Ins are in similar vector spaces and are thus similarly correlated to the attributes in that vector space. Similarly the wines treated with Chips Heavy Toast are in the same vector space and are correlated to the attributes in that vector space.

2.4. Conclusion

In summary, this study was designed to evaluate 24 Oak Add In treatments, based on 12 red wine sensory attributes. The statistical significance of the 24 Oak Add In treatments was found using a two-way ANOVA. The attributes found to be statistically significantly different by the descriptive analysis sensory tasting are Overall Oak, Vanilla/Sweet Oak, Spicy, Roasted, Smoky, Creaminess, Overall Fruit, Overall Taste and Flavor Duration. The attributes Astringency, Raw Oak, and Bitterness were not found to be statistically significantly different.

The ANOVA outcome was used to generate a table of significant attributes according to the set alpha criterion, = 0.05, to generate a graph of F-values according to attributes, and to carry out a Principal Component Analysis. The results of these tables and graphs aid in the determination of the significance of the attributes according to the Oak Add In treatments.

We found that the Cube Oak Add Ins were positively correlated to the Smoky, Overall Oak, and Roasted attributes, while negatively correlated to the Bitterness and Overall Fruit attributes. The Chips Medium and Heavy Toast Oak Add In treatments are positively correlated to Overall Fruit, while negatively correlated to the Smoky, Overall Oak, and Roasted attributes. A particular aspect of the Principal Component Analysis that could be expanded upon would be to determine if some of the red wine attributes can be lumped into one similar term. This may be inferred with attributes found in the same vector space, but could be more accurately determined with the aid of correlation tables.

The study will aid winemakers in determining the effects of various Oak Add Ins. It can be used to explain the affect of a particular treatment in a red wine, as well as the perceived sensory characteristics and their intensity in the wine.

It was determined that Oak Chips Medium and Heavy Toast yield similar effects, as do Cubes regardless of the length of the treatment. The study could yield further data as to the statistical significance of attributes and the judges if more training and more repetitions were conducted.

Thank you to Erin Miller, UC Davis

3. Chemical analysis

3.1. Chemical analysis overview

For each treatment at each stage, the samples of wines were analyzed by ETS laboratories for their oak aroma compounds. The data has been compiled in order to extract meaningful comparison between products and for the same product at different times. The chemical analysis study will therefore present in a first part, a temporal analysis comparing the same products at different stages and in a second part, the comparison of extraction at the same time between products of different sizes and level of toasting.
The ETS Oak Aroma Analysis is reported in concentration of µg/L (ppb) for each compound. The measured compounds are :

eugenol
isoeugenol
4-methylguaiacol
guaiacol
5-methylfurfural
furfural
trans-oak lactone
cis-oak lactone
vanillin

3.1.1. Oak aroma Coumpounds

Eugenol and Isoeugenol :
Eugenol is the main aroma compound found in cloves. Present in raw oak, eugenol is reported to increase during open-air wood seasoning. Eugenol and isoeugenol possess a very similar spicy**,** clove aroma.
In our experiment, eugenol and isoeugenol showed the same extraction kinetics and seem to have additive and cumulative sensory effects, we will therefore use the average of the two, referred to as « eugenols », as a global marker for **clove and spice character**.

Guaiacol and 4-methylguaiacol :
Wood lignin degradation at very high temperatures results in formation of a wide range of volatile phenols including guaiacol and 4-methylguaiacol. These compounds have smoky aromas, and are markers of the smoky character imparted by heavily toasted oak. Guaiacol has more of a char aroma, while 4-methylguaiacol has both a char and spicy characters. Considering the fact that their individual concentrations may be well below their sensory thresholds, their combined concentrations may result in a perceived sensory effect. So, by using the terms “guaiacols” we will be referring to the combined effect of both markers as a global marker for **smoke and char character**.

Cis-oak lactone and trans-oak lactone :
The main aroma constituents of raw oak are these two isomers of oak lactone. Their associated sensory descriptors are **fresh oak and coconut**. The cis-isomer is a more powerful aromatic than the trans- isomer. Indeed, sensory threshold found in literature (Chatonnet 1995) shows that the trans-oak lactone

aroma impact can be approximated by about 4.5 times less than the cis-oak lactone. Therefore, in order to summarize the oak and coconut aroma compounds under the term “lactones’”, we used a weighted average of the two lactones.

Furfural and 5-Methylfurfural:
These compounds result from degradation of carbohydes by heat. In wood, the carbohydrates cellulose and hemicellulose are degraded during barrel toasting. Furfural and 5-methylfurfural possess sweet, butterscotch, light caramel and faint almond-like aromas. The term “furfurals” will be used as a global marker for **sweet and butterscotch flavors.**

Vanillin:
Vanillin, the main aromas compound in **natural vanilla**, is also present in raw oak. The quantities of vanillin reported in wine vary with oak species and seasoning. Vanillin increases with medium toast levels, but decreases with very high toast.

3.1.2. A key factor on oak aroma compounds : Toasting level

Very general tendencies could be identified: Increased toasting diminishes the fresh aromas generally attributed to oak lactones. Simultaneously vanilla and caramel aromas associated with vanillin, furfural and 5-methylfurfural increase. At higher toast levels, these compounds decrease and are replaced by spicy and smoky character.

3.1.3. Oak aromas compounds and their sensory descriptors

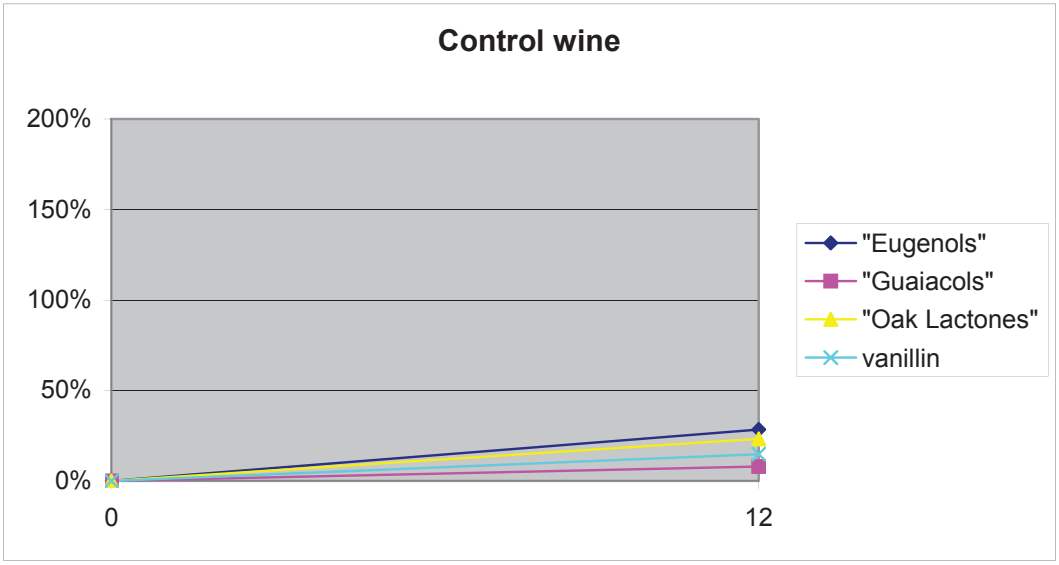
MARKERS	AROMAS
“Eugenols”	Clove, spices
“Guaiacols”	Smoke, char
“Lactones”	Oak, coconut
“Furfurals”	Sweet, butterscotch
Vanillin	Vanilla

One should know that for each marker, threshold levels are different. That means that the high amount of a marker doesn’t always relate to a high sensory evaluation.

3.2. Analysis of Oak Add Ins treatments at 4,8 and 12 months

In this part, we monitor the oak aroma compound over a total period of 12 months.
Furfurals through time are involved in cross-linking reactions with tannins and anthocyanins, and therefore are not relevant markers to monitor the aromas of caramel and butterscotch over time. So, for the purpose of the time framed analysis, the results for the furfurals compounds have not been taken into account.
Results for oak aromas compounds are presented on a relative scale. One hundred percent, for each compound, is defined as the average calculated for all wines at the end of the experiment (12 months).

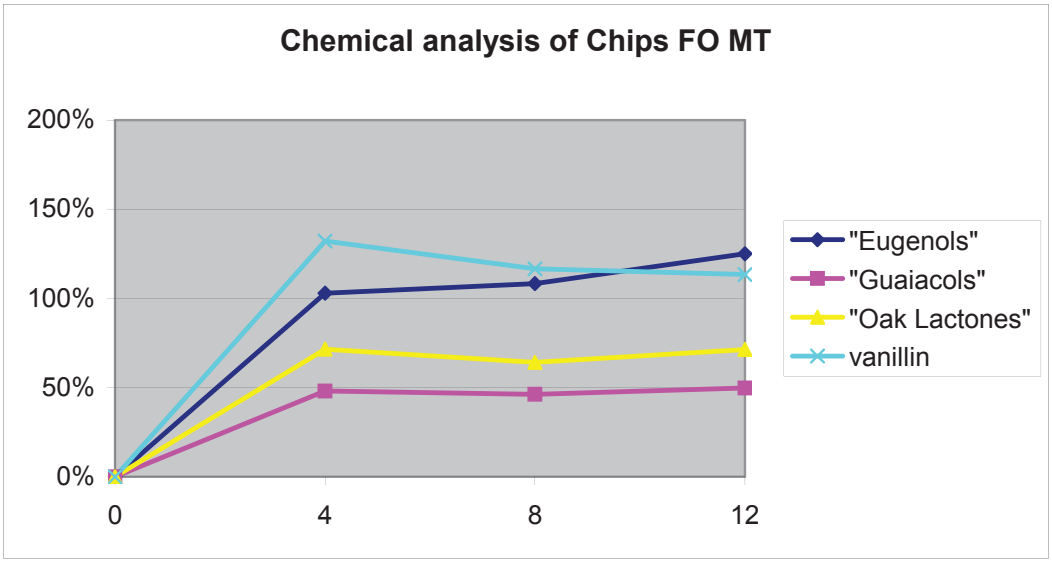
3.2.1. Control wine



100% = average of all products at 12 months

The control is the same wine aged partially in neutral barrels and partially in stainless steel tank. Relatively low amount of each compounds are present at 12 months.

3.2.2. Chips FO MT

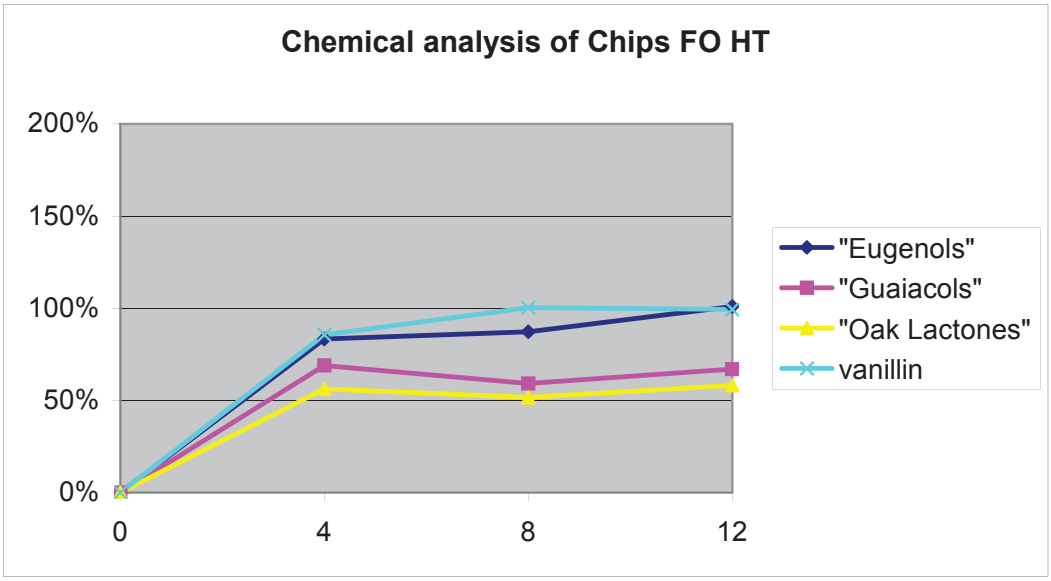


100% = average of all products at 12 months

Results show a fast extraction rate for all compounds for the first four months. The extraction rate is much slower. An apparent decrease can even be noticeable for vanillin. A loss may be explained by polymerization with wine phenolics.
By comparison with the other wines from the experiment, aroma compounds of oak chips FO MT are close to the average for vanillin and eugenol. Guaiacol and oak lactones are relatively low.

Expected sensory impact would be mild overall intensity with predominant vanillin and spicy aromas.

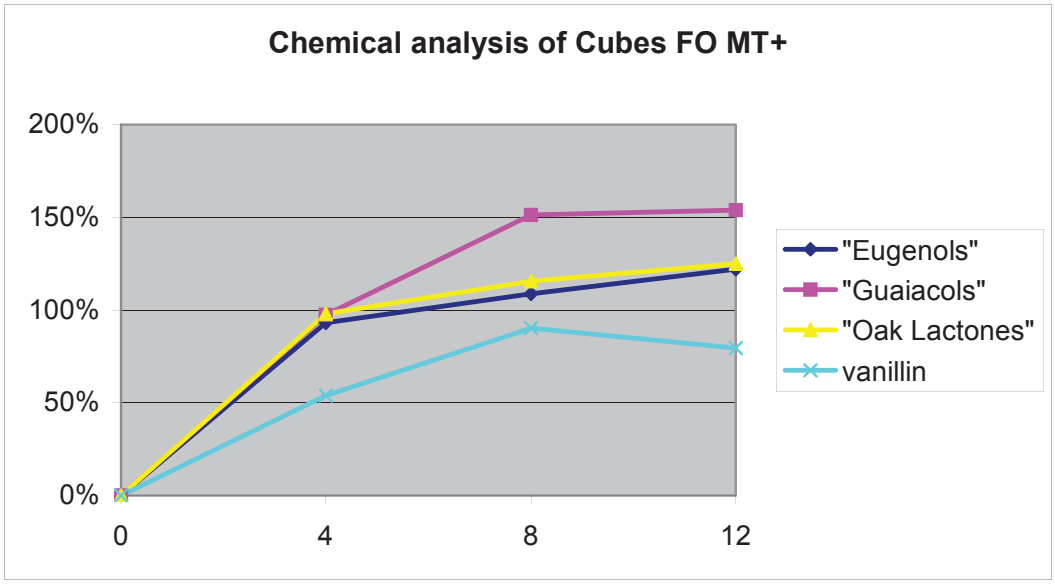
3.2.3. Chips FO HT



100% = average of all products at 12 months

Extraction kinetics and relative concentration for all compounds are similar with the oak chips MT. The level of vanillin stays very limited compared with the medium toast, because of possible degradation by heat. In opposition, guaiacols levels are higher.

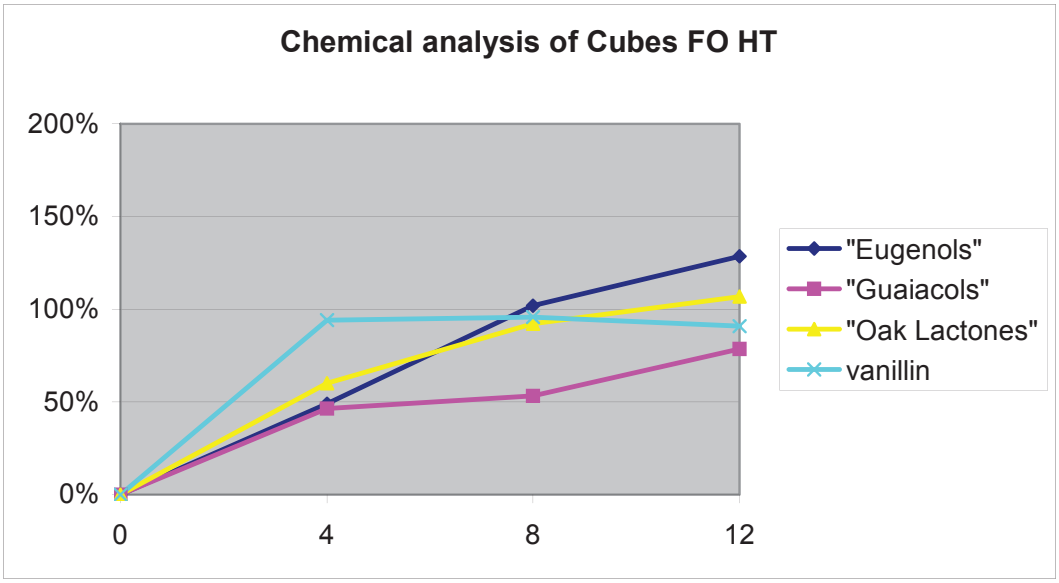
3.2.4. Cubes FO MT+



100% = average of all products at 12 months

Because if the size of the pieces, the extraction gets a little longer to come out. After 4 months, the extraction continues to grow and starts to level out only after 8 months. Relative amounts of guaiacols are particularly high, suggesting that corresponding wines may be marked by smoky aromas.

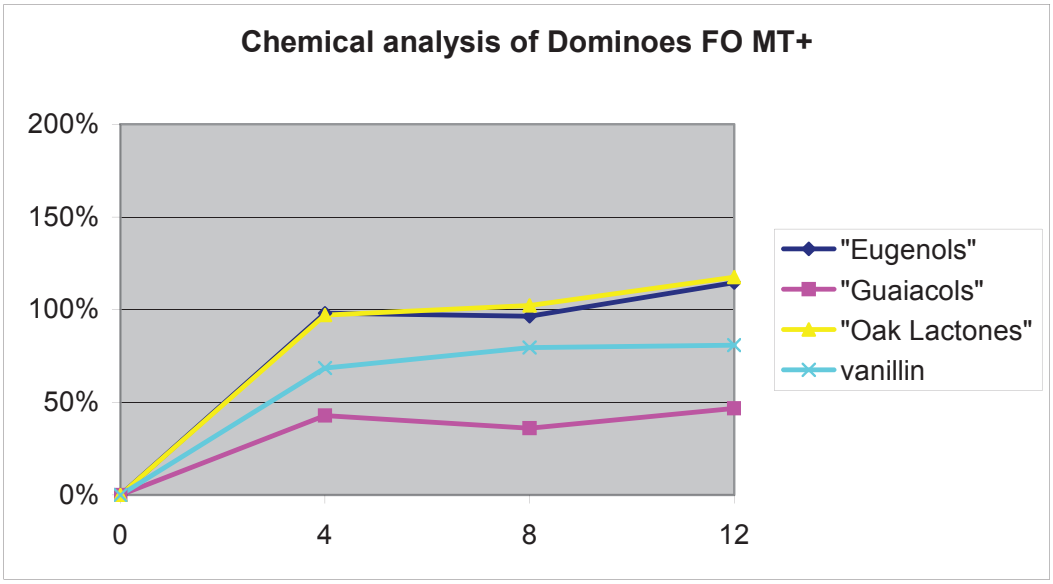
3.2.5. Cubes FO HT



100% = average of all products at 12 months

Surprisingly, the HT cubes show less guaiacols (smoky characters) markers than the MT. This was a conclusion of sensory tasting along the process of the experiment, when the wines were tasted by 3 people over time. This product was not included in the sensory tasting.

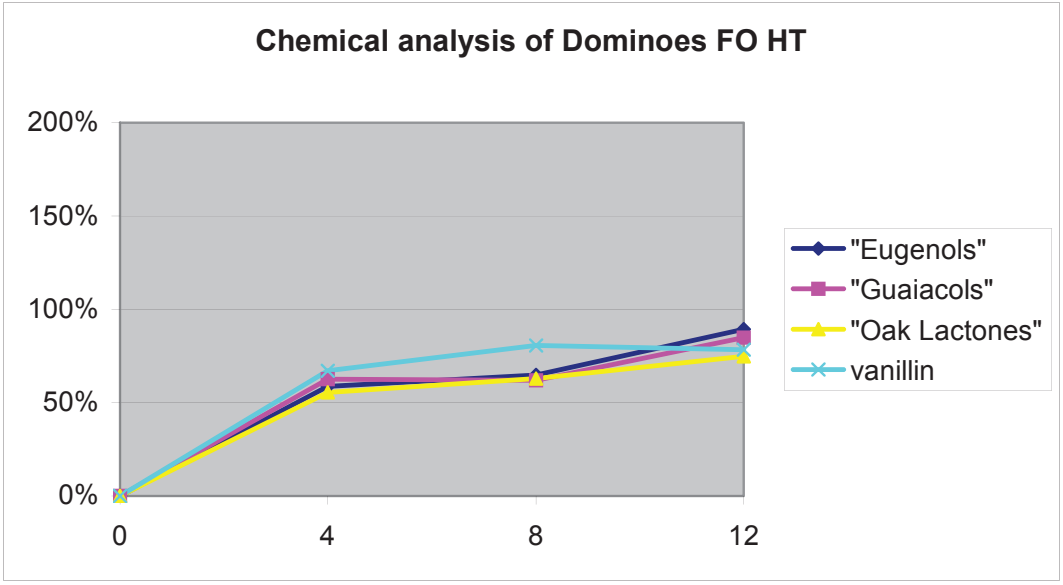
3.2.6. Dominoes FO MT+



100% = average of all products at 12 months

Extraction kinetics are similar with those observed with chips. Level of guaiacols markers are very low compared to the cubes of the same toasting level. Concentrations of all other compounds are below and close to average.

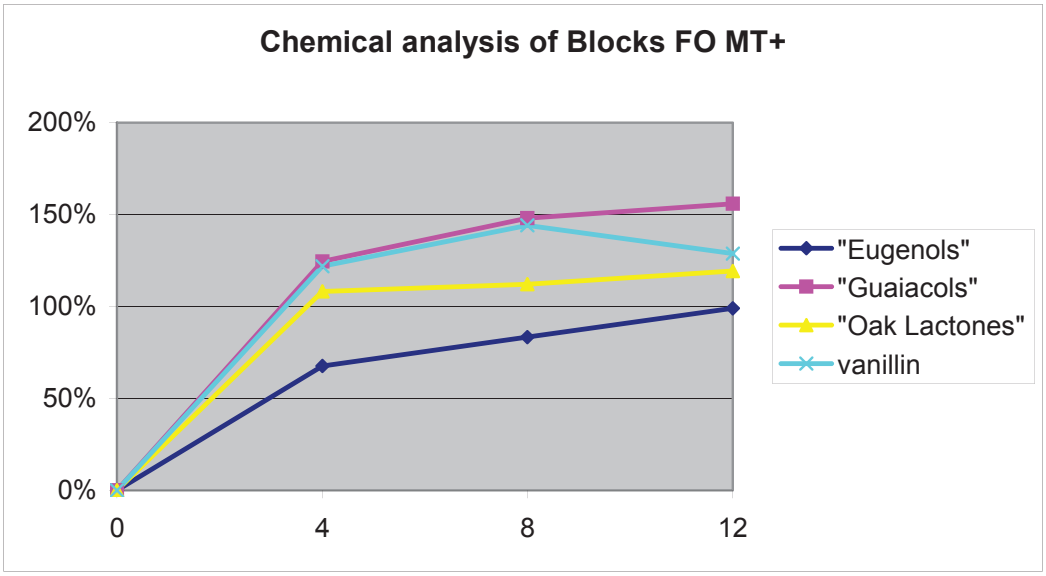
3.2.7. Dominoes FO HT



100% = average of all products at 12 months

Results are very similar to the dominoes MT+ with the exception of the guaiacols, typical of Heavier toast level.

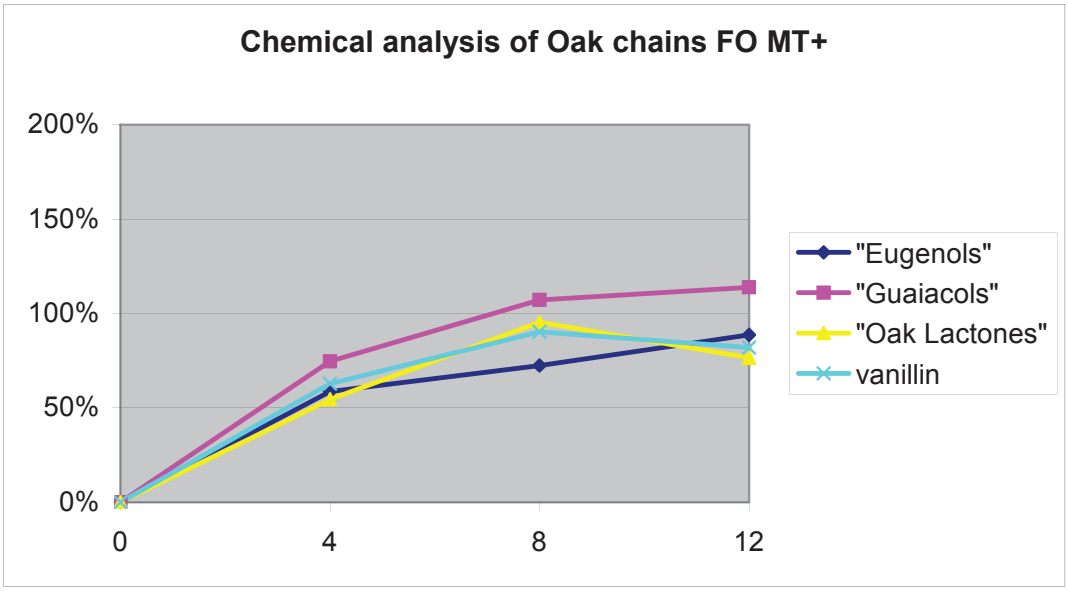
3.2.8. Blocks FO MT+



100% = average of all products at 12 months

The kinetics of extraction is faster from 0 to 4 months but continues to grow steadily after 4 months and as well as after 8 months. This can be explained by the bigger size of the piece of oak which allows a continuous release of aromas compounds for longer period of time. We can assume that the penetration of wine through the whole thickness of the oak takes longer time to be achieved.

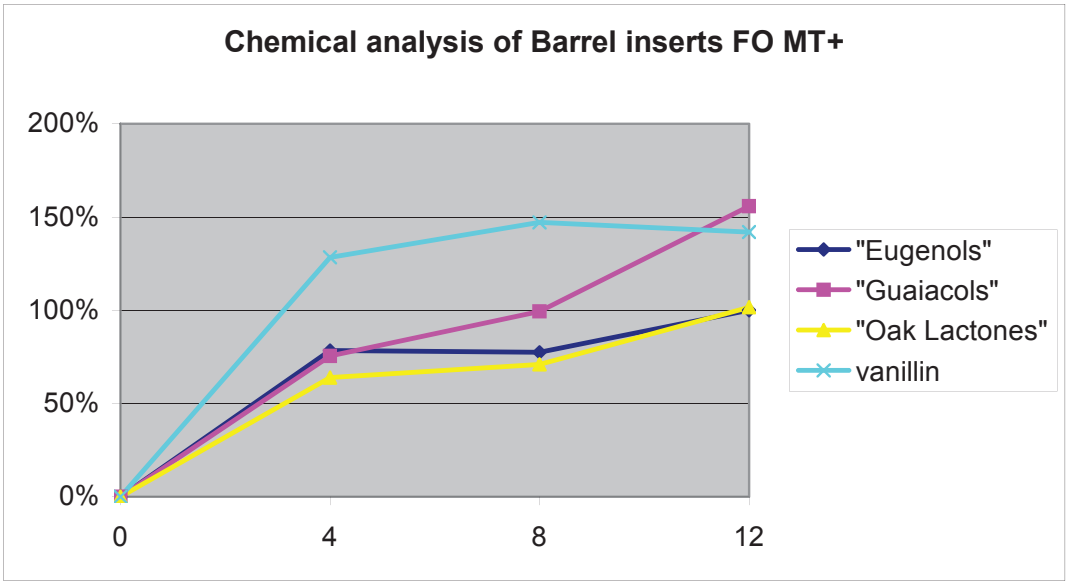
3.2.9. Oak Chain FO MT+



100% = average of all products at 12 months

This shows the same kinetic extraction as the blocks. All compounds levels are close to the average.

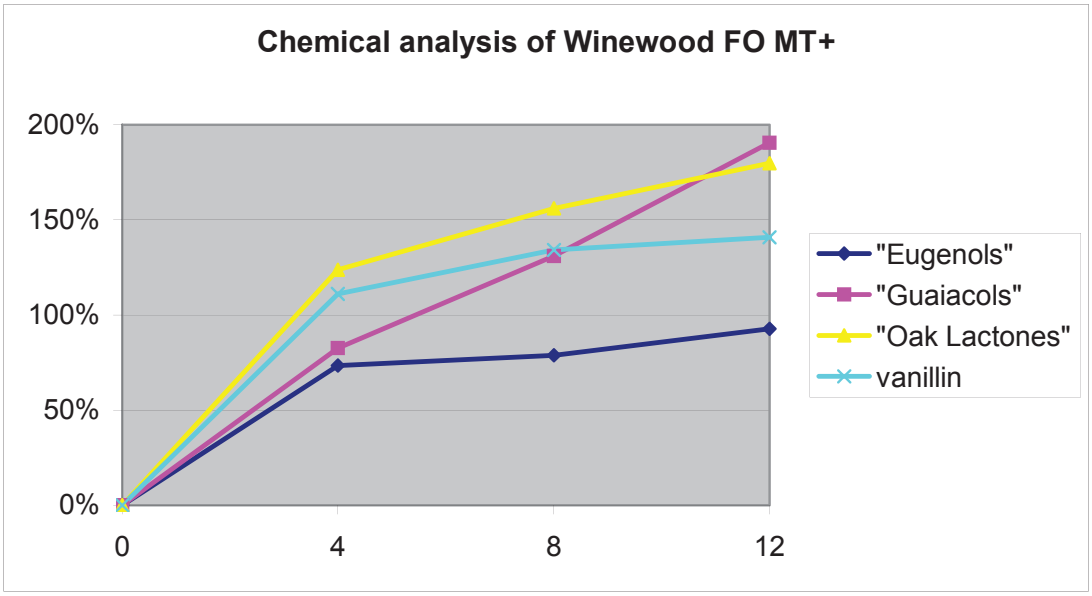
3.2.10. Barrel Inserts FO MT+



100% = average of all products at 12 months

These extraction kinetics are unique for Oak Add Ins. The 8 months continued extraction justifies the recommended use of barrel inserts for a one-year time frame. Note the relatively high or very high amount of both vanillin and guaiacols suggest that the wine will have both intense aromas of sweet and spicy/smoky character.

3.2.11. Winewood FO MT+



100% = average of all products at 12 months

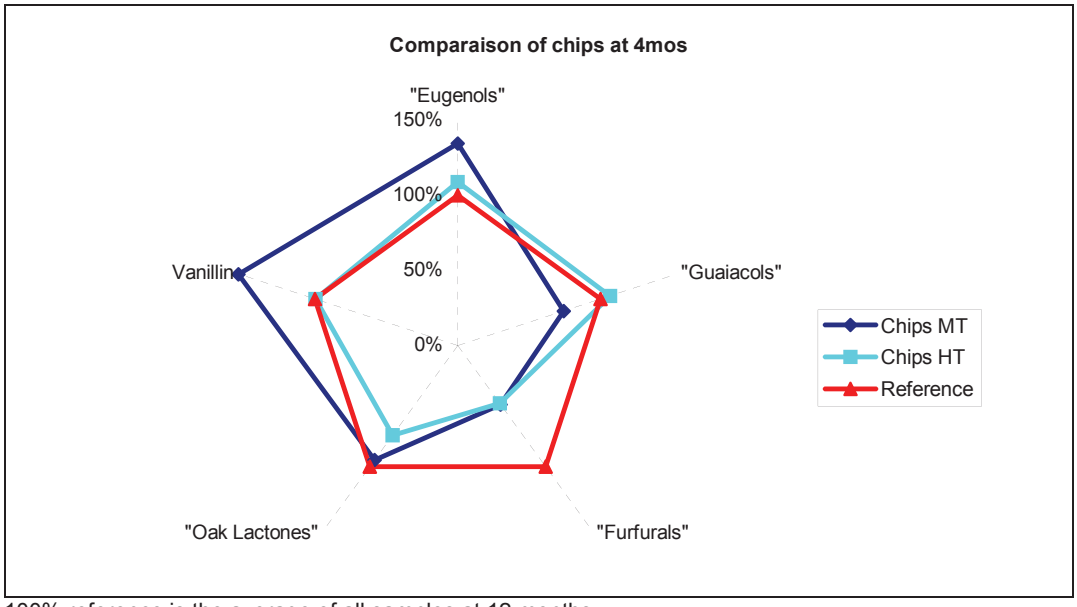
Relative amount for all compounds except eugenol are much higher than average. Winewood is a product designed for use in tank. The amount to be used was based on tank recommendation dosages and seems to have been a little high. This quantity can be adjusted very easily.

Again, as a stave product, the kinetics is showing a long and continuous extraction of all aromas compounds up to at least 12 months.

3.3. Comparative analysis of different Oak Add Ins treatments

These radar plots are an attempt to compare the various products at a given time. We decided to group the products by similar size and/or shape.
Based on the preceding time analysis, we have seen little evolution for chips and small pieces after 4 months. In addition, the recommended time of extraction for chips and small pieces is usually around 4 months.
Bigger pieces are meant to be used for a longer amount of time. Therefore, the profiles obtained at 12 months are presented.

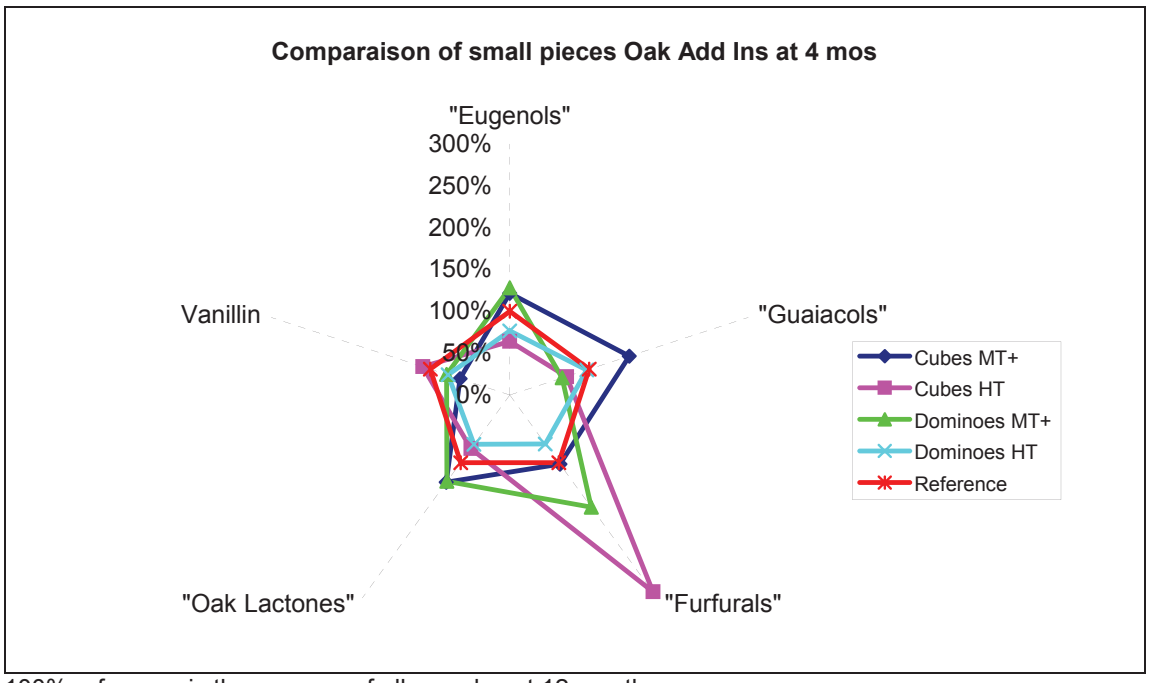
3.3.1. Oak Chips at 4 months



100% reference is the average of all samples at 12 months.

Significant variation compared to the average can be seen. Heating at a higher toasting level increases guaiacols at the expenses of all other compounds except for furfurals. Chips MT are seen to be showing more vanillin than HT. This confirms the hypothesis that intense heat could degrade the vanillin compound.

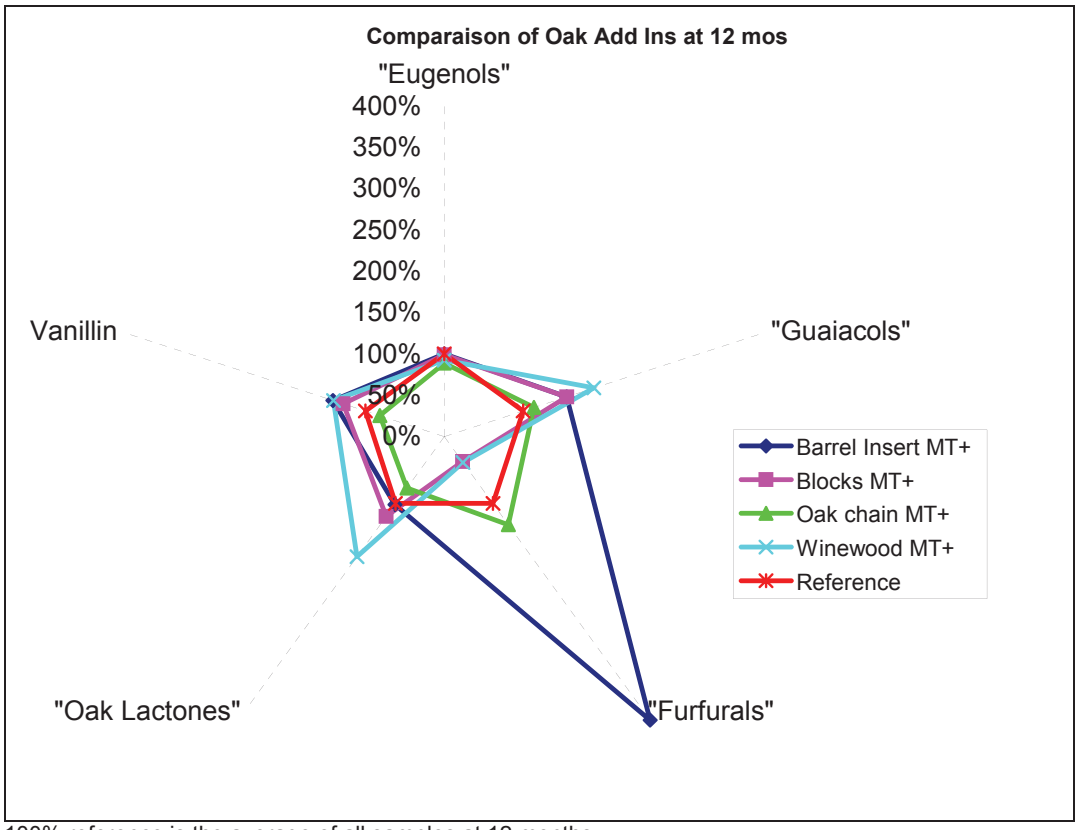
3.3.2. “Small pieces” at 4 months



100% reference is the average of all samples at 12 months.

Significant variations compared to the average are seen for all compounds. Both cubes HT and dominoes MT+ show a dominance of furfurals (caramelized aromas). Only cubes MT+ show a dominance of guaiacols (smoky markers).

3.3.3. “Bigger pieces” at 12 months



100% reference is the average of all samples at 12 months.

The “Bigger pieces” size group contains products of shape and size quite different. Not surprisingly, the profiles obtained for aromas compounds appear very distinctive. Oak chain MT+ product shows very balanced, close to the average rate of extraction. Only barrel inserts MT+ show a very high amount of furfurals at 12 months as opposed to winewood MT+ and blocks MT+ which appear to be showing a much smaller amount of smoky markers. Again, the interpretation of this graph should be made based on threshold levels of different markers for this specific wine.

4. Sensory analysis

4.1. Sensory analysis overview : Grand Tasting, June 10th 2004

8 products out of the 12 products analyzed by ETS were selected for the purpose of the Grand Tasting logistics.
Each taster had a set of 12 glasses for the first session. Those 12 glasses contained wine from 4 different products at 3 three stages of extraction for each of them. Another glass was used as a reference glass.

The tasting was divided in two sessions :

- The first session was introduced by a smelling session of 5 essences used as references for all the compounds evaluated during the tasting. Then, all the participants went through and tasted the first set of 12 wines.
- The second session included another set of 12 wines. At the end of the tasting the identity of the wines was revealed.

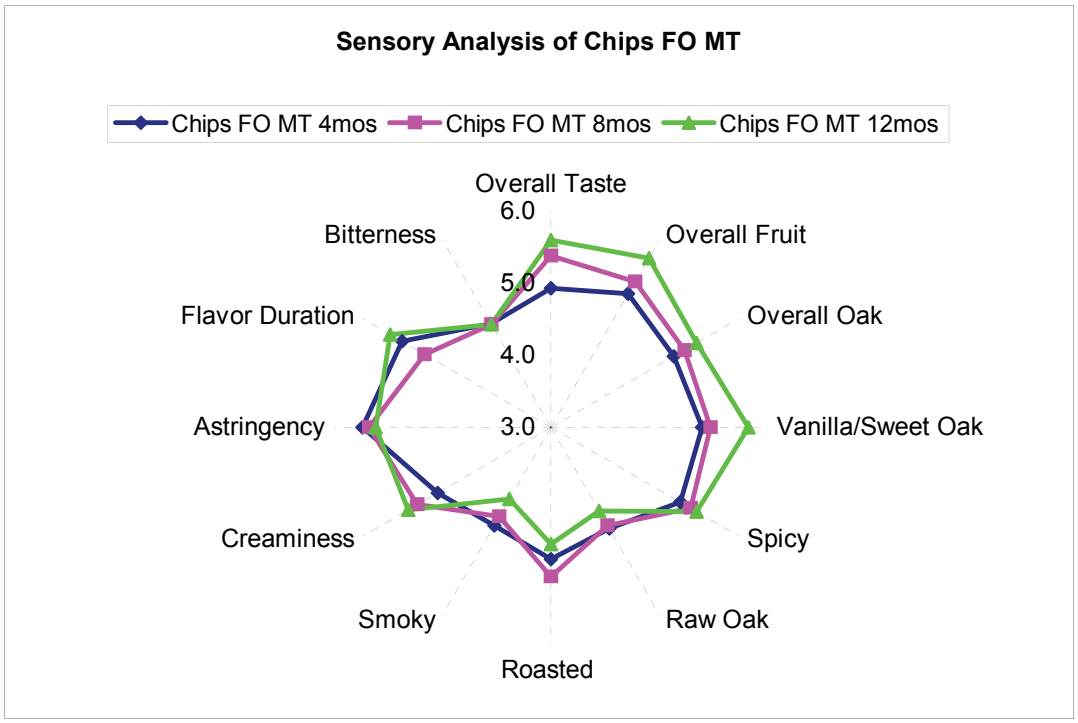
In order to have sensory results of this tasting as accurate as possible, each tasting sheet was personalized which means that nobody in the room tasted the same wines in the same order. In addition to that, we divided the room in two, so that before the break, half the room tasted one set of wines while the other half of the room tasted a different set of wines.
Following the break, the wine sets were poured in reverse for each half of the room.

Each compound was ranked from 1 (lowest intensity) to 9 (highest intensity). On all the graphs the average of all entries were calculated to give a final score between 1 and 9 as well.

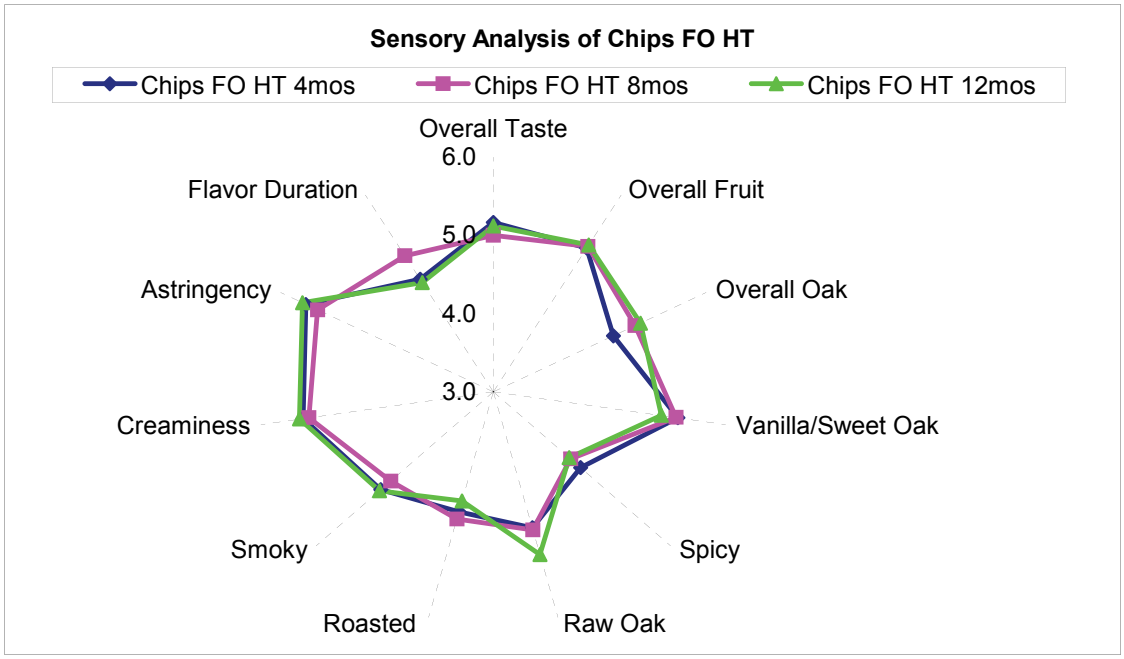
4.2. Sensory analysis of Oak Add Ins treatments at different times

The purpose of this section is to analyze the sensory evaluation of one type of product at different stages in order to track the evolution of extraction and integration.

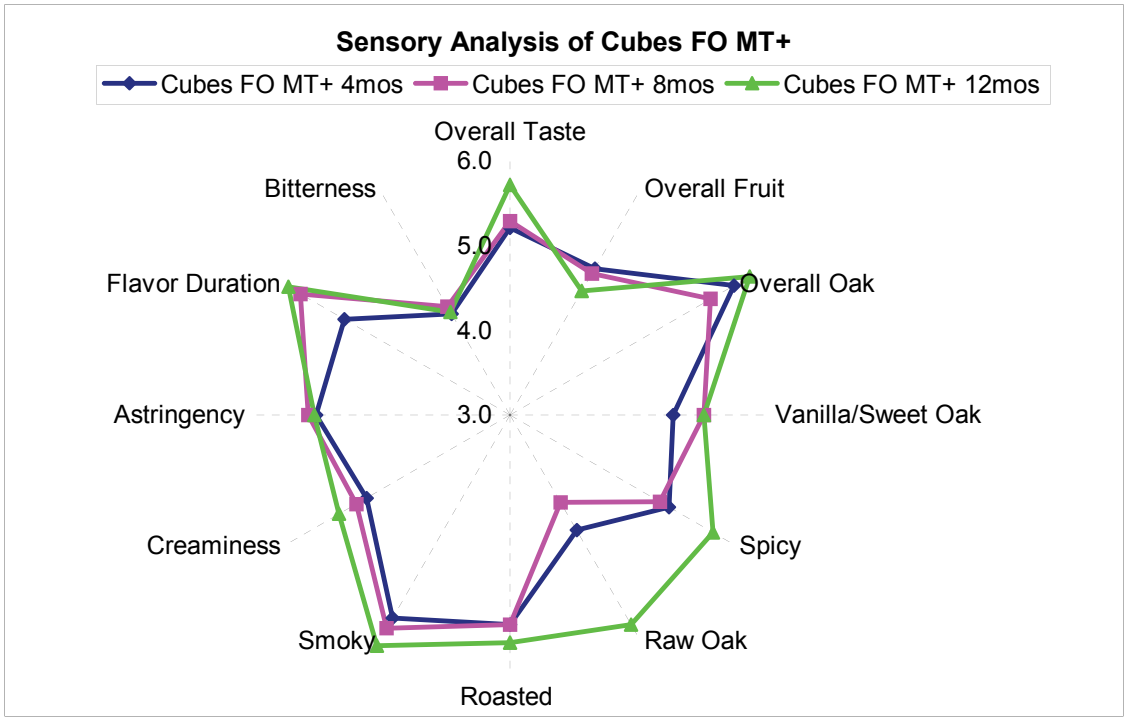
4.2.1. Chips FO MT



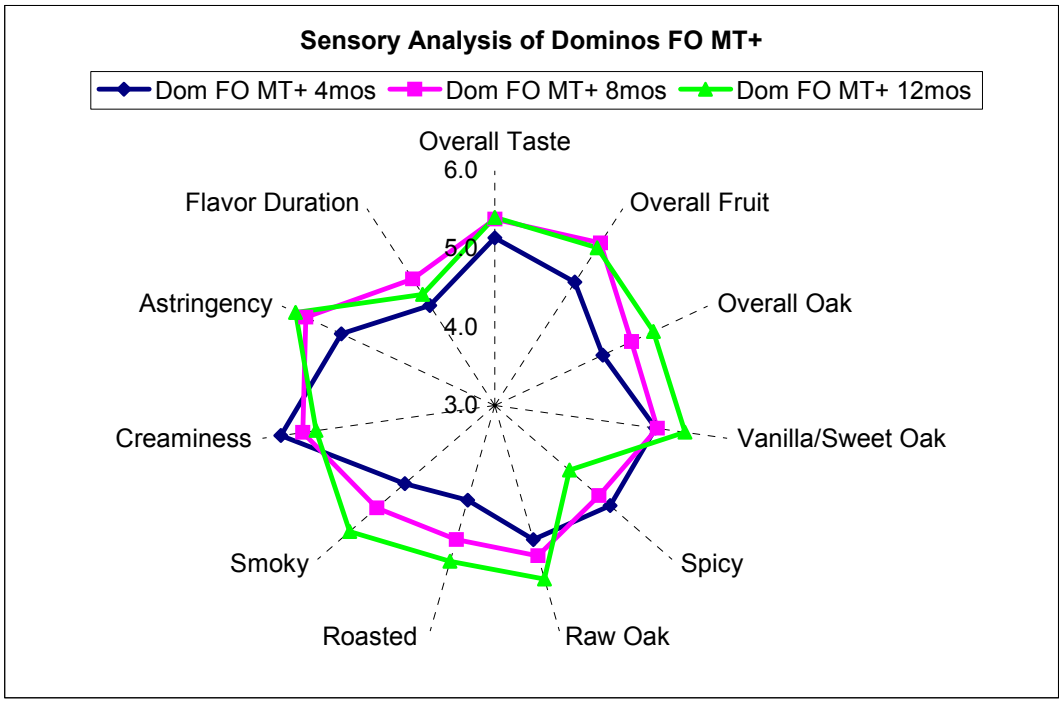
4.2.2. Chips FO HT



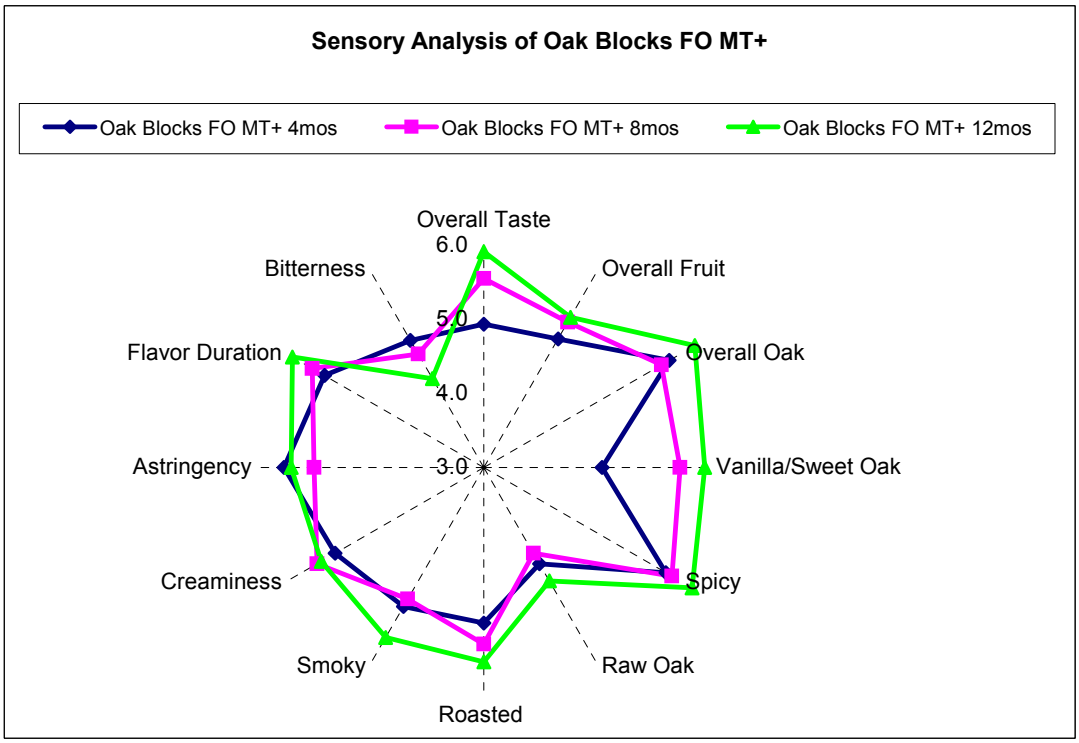
4.2.3. Cubes FO MT+



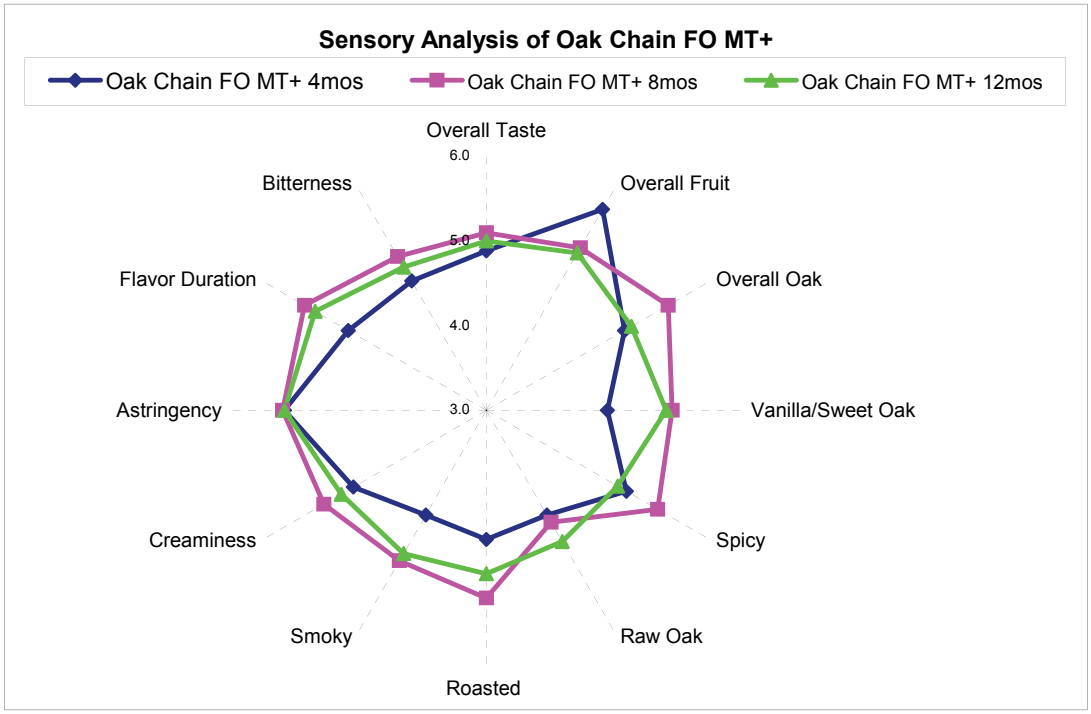
4.2.4. Dominoes FO MT+



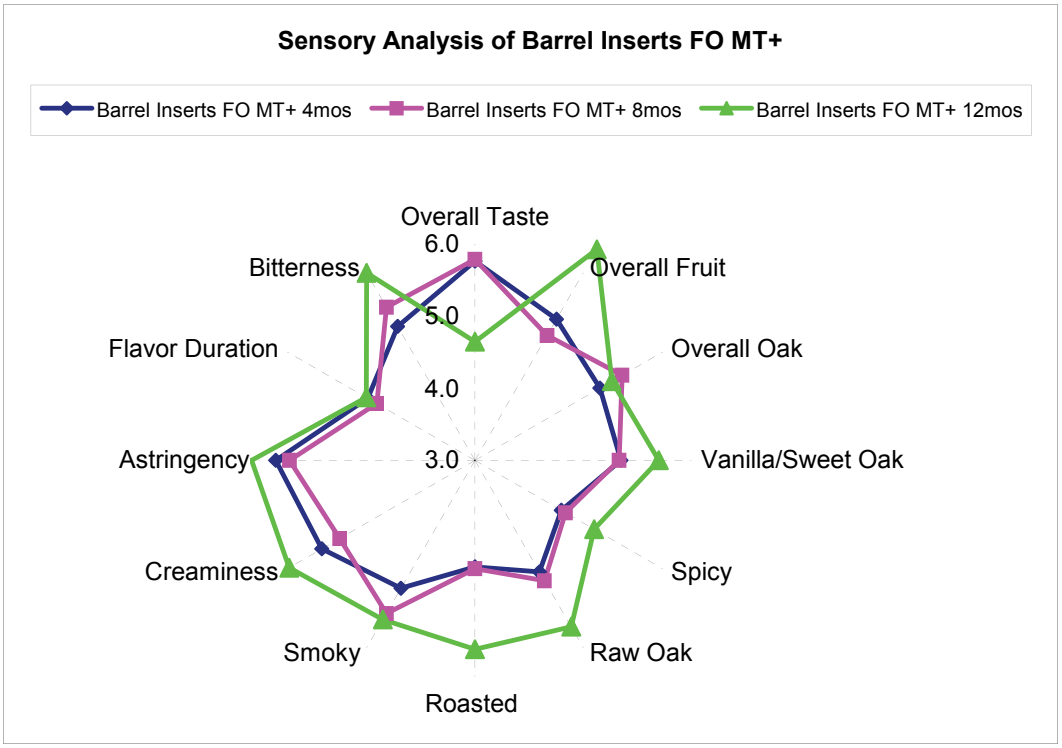
4.2.5. Blocks FO MT+



4.2.6. Oak Chain FO MT+

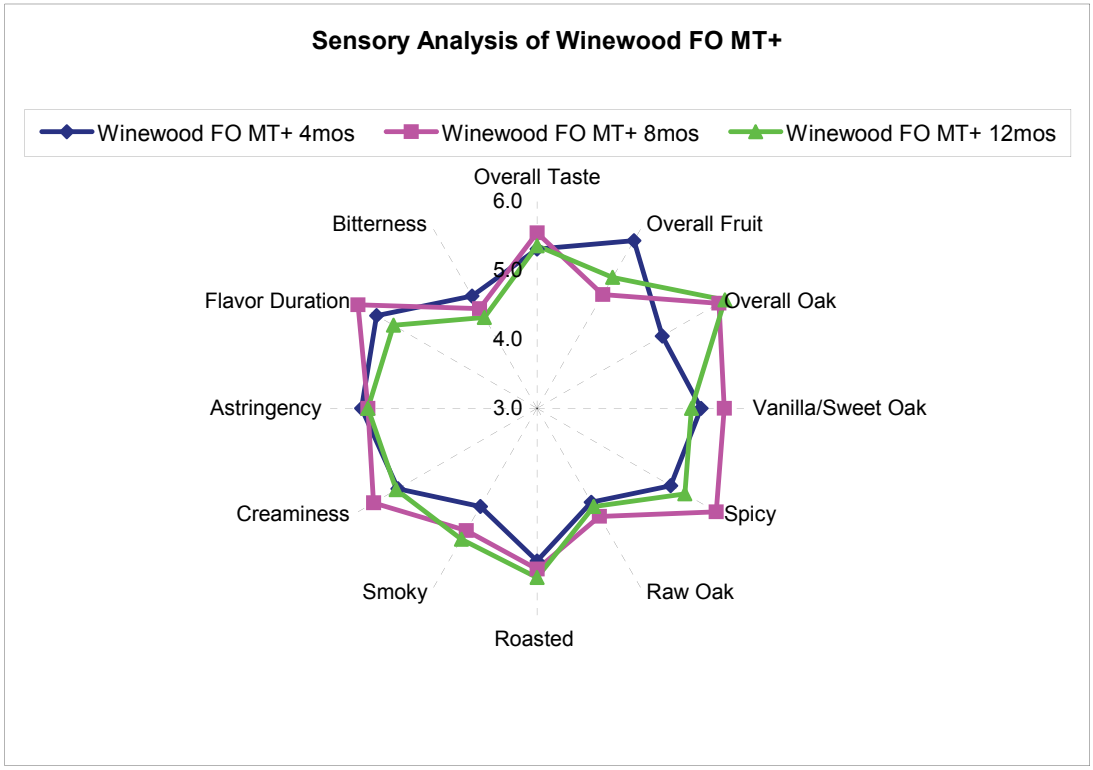


4.2.7. Barrel inserts FO MT+



One can note that the high furfurals showed in the chemical analysis don't seem to be related to a sensory evaluation. That might be explained by the combination of furfurals with other flavor compounds which diminishes the "smoky flavors" in terms of threshold.

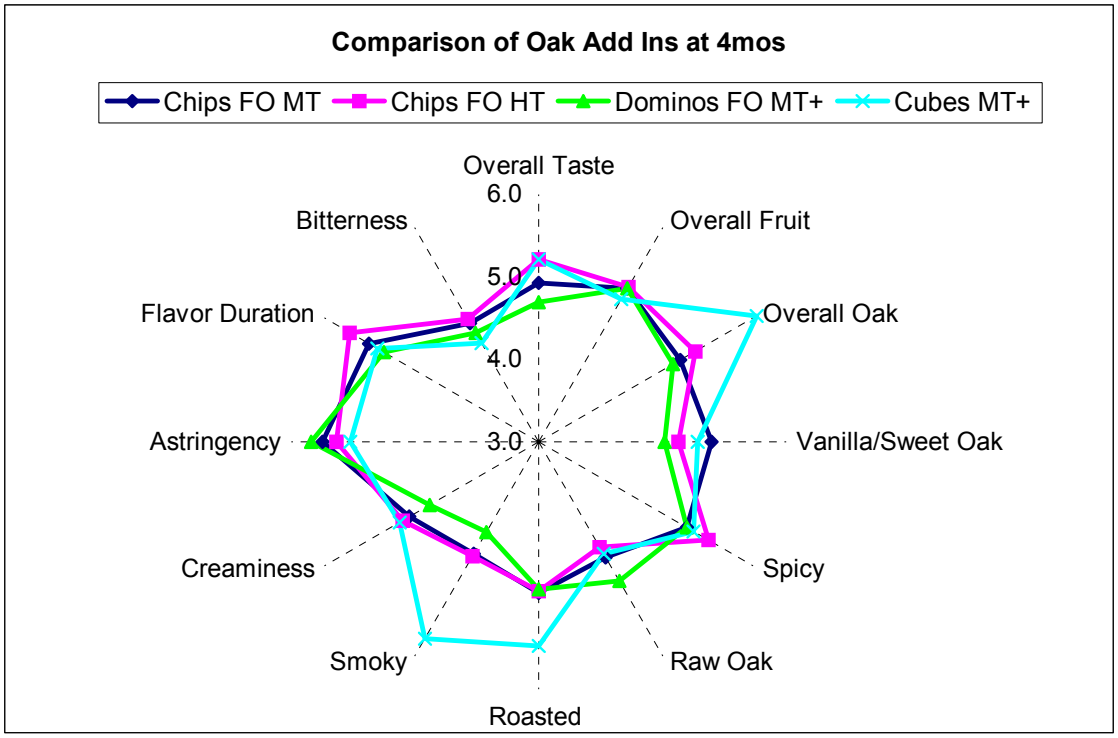
4.2.8. Winewood FO MT+



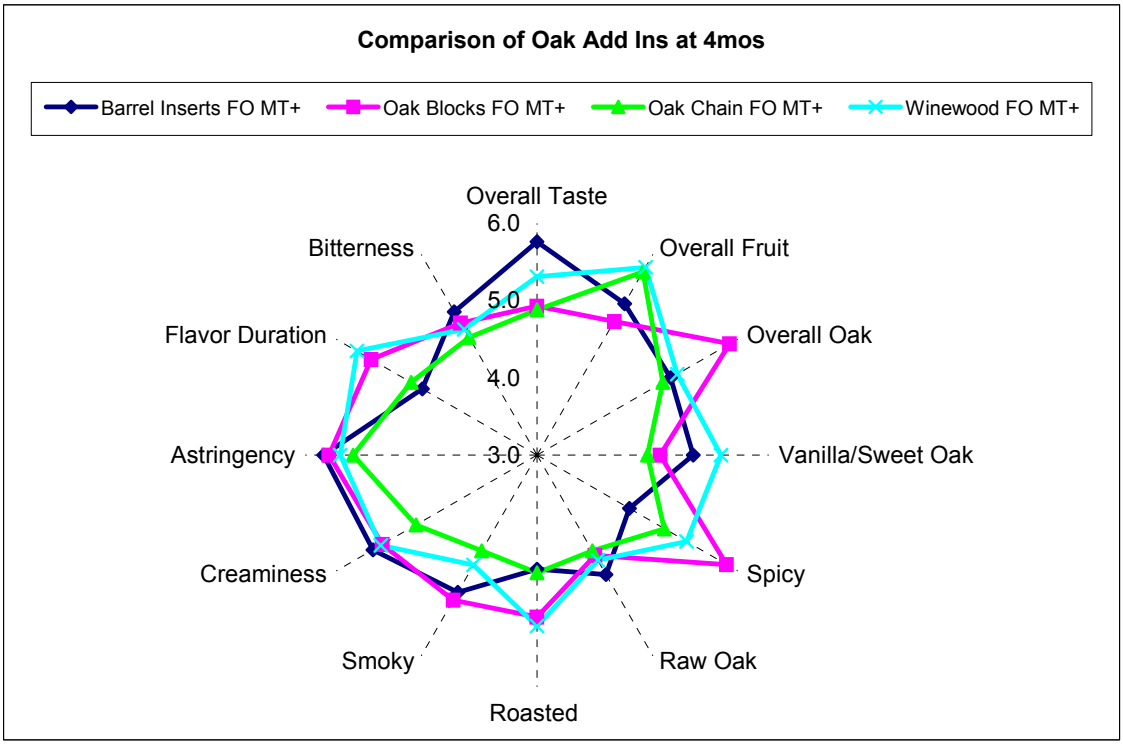
4.3. Comparative analysis of different Oak Add Ins treatments

4.3.1. At 4 months of treatment

- **Small pieces**

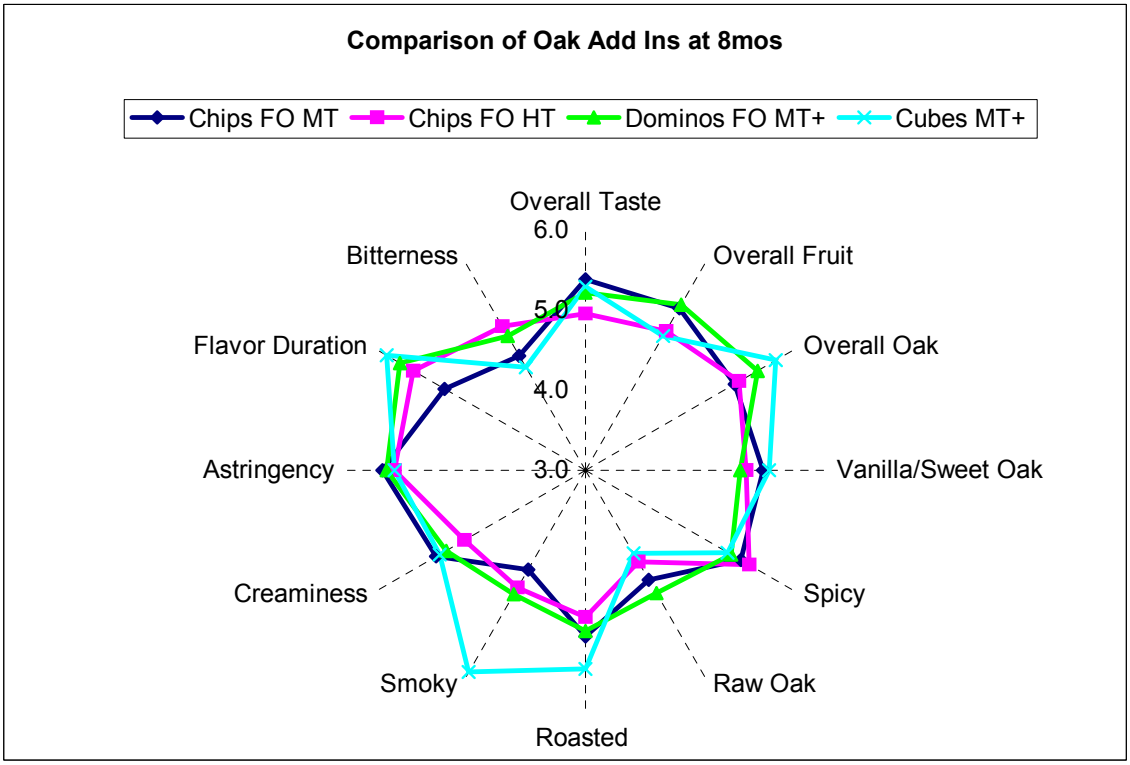


- **Bigger pieces**

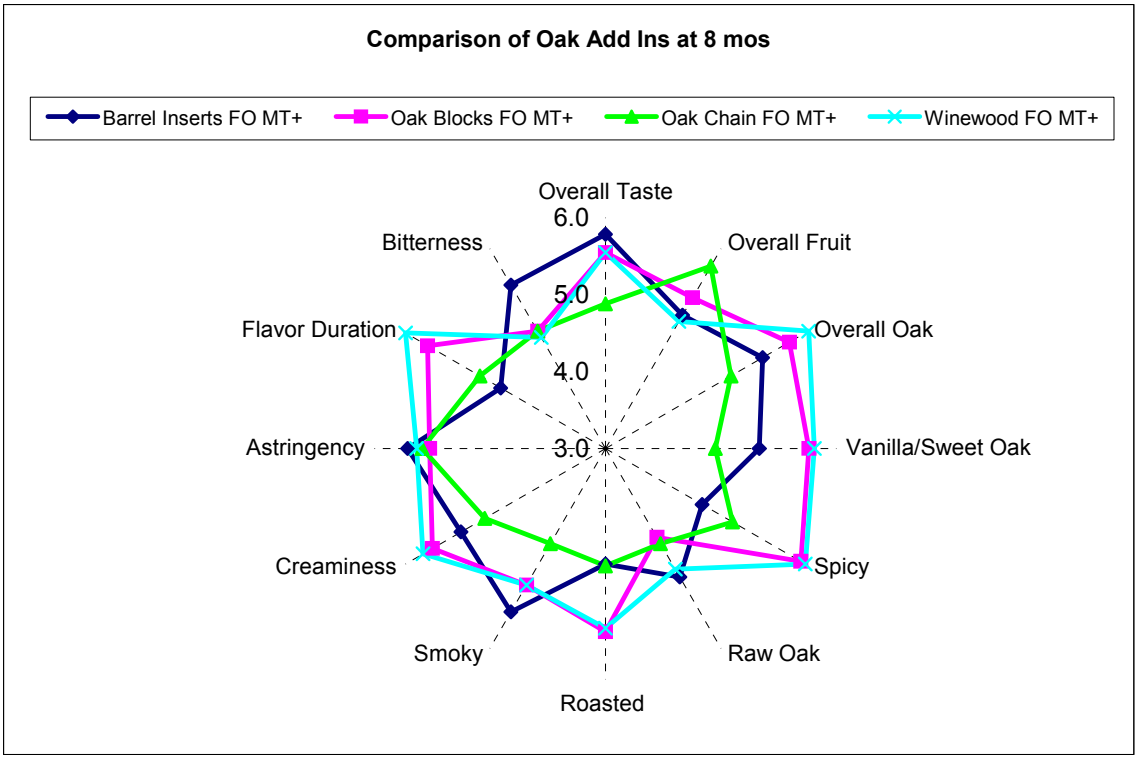


4.3.2. At 8 months of treatment

- **Small pieces**

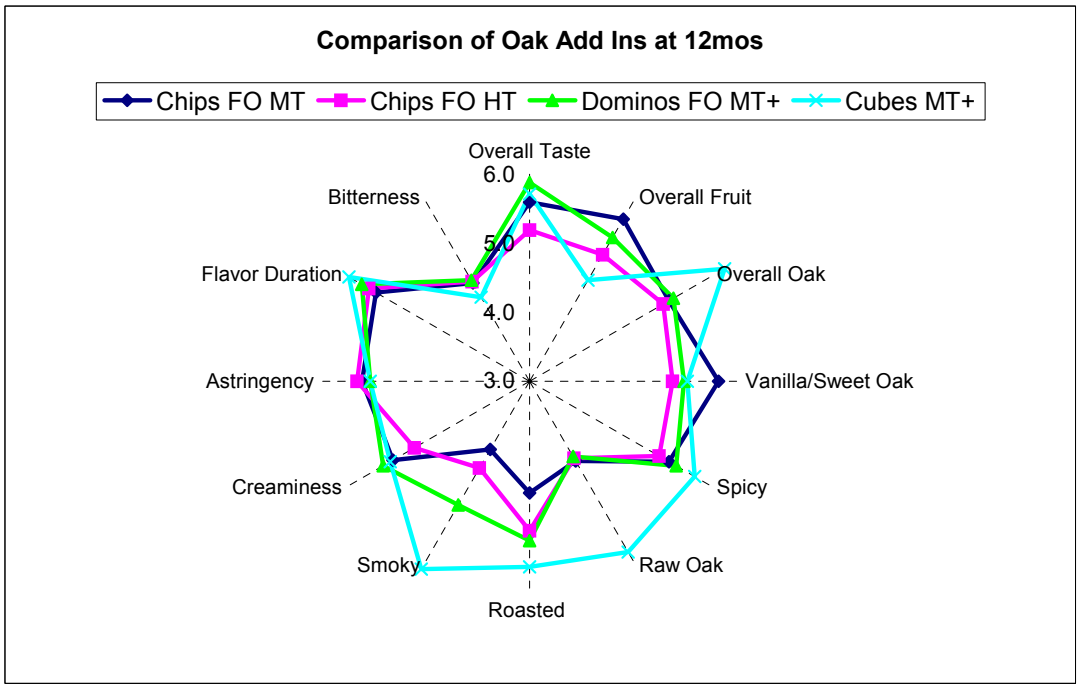


- **Bigger pieces**

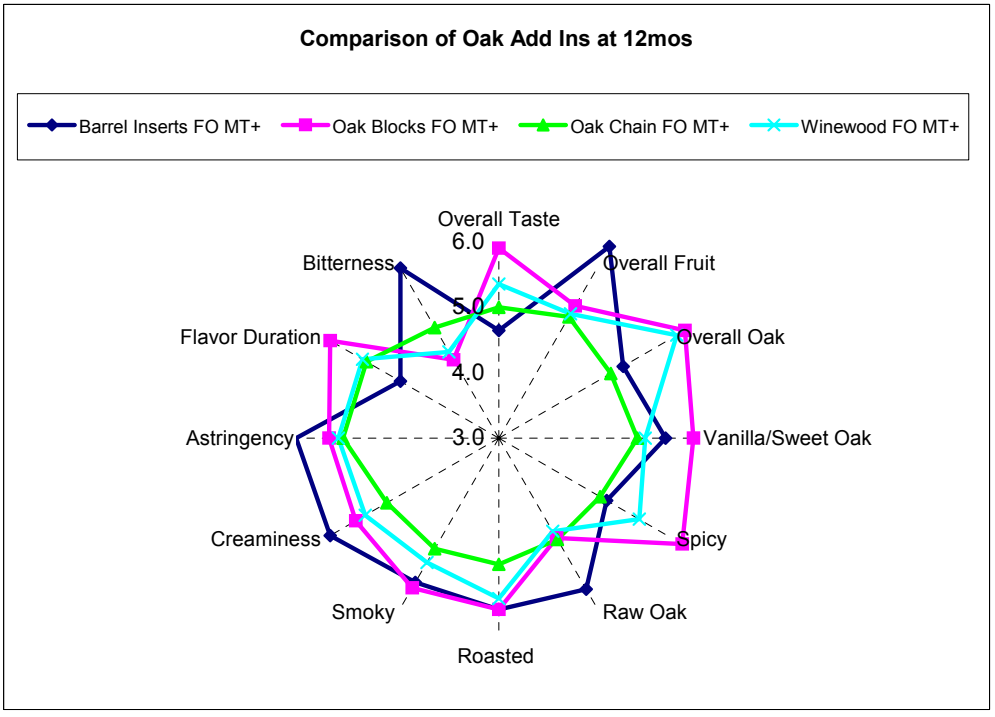


4.3.3. At 12 months of treatment

- **Small pieces**



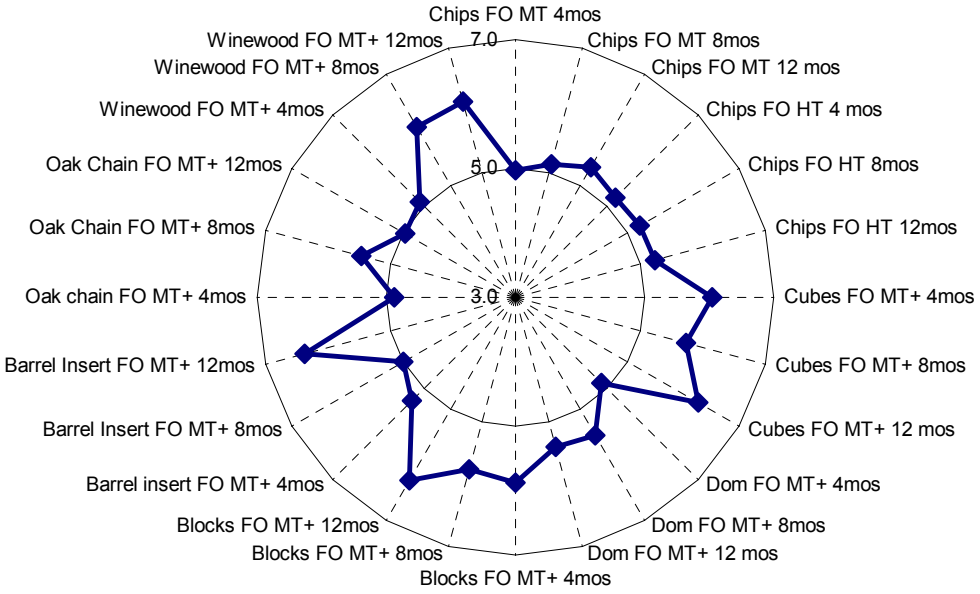
- **Bigger pieces**



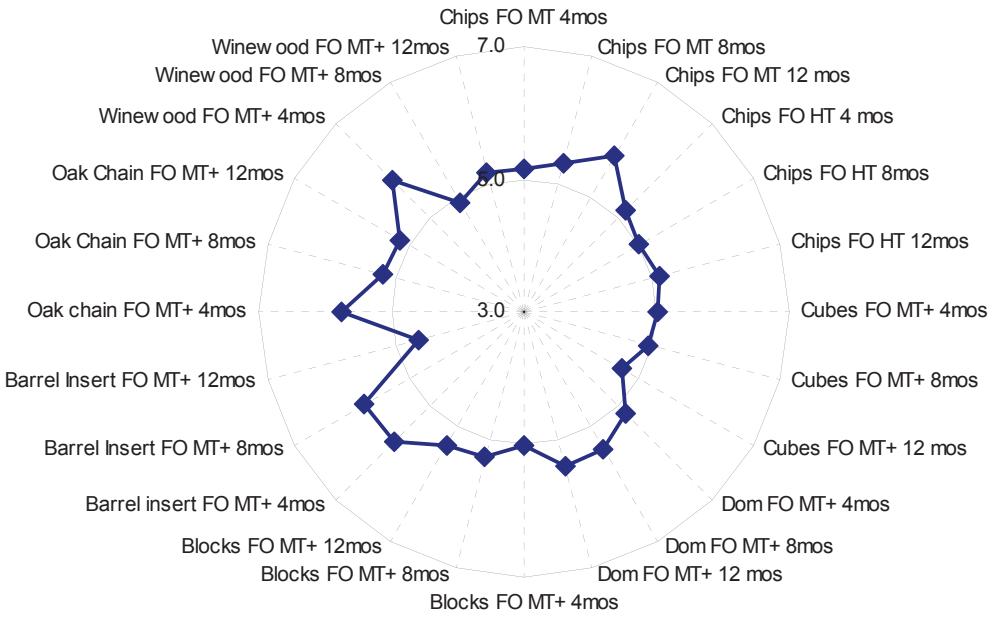
4.4. Comparison of all products by significant aromas

Based on the statistical analysis, we have identified the significant compounds of the sensory evaluation tasting. Thereby, we have decided to focus on the significant ones. Considering the aromas compounds (excluding the mouthfeel), the only “not significant” aroma is “raw oak”. Therefore, it has been removed from this analysis to keep the focus on significant aromas.

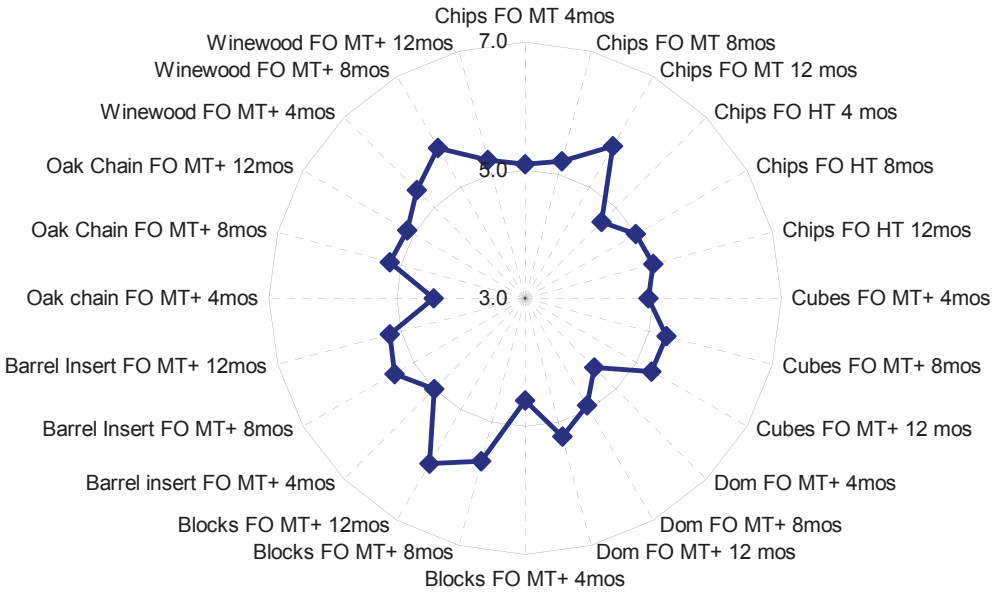
- **Overall oak**



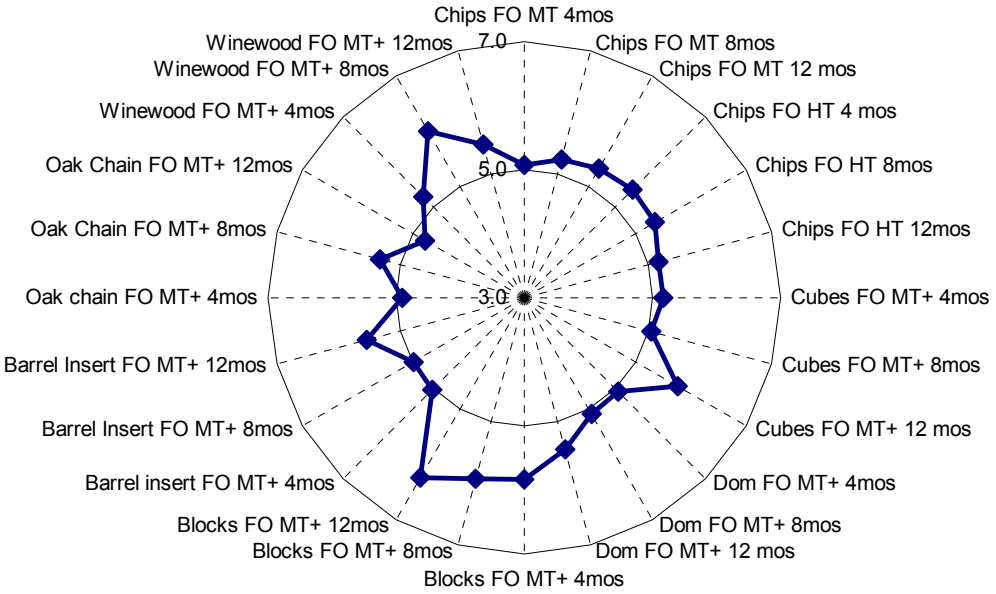
- **Overall Fruit**



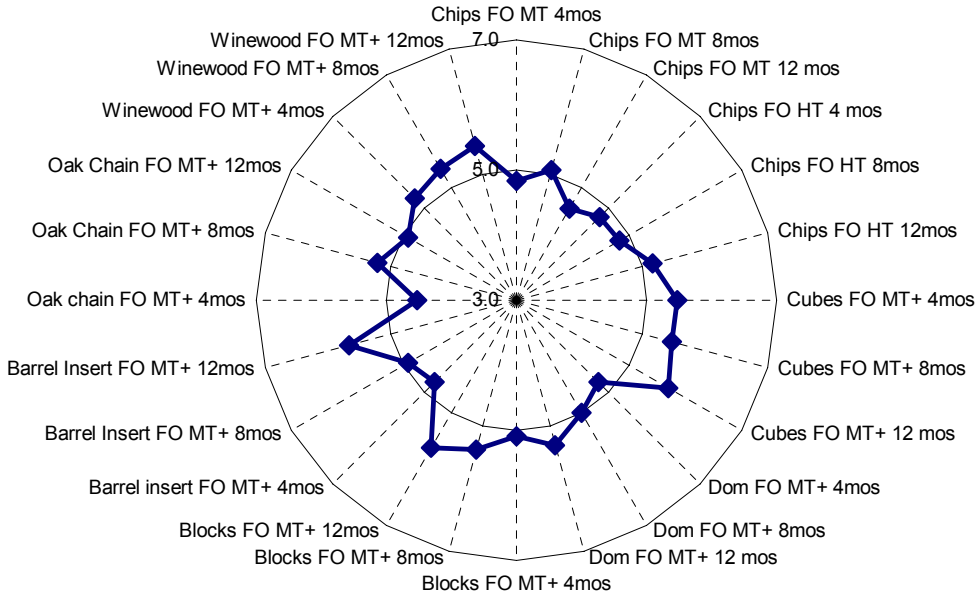
- **Vanilla/sweet oak**



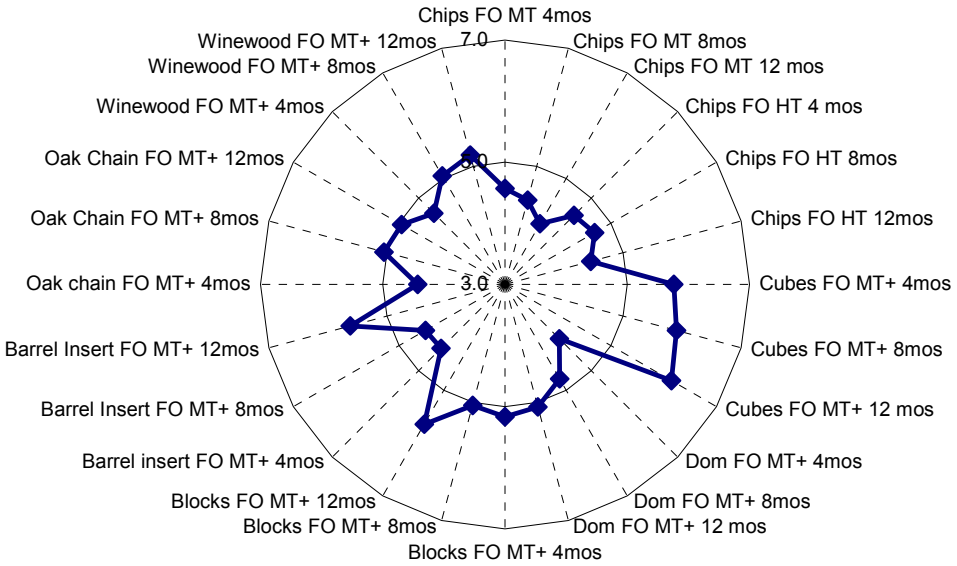
- **Spicy**



- **Roasted**

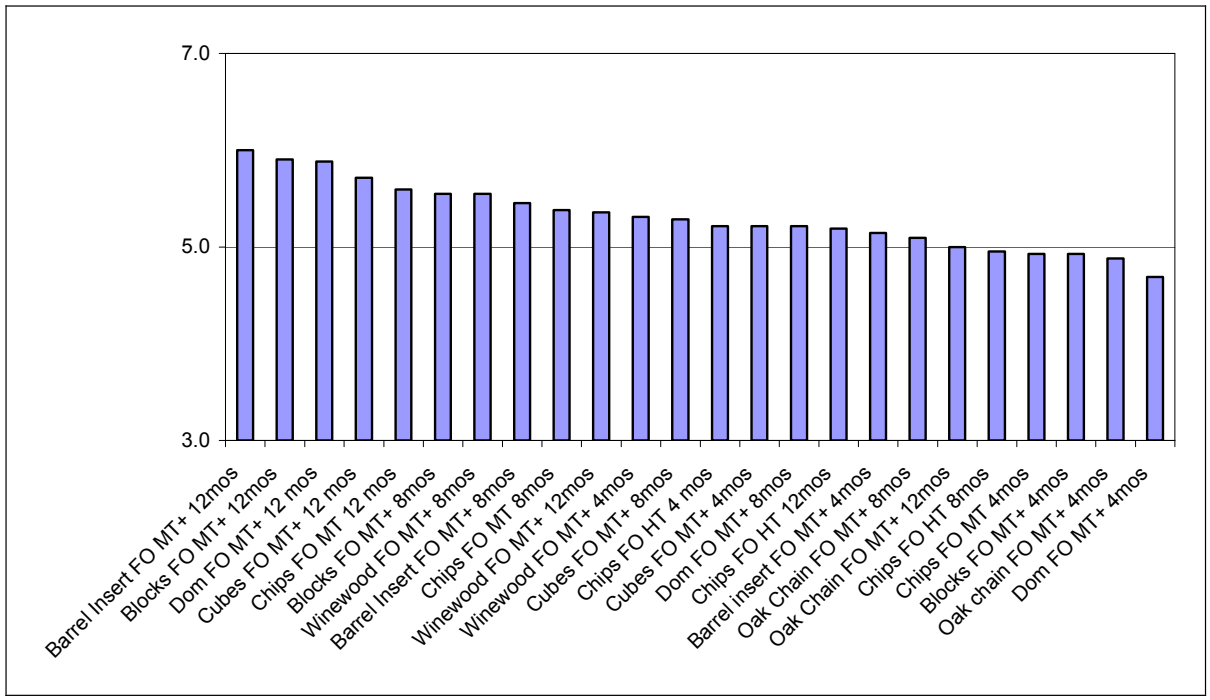


- **Smoky**



4.5. Overall Taste

The overall taste has been described to judges as the hedonic or preference. It is independent from the ranking of intensity. All wines were ranked from 1 (1= don't like extremely) to 9 (9=like extremely). This chart presents the average score for each wine, from all judges.



5. Conclusion

Oak Add Ins and their applications to various wines and wine processing procedures are just beginning to be understood. Future experiments with different varieties and different regions, using creative applications will reshape the product lines and procedures to optimize Oak Add Ins.
Each winery with its unique grape sources, processing procedures and market focus needs to experiment with Oak Add Ins to find the combinations that works for them.
It is Nadalié's goal that Oak Add Ins will be an essential part of your journey in making better wines.

Nadalié USA
Tonnellerie Francaise
1401 Tubbs Lane – PO Box 798
Calistoga, CA 94515 – USA
Tel.: +1 (707) 9429301
Fax.: +1 (707) 9425037
E-mail: nadalie@napanet.net

Nadalié France
99, rue Lafont
Ludon – Médoc
33295 Blanquefort, Cedex – FRANCE
Tel.: +33 557 100 202
Fax.: +33 557 100 200
E-mail : info@nadalie.fr

Nadalié Chile
Santa Florencia 751, Parque Estrella del Sur
San Bernardo
Santiago – CHILE
Tel.: +56 2 871 6566
E-mail: info@nadalie.cl

Nadalié Italy
Via Palestro, 134
51015 Monummano Terme (PT) – ITALY
Tel.: +39 572954946
Fax.: +39 572521753
E-mail : nadalie@virgilio.it

Nadalié Australia
Medinie House Executive Offices
1 Northcote Terrace
Medindie, SA 5081 – AUTRALIA
Tel.: +61 883 429474
Fax.: +61 883 429568
E-mail: fwb@bigpond.com.au