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Influence of Yield and Maturation Index on Polysaccharides and Other Compounds of Grape Juice

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Wine producers may attempt to increase vine productivity, which usually decreases the quality. The quality of Cava (Spanish sparkling wine; Certified Brand of Origin in Spain) mainly depends on the composition of its colloids, which also determine foam quality. The yield (kg of grape/ha) and maturation index (ratio between soluble solids and titratable acidity) are two external factors that may alter grape characteristics, especially its composition. Twenty white grapes of the same variety (Parellada), but different yields (between 6000 and 17 000 kg/ha) were studied. By PCA, two grape groups were separated according to yield (<10 500 and >10 500 kg/ha). Yield and maturation index were not significantly correlated. Grapes obtained with yield >10 500 kg/ha had significantly higher content of soluble proteins and lower content of total polysaccharides and some polysaccharides fractions (M_r 62 000−48 000, M_r 28 000−24 000, and M_r 7000−5000) than the grapes of the low-yield group (<10 500 kg/ha). Thus, it may be interesting to monitor yield, below 10 500 kg/ha, in vines used to produce Cava.

KEYWORDS: Maturation index; grape; polysaccharide; yield

INTRODUCTION

Grape is the raw material of wine and Cava (Spanish sparkling wine; Certified Brand of Origin in Spain). The quality of grape is essential to the quality of the final product (foam capacity, flavor, and color). Grape quality depends on numerous factors such as climatic and soil conditions, cultural practices (pruning and rootstock), yield (kg of grape/ha), grade of ripening, variety, and sanitary conditions (*1*−*5*). Certain oenologists believe that excessive yields (kg of grape/ha) decrease quality. Some studies (*2*) show the effects of yield on grape composition, although the results disagree. Some authors do not find any association between yield and grape characteristics. Others relate high yields with a delay in maturation. The loss of quality of wines elaborated with high-yield grapes is due to a decrease in maturation. Moreover, we believe that yield can affect grape composition and thus its quality, because the Certified Brand of Origin (CBO) regulations establish a maximum yield based on kilograms of grape per hectare.

Grape composition affects the organoleptic characteristics of wine, including flavor (*6*, *7*), color (*8*, *9*), and foam capacity (*10*). The last property differentiates sparkling wines (such as Cava) from still wines. Several studies (*10*−*17*), denote the importance of polyphenols, polysaccharides, and soluble proteins on foam behavior. López-Barajas et al. (*15*) show that the must quality determines the foam capacity of base wine, and they indicate also that the maturation index (between 4 and 5.5) of grape berries increases the wine foam capacity. The same authors (*18*) suggest that three wine polysaccharide fractions (M_r 62 000−48 000, 13 000−11 000, and 3000−2000) enhance the foam properties.

The yield (kg of grape/ha) and maturation index (ratio between soluble solid content and titratable acidity) are independent of oenological practices, but they affect grape juice composition and vary according to climatic and cultural conditions, the ground, and the grape variety. We aimed to study the correlation between maturation index and yield and grape composition. The colloids that affect foam capacity, polysaccharides (total content and polysaccharides separated by molecular mass), soluble proteins, and polyphenols were examined. We used 20 white grapes of the same variety (Parellada), from several vineyards, cultivated in the Penedès region, each with a specific yield.

MATERIALS AND METHODS

Samples. Twenty white grapes from different fields of the Penedès region, to produce Penedès wines or Cava (both Certified Brands of Origin in Spain), were hand-harvested. All samples were the same variety (Parellada) to avoid varietal variability. Samples with various levels of yields (between 6000 kg/ha and 17 000 kg/ha) were collected. Berry samples were crushed. Cloudy juices were filtered and then

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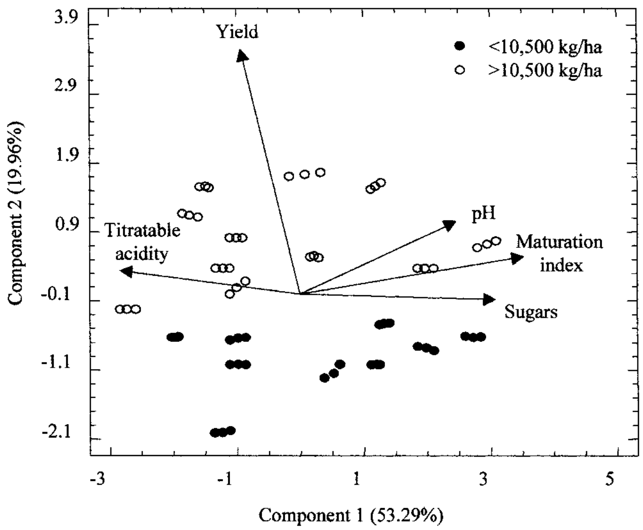

Figure 1. Principal component analysis applied to the main parameters determined.

centrifuged (2500*g* for 20 min at 10 °C). Clear juice volume was measured to calculate the juice output expressed as mL of grape juice/100 g of grape. The use output values were calculated to show the composition results in kg of grape, and also to establish the relationships between all the compounds with yield (kg of grape/ha). Samples were picked when they were at industrial maturity.

Analytical Methods. Oenological parameters of pH, soluble solid content, sugar content (g sugar/kg grape; obtained from °Brix, applying the OIV tables (*19*)), and titratable acidity (g tartaric acid/kg grape) were measured by OIV methods (*19*); and absorbance at 280 nm (polyphenolic content) was measured following the spectrophotometric method, with a 1-mm cell (*20*). Maturity index was calculated as the ratio between soluble solid (°Brix) and titratable acidity (g tartaric acid/L juice).

The concentration of soluble proteins was determined following the Bradford method (*21*). Results were expressed in mg of bovine serum albumin (BSA) per kg of grape.

The concentrations of organic acids, glucose, fructose, and glycerol were determined by ionic exchange/size exclusion HPLC−RID as described by López-Tamames et al. (*22*).

Polysaccharides were extracted from grape juice with ethanol, following the method of Segarra et al. (*23*). Total, neutral, and acid polysaccharide contents were determined by spectrophotometric methods. Starting with the same ethanol extract, polysaccharides of different molecular mass (M_r) were also separated by gel permeation chromatography (GPC) and quantified as described by López-Barajas et al. (*24*). Their molecular mass was identified with a calibration curve obtained with six poly(acrylic acid)s (Aldrich) of M_r values between 240 000 and 2000.

Statistical Methods. Using Statgraphics 7.0 (*25*), principal components analysis (PCA) was performed. Correlation regression was applied to the physical and chemical characteristics of all the samples, and analysis of variance (one-way ANOVA) was performed using the yield as an independent variable and all the parameters as dependent variables.

RESULTS AND DISCUSSION

The principal component analysis (PCA) was carried out with the main parameters studied: pH, sugars, titratable acidity, maturation index, and yield (kg of grape/ha) (**Figure 1**). Two groups with distinct yield were obtained. One of them, in the top zone of the figure, grouped the grapes from fields with yields higher than 10 500 kg/ha, and the lower zone grouped the samples with yields lower than 10 500 kg/ha. The analysis of variance (one-way ANOVA) shows the compositional differences between these two groups (<10 500 kg and >10 500 kg grape/ha) (**Table 1**). Both titratable acidity and pH were significantly higher in samples with higher yield (**Table 1**). However, the maturation index did not vary significantly. Thus, although the acidity was lower, the samples with lower yield were not riper than the other group. Lower yield did not imply a higher maturation index.

Table 1. Confidence Intervals of the Means of Significance Levels (*p*) of the Parameters Which Had Significant Differences between Low Yield (<10 500 kg/ha) and High Yield (>10 500 kg/ha)

parameter	significance level *p*	low yield (<10 500 kg/ha) (*n* = 9)	high yield (>10 500 kg/ha) (*n* = 11)
pH	0.036	3.52–3.63	3.64–3.74
sugars (g/kg)	ns	87.58–100.60	88.63–100.41
titratable acidity (g/kg)	0.045	2.13–2.51	2.51–2.85
maturation index	ns	4.39–5.36	4.37–5.25
absorbance 280 nm	ns	0.67–0.84	0.53–0.69
protein (mg/kg)	0.000	95.50–117.02	137.05–156.51
total polysaccharides (mg/kg)	0.026	473.40–555.17	389.75–463.68
acid polysaccharides (mg/kg)	ns	171.28–208.79	175.56–209.49
neutral polysaccharides (mg/kg)	0.001	296.47–351.98	209.08–259.29
M_r 206 000–193 000[a] (mg/kg)	0.012	3.05–10.33	12.45–19.03
M_r 62 000–48 000 (mg/kg)	0.001	192.58–231.32	132.38–167.43
M_r 28 000–24 000 (mg/kg)	0.001	31.74–41.17	16.64–25.17
M_r 7000–5000 (mg/kg)	0.001	16.84–20.32	11.24–14.38
M_r 3000–2000 (mg/kg)	ns	9.53–17.65	11.17–18.52
M_r <2000 (mg/kg)	ns	193.28–272.31	181.07–252.55
citric acid (g/kg)	0.016	0.15–0.38	0.009* – 0.09
tartaric acid (g/kg)	0.010	2.59–3.16	3.34–3.83
galacturonic acid (g/kg)	ns	0.15–0.19	0.18–0.20
malic acid (g/kg)	ns	1.16–1.47	1.28–1.57
succinic acid (g/kg)	ns	< 0.009*	< 0.009
lactic acid (g/kg)	ns	< 0.009	< 0.009
glucose (g/kg)	ns	58.94–64.67	54.61–59.78
fructose (g/kg)	ns	56.25–56.95	52.01–56.95

[a] M_r = Molecular mass; ns = not significant; * limit of quantitation.

Furthermore, ANOVA results showed that, like pH, protein content was higher in high-yield samples (>10 500 kg/ha) (**Table 1**). The correlation between pH and protein content has been reported elsewhere by Murphey et al. (*26*). The enzymatic activity that hydrolyzes structural proteins probably depended on pH.

Polysaccharide concentrations were lower in the samples obtained from a field with high yield. A large number of vineyards per hectare may result in thinner cellular walls and grape skin and lower polysaccharide content owing to the main distribution of nutrients in fruits. Total and neutral polysaccharides, and M_r 206 000−193 000, M_r 62 000−48 000, M_r 28 000−24 000, and M_r 7000−5000 polysaccharide fractions significantly differed between these two groups (**Table 1**). According to Jackson (*2*), the yield can directly affect grape composition by intrinsic changes. Thus, we established the distinct behavior of these two groups of samples [low yield (<10 500 kg of grape/ha) and high yield (>10 500 kg of grape/ha)] depending on their yield (**Table 2**). The correlation between polysaccharides and yield was confirmed in each group by regression analysis. In low-yield samples, this parameter presents negative correlation with total and neutral polysaccharide content. In samples from the other group, total, acid, and neutral polysaccharide content, and M_r 206 000−193 000, M_r 62 000−48 000, M_r 28 000−24 000, and M_r < 2000 polysaccharide fractions were significantly correlated with yield.

Moreover, in the PCA (**Figure 1**), the vector of maturation index was near that of sugars and opposite that of titratable acidity as confirmed by regression analysis. **Figure 2** shows the association between maturation index and other parameters. Most of these correlations were expected, because the maturation

Table 2. Correlation Coefficients (*r*) and Significance Levels (*p*) between Yield and Maturation Index and the Other Parameters Determined

	low yield (<10 500 kg/ha) ($n = 9$)				high yield (>10 500 kg/ha) ($n = 11$)			
	yield		MI[a]		yield		MI[a]	
parameter	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
pH	–0.430	<0.050	0.474	<0.050	–0.456	<0.010	0.618	<0.001
sugars	–0.466	<0.050	0.771	<0.001			0.750	<0.001
titratable acidity			–0.850	<0.001			–0.757	<0.001
absorbance 280 nm			–0.396	<0.050				
protein content			0.521	<0.010				
total polysaccharides	–0.645	<0.001	–0.451	<0.050	–0.555	<0.001		
acid polysaccharides			–0.780	<0.001	–0.544	<0.010		
neutral polysaccharides	–0.618	<0.001			–0.528	<0.010	0.398	<0.050
M_r 206 000–193 000					–0.366	<0.050		
M_r 62 000–48 000					–0.529	<0.010	0.554	<0.001
M_r 28 000–24 000					–0.401	<0.050	0.529	<0.010
M_r 3000–2000							0.550	<0.001
M_r <2000			–0.427	<0.050	–0.372	<0.050		
glucose			0.849	<0.001				
fructose			0.859	<0.001			0.371	<0.050
tartaric acid	0.593	<0.010						
galacturonic acid			–0.417	<0.050				
malic acid			–0.592	<0.010			–0.647	<0.001
succinic acid							0.450	<0.010
lactic acid	–0.431	<0.050						

[a] MI= Maturation index; M_r= molecular mass.

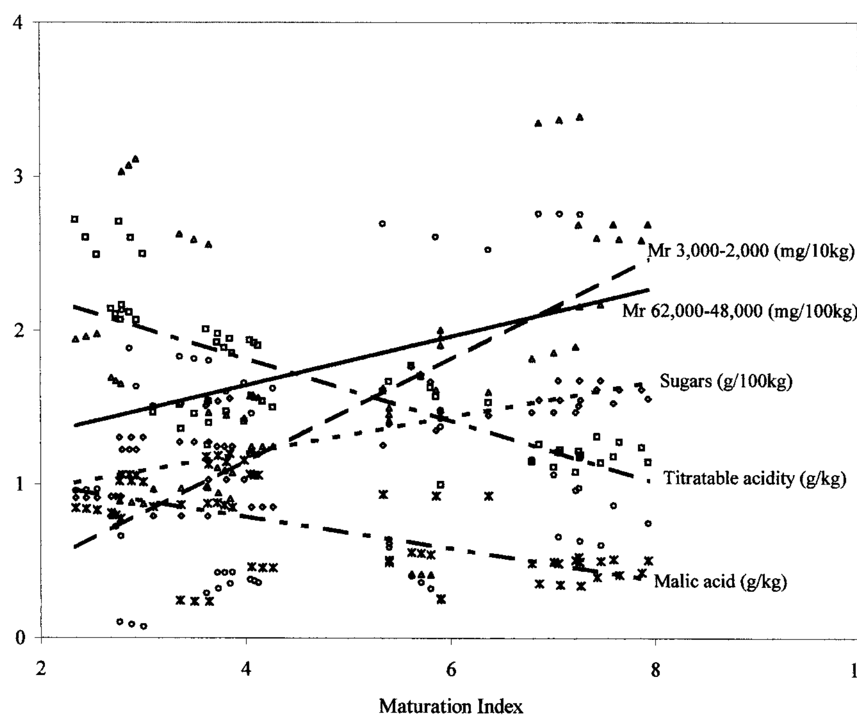

Figure 2. Regression analysis between the maturation index and sugars (g/kg) ($r = 0.7458$), titratable acidity (g tartaric acid/kg) ($r = –0.7728$), malic acid (g/kg) ($r = –0.6024$), and polysaccharides of M_r 62 000–48 000 (g/kg) ($r = 0.3629$), and polysaccharides of M_r 3000–2000 (g/kg) ($r = 0.4001$). All relations were significant ($p < 0.05$).

index is the ratio between sugars ($r = 0.7458$; $p < 0.001$) and titratable acidity ($r = -0.7728$; $p < 0.001$). Furthermore, the correlation with malic acid was negative ($r = -0.6024$; $p < 0.001$) at the highest maturation index. The same correlations were found when these two groups were studied separately (**Table 2**). In both groups, the maturation index was positively correlated with pH and sugars and negatively correlated with titratable acidity and malic acid.

Moreover (**Figure 2**), the maturation index was positively correlated with some polysaccharide fractions (M_r 62 000−48 000 and M_r 3000−2000). According to Flanzy (*27*), during the course of maturation cell-walls soften because pectins from the middle lamella are solubilized by endopolygalacturonase and pectinmethylesterase. That may account for the increase in polysaccharides fractions at higher maturation indices. When the two groups were studied separately, in the group of high yield (>10 500 kg/ha) the maturation index was also positively correlated with the polysaccharide fractions of M_r 62 000−48 000, M_r 28 000−24 000, and M_r 3000−2000 (**Table 2**). According to López-Barajas (*18*), the polysaccharide fractions M_r 62 000−48 000 and 3000−2000 affect foam properties. Despite the reduction in content of these polysaccharide fractions in the course of the wine production (mean decrease of 32%) (*18*), its presence in wines benefits the foam capacity.

In the group of low yield, the maturation index was positively correlated with protein content and negatively correlated with total and acid polysaccharide, and with the polisaccharide fraction of M_r <2000 (**Table 2**). Only in the group of low yield were polyphenols negatively correlated with maturation index (**Table 2**). Several factors may modify the polyphenol content in grapes, e. g., sun exposure, temperature, topography, and kind of pruning. The evolution of polyphenols during maturation is not uniform. Lamuela (*28*) established a negative correlation between polyphenols and maturation index in a Parellada variety. In the current study, polyphenols presented a positive correlation with polysaccharide content ($r = 0.5220$; $p < 0.01$).

When the vines produce more than 10 500 kg of grape/ha (high yield), the correlations between grape parameters (**Table 2**) and yield or maturation index differ from those of low-yield samples. This may be due to differences in physiology or metabolism of the plant when the production is over 10 500 kg of grape/ha.

In conclusion, the yield (kg of grape/ha) may not affect the maturation index value, but it could modify ripening, and furthermore, grape composition. Polysaccharide content was higher at lower yield. It would be useful to monitor the yield in vines destined to elaborate Cava. We could thus obtain grapes with optimal composition.

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