Foaming in Grape Juices of White Varieties

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The foam capacity of grape juice of white varieties (Macabeo, Xarel.lo, Parellada, and Chardonnay) was related to juice characteristics to achieve the quality of raw material of sparkling wine production or to avoid foam problems in fermentation deposits. Grape juices came from the Penedès Region and were obtained at industrial scale in three consecutive years of harvest. Juices with a maturation index [ratio between soluble solids (°Brix) and titratable acidity (grams of tartaric acid per liter of juice)] ranging from 4 to 5.5 had high foamability. Chardonnay juices had the best ripeness characteristics, and as result, these varietal juices showed the best foam capacity. It was also established that foaming properties also depend on several compounds (proteins, sugars, polyphenols, and alcohols) that can decrease the surface tension of the juices and, thus, increase foamability. Foam characteristics of grape juices could be predicted using equations based on simple enological parameters related to ripening and could be adjusted with practices such as SO_2 addition and acidity correction.

Keywords: *Foam capacity; grape juices; surface tension; maturation index; Mosalux*

INTRODUCTION

Knowledge of the foam capacity of varietal grape juices is of interest to winemakers, since it provides information at the starting point of wine and/or sparkling wine production. They can then choose the appropriate grape juice and thus control the raw material for the foaming of juices, and, as a result, the foam quality of final products, such as the sparkling wines, will be increased (Maujean et al., 1990). Moreover, the control of foam capacity could have interest for the opposite reason: foam is sometimes a problem in tanks and/or pipelines of winery industries.

According to Maujean et al. (1990), the greater the foam capacity of base wines, the better the quality of sparkling wine foam. For this reason, some authors analyzed the relationship between the composition of base wines and their foaming characteristics (Brissonnet and Maujean, 1991, 1993; Pueyo, 1995; Andrés-Lacueva et al., 1996). However, there is no reference to foam capacity of grape juices.

In the current study, the foaming properties of grape juice of white varieties from Penedès (Macabeo, Xarel.lo, Parellada, and Chardonnay), which were to be used in Penedès wine or cava (Spanish sparkling wine) (both Certified Brand of Origin in Spain), have been analyzed. The different grape juices were obtained on an industrial scale in three consecutive years of harvest (1993, 1994, and 1995). Foam capacity (measured with Mosalux) and physical and chemical parameters that can modify foam were determined to establish some relationships. These relations could allow the prediction and the control of juice foaming.

MATERIALS AND METHODS

Samples. The 24 samples were varietal (Macabeo, Xarel.lo, Parellada, and Chardonnay) free run juices from grapes grown in the Penedès region to produce Penedès wines or cava (both Certified Brand of Origin in Spain). Grape juices were obtained with pneumatic press (at 0.2 bar for 4 min), treated with SO_2 (ca. 80 mg/L of juice), and then racked by settling for 24 h. Samples were taken in three consecutive years of harvest (1993, 1994, and 1995; eight samples each year) and at two stages of grape juice treatement: after SO_2 addition (sulfited juices) and after raking (settled juices).

Analytical Methods. *Foam measurements* were performed using the Mosalux method (Maujean et al., 1990); according to the procedure of Poinsaut (1991), 2% ethanol was added to avoid the excess of foam that produces detection problems. Foamability (HM) and Bickerman coeffient (Σ) (Robillard et al., 1993) were obtained. HM is the maximum height (millimeters) reached by the foam after CO_2 injection through the glass frit, and Σ characterizes the bubble average lifetime (seconds) at constant height of foam collar during CO_2 injection.

Enological parameters such as soluble solid content (°Brix), pH, titratable acidity (grams of tartaric acid per liter), conductivity (millisiemens per centimeter), free, combined, and total sulfur concentrations (milligrams of SO_2 per liter), and absorbances at 280 and 420 nm were measured according to OIV methods. Maturity index was calculated as the ratio between soluble solid content and titratable acidity. Surface tension (millinewtons per meter) was measured at room temperature (22 ± 1 °C) with a Krüss GMBH K6 tensiometer (Weser, 1980); a correction factor [ratio between theoretical (72 mN/m) and experimental surface tension of double-distilled water] was used. The concentration of soluble proteins was determined following the Bradford method (1976); total, neutral, and acid polysaccharide contents were determined following the procedure of Segarra et al. (1995). Concentrations of organic acids, glucose, fructose, and glycerol were determined according to the method of López-Tamames et al. (1996). To determine the total polyphenol concentration, the Folin−Ciocalteu method was used (Singleton and Rossi, 1965), and flavonoid and nonflavonoid concentrations were measured according to the Kramling and Singleton (1969) method. Methanol analysis was performed by gas chromatography [direct injection of 0.2 μL of sample (containing 4-methyl-2-pentanol as internal standard) into a Seelcosteal Alcohol Carbowax 1500 (4 m × $^1/_8$ cm) column with a 15 cm precolumn; initial oven temperature was 45 °C for 1 min, raised at 2 °C/min to a final oven temperature of 70 °C for 45 min; FID detector and injector were both at 180 °C; nitrogen (20 mL/min) was the carrier gas].

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Table 1. Characteristics of Sulfited Grape Juices

	Macabeo			Xarel.lo			Parellada			Chardonnay		
	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995
HM (max ht, mm)	35	70	20	40	73	30	38	68	31	122	199	60
Σ (Bickerman coeff, s)	14	25	14	17	26	12	16	24	11	27	32	23
surface tension (mN/m)	69.9	69.1	65.0	69.7	66.8	61.4	68.8	68.1	62.3	64.9	61.4	62.5
maturation index	2.41	4.11	2.52	2.98	4.98	2.32	3.53	4.64	2.58	4.56	5.55	2.74
soluble solids (°Brix)	16.6	18.4	16.6	18.5	20.4	18.6	16.1	17.3	16.7	20.3	22.1	19.5
pH	3.17	3.18	3.25	3.34	3.17	3.17	3.36	3.22	3.21	3.94	3.62	3.14
titratable acidity (g of tartaric acid/L)	6.90	4.48	6.58	6.20	4.10	8.03	4.56	3.73	6.47	4.45	3.98	7.12
total sulfur dioxide (mg/L)	96	64	106	85	112	99	70	103	81	100	49	100
free sulfur dioxide (mg/L)	55	25	45	41	51	45	41	52	35	34	9	29
bound sulfur dioxide (mg/L)	41	39	62	45	62	54	29	51	46	66	40	71
OD 420 nm	78.8	104.5	44.8	120.6	89.0	53.3	248.0	119.0	67.8	125.8	198.3	69.5
OD 280 nm	4.86	6.56	4.58	4.84	5.26	5.03	6.22	5.99	4.93	7.39	10.45	6.97
conductivity (mS/cm)	2.40	2.30	2.72	2.71	2.05	2.98	2.29	2.33	2.68	3.59	2.63	2.33
proteins (mg/L)	33.17	48.16	21.07	41.04	53.40	27.13	43.10	41.44	36.06	65.92	117.76	29.66
total polysaccharides (mg/L)	745	955	1139	452	600	411	437	336	442	510	855	495
acid polysaccharides (mg/L)	463	583	342	203	249	184	208	149	126	143	422	123
neutral polysaccharides (mg/L)	282	372	797	249	351	246	230	188	317	367	433	372
total polyphenols (mg/L)	211.0	224.9	284.0	228.8	243.4	262.1	239.1	262.1	224.9	285.5	369.2	329.6
nonflavonoid phenols (mg/L)	123.4	141.0	162.4	145.5	128.5	169.7	143.2	132.6	174.4	194.9	213.8	217.2
flavonoid phenols (mg/L)	87.6	113.4	121.7	83.3	127.8	92.5	96.0	133.6	50.6	90.4	155.4	112.4
citric acid (g/L)	0.21	0.21	0.19	0.21	0.19	0.19	0.18	0.18	0.23	0.24	0.28	0.44
tartaric acid (g/L)	4.87	5.11	4.65	4.37	5.03	4.97	4.36	4.64	5.20	4.39	4.07	4.22
galacturonic acid (g/L)	0.25	0.21	0.20	0.15	0.22	0.26	0.31	0.26	0.16	0.48	0.26	0.51
malic acid (g/L)	2.43	0.63	2.99	2.27	0.76	3.10	1.40	0.55	2.90	2.22	1.15	4.66
glucose (g/L)	85.72	104.20	85.83	95.81	109.31	85.96	78.64	90.29	84.71	98.84	107.89	104.68
fructose (g/L)	75.60	94.74	79.58	88.04	100.89	79.01	78.42	88.00	77.98	98.87	111.00	102.72
glycerol (g/L)	0.10	0.10	0.33	01.2	0.15	0.27	0.25	0.15	0.34	0.36	0.42	0.83
methanol (mg/L)	29.0	36.5	27.7	25.1	22.5	26.7	29.2	22.9	19.2	62.1	70.9	61.3

All experiments were performed in duplicate, except the Mosalux procedure, which was performed in triplicate, and the surface tension measurements, which were repeated at least five times.

Statistical Procedures. Using the STATGRAPHICS 7.0 program, principal component analysis (PCA) was applied to foamability (HM), Bickerman coefficient (Σ), maturation index, and surface tension of all grape juices ($n = 24$); correlation analysis was applied to the physical and chemical characteristics of all grape juices ($n = 24$), and stepwise regression was performed on sulfited grape juices ($n = 12$). The last analysis was only carried out on sulfited grape juices because the objective of stepwise regression analysis was to obtain predictive equations which could be used in wineries: winemakers always add SO_2 to clarify the grape juices to produce wines or sparkling wines, and sometimes they buy the sulfited grape juices from other cellars, so the knowledge of their foam capacity is of the great interest of them.

RESULTS AND DISCUSSION

There was a positive relationship between foamability (HM) and Bickerman coeffient (Σ) ($r = 0.8212$; $p < 0.0001$): grape juices with high foamability had long bubble lifetime (Figure 1). However, surface tension was negatively correlated with HM ($r = -0.3979$; $p = 0.0007$): a low surface tension would facilitate foam production, although the correlation coefficient ($r < 0.5000$) showed the difficulty in obtaining an unequivocal relationship between the foaming power and the surface tension, as Kitabatake and Doi (1988) noted for protein solution.

A clear separation between the foam properties of juices of different years was observed (Figure 1): juices of 1994 harvest had the best foam behavior, whereas samples of 1995 showed the worst foam characteristics. The different maturity indices of grapes could explain why harvest date is a decisive factor in foaming: grape juices (from all varieties) of 1994 harvest had the highest ripeness characteristics (Table 1), and HM and Σ values depended on maturation index [$r = 0.7766$ ($p < 0.0001$) and $r = 0.8138$ ($p < 0.0001$), respectively]

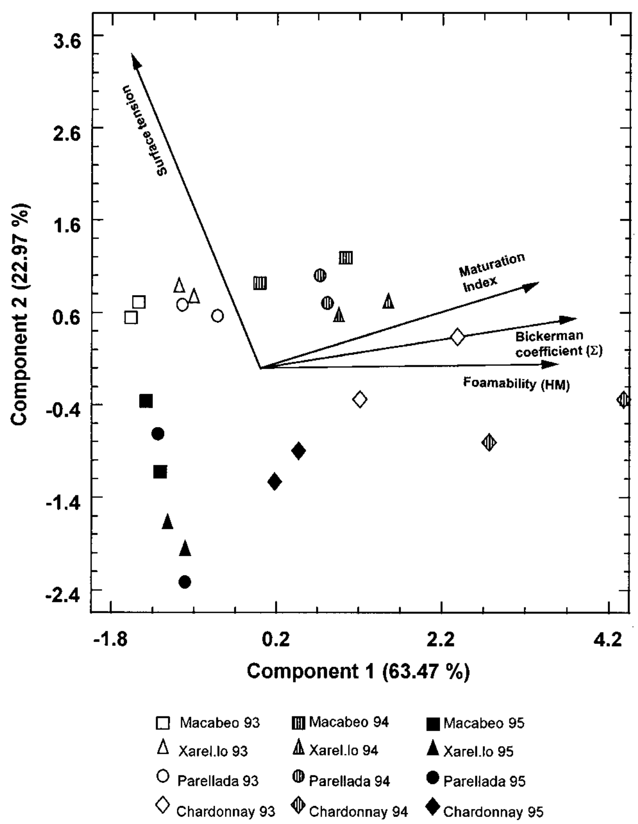

Figure 1. PCA for foam properties of grape juices.

(Figure 1). Furthermore, Chardonnay juices had the best ripeness characteristics, within years, so these grape juices showed the best foam properties (Figure 1).

Several relationships between HM and juice characteristics were obtained: soluble solid concentration ($r = 0.7539$; $p < 0.0001$), pH ($r = 0.7064$; $p < 0.0001$), maturity index ($r = 0.7766$; $p < 0.0001$), OD 280 ($r = 0.9170$; $p < 0.0001$), protein ($r = 0.9143$; $p < 0.0001$), total polyphenol ($r = 0.7629$; $p < 0.0001$), nonflavonoid phenol ($r = 0.5866$; $p < 0.0001$), flavonoid phenol ($r = 0.5218$; $p < 0.0001$), fructose ($r = 0.7293$; $p < 0.0001$), glucose ($r = 0.5840$; $p < 0.0001$), and methanol ($r = 0.7980$; $p < 0.0001$) concentrations. Some authors have cited the relationship between wine colloids (mainly proteins) and foam characteristics (Brissonnet and Maujean, 1993; Robillard, 1993; Pueyo et al., 1995; Andrés-Lacueva et al., 1996). This is the first time that foam behavior has been directly related to grape ripening.

The role in foaming of most of the juice components could be attributed to the fact that they affect the surface tension. The surface tension of the juices was significantly correlated with the concentrations of soluble solids ($r = -0.4073$; $p = 0.0005$), free SO_2 ($r = 0.3723$; $p = 0.0016$), proteins ($r = -0.2345$; $p = 0.0525$), total polyphenols ($r = -0.5097$; $p < 0.0001$), nonflavonoid phenols ($r = -0.7134$; $p < 0.0001$), malic acid ($r = -0.4090$; $p = 0.0005$), glycerol ($r = -0.6362$; $p < 0.0001$), and methanol ($r = -0.3783$; $p = 0.0013$) and also the value of titratable acidity ($r = -0.2503$; $p = 0.0380$). Compounds that decrease surface tension would stabilize the film, and the bubbles could be more resistant to coalescence. However, these significant regressions ($p < 0.05$) did not imply that the juice components were direct surfactants, since some correlation coefficients were <0.5. This could be because juice samples are more complex than samples analyzed by other authors who noted a relationship between surface tension and chemical compounds (Kitabatake and Doi, 1988; Dussaud et al., 1994; Tuinier, 1996).

Free sulfur dioxide and total acidity are negatively related with foamability (HM) [$r = -0.6515$ ($p < 0.001$) and $r = -0.5846$ ($p < 0.0001$), respectively]. Maujean (1990) noted that SO_2 is a denaturing agent of proteins, and Brissonet and Maujean (1993) observed that acidity has a marked effect on foam since it modifies protein solubility: if the juice acidity was low, protein hydrophobicity would be high, the surface activity could be increased, and then juice would have a higher foamability. As SO_2 and tartaric acid are two usual grape juice additives, if their levels were modified, foam capacity could be influenced.

Stepwise analysis (Figure 2) shows that the foam parameters (HM and Σ) of sulfited grape juices can be predicted (with a probability >89.97%), without using the Mosalux, by the following polynomial equations: $HM = -126.80 + 1.04[\text{combined } SO_2] + 16.85(\text{OD } 280) + 1.07[\text{proteins}] - 44.40[\text{glycerol}]$ and $\Sigma = 4.76 + 1.68(\text{maturation index}) - 5.48[\text{tartaric acid}] + 0.34[\text{glucose}]$. The parameters of these predictive equations are provided by routine determinations in wine cellars. The application of these equations could make information available to winemakers as to which grape juices can be selected for sparkling wine production.

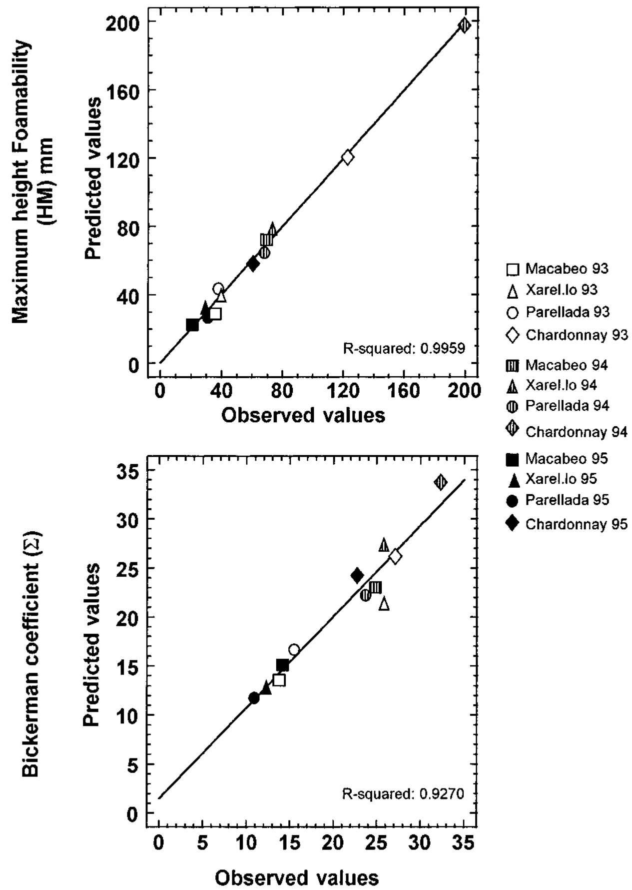

Figure 2. Plots of predicted values obtained by stepwise regression for foam characteristics of sulfited grape musts.

CONCLUSIONS

Juices of white grapes (Macabeo, Xarel.lo, Parellada, and Chardonnay) used to produce cava (Spanish sparkling wine) with a maturation index ranging between 4 and 5.5 have the best foam characteristics. Chardonnay shows the most appropriate maturity conditions (within years), so varietal juices of Chardonnay have the best foaming properties. The foam behavior of grape juices is related with the concentration of several compounds, which may also affect surface tension. Foam quality can be adjusted with enological practices such as SO_2 addition and acidity correction. Foamability can be predicted at the starting point of wine and/or sparkling wine production using equations based on simple enological parameters related to ripening.

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