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Characteristics of Sparkling Base Wines Affecting Foam Behavior

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Forty-four base wines, from the three white varieties for the production of sparkling wine most used in the Apellation (Certified Brand of Origin) *cava*, were analyzed to evaluate their foam capacity. The wines were from three different harvests and produced in eight different wineries. Foaming properties, determined with Mosalux, were affected by variety, harvest, and winemaking process. In foaming, there were two independent phenomena, foam formation and time stability, which were affected by different compounds: Proteins and acids produced more foam in wines, while low acidity, amino acids, and proteins had a negative correlation with time stability. The must extraction by crusher, static settling, and prefermentative fining with bentonite (dose < 20 g/100 L) were the winery factors that were most favorable for the foaming properties of the wines studied. Xarel.lo was the variety with the best foaming properties.

Keywords: *Foaming properties; sparkling base wines; winemaking process; variety; harvest*

INTRODUCTION

The foam is the first characteristic that is observed by the consumer after the wine is poured into the glass. However, it is not a factor that determines the selection of the base wine to produce the highest quality sparkling wines, since, to date, there has not been any standard method to measure these foaming properties. There are not many studies devoted to foam formation in vinification products or to the use of automatic method to measure foam (Edwards et al., 1982; Molan et al., 1982; Maujean et al., 1988; Gomerieux, 1989; Comelles et al., 1991), so it is difficult to compare results with those of other research groups. The enology industry can now use the Mosalux method (Maujean et al., 1990), although some of the measurements obtained with this could have some problems with reproducibility (Robillard et al., 1993). However, the studies use Mosalux, (Maujean et al., 1990; Hardy, 1990; Brissonnet and Maujean, 1991; Marchal et al., 1993; Malvy et al., 1994; Robillard et al., 1993) because it provides normalized foam measures.

The wines destined to produce the highest quality sparkling wines should be chosen not only for their flavor but also for their capacity to produce foam. The foam that is produced in the second fermentation is related to the chemical composition of the wines chosen for the *coupage* (Gomerieux, 1989; Brissonnet and Maujean, 1991; Marchal et al., 1993; Malvy et al., 1994).

It is important to determine how the variations in chemical composition of the wines produced by the variety, harvest, or technological process affect the foaming properties. Some studies report the influence of extraction system (Hardy, 1990), fining agent (Maujean et al., 1990; Brissonnet and Maujean, 1991), or filtration (Robillard et al., 1993; Viaux et al., 1994).

In previous studies, only one or two wines were usually analyzed (Gomerieux, 1989; Brissonnet and Maujean, 1991, 1993; Malvy et al., 1994; Robillard et al., 1993; Viaux et al., 1994) to avoid the difficulty in interpreting the complex results obtained from different wines. These studies were performed at the laboratory scale, so they only attempted to identify the compounds that enhance the foam (Brissonet and Maujean, 1991), which are usually proteic and glucidic colloids.

Since the chemical composition of wine is decisive for the foam quality, we believe that it is important to consider not only the variety but also the harvest and the winemaking process, which may change the wine composition (de la Presa-Owens et al., 1995). Moreover, it is important to evaluate the process at the industrial scale, since the results may be different from those obtained at the laboratory scale.

In this study, 44 varietal wines (Macabeo, Xarel.lo, and Parellada), from three consecutive harvests (1990−1992) and made by eight wineries were analyzed. We attempt to evaluate the importance of the variables: variety, harvest, and *modus operandi* of the winery in the wine components that affect the foam properties. With the Mosalux method and analyzing 50 parameters, we have established which factors could affect the foam capacity.

MATERIALS AND METHODS

Samples. Forty-four white wines from Macabeo (n = 13), Xarel.lo (n = 11), and Parellada (n = 20) varieties were collected during three consecutive harvests [1990 (n = 9), 1991 (n = 11), and 1992 (n = 24)], from eight different wineries [winery A (n = 8), winery B (n = 16), winery C (n = 6), winery D (n = 2), winery E (n = 2), winery F (n = 3), winery G (n = 6), and winery H (n = 1)] (Table 1). All wines are base wine for the production of *cava* certified by the Spanish DOC (Denominación de Origen Controlada, Certified Brand of Origin). The characteristics of these wines are in Table 2.

Wines were obtained from free run juice, with a crusher or a pneumatic press at ≤0.2 atm of pressure [crusher (n = 11) and pneumatic press (n = 33)]. Musts were treated with SO_2 (ca. 70 mg/L) and racked before fermentation by settling for 24 h (n = 26) or by filtration with a rotary-vacuum filter (n = 18). The fermentation took place in stainless steel tanks (100 000 L) at 15−

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Table 1. Characteristics and Codes of the Samples Included in This Study[a]

	wineries								harvest			variety			must extraction		racking		fining agent	
code sample	A	B	C	D	E	F	G	H	90	91	92	M	X	P	p	c	s	f	b	m
B90M		*							*			*			*		*		*	
B90X		*							*				*		*		*		*	
B90P		*							*					*	*		*		*	
C90M			*						*			*			*			*		*
C90X			*						*				*		*			*		*
C90P			*						*					*	*			*		*
F90P						*			*					*	*		*		*	
G90P							*		*					*		*	*		*	
G90M							*		*			*				*	*		*	
B91P1		*								*				*	*		*		*	
B91P2		*								*				*	*			*	*	
B91X1		*								*			*		*		*		*	
B91P3		*								*				*	*		*		*	
B91M1		*								*		*			*		*		*	
B91M2		*								*		*			*		*		*	
B91X2		*								*			*		*		*		*	
D91P				*						*				*		*		*		*
E91P					*					*				*		*	*			*
G91M							*			*		*				*	*		*	
G91P							*			*				*		*	*		*	
A92M1	*										*	*			*			*		*
A92M2	*										*	*			*			*		*
A92X1	*										*		*		*			*		*
A92X2	*										*		*		*			*		*
A92X3	*										*		*		*			*		*
A92P1	*										*			*	*			*		*
A92P2	*										*			*	*			*		*
A92P3	*										*			*	*			*		*
B92M1		*									*	*			*		*		*	
B92M2		*									*	*			*		*		*	
B92X1		*									*		*		*		*		*	
B92X2		*									*		*		*		*		*	
B92P1		*									*			*	*		*		*	
B92P2		*									*			*	*		*		*	
C92M			*								*	*			*			*		*
C92P			*								*			*	*			*		*
C92X			*								*		*		*			*		*
D92X				*							*		*			*		*		*
E92P					*						*			*		*	*			*
F92M						*					*	*			*		*		*	
F92P						*					*			*	*		*		*	
G92P1							*				*			*		*	*		*	
G92P2							*				*			*		*	*		*	
H92M								*			*	*				*		*		*
total $n = 44$	8	16	6	2	2	3	6	1	9	11	24	13	11	20	33	11	26	18	25	19

[a] Wineries, A–H; harvest, 90 (1990), 91 (1991), and 92 (1992); variety, M (Macabeo), X (Xarel.lo), and P (Parellada); must extraction, p (pneumatic press) and c (crusher); racking, s (settling) and f (filtration with rotary vacuum); fining agent, b (bentonite) and m (Microcel).

Table 2. 95% Confidence Intervals for Mean of Wine Characteristics

	$n = 44$
alcohol content (%, v/v)	9.99–10.48
titratable acidity (g/L of tartaric acid)	3.99–4.36
volatile acidity (g/L of acetic acid)	0.20–0.24
pH	2.98–3.04
total SO_2 (mg/L)	63.2–73.3
absorbance 280 (nm × 1000)	454–491
420	69–88
520	25–39
tartaric acid (g/L)	2.91–3.51
glucose (g/L)	0.43–0.57
fructose (g/L)	0.58–0.81
malic acid (g/L)	1.02–1.58
lactic acid (g/L)	0.45–1.05
total polysaccharides (mg of galactose/L)	285–321

18 °C, after the addition of selected winery yeast strains (*Saccharomyces cerevisiae*) and a fining agent, bentonite ($n = 25$), doses at 10–20 g/100 L, or a bentonite association ($n = 19$) (Microcel, whose composition was determined by us: bentonite, 45%; caseinate, 50%; and microcrystalline cellulose, 5%), doses at 80–100 g/100 L. Wine racking was carried out as soon as fermentation was completed, and the wines were cold stabilized. Samples were kept in the freezer (−18 °C) until analysis.

Analytical Methods. The following parameters were determined on all 44 wines. All experiments were performed in duplicate except for Mosalux procedures that were performed in quatriplicate.

Measurement of Foaming Properties. All foam measurements were carried out using the Mosalux procedure (Maujean et al., 1990). Three parameters were measured. (1) HM = maximum height reached by the foam after carbon dioxide injection through the glass frit, expressed in mm; this could represent the foamability, the wine's ability to foam. (2) HS = foam stability height during carbon dioxide injection, expressed in mm; this could represent the foam stability, the wine's ability to produce stable foam or persistence of foam collar. (3) TS = foam stability time, until all bubbles collapse, when CO_2 injection is interrupted, expressed in s; this could represent the foam stability time, once effervescence has decreased. Mosalux procedures were performed in quatriplicate. The average of the coefficients of variation for HM, HS, and TS was <4%, 7%, and 9%, respectively.

Conventional Parameters. Parameters such as alcohol content, titratable acidity, volatile acidity, total SO_2, and pH were measured according to Office International de la Vigne et du Vin (OIV) methods.

Absorbance. Absorbances at 280 and at 420 and 520 nm were determined in a 1 and 10 mm cells, respectively, with a Hewlett-Packard 8452A diode array spectrophotometer.

Organic Acids, Glucose, Fructose, and Glycerol. These were determined by ionic exchange/ion exclusion HPLC and detected by refractive index, according to López-Tamames et al. (1996).

Soluble Proteins. The Bradford method was used directly on the sample (Bradford, 1976).

Free Amino Acids and Ethanolamine. These were determined by HPLC after derivatization of the wine samples with PITC (phenyl isothiocyanate) according to Puig-Deu and Buxaderas (1994).

Volatile Compounds. Wine samples containing 4-methyl-2-pentanol as internal standard were directly injected on a Perkin-Elmer Sigma 3B gas chromatograph equipped with flame ionization detector (FID) and a packed Seelcosteal Alcohol, Carbowax 1500 (4 m × $^{1}/_{8}$ cm) column with a 15 m precolumn. Oven temperature was kept at 45 °C for 1 min, programmed to 80 °C at 2 °C/min, and then kept at 80 °C for 45 min. Injector and detector temperatures were 180 °C; 2.0 μL was injected. Nitrogen was used as the carrier gas at 18 mL/min. Higher (fusel) alcohols and other volatile components such as acetaldehyde, methyl acetate, ethyl acetate, and diacetaldehyde were identified by retention times relative to the internal standard and quantified by the same procedure.

Total Polysaccharide Content. The phenol–sulfuric acid method of Segarra et al. (1995) was used. This method determines neutral and acid polysaccharides.

Statistical Treatment. Taking into account the types of samples, we can distinguish two different kinds of variables. First, the six different *qualitative variables*: winery variable (A–H), harvest variable (1990–1992), variety variable (Macabeo, Xarel.lo, and Parellada), extraction must system variable (crusher and pneumatic press), racking variable (settling and filtration), and fining agent variable (bentonite and Microcel). Second, we can distinguish the *quantitative variables*, which are the 50 determinations and the 3 parameters of foam obtained with Mosalux (HM, HS, and TS).

We used the STATGRAPHICS 7.0. method to carry out principal components analysis, biplot (PCA), with HM, HS, and TS from the 44 base wines; analysis of variance (one-way ANOVA), considering as *qualitative independent variables* harvest, variety, winery, extraction must system, racking, and fining agent, and as *quantitative dependent variables* the HM, HS, and TS; and correlation analysis among the parameters HM, HS, and TS and the 50 chemical determinations. Moreover, the chemical parameters correlated with the foam were treated by (one-way ANOVA) considering as qualitative variables variety and harvest.

RESULTS AND DISCUSSION

To study the differences among the foaming properties in wines, we carried out a screening with PCA, biplot (Figure 1). Foamability (HM), persistence of the foam collar (HS), and stability time (TS) are represented as vectors: HM and HS are highly correlated ($p < 0.001$)

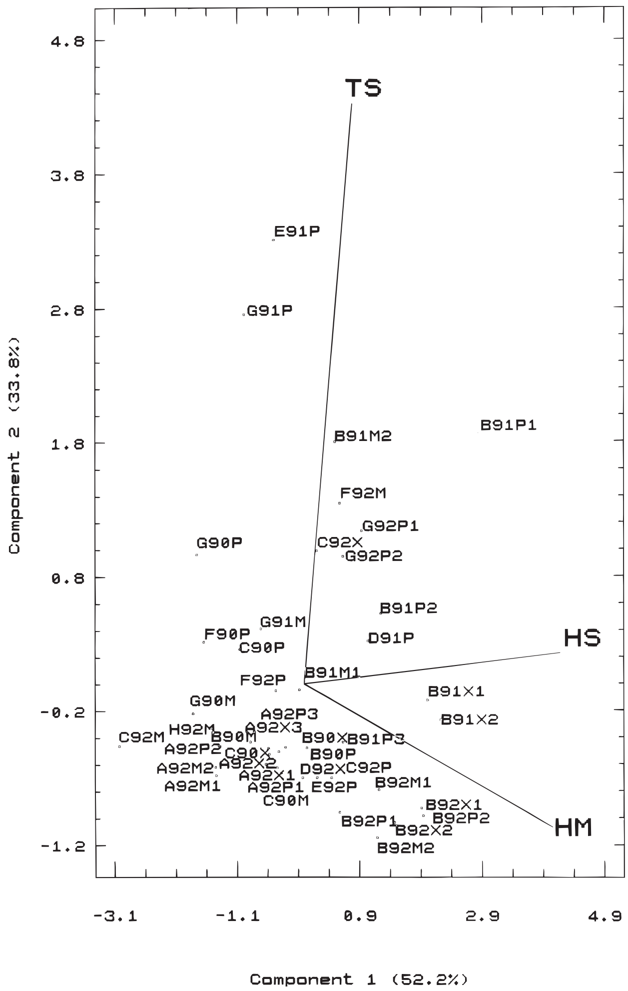

Figure 1. Sample distribution according to the PCA (biplot) considering HM, HS, and TS: HM, foamability HS, permanence of the foam collar; TS, stability time; %, percent of the variance justified by each component; A–H, wineries; 90 (1990), 91 (1991), and 92 (1992), harvest; M (Macabeo), X (Xarel.lo), and P (Parellada), varieties.

but not with TS. So, the samples with high HM would have persistent collar (HS), but they are not necessarily stable over time (TS). The same relation between HM and TS was noted by Maujean et al. (1990), although they did not find any relationship between HM and HS. Xarel.lo wines showed the best foaming properties (Figure 1 and Table 4) (higher values of HS). This would indicate that Xarel.lo wines would produce the sparkling wines with the best foam. When the variable harvest was considered, the wines from 1991 had higher TS than the wines from the other two harvests (1990 and 1992). Wine from cellar B also had the best foam, which would indicate that the winemaking process is decisive for the foam capacity of a wine.

Table 3 shows the significant correlation of each qualitative variable with the foaming properties of the 44 wines by ANOVA. Table 4 shows the 95% confidence interval for HM, HS, and TS, considering the qualitative variables that were significant by ANOVA. Harvest conditioned TS ($p \leq 0.0001$) (Table 3); in 1991, was the highest of the three harvests studied (Table 4). Variety affects HS ($p < 0.005$) (Table 3). Xarel.lo wines had higher HS than the other varietal wines (Table 4). The HS overlap of the 95% confidence interval between Xarel.lo and Parellada may be due to the fact that Xarel.lo wines were not always 100% monovarietal.

Table 3. Significance Levels (p) Related to the One-Way Analysis of Variance[a]

qualitative variable	HM	HS	TS
	quantitative variable		
harvest	0.0685	0.0557	**0.0001**
variety	0.6156	**0.0081**	0.0952
winery	**0.0002**	0.0596	**0.0451**
must extration	0.1097	0.2768	**0.0106**
racking	0.0513	**0.0311**	**0.0281**
fining agent	**0.0151**	**0.0133**	0.1102

[a] HM, foamability; HS, permanence of the foam collar; TS, time stability. The significance levels ($p < 0.05$) are indicated in bold.

Macabeo is the first to be harvested and then Xarel.lo and finally Parellada. Some Xarel.lo wines contained <20% of Parellada. One explanation for this varietal difference could be the nitrogen content. Many studies correlate proteins with foam capacity (Gomerieux, 1989; Brissonnet and Maujean, 1991, 1993; Malvy et al., 1994). Xarel.lo wines contained more soluble proteins ($p < 0.0001$) and proline ($p < 0.05$) (Table 6) which could produce the best permanent collar foam. Similar results were obtained by Pueyo (1994), when these three varieties were compared.

The variable winery conditioned HM and TS (Table 3), since there are many factors such as must extraction system, settling, and fining agent that are different in each winery. Winery B produces the wines with best HM and HS (Figure 1). One reason could be that this winery uses the lowest amount of bentonite (dose < 20 g/100 L) and static settling which have a significant correlation with HM and HS (Tables 3 and 4). The extraction of the must system could condition the stability time values (Table 3). The TS values in wines that were obtained from the crusher were better than those obtain by a pneumatic press (Table 4). Winery B uses a pneumatic press, which may explain the low TS (Figure 1), although these wines had the best HM and TS. HS and TS also depend on settling, static or dynamic, in both cases $p < 0.05$ (Table 3); the wines from static settling had the highest values of persistence of the collar foam (HS) and stability time (TS) (Table 4). Vacuum dynamic filtration removes hydrophobic substances, which would help to stabilize the gas/liquid interface (Hudales and Stein, 1990) and consequently could stabilize the foam. Finally, the other cellar factor considered, the fining agent added before fermentation, influences the HM and HS ($p < 0.05$) (Table 3).

In wine made with low bentonite doses, HM and HS were higher (Table 4) than those wines made with Microcel, which is composed of caseinate (50%), bentonite (45%), and microcrystalline cellulose (5%). The amount of bentonite added is higher when Microcel is used, due to the high doses used, 80−100 g/100 L compared with 10−20 g/100 L when bentonite is added directly. High levels of bentonite adsorb many compounds such as proteins and polysaccharides that can affect the foam quality of the wine (Maujean et al., 1990; Brissonnet and Maujean, 1991).

Table 5 shows the correlations (r) between the foam characteristics (HM, HS, and TS) and the compounds analyzed, together with the level of significance (p). The correlation coefficients observed were <0.558. So, with this correlation study, we can only show which components may influence the foam properties but not establish equations between the variables. The correlation coefficients only identify the sign of the correlation between the compounds analyzed and the foam measures.

HM is positively correlated with the alcohol content, titratable acidity, malic acid, fructose, proteins, and glutamine (Table 5): Wines with a greater content of these compunds should have higher foam. On the other hand, wines with more glucose or lactic acid have the least foam. The influence of proteins in foaming has been described previously, in standard solutions as well as in wine and beer (Nakai, 1983; Shimizu et al., 1983; Kato et al., 1985; Kinsella and Whitehead, 1989; Patel and Kilara, 1990; Maeda et al., 1991; Brissonet and Maujean, 1991, 1993; Malvy, 1994).

Titratable acidity and malic acid show good correlation with HM (Table 5). Pueyo et al. (1995) observed the same correlation. However, the development of the malolactic fermentation in the Penedès region is not the normal practice, and in our wines, from the Macabeo, Xarel.lo, and Parellada varieties, it is not desirable for foaming properties, since titratable acidity decreases and lactic acid increases (Tables 2 and 5).

Curiously, alcohol content is associated with HM and HS. In previous studies, Molan et al. (1982) and Blade and Boulton (1988) observed the opposite, which could

Table 4. Mean Values and 95% Confidence Intervals for Means That Were Significantly Different among HM, HS, and TS According to Harvest, Variety, Must Extraction, Racking, and Fining Agent[a]

	quantitative variable					
	HM (mm)		HS (mm)		TS (s)	
qualitative variable	$\bar{x}$ (mm)	95% CI	$\bar{x}$ (mm)	95% CI	$\bar{x}$ (s)	95% CI
harvest						
1990 ($n = 9$)					83	(27−139)
1991 ($n = 11$)	NS		NS		268	(217−318)
1992 ($n = 24$)					69	(35−104)
variety						
Macabeo ($n = 13$)			25	(23−27)		
Xarel.lo ($n = 11$)	NS		31	(29−33)	NS	
Parellada ($n = 20$)			28	(27−30)		
must extraction						
pneumatic press ($n = 33$)	NS		NS		91	(57−123)
crusher ($n = 11$)					215	(157−272)
racking						
static ($n = 26$)	NS		30	(28−31)	161	(123−199)
dynamic ($n = 18$)			26	(25−28)	65	(19−111)
fining agent						
bentonite ($n = 25$)	175	(155−194)	30	(28−31)	NS	
microcel ($n = 19$)	122	(94−144)	26	(24−28)		

[a] NS, not significant; HM, foamability; HS, permanence of the foam collar; TS, stability time.

Table 5. Correlation Coefficients (*r*) and Significance Levels (*p*) between Parameters That Determine Foam Capacity (HM, HS, and TS) and the Compounds Determined[a]

determination accomplished	HM *r*	HM *p*	HS *r*	HS *p*	TS *r*	TS *p*
alcohol content	0.470	**0.0019**	0.460	**0.0025**	−0.231	0.1471
titratable acidity	0.459	**0.0025**	0.252	0.1126	0.190	0.5766
volatile acidity	−0.158	0.3233	0.013	0.9379	0.028	0.8632
pH	0.010	0.9489	0.218	0.1726	−0.320	**0.0416**
total SO_2	−0.076	0.6222	−0.026	0.8675	−0.088	0.5702
absorbance 280 (nm)	−0.196	0.2034	−0.195	0.2036	−0.271	0.0748
420	0.026	0.8659	0.072	0.6413	−0.286	0.0601
520	−0.066	0.6724	−0.178	0.2486	−0.346	**0.0216**
citric acid	−0.236	0.1231	−0.049	0.7542	−0.382	**0.0105**
tartaric acid	0.160	0.3012	0.158	0.3049	−0.086	0.5771
galacturonic acid	−0.092	0.5534	−0.221	0.1488	−0.417	**0.0048**
malic acid	0.457	**0.0018**	0.210	0.1713	−0.197	0.1989
glucose	−0.313	**0.0383**	−0.064	0.6797	−0.097	0.5294
fructose	0.558	**0.0001**	0.316	**0.0367**	−0.171	0.2676
succinic	−0.173	0.2628	−0.112	0.4703	0.103	0.5040
lactic acid	−0.427	**0.0054**	−0.163	0.3084	−0.178	0.2661
glycerol	0.166	0.2999	0.184	0.2506	0.064	0.6921
total polysaccharides	−0.162	0.2946	0.054	0.7271	−0.078	0.6132
proteins	0.321	**0.0338**	0.107	0.4901	−0.509	**0.0004**
ethanolamine	0.306	0.0524	0.310	**0.0486**	0.095	0.5565
Asp	−0.181	0.2586	−0.107	0.5046	−0.283	0.0728
Hyp	−0.021	0.8979	0.037	0.8188	−0.392	**0.0112**
Glu	−0.023	0.8843	0.077	0.6310	−0.495	**0.0010**
Ser	−0.164	0.3070	−0.100	0.5361	−0.425	**0.0057**
Asn	0.269	0.0894	0.223	0.1605	−0.381	**0.0140**
Gly	0.072	0.6569	0.245	0.1234	−0.391	**0.0114**
Gln	0.369	**0.0177**	0.207	0.1932	−0.361	**0.0205**
Thr	−0.111	0.4895	0.218	0.1709	−0.212	0.1842
Ala	−0.055	0.7307	0.175	0.2752	−0.369	**0.0175**
His	0.107	0.5063	0.164	0.3063	−0.227	0.1535
Pro	0.244	0.1242	0.341	**0.0290**	−0.219	0.1698
GABA	0.024	0.8815	0.058	0.7192	−0.381	**0.0141**
Arg	0.165	0.3025	0.065	0.6859	−0.359	**0.0211**
Tyr	−0.021	0.8985	0.082	0.6118	−0.531	**0.0004**
Val	−0.283	0.0728	−0.261	0.0998	−0.497	**0.0009**
Met	−0.055	0.7352	−0.219	0.1691	−0.344	**0.0277**
Ile	−0.066	0.6818	−0.079	0.6215	−0.306	0.0519
Leu	−0.274	0.0834	−0.272	0.0855	−0.335	**0.0324**
Phe	−0.140	0.3815	0.059	0.7145	−0.294	0.0622
Orn	0.146	0.3621	0.184	0.2506	−0.309	**0.0496**
Trp	−0.021	0.8990	0.060	0.7099	−0.370	**0.0172**
Lys	−0.222	0.1626	−0.179	0.2638	−0.364	**0.0192**
acetaldehyde	0.285	0.0713	−0.122	0.4478	−0.345	**0.0270**
methyl acetate	−0.152	0.3436	−0.120	0.4537	−0.295	0.0611
ethyl acetate	0.225	0.1572	0.126	0.4313	−0.505	**0.0008**
diacetaldehyde	−0.132	0.4096	−0.200	0.2091	−0.360	**0.0209**
methanol	−0.135	0.9006	−0.136	0.3974	−0.271	0.0869
propanol	0.011	0.9440	0.247	0.1189	−0.227	0.1546
isobutyl alcohol	−0.303	0.0542	−0.198	0.2117	−0.284	0.0719
isoamylic alcohols	0.030	0.8546	−0.028	0.8636	−0.426	**0.0055**

[a] *r*, correlation coefficient; *p*, significance level; HM, foamability; HS, permanence of the foam collar; TS, stability time. The significance levels ($p < 0.05$) are indicated in bold.

be due to the ethanol solvent capacity (Comelles, 1991). This has no influence in our wines, which have a very similar ethanol content (9.99−10.48) (95% CI) (Table 2), so the tensioactivity capacity of ethanol could be greater than its solvent properties. Xarel.lo wines not only show the highest protein content but are also the richest in malic acid, proline, and alcohol content ($p < 0.05$) (Table 6). So, of the varieties studied, Xarel.lo shows the best foaming properties.

HS is correlated with HM (Figure 1), so some of the compounds that favor one also favor the other, such as alcohol content and fructose (Table 5). Moreover, HS is correlated with proline and ethanolamine. The effect of the proline on foaming properties was observed in wine by Gomerieux (1989). Proteins and amino acids are negatively correlated with TS (Table 5). When PCA was performed, TS was not correlated with HM or with HS (Figure 1).

Other chemical parameters of the 44 wines were also negatively correlated with TS, such as pH, A520, citric acid, galacturonic acid, acetaldehyde, ethyl acetate, diacetal, and isoamylic alcohols. Wines with the lowest galacturonic content had better TS (Table 5): Higher levels of galacturonic acid would be produced by greater pectolytic activity and thus increased pectine hydrolysis. Polysaccharides favor foaming capacity (Gomerieux, 1989; Brissonnet and Maujean, 1991), so pectic hydrolysis increases galacturonic acid and reduces the foam capacity. However, in this study, only total polysaccharides were considered, which showed a significant relation with HM following a reciprocal model.

Volatile compounds determined (acetaldehyde, ethyl

Table 6. 95% Confidence Intervals for Means of the Compounds That Contribute to Foam Properties and Are Significantly Different, According to Variety or Harvest (p < 0.05)

	Macabeo (n = 13)	Xarel.lo (n = 11)	Parellada (n = 20)
alcohol content (%, v/v)	9.74−10.54	10.12−11.09	9.59−10.24
malic acid (g/L)	1.04−1.68	1.39−2.09	0.76−1.28
proteins (mg/L albumin)	5.8−8.0	8.9−11.5	5.6−7.4
ethanolamine (mg/L)	11.9−17.8	15.3−21.8	17.5−22.2
Pro (mg/L)	218.8−324.7	349.4−469.1	284.5−370.0
	1990 (n = 9)	1991 (n = 11)	1992 (n = 24)
pH	2.84−2.98	2.95−3.06	3.08−3.15
absorbance 520 (nm × 1000)	16−44	10−35	34−51
Hyp (mg/L)	3.4−6.4	3.5−5.9	5.6−7.1
Glu (mg/L)	16.6−31.5	13.3−24.4	25.2−32.6
Ser (mg/L)	4.8−9.9	3.2−7.1	8.1−10.6
Asn (mg/L)	4.9−15.1	4.9−12.5	14.2−19.3
Gly (mg/L)	2.9−7.9	4.1−7.8	7.5−10.0
Ala (mg/L)	7.2−25.2	7.6−21.1	23.4−32.3
GABA (mg/L)	0.0−21.5	0.0−17.5	28.5−41.4
Arg (mg/L)	0.0−52.9	0.0−38.3	45.4−81.3
Tyr (mg/L)	9.9−15.4	7.5−11.6	13.3−16.0
Val (mg/L)	5.1−8.4	3.2−5.7	6.6−8.3
Met (mg/L)	0.7−8.2	1.2−6.8	6.5−10.3
Leu (mg/L)	16.4−25.9	9.8−16.9	14.7−19.4
Trp (mg/L)	1.2−3.9	2.8−4.8	3.9−5.2
Lys (mg/L)	11.1−18.5	7.7−13.2	12.7−16.4
acetaldehyde (g/L)	7.55−13.95	10.33−15.13	14.37−17.57
ethyl acetate (g/L)	18.37−35.90	22.57−35.70	41.01−49.74
diacetaldehyde (g/L)	0.70−4.88	1.03−4.17	4.84−6.93

acetate, diacetaldehyde, and isoamylic alcohols) also show a negative relationship with TS (Table 5).

CONCLUSIONS

Forty-four base wines to make sparkling wine (*cava*) were analyzed by Mosalux. The HM and HS in these wines were correlated with each other but not with TS. So there are two different phenomena in foaming: formation and time stability; each property can be affected by different compounds. Proteins and glutamine help foam formation, although they do not favor stability time. Acid substances are also important for foaming (HM and HS). For this reason, malolactic fermentation in our wines, which have low acidity, does not seem to be positive.

In foam stability time, not only are nitrogen compounds negative but also galacturonic acid, from the hydrolysis of colloids, and volatile compounds. Of the varieties most generally used in the production of base wines to be converted into *cava* in the Penedès region, Xarel.lo shows the best foaming properties.

Treatments involving the drastic removal of nitrogen compounds should be avoided in white vinification. Wines with the best foaming properties from the Penedès region DOC (Certified Brand of Origin) for the production of *cava* are obtained with the following conditions: must obtained from a crusher, static settling, and clarification with bentonite (<20 g/100 L).

However, we take into consideration that foaming is very complex and depends on an equilibrium of many compounds rather than on any absolute value. The correlation between foaming properties and compounds may be valid only for a limited range of concentrations. Moreover, the different variables that affect wine composition (variety, harvest, and winery) could modify the results.

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