Sensory Study of the Effect of Fluorescent Light on a Sparkling Wine and Its Base Wine

N. M. DOZON[1] and A. C. NOBLE[2]*

The effect of exposure to fluorescent light on sparkling wine and the still wine from which it was made was studied in green and flint (clear) bottles. Although the green glass afforded some protection against the light, a significant difference in aroma was produced after 18 hours and 31.1 hours of exposure, respectively, in the still and the sparkling wines. In flint glass, significant differences in aroma were produced after 3.4 hours and 3.3 hours, respectively, in the still and the sparkling wines. Because of the extreme light sensitivity of white wine bottled in clear glass, serious consideration should be paid to using uv-screening agents in clear glass or to switching to green or brown glass. The lightstruck aroma (goûts de lumière) produced on exposure of still and sparkling wines to fluorescent light was characterized by descriptive analysis. With increased time of exposure, a decrease in citrus aroma intensity occurred, while the intensity of cooked cabbage, corn nuts, wet dog/wet wool, and soy/marmite aromas increased.

KEY WORDS: aroma, fluorescent light, sparkling wine

An off-flavor is produced when still white wines or sparkling wines are exposed to sunlight or to fluorescent light. The latter, commonly used in stores, emits a light which spectrum includes ultraviolet and visible wavelengths. This off-flavor is usually called lightstruck or sunstruck flavor or 'goûts de lumiére'.

Possible origins of this problem have been investigated by Maujean (8). A decrease in the quality of the glass since 1970 results in less protection of the wine against the light. Moreover, the new marketing techniques, *i.e.*, white wines sold in flint bottles and/or exposed to the light in retail store displays, contribute also to the increase in this phenomenon.

This sensitivity to light, which is not unique to wine, has been extensively studied in milk (12) and in beer (4,7). Kuroiwa *et al.* (7) and Gunst and Verzele (4) demonstrated that 'lightstruck' flavor in beer is due to the formation of 3-methyl-2-butene-1-thiol by photolysis of *iso*-alpha-acids in the presence of sulfur-containing amino acids. Wainwright (13) reported that methionine and cysteine solutions containing flavins are decomposed in sunlight to give H_2S and other compounds detected during the analysis for mercaptans.

Upon exposure to fluorescent light, a disgorged Champagne wine, stored in clear bottles under a nitogen atmosphere, exhibited a decrease in redox potential with the appearance of sulfur compounds (5,9). However, exposing solutions containing sulfur amino acids to light did not result in any degradation without the presence of photosensitizers, such as riboflavin (10). Riboflavin, once activated by light at wavelengths of 370 and 440 nm, is able to accept two protons from methionine. Methional, the product of the reaction, is in turn photodegraded through RetroMichael reactions to form dimethylsulfide (DMS), dimethyldisulfide (DMDS), methanethiol, and hydrogen sulfide (10). Some preventive additives like cupric cations, sodium dithionite, and tannins were investigated (11). The cupric cations only delay the appearance of the defect. The results for sodium dithionite and tannins were more encouraging, but their efficiency and effect on sensory properties still need to be examined. Recent research by Heelis *et al.* (6) suggested that ascorbic acid could also be used because of its interaction with riboflavin.

The purpose of this study was to characterize 'lightstruck flavor' in still and sparkling wines using sensory evaluation techniques. In the first part, duo-trio difference tests were used to determine the time of exposure needed to produce a significant effect on wine aroma. In the second part, the 'lightstruck' aroma in light-exposed still and sparkling wines was characterized by descriptive analysis.

Materials and Methods

Wines: Wines were provided by Domaine Chandon Winery (Yountville, CA). Two percent Pinot meunier, 10% Pinot blanc, 25% Chardonnay, and 63% Pinot noir from the 1984 (14%) and 1986 (86%) vintage were blended and prepared by standard wine practices to make the still wine (cuvée). The sparkling wine was made by standard wine procedure (méthode champenoise) from the same still wine.

These wines were bottled in two different types of glass: flint (clear), #WP70 (Owens, IL) and champagne green, #WP106 (Owens, IL).

The white base wine used to make the standard references for the descriptive analysis was a 90% Chardonnay wine.

Chemical analyses were performed on all the wines, using methods described by Amerine *et al.* (2), and Maujean *et al.* (9) for determination of the redox potential. The compositional data are shown in Table 1.

[1]Graduate Student, E.N.S.B.A.N.A., Campus Universitaire, 21100 DIJON, France; [2]Professor of Enology, Departement of Viticulture and Enology, University of California, Davis, CA 95616-5270.

*Author to whom correspondence should be addressed.

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Table 1: Chemical composition of the wines.

	Base wine[a]	Still wine	Sparkling wine
pH	3.18	2.80	3.00
Titratable acidity (g/L)	9.35	9.3	9
Ethanol (v/v %)	10.3	10.3	12.2
Free SO_2 (mg/L)	11.6	14	18
Total SO_2 (mg/L)	77.9	84	95
Reducing sugar (g/L)	0	<0.1	9

[a]Used for preparation of reference standards.

Exposure to light: Wines were exposed to light in a room maintained at 21°C ± 1°C. Bottles were placed 35 cm from two 40-watt fluorescent light bulbs (VITA-LITE, Duro-test, USA). The spectral distribution of these fluorescent bulbs, which includes ultraviolet and visible wavelengths, is similar to that of sunlight. The unexposed wines were covered with aluminum foil and placed 35 cm from the light source, to provide same increase in temperature (to 25°C ± 1°C) which occurred during the exposure. At the end of the exposure interval, the bottles were covered with aluminum foil to avoid extra exposure to the light before and during the sensory tests.

Sensory evaluation. *Determination of minimum time of exposure to produce a detectable difference in aroma:* Sixteen judges (9 male and 7 female, ranging in age from 23 to 38 years) were selected on the basis of their availability and motivation. They were initially trained using the same methods as those utilized in formal testings.

Experimental procedures: Duo-trio difference tests as described by Amerine *et al.* (3) were used to evaluate the aroma of the wines, in a modification of the method of the ascending limits (1). At each session, four duo-trio sets were presented, each of which contained one labeled reference wine and two coded samples. In each coded pair, one wine had been exposed to light, the other one had not. The reference wine was the unexposed wine. Wines were presented in an ascending order of the increased time of exposure. Judges were given no information about the nature of the treatment being studied or the experimental design (ascending limits).

To standardize the evolution of carbon dioxide, for both still and sparkling wines, 20-mL samples were served in clear, tulip-shaped, wine glasses and covered 15 minutes later with plastic petri dishes. All samples were evaluated at least five minutes after being covered and before 30 minutes had elapsed. All evaluations were conducted at 23°C ± 1°C in isolated booths under red light. Only one type of wine in one type of bottle was investigated in each session: *i.e.*, still or sparkling wines, in green or flint bottles.

Descriptive analysis of 'lightstruck' flavor: *Wines:* Still and sparkling wines in flint bottles were exposed for 0, 24, and 72 hours under the conditions de-

Table 2. Composition of the reference standards.

Term	Composition of reference standards
Cooked cabbage	10 mL brine of cooked cabbage in 10 mL base wine (brine obtained by cooking 2 cabbage leaves in 200 mL water for 1 h).
Wet dog/wet wool	Wet dog hair and a piece of wet wool.
Citrus	5 mL of treated lemon juice in 15 mL of base wine (juice obtained by macerating lemon skin in 50 mL of freshly squeezed lemon juice and 50 mL of base wine for 20 min).
Corn nuts	6 mL of toasted corn extract in 14 mL base wine (extract made by soaking 5 g of toasted corn (Cornnuts, Inc., Oakland, CA) in 100 mL base wine for 2 h).
Soy/marmite	0.1 g of marmite and 0.4 g of soy sauce in 20 mL of base wine.
Honey	17 g of honey and 2 g of molasses in 20 mL of base wine.

Table 3. Analyses of variance with degrees of freedom (df), F-Ratios, error mean square (MSE) and least significative difference (LSD) of the six sensory terms.

		F-ratios					
Source of variations	df	Cooked cabbage	Wet dog/ Wet wool	Citrus	Corn nuts	Soy/ Marmite	Honey
Reps (R)	2	0.11	0.27	0.58	1.91	1.03	2.75
Judges (J)	10	7.38***	7.21***	6.14***	7.90***	4.00***	7.80***
Wines (W)	5	5.86***	8.97***	7.34***	5.04***	3.55**	4.19**
R × J	20	1.05	0.77	1.42	1.57	1.11	0.94
R × W	10	1.05	1.72	0.77	0.6	1.77	1.09
J × W	50	1.72*	2.58***	1.43	2.64***	1.72*	1.69
MSE	10	1.93	1.16	1.48	1.78	1.16	1.30
LSD	2	0.68	0.52	0.59	0.65	0.53	0.56

*, **, *** indicate significance at $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively.

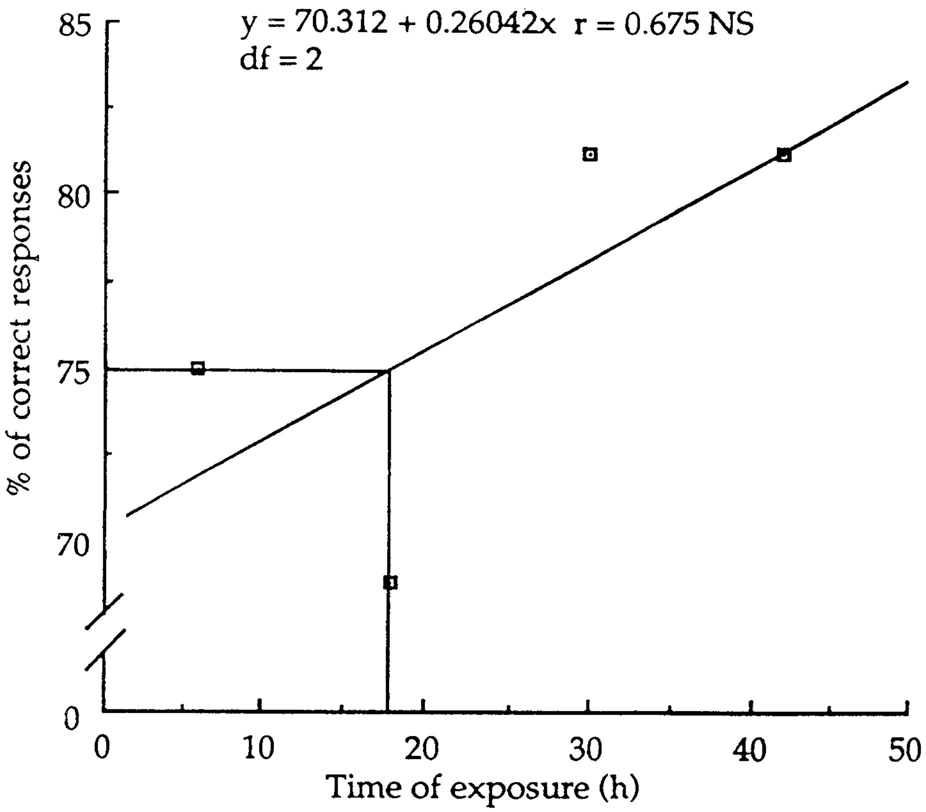

Fig. 1. Effect of light exposure on still wine in green glass. Percentage of judges selecting light-exposed wine *vs.* time of exposure (n = 16).

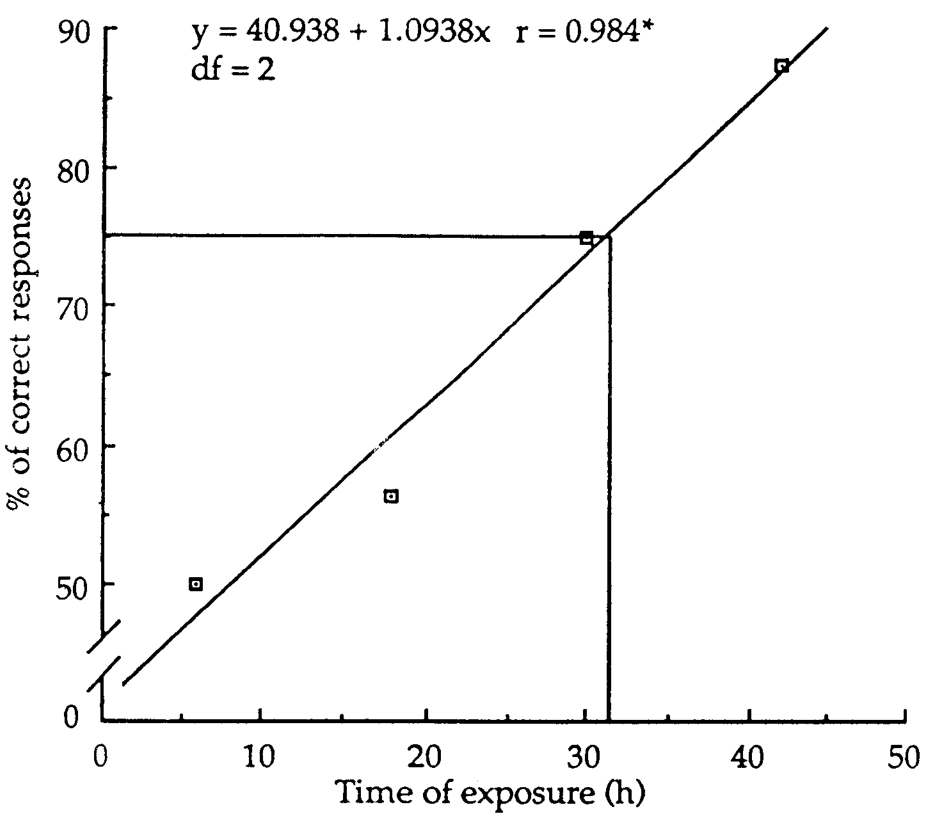

Fig. 2. Effect of light exposure on sparkling wine in green glass. Percentage of judges selecting light-exposed wine *vs.* time of exposure (n = 16).

scribed above.

Panel: Fourteen judges who had participated in the previous panel, eight males and six females ranging in age from 26 to 38 years, volunteered to participate in this study.

Selection of descriptive terms and preparation of the corresponding standards: In the first two sessions, two wine samples were presented with various standards corresponding to the terms selected by the judges during the difference tests. In a third session, four wine samples (still and sparkling wines exposed for 0 and 72 h) were presented with 22 reference standards. Upon discussion, six reference standards were selected to describe the wine samples. The list of terms and the composition of the corresponding standards are presented in Table 2 .

Experimental procedures: The wines were poured and presented as described above. At each training or formal session, judges smelled the reference standards before entering the booths and, if necessary, before evaluating each attribute. Judges smelled distilled water between the ratings of different attributes. The intensity of each attribute was evaluated across the wines on an unstructured, 10-cm scale anchored at the ends by the terms 'low' and 'high'. Each judge evaluated the terms in a different randomized order every day. The six coded samples were served in a randomized order.

Data analysis: All statistical analyses were performed using Statistical Analysis System (SAS). Individual analyses of variance (AOV) were run on each attribute. If a significant difference appeared among the wines for an attribute, a Fisher's LSD test was calculated (at $p < 0.05$). The correlation matrix from the mean ratings of the six wines for the six attributes was then analyzed by principal component analysis (PCA), using no rotation.

Results and Discussion

Sensory evaluation: *Determination of minimum time of exposure to produce a detectable difference aroma:* In Figures 1 and 2, the results from difference tests for still and sparkling wines in green bottles are shown. The percentage of correct responses is plotted versus the time of exposure. By convention (3), the threshold level of response is selected as that at which 75% correct responses are observed. For tests in which p = , this corresponds to 50% above chance. In this case, the level of light exposure at which the 'threshold' is reached is 18 hours for still wine and 31.1 hours for sparkling wine.

As shown in Figures 3 and 4, the exposure times to produce a significant difference in aroma were 3.4 and 3.3 hours for still and sparkling wines, respectively.

From these results, it can be readily observed that a detectable change in aroma with minimal exposure to fluorescent light is produced in both still and sparkling wines in flint bottles. Although the green glass does not afford unlimited protection against light damage, it increases the minimum time of exposure before a detectable difference is observed six- and 10-fold, respectively, for the still and the sparkling wines.

Descriptive analysis of 'lightstruck' flavor: The analysis of variance (AOV) for each of the six terms rated by the 14 judges showed that all terms varied significantly across wines; however, significant judge × rep (J × R) and judge × wine (J × W) interactions occurred for several terms. These interactions reflect the inconsistency of the judges in their use of the terms. Upon examination of the data, three judges were removed from subsequent analysis because of their inconsistency among replications.

In Table 3, the AOV for the remaining 11 judges are summarized. Although the J × W interactions are reduced, they are still significant for five terms. This may have occurred because of insufficient training or more probably the 'lightstruck' aroma characteristics were not well enough defined by the reference standards. Further more, Maujean *et al.* (10) suggested that several compounds are involved in this defect but in very low levels, thus different judges might have different threshold levels for a same compound.

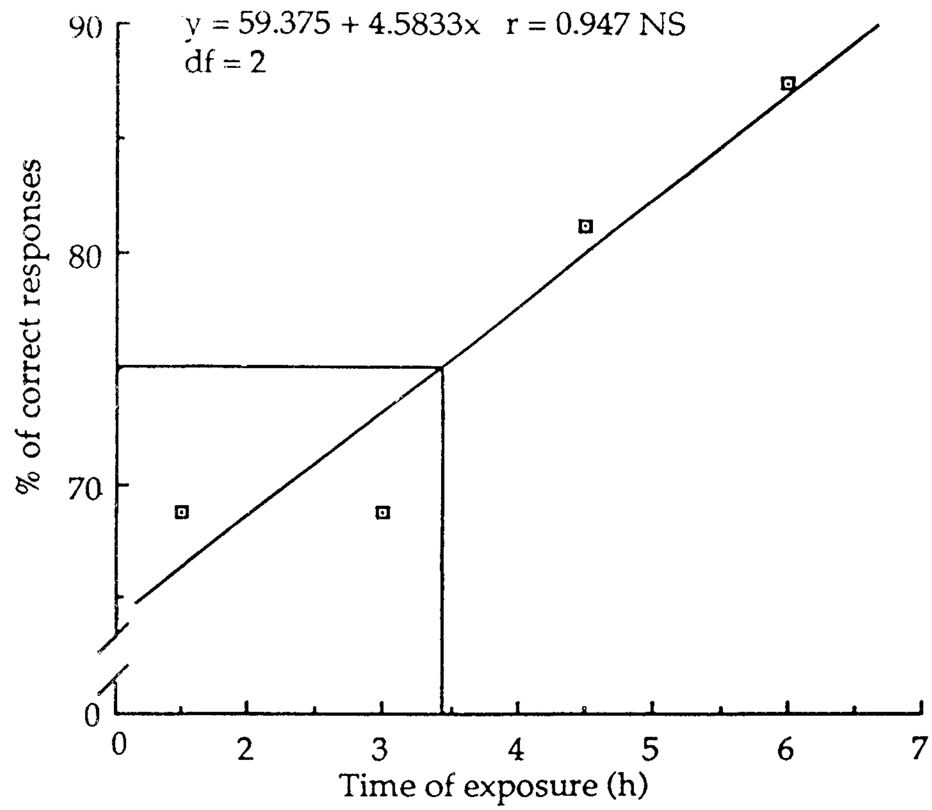

Fig. 3. Effect of light exposure on still wine in flint glass. Percentage of judges selecting light-exposed wine *vs.* time of exposure (n = 16).

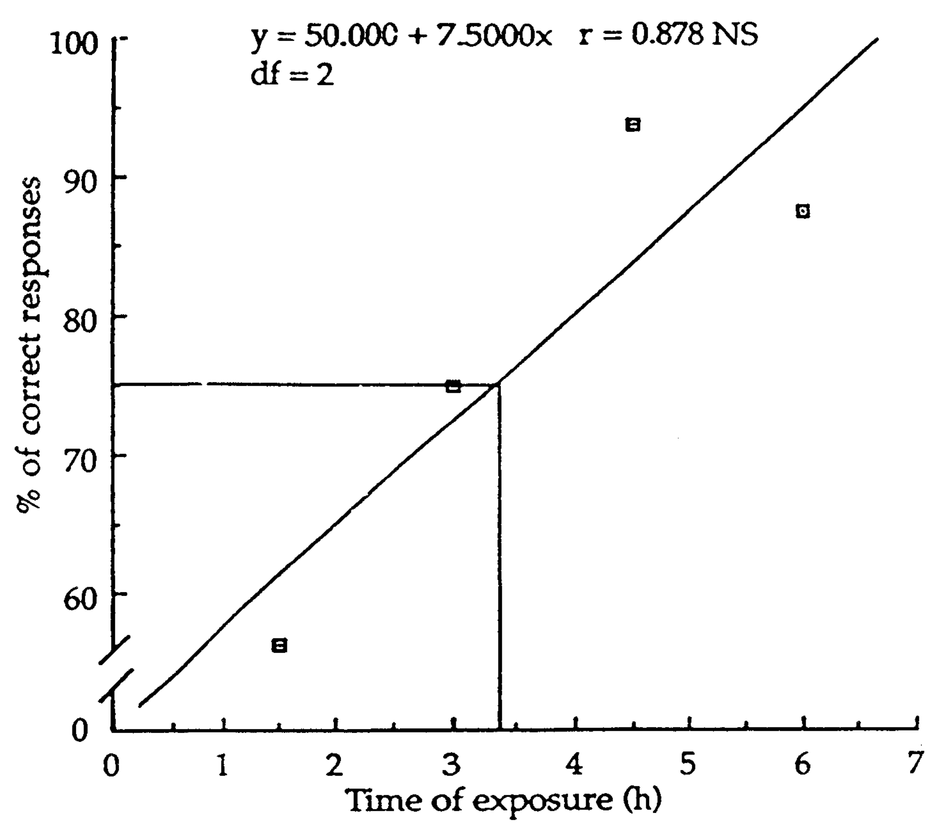

Fig. 4. Effect of light exposure on sparkling wine in flint glass. Percentage of judges selecting light-exposed wine *vs.* time of exposure (n = 16).

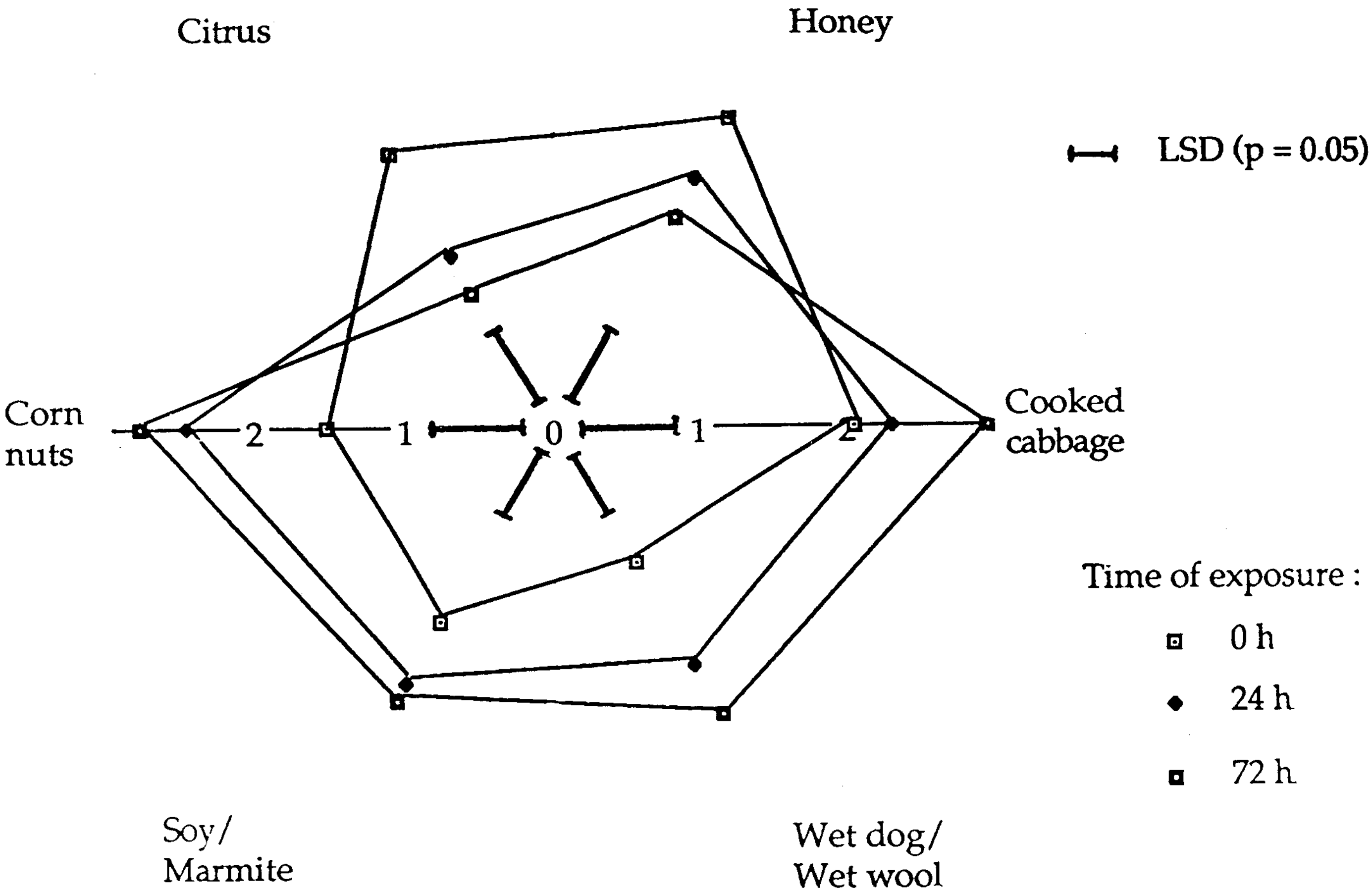

Fig. 5. Descriptive analysis of still wines. Mean intensity ratings and least significant differences (LSD) for wines exposed to light for 1, 24, and 72 hours (n = 11 judges × 3 reps).

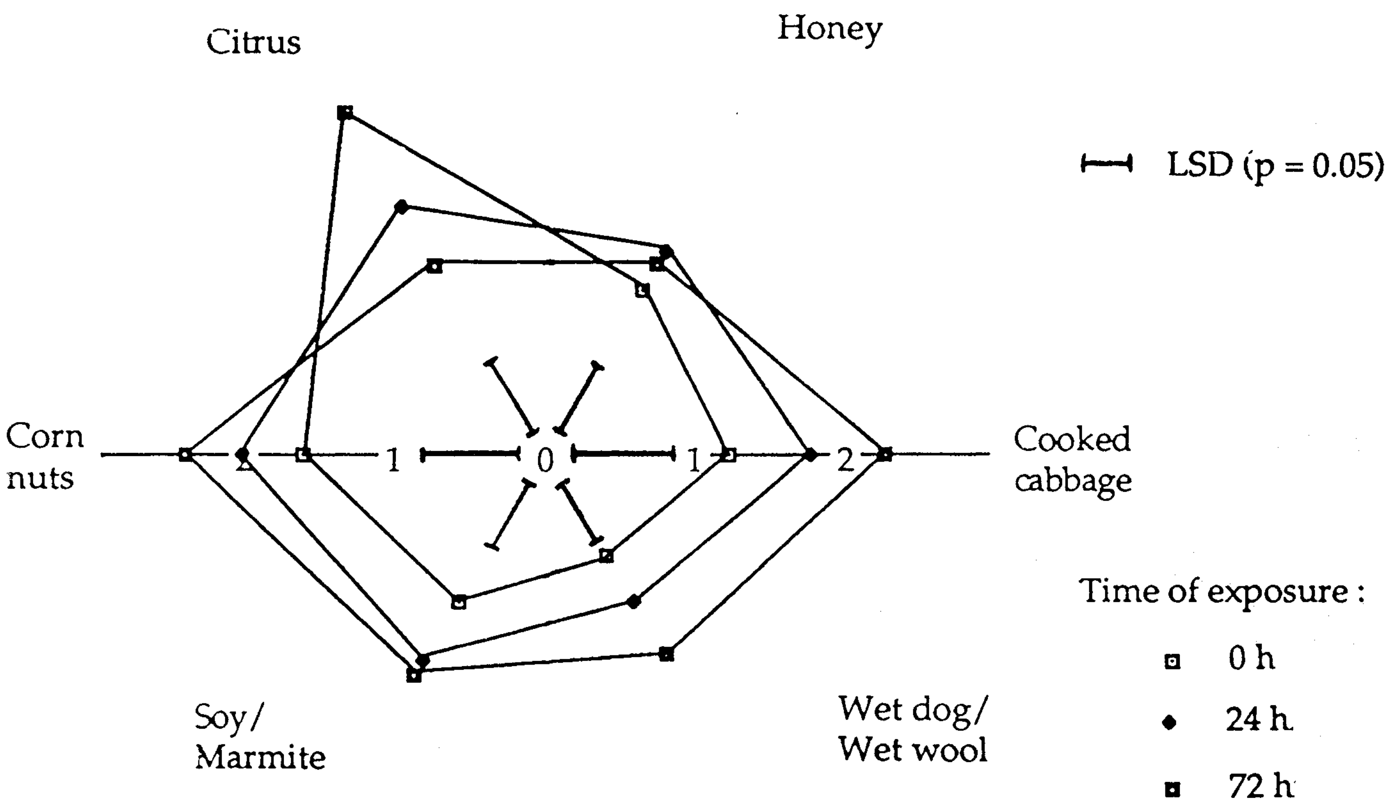

Fig. 6. Descriptive analysis of sparkling wines. Mean intensity ratings and least significant differences (LSD) for wines exposed to light for 1, 24, and 72 hours (n = 11 judges × 3 reps).

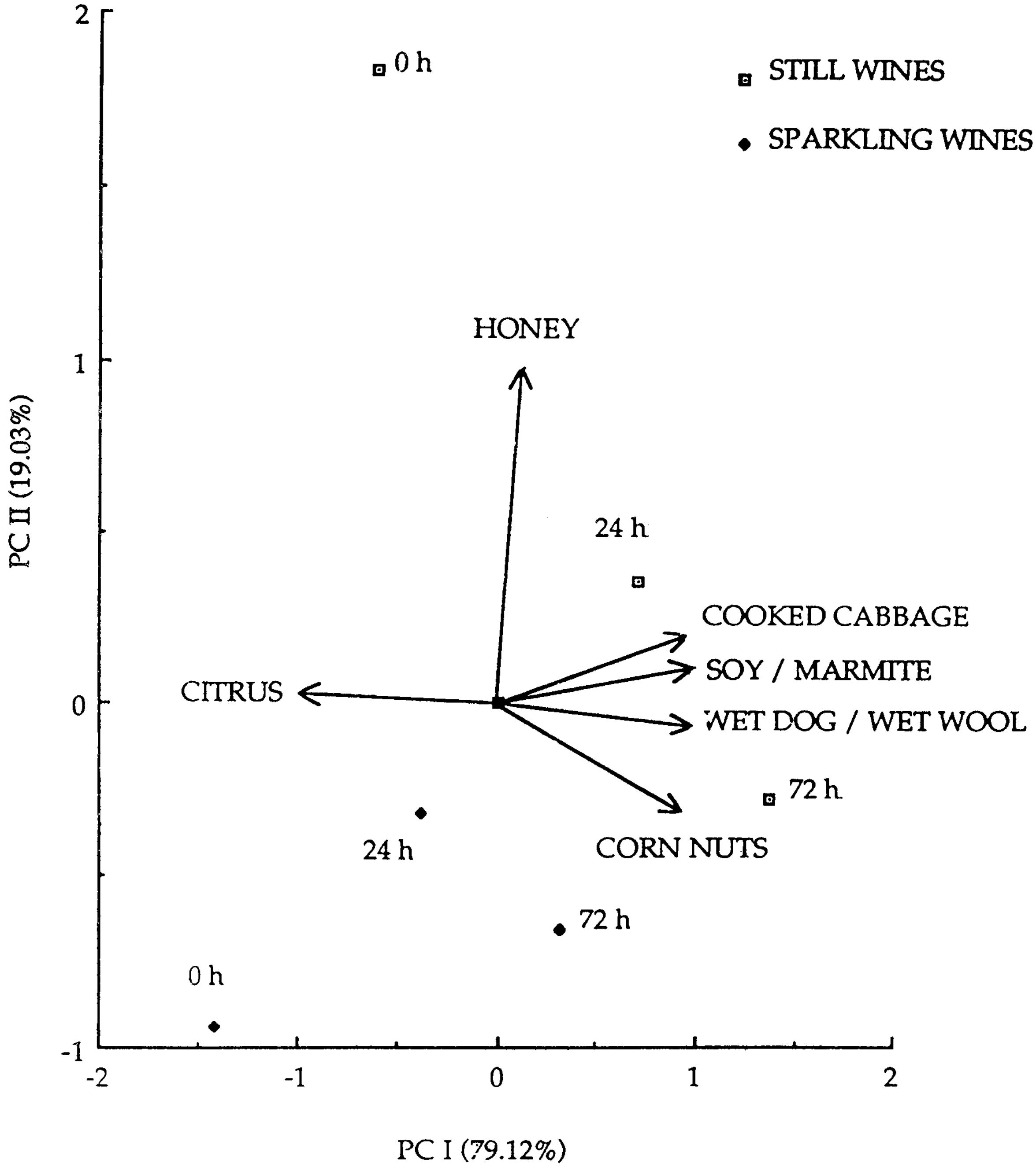

Fig. 7. Projection of sensory terms on principal components I and II. Aroma loadings (vectors) and wine factor scores (points).

In Figures 5 and 6, the mean ratings for the still and the sparkling wines, respectively, are plotted in polar coordinate graphs. In these diagrams, the center of the figure represents low intensity, and the intensity of each attribute increases with the distance from the center. The mean scores for each attribute for a specific wine sample are connected to give a sensory profile for each wine.

As shown in Figure 5, it can be seen that cooked cabbage, wet dog/wet wool, soy/marmite, and corn nut aromas increase with the time of exposure while citrus and honey aromas decrease in the still wine samples. In Figure 6, it can be seen that the sparkling wine samples follow the same trend, but with lower intensities of the attributes. The honey aroma shows no significant difference with the time of exposure in sparkling wine, although it decreases upon exposure in the still wines.

To simplify evaluation of the data, principal component analyses were run on the mean sensory ratings. In Figure 7, the attribute loadings and wine factor scores are plotted for the first two principal components (PC), which together account for 88.15% of the total variance.

The first PC represents the time of exposure, increasing from left to right, contrasting the citrus term (highest in the unexposed wines) with cooked cabbage, soy/marmite, wet dog/wet wool, and corn nuts, which increase with light exposure.

The second PC nearly separates the still from the sparkling wines, largely on the basis of the honey attribute which does not vary with exposure, but is lower in the sparkling wines.

Conclusions

The sensory effect of light on sparkling wine and the base wine from which it was made was examined. Minimal exposure of wine in flint bottles to light produced an effect, with significant differences in aroma being observed after 3.4 and 3.3 hours for the still and the sparkling wines, respectively. In green bottles, significant differences were detected after 18 and 31.1 hours of exposure for the still and sparkling wines, respectively. Although green glass is unable to protect the wines against extended light exposure, it offers some protection over clear glass. Under commercial retail conditions, with wines further from the light source and protected somewhat by labels, the time of exposure to produce a detectable difference would increase. Because of the extreme light sensitivity of white wines bottled in clear glass, serious consideration should be given to using uv-screening agents in clear glass or to switching to green or brown glass.

The 'lightstruck' aroma produced on exposure to light was characterized by a decrease in citrus aroma and an increase in intensity of cooked cabbage, corn nuts, wet dog/wet wool, and soy/marmite aromas. The intensity of the honey aroma was higher in the still wine than in the sparkling wine.

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