

Effect of storage time and temperature on the volatile composition and quality of dry white table wines

by

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Einfluß der Lagerungsdauer und -temperatur auf die Aromazusammensetzung und Qualität trockener weißer Tafelweine

Zusammenfassung. — Trockene Weißweine der Sorten Chenin blanc, Riesling und Colombar (Jahrgang 1978) wurden bei 0, 10, 20 und 30 °C 12 Monate lang gelagert. Ein anderer Colombar-Wein (Jahrgang 1977) wurde unter ähnlichen Bedingungen 2 Jahre lang gelagert. Die 1978er Weine wurden mittels Gaschromatographie regelmäßig auf Ester, höhere Alkohole und Dimethylsulfid analysiert sowie sensorisch auf Jungweimbukett, Reifebukett und gesamte Weinqualität geprüft. Zunehmende Lagerungsdauer und Lagerungstemperatur bewirkten eine deutliche Abnahme bei der Konzentration von i-Amylacetat, Hexylacetat, 2-Phenyläthylacetat, Äthylbutyrat, Äthylcapronat, Äthylcaprylat, Äthylcaprinat, gesamten Estern und beim Jungweimbukett sowie eine ausgeprägte Zunahme bei der Konzentration von Dimethylsulfid, Diäthylsuccinat, Äthylacetat und gesamten Aldehyden, bei der optischen Dichte wie auch beim Reifebukett. Zwischen den Inhaltsstoffen und den Ergebnissen der sensorischen Prüfung wurden hochsignifikante Korrelationen gefunden.

Der Einfluß von Lagerungsdauer und -temperatur auf die Alterung von Weißweinen kann praktisch genutzt werden, um entweder das Jungweimbukett über einen längeren Zeitraum hinweg zu erhalten oder um innerhalb kurzer Zeit einen angenehmen gealterten Wein zu erzielen.

Introduction

Ageing may drastically change the character of a wine. A number of research workers investigated this effect on the chemical composition and quality of wine and other alcoholic beverages. The important contribution of volatile components such as fatty acid esters and higher alcohols to the quality of these beverages was stressed and increases as well as decreases in the concentrations of these components were observed during ageing (OUGH *et al.* 1960, ENGAN 1969, STENROOS 1973, STERN *et al.* 1975, GVALADZE and SIRBILADZE 1976, KISHKOVSKII *et al.* 1976, ONISHI *et al.* 1977, SPIROV and GORANOV 1977, SIMPSON 1978 b). In general, it can be concluded from published data that the concentrations of certain esters such as ethyl acetate, diethyl succinate and, to a lesser extent, the ethyl esters of caproic, caprylic and capric acids, increase during ageing. Opposite tendencies, however, may also occur. The concentrations of acetate esters of higher alcohols, especially those of iso-amyl, hexyl and 2-phenethyl alcohols decrease during ageing while the higher alcohols remain practically constant.

The concentrations of volatile aldehydes were generally found to increase during ageing of wine (WILDENRADT and SINGLETON 1974, AVAKYANTS 1977, BARO and QUIROS CARRASCO 1977). Browning of white wines during ageing is a negative quality factor

and phenolic compounds can contribute significantly towards this phenomenon (SINGLETON 1974, SINGLETON and KRAMLING 1976, SIMPSON 1978 b). The formation of certain sulphur containing compounds during ageing can contribute negatively or positively to quality. For instance, dimethyl sulphide was identified (DU PLESSIS and LOUBSER 1974, LOUBSER and DU PLESSIS 1977) and found to increase and contribute significantly towards the bottle maturation bouquet of white wines (MARAIS 1979). In conjunction with this is the finding of the formation of vitispirane and 1,1,6-trimethyl-1,2-dihydronaphthalene during ageing and their important contribution to the bottle maturation bouquet of Riesling wines (SIMPSON *et al.* 1977, SIMPSON 1978 a and b).

It is well-known that wines of different cultivars, with specific reference to bottle ageing, do not all age well and that the period between bottling and attainment of the desired character may differ drastically from wine to wine, even when they are stored under identical conditions (SINGLETON 1974, ANONYMOUS 1977).

Because the changes in wine during ageing are due to chemical changes and the rate of chemical changes being drastically affected by temperature, studies were undertaken to gain insight into the effect of temperature in the range between 0 and 30 °C and of storage time on the quality and composition of bottled dry white wines.

Materials and methods

Dry white wines made from the cultivars Chenin blanc, Riesling and Colombar (1978 vintage) were used in this study. Colombar, grown on the experimental farm, Nietvoorbij, in the Stellenbosch area, was made under standard conditions from free-run juice and fermented at 12 °C. The Chenin blanc and Riesling wines were obtained as bulk wines from commercial cellars.

The bottles were flushed with high-purity nitrogen prior to bottling. The wines were then bottled under identical conditions at 10 °C with a free sulphur dioxide content of approximately 25 mg/l and sealed with airtight screw-caps.

Different batches of the wines were stored in dark rooms at each of four constant temperatures, i.e. 0, 10, 20 and 30 °C. Bottles were removed for analysis and sensory evaluation immediately after bottling and 0.5, 1, 2, 3, 4, 9 and 12 months after bottling.

A Colombar wine, made in 1977 from grapes from the same vineyard used in this study, was stored under similar conditions for 2 years and only analysed at the end of the 2-year storage period.

1. Analyses

The wines were analysed quantitatively by gas chromatography for esters and higher alcohols using Freon 11 extraction (MARAIS and HOUTMAN 1979). A Hewlett Packard 5840 A gas chromatograph fitted with an automatic peak integrator was used. The components determined were ethyl acetate, ethyl butyrate, i-amyl acetate, ethyl caproate, hexyl acetate, ethyl caprylate, ethyl caprate, 2-phenethyl acetate, diethyl succinate, i-butanol, amyl alcohols, hexanol, 2-phenyl ethanol, hexanoic acid and octanoic acid. The wines were also analysed quantitatively by gas chromatography for dimethyl sulphide and ethyl acetate using the headspace method as adapted by LOUBSER and DU PLESSIS (1977) as well as for total esters (ANONYMOUS 1970), total aldehydes (REBELEIN 1970) and optical density at 420 nm.

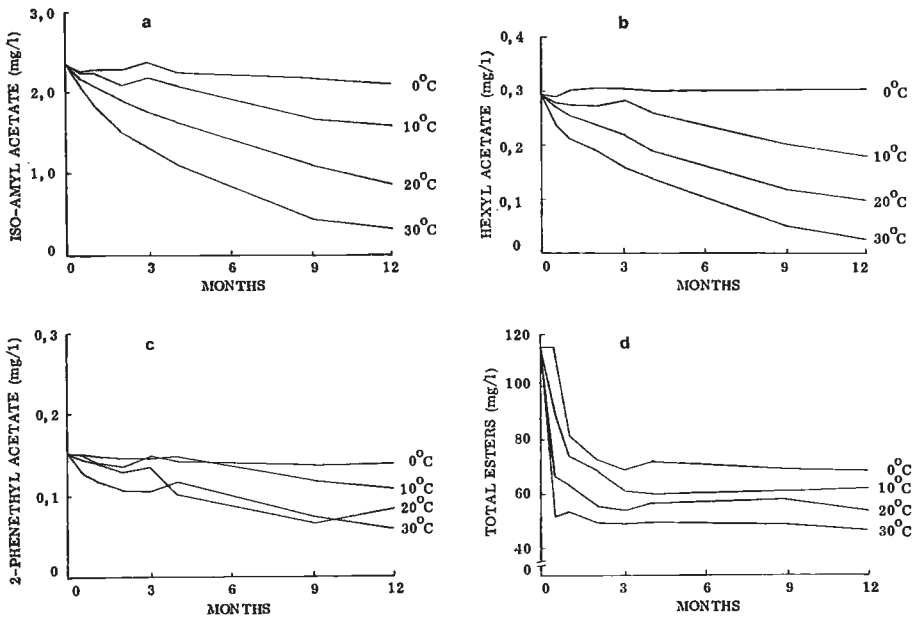


Fig. 1: Effect of storage time and temperature on the concentrations of a) i-amyl acetate, b) hexyl acetate, c) 2-phenethyl acetate and d) total esters of Chenin blanc wines.
Einfluß der Lagerungsdauer und -temperatur auf die Konzentration von a) i-Amylacetat, b) Hexylacetat, c) Phenyläthylacetat und d) gesamten Estern von Chenin-blanc-Weinen.

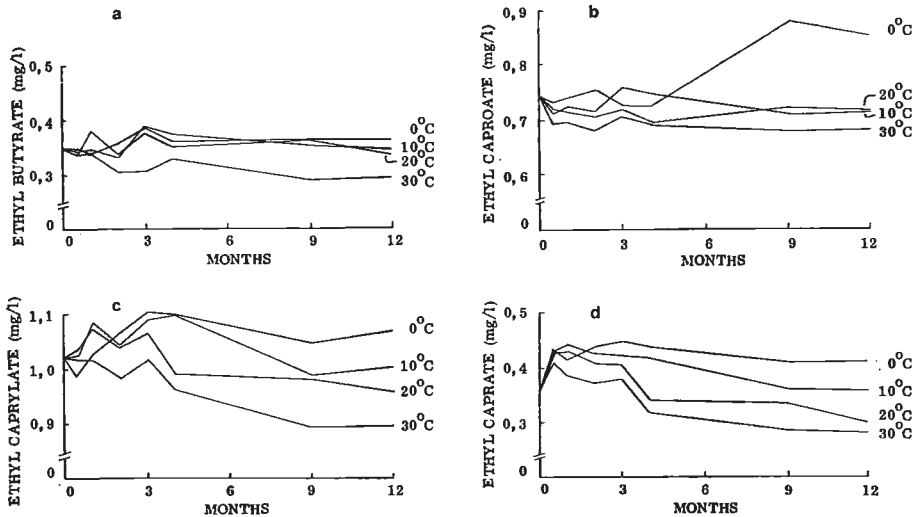


Fig. 2: Effect of storage time and temperature on the concentrations of a) ethyl butyrate, b) ethyl caproate, c) ethyl caprylate and d) ethyl caprate of Chenin blanc wines.
Einfluß der Lagerungsdauer und -temperatur auf die Konzentration von a) Äthylbutyrat, b) Äthylcapronat, c) Äthylcaprylat und d) Äthylcaprinat von Chenin-blanc-Weinen.

2. Sensory evaluation

Sensory evaluation of wine quality was carried out by a panel of 12 experienced judges by means of a 9-point scoring system described by TROMP (1977). The judges were also asked to score the young wine and maturation (bottle) bouquet of the wines on a 10-point scale. These results were statistically correlated with the chemical data.

Results and discussion

In spite of the fact that the grapes of the three cultivars originated from two different areas and that the wines were made under different conditions, the results clearly indicated that the measured wine components generally underwent similar

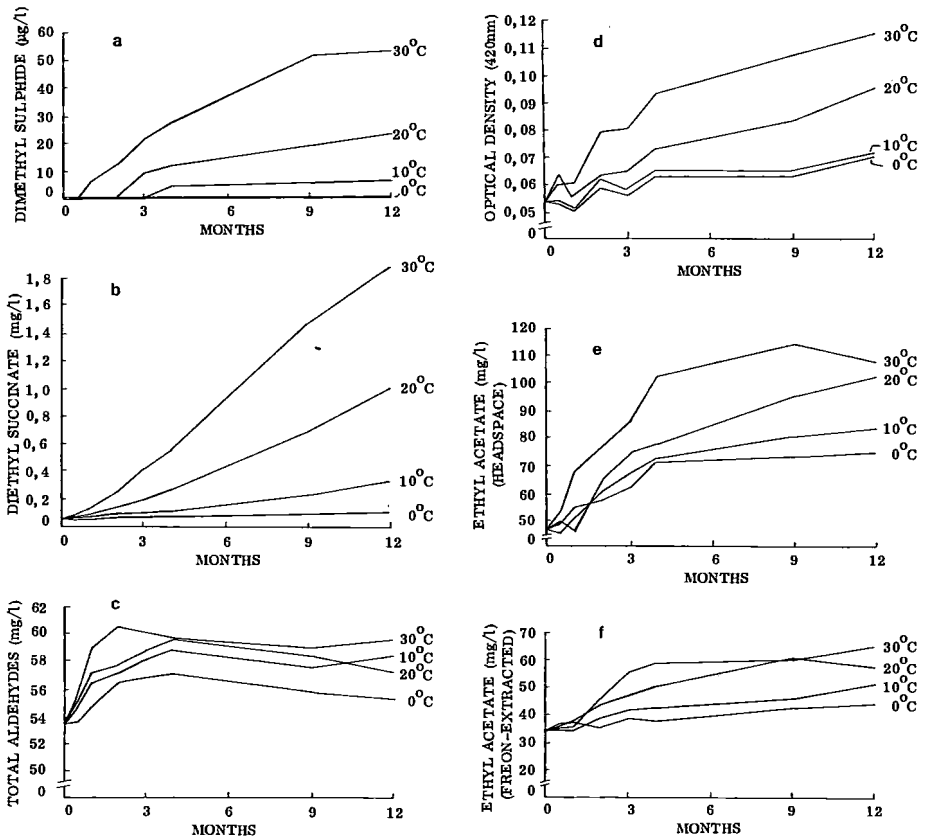


Fig. 3: Effect of storage time and temperature on the values of a) dimethyl sulphide, b) diethyl succinate, c) total aldehydes, d) optical density, e) ethyl acetate (headspace) and f) ethyl acetate (freon-extracted) of Chenin blanc wines.

Einfluß der Lagerungsdauer und -temperatur auf die Werte von a) Dimethylsulfid, b) Diäthylsuccinat, c) gesamte Aldehyden, d) optischer Dichte, e) Äthylacetat (Dampfraum) und f) Äthylacetat (Freon-extrahiert) von Chenin-blanc-Weinen.

changes during storage. Consequently, only the results for Chenin blanc, which is the most important white wine cultivar in South Africa, will be given.

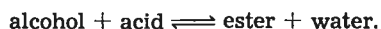
1. Changes in concentrations of wine components

Changes in the concentrations of the relevant wine components over 12 months at the stipulated storage temperatures are illustrated in Figs. 1—5. When the specific effects of storage time and temperature are considered individually, it is clear from the figures that both factors generally caused similar trends in the concentrations of the relevant wine components.

The following changes in the concentrations of wine components occurred with an increase in storage time and/or temperature:

- a) The concentrations of the acetate esters namely *i*-amyl acetate, hexyl acetate and 2-phenethyl acetate, total esters and young wine bouquet decreased markedly (Figs. 1, a—d, and 5, b).
- b) Decreases in the concentrations of the ethyl esters namely ethyl butyrate, ethyl caproate, ethyl caprylate and ethyl caprate were not as marked as in the case of the acetate esters (Fig. 2, a—d). Sometimes increases in the concentrations of ethyl esters occurred over time, especially in ethyl caproate and caprylate (0 °C, Fig. 2, b and c).
- c) The concentration of ethyl acetate as determined by means of both headspace and freon-extraction methods, increased markedly (Fig. 3, e and f). These results differed from a previous investigation where ethyl acetate decreased in concentration during storage (MARAIS 1979).
- d) The concentrations of dimethyl sulphide, diethyl succinate and total aldehydes, as well as optical density and maturation bouquet increased markedly (Figs. 3, a—d, and 5, c).
- e) The concentrations of the higher alcohols, namely *i*-butanol and hexanol generally increased whereas amyl alcohols and 2-phenyl ethanol showed decreases (Fig. 4, a—d).
- f) The concentrations of hexanoic acid and octanoic acid showed no changes.
- g) The sensory evaluation values of the wines showed no significant changes during the 12 months period, although the wines stored at 30 °C showed a slight decrease in quality towards the end of the storage period (Fig. 5, a).

The changes in the concentrations of esters and other wine components as well as contradicting findings with regard to specific esters (cf. points b and c) can be explained as follows. The concentrations of esters in wine are governed by the reaction



The changes in ester concentration during ageing can therefore be ascribed to the progress of the above reversible reaction towards a state of equilibrium. The rate at which the reaction proceeds is dependent on, amongst others, the concentration of the reactants and the temperature. The fact that the ester concentrations decreased very little when the wines were kept at 0 °C confirms the finding of SIMPSON (1978 b) who concluded that the rate of esterification or hydrolysis is exceedingly slow at low temperatures so that equilibrium is not attained even after years of storage at these low temperatures. The fact that most esters decreased with increasing time and temperature shows that the reaction is predominantly a hydrolysis of the esters. It has also been determined that pH may have significant effects on the rate of hydrolysis of the esters (MARAIS 1978).

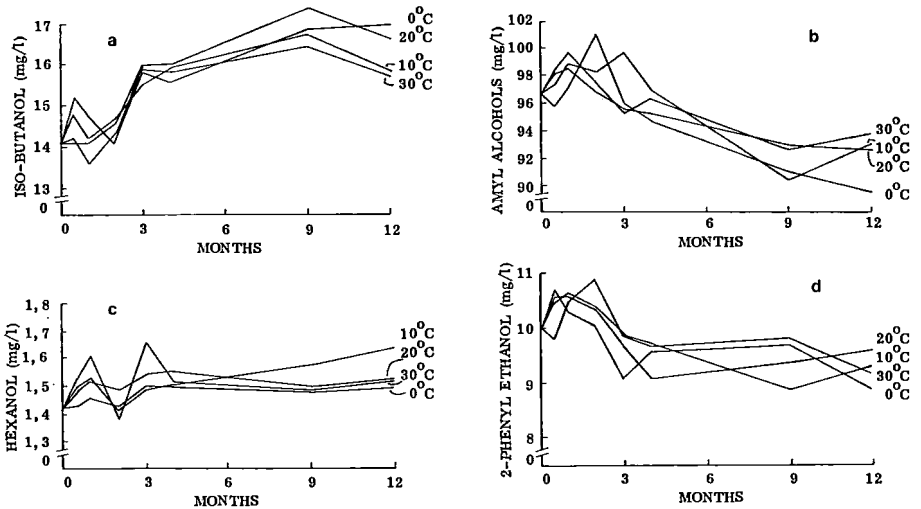


Fig. 4: Effect of storage time and temperature on the concentrations of a) i-butanol, b) amyl alcohols, c) hexanol and d) 2-phenyl ethanol of Chenin blanc wines.

Einfluß der Lagerungsdauer und -temperatur auf die Konzentration von a) i-Butanol, b) Amylalkoholen, c) Hexanol und d) 2-Phenyläthanol von Chenin-blanc-Weinen.

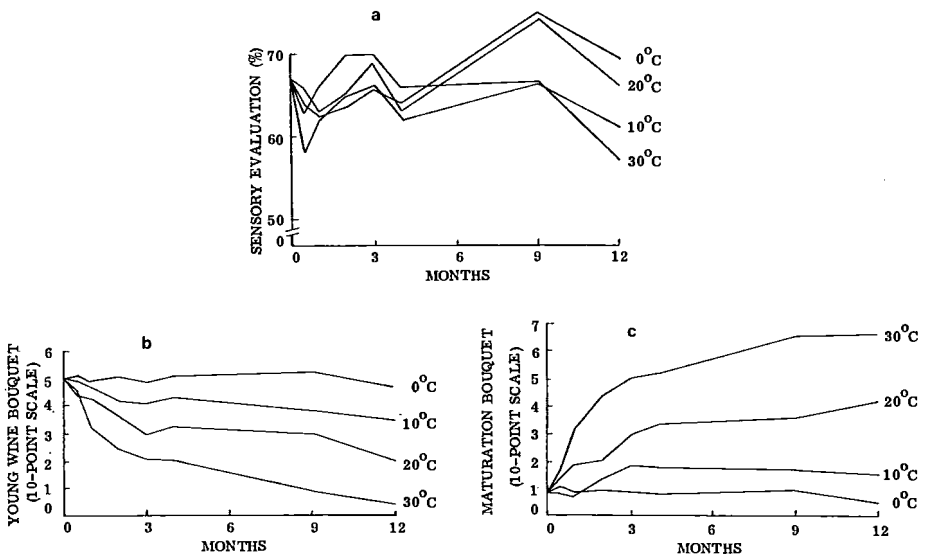


Fig. 5: Effect of storage time and temperature on a) sensory evaluations, b) young wine bouquets and c) maturation bouquets of Chenin blanc wines (least significant difference = 8 %).

Einfluß der Lagerungsdauer und -temperatur auf a) sensorische Beurteilung, b) Jungweibukett und c) Reifebukett von Chenin-blanc-Weinen (Grenzdifferenz = 8 %).

With regard to ethyl acetate it is clear that its concentrations as determined by the headspace method are much higher than those determined by means of freon extraction (Fig. 3, e and f). The distribution coefficient of ethyl acetate between the liquid and the vapour phases could be mainly responsible for this tendency.

A further observation was that, while the total ester concentrations at bottling were well above the individual ethyl acetate concentrations, these values dropped below the corresponding ethyl acetate values as determined by both headspace and freon-extraction techniques (cf. Figs. 1, d, 3, e and f). Consequently it appears that the total ester determination method, in which esters are expressed in terms of ethyl acetate, does not reflect gas chromatographic analyses and the data obtained by the method for total ester determination should be interpreted with caution. Another tendency is that the total ester concentrations decreased rapidly during the 1st month after bottling, especially at 20 and 30 °C storage and attained a state of equilibrium within 2 months which is in contrast to the tendency shown by the individual esters.

A Colombar wine from a previous investigation was stored for 2 years under conditions similar to those used in the present experiment. The effects of ageing on the gas chromatographic profile of the Colombar wine are shown in the chromatograms of Fig. 6. Distinct differences can be seen between the chromatograms of the wines stored at 0 °C and at 30 °C for 2 years. The chromatograms of the wines stored for the same period at 10 °C and 20 °C are intermediate between the above-mentioned extremes and are therefore not illustrated.

A gas chromatographic analysis of the relevant components of the Colombar wines stored at 0, 10, 20 and 30 °C for 2 years, as extracted by Freon 11 (MARAIS and

Table 1

Effect of storage temperature on the concentrations of several components of Colombar wines (1977 vintage) after 2 years storage

Einfluß der Lagertemperatur auf die Konzentration verschiedener Inhaltsstoffe von Colombar-Weinen (Jahrgang 1977) nach 2jähriger Lagerung

Components (mg/l)		Storage temperature (°C)			
		0	10	20	30
Ethyl acetate	(B) ¹⁾	50.7	51.0	49.0	48.3
Ethyl butyrate	(E)	0.40	0.35	0.31	0.31
i-Butanol	(G)	34.1	34.4	33.9	30.3
i-Amyl acetate	(H)	3.63	1.63	0.33	0.07
Amyl alcohols	(I)	145.4	144.5	147.6	148.6
Ethyl caproate	(J)	1.13	1.03	0.99	0.95
Hexyl acetate	(K)	0.15	0.07	0.00	0.00
Hexanol	(M)	0.62	0.65	0.69	0.70
Ethyl caprylate	(N)	1.52	1.41	1.33	1.20
Ethyl caprate	(Q)	0.42	0.33	0.29	0.23
Diethyl succinate	(R)	0.14	0.75	2.61	5.16
2-Phenethyl acetate	(T)	0.53	0.32	0.08	0.03
Hexanoic acid	(U)	5.71	5.67	5.70	5.52
2-Phenyl ethanol	(V)	25.1	23.9	24.6	23.8
Octanoic acid	(X)	8.19	7.88	7.59	7.05

¹⁾ The bracketed letters refer to Fig. 6.

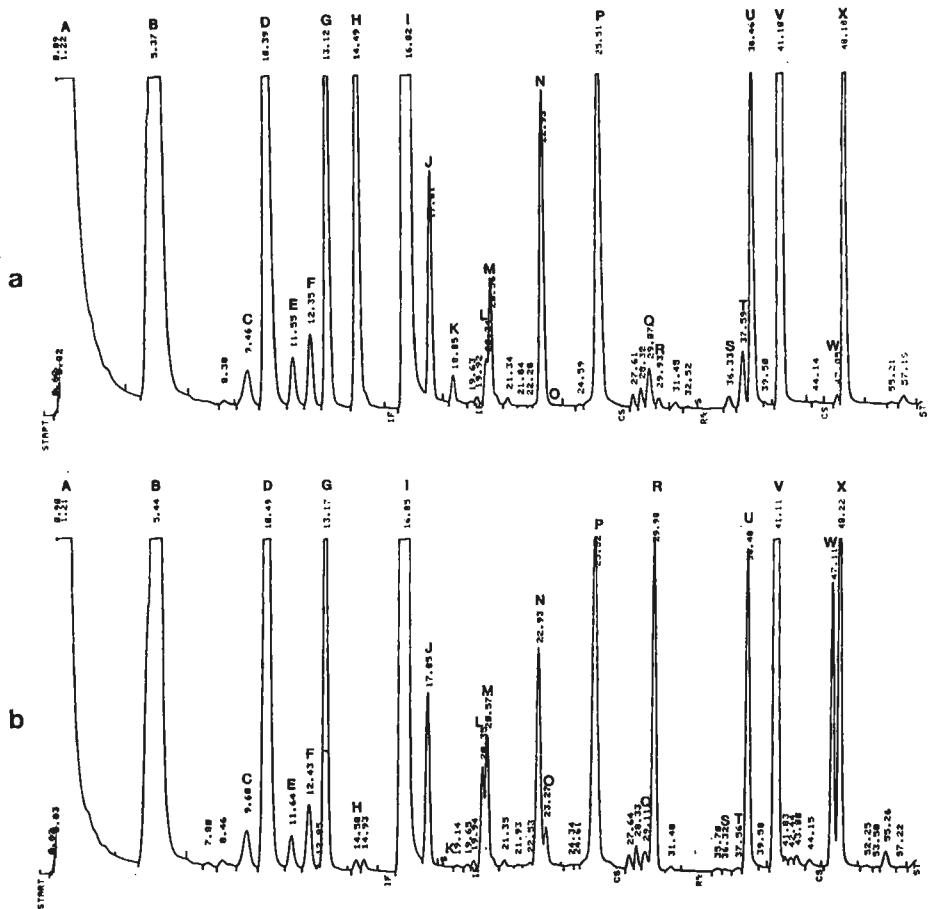


Fig. 6: Gas chromatograms showing components in a freon-extracted concentrate of Colombar wines stored for 2 years at 0 °C (a) and 30 °C (b). The components have been identified by using relative retention times. — A = Freon 11, B = ethyl acetate, C = unknown, D = tert.-amyl alcohol (internal standard), E = ethyl butyrate, F = unknown, G = i-butanol, H = i-amyl acetate, I = amyl alcohols, J = ethyl caproate, K = hexyl acetate, L = ethyl lactate, M = hexanol, N = ethyl caprylate, O = unknown, P = ethyl nonanoate (internal standard), Q = ethyl caprate, R = diethyl succinate, S = unknown, T = 2-phenethyl acetate, U = hexanoic acid, V = 2-phenyl ethanol, W = unknown, X = octanoic acid.

Gaschromatogramme der Komponenten des Freon-extrahierten Konzentrates eines Colombar-Weines nach 2jähriger Lagerung bei 0 °C (a) und 30 °C (b). Identifizierung der Komponenten mit Hilfe der relativen Retentionszeit. — A = Freon 11, B = Äthylacetat, C = unbekannt, D = tertiärer Amylalkohol (innerer Standard), E = Äthylbutyrat, F = unbekannt, G = i-Butanol, H = i-Amylacetat, I = Amylalkohole, J = Äthylcapronat, K = Hexylacetat, L = Äthyllactat, M = Hexanol, N = Hexylcaprylat, O = unbekannt, P = Äthylpelargonat (innerer Standard), Q = Äthylcaprinat, R = Diäthylsuccinat, S = unbekannt, T = 2-Phenyläthylacetat, U = Capronsäure, V = 2-Phenyläthanol, W = unbekannt, X = Caprylsäure.

HOUTMAN 1979), is given in Table 1. These results clearly indicate the marked effect of elevated storage temperature on certain wine constituents and the similarity between these changes and those observed for Chenin blanc wines of this study. Non-quantified components e.g. L (ethyl lactate), O and W (unknown) also increased in concentration with an increase in storage temperature (Fig. 6). Unfortunately, the Freon-extraction method was not in use at the start of this experiment and an analysis of the initial wine immediately after bottling is therefore not available.

2. Young wine bouquet

The young wine bouquet decreased drastically at storage temperatures of 20 °C (5.0 to 2.0) and 30 °C (5.0 to 0.4), while at 0 °C (5.0 to 4.7) and, to a lesser degree, at 10 °C (5.0 to 3.5) it was practically unchanged for as long as 12 months after bottling (Fig. 5, b). These decreases in young wine bouquet coincided, at each individual storage temperature, with the marked decreases in the concentrations of the acetate

Table 2

Correlations between the concentrations of certain components and the sensory evaluations of young wine and maturation bouquets of Chenin blanc, Riesling and Colombar wines (1978 vintage)

Korrelationen zwischen der Konzentration verschiedener Inhaltsstoffe und der sensorischen Beurteilung des Jungwein- und Reifebuketts von Chenin-blanc-, Riesling- und Colombar-Weinen (Jahrgang 1978)

Correlations	Correlation coefficients (r)		
	Chenin blanc	Riesling	Colombar
Young wine bouquet vs. the concentration of:			
Ethyl acetate (headspace)	-0.855**	-0.139	-0.893**
Ethyl acetate (freon-extracted)	-0.874**	0.356*	-0.859**
Ethyl butyrate	0.641**	0.939**	-0.424*
i-Amyl acetate	0.960**	0.936**	0.946**
Ethyl caproate	0.547**	0.427*	0.064
Hexyl acetate	0.957**	0.907**	0.894**
Ethyl caprylate	0.712**	-0.082	0.475*
Ethyl caprate	0.730**	0.801**	0.726**
2-Phenethyl acetate	0.870**	0.858**	0.825**
i-Butanol	-0.372*	-0.340	-0.406*
Amyl alcohols	0.270	0.258	0.246
Hexanol	-0.380*	-0.287	-0.225
2-Phenyl ethanol	0.202	0.324	0.129
Hexanoic acid	0.050	0.263	0.359
Octanoic acid	0.764**	0.757**	-0.019
Total esters	0.674**	0.615**	0.595**
Maturation bouquet vs. the concentration of:			
Diethyl succinate	0.840**	0.854**	0.890**
Dimethyl sulphide	0.923**	0.898**	0.861**
Total aldehydes	0.738**	0.671**	0.603**
Optical density	0.423*	0.947**	0.921**

* = Significant at $P \leq 0.05$.

** = Highly significant at $P \leq 0.01$.

Table 3

Effect of storage time and temperature on the sensory evaluation, young wine bouquet and maturation bouquet of Colombar wines (1977 vintage)

Einfluß der Lagerungsdauer und -temperatur auf die sensorische Bewertung sowie das Jungwein- und Reifebukett von Colombar-Weinen (Jahrgang 1977)

Wine quality and bouquet	0	Storage time (years)			
		2			
		Storage temperature (°C)			
—	0	10	20	30	
Sensory evaluation (‰)	66	76	69	69	57
Young wine bouquet (10-point scale)	4.6	5.3	3.5	1.2	0.4
Maturation bouquet (10-point scale)	0.8	0.8	1.8	5.9	7.6

esters viz. *i*-amyl acetate, hexyl acetate and 2-phenethyl acetate (Fig. 1, a—c). This was also confirmed by the highly significant linear correlations which were found between young wine bouquet and the ester concentrations ($r = 0.960, 0.957$ and 0.870 for *i*-amyl acetate, hexyl acetate and 2-phenethyl acetate of Chenin blanc wines [Table 2]). Similar patterns for Riesling and Colombar wines are shown.

Results of the original sensory evaluation of the Colombar wine previously referred to together with results obtained at the termination of the experiment, after 2 years, are given in Table 3. The young wine bouquet of this wine was preserved at 0 °C storage for the entire period of 2 years. The score for young wine bouquet was 4.6 at bottling and 5.3 after 2 years storage. At 10 °C storage the young wine bouquet decreased slightly from 4.6 to 3.5 while at 20 °C storage little (1.2) and at 30 °C practically no (0.4) young wine bouquet was perceptible after 2 years. These results together with those for Chenin blanc wines stress the importance of keeping white wines cool where preservation of the fresh fruity bouquet, typical of a young wine, is to be retained.

3. Maturation (bottle) bouquet

In contrast to the decrease in young wine bouquet, the maturation bouquet increased rapidly at storage temperatures of 20 °C (0.8 to 4.2) and 30 °C (0.8 to 6.6), while practically no maturation bouquet developed at 0 °C (0.8 to 0.5) and 10 °C (0.8 to 1.5) over a storage period of 12 months (Fig. 5, c). These increases in maturation bouquet coincided with a marked increase in the dimethyl sulphide concentration determined in the same wines (Fig. 3, a) confirming previous work by MARAIS (1979). A highly significant linear correlation ($r = 0.923$) was found between maturation bouquet and the concentration of dimethyl sulphide of Chenin blanc wines (Table 2). Similar findings for Riesling and Colombar wines are shown. Increases in the concentrations of diethyl succinate and total aldehydes as well as an increase in optical density (Fig. 3, b—d) also coincided with the increase in maturation bouquet.

A comparison of Figs. 3, a and 5, c strengthens the assumption that dimethyl sulphide is an important contributor to the typical bottle maturation bouquet of white wines because the graphs of dimethyl sulphide and maturation bouquet show a remarkable similarity, both reaching a plateau at the same time. This confirms previous findings by MARAIS (1979). The possible contribution of diethyl succinate and total aldehydes to maturation bouquet has not yet been investigated.

It is noteworthy that, with regard to the rate of dimethyl sulphide formation, marked differences were found among the cultivars Chenin blanc, Riesling and Colombar under the conditions of this study. Riesling and Colombar wines developed approximately three times the amount of dimethyl sulphide than Chenin blanc wines at 30 °C storage over 12 months. This is in accordance with previous findings (MARAIS 1979).

The marked effect of storage time and temperature on the formation of maturation bouquet in a Colombar wine, investigated earlier, is shown in Table 3. It is clear that practically no maturation bouquet (0.8) was formed during 2 years storage at 0 °C while it increased rapidly with an increase in temperature.

4. Wine quality

The total sensory evaluation values, i.e. wine quality (Fig. 5, a), did not show the same drastic changes observed in the young wine and maturation bouquets. The reason for this tendency was the increase of the maturation bouquet simultaneously with the decrease of the young wine bouquet (MARAIS 1979). As both bouquets are regarded as quality-enhancing factors, the overall wine quality never reflected the complete changes in character actually taking place. The young wine bouquet may decrease or may be masked by the increase of the maturation bouquet till such a point is reached where the young wine bouquet can no longer be perceived. It is possible that the maturation bouquet can increase to such an extent that it affects wine quality negatively. In studies of this kind, wine quality values should be considered in conjunction with the individual ratings for young wine and maturation bouquet. A true picture of the effect of a specific treatment on each wine can then be obtained.

In the case of Chenin blanc, the wines stored at 30 °C for 12 months scored only 57 % (Fig. 5, a). These wines developed so much maturation bouquet (6.6; Fig. 5, c) that the judges found them over-aged. The wines had also developed a yellow colour. However, the wines stored at 20 °C for 12 months were judged to be well-balanced (66 %) with regard to the maturation and young wine bouquets. The wines stored at 10 °C for 12 months showed less young wine bouquet than those stored at 0 °C, as well as little maturation bouquet and unexpectedly had a lower quality rating (61 %) than those stored at 20 °C. Wines stored at 0 °C retained their original fruity bouquet and were judged to have a slightly improved quality (69 %) as compared with the initial product (Fig. 5, a).

It is noteworthy that a slight decrease in total wine quality occurred consistently in all the wines just after bottling at all the relevant storage temperatures (Fig. 5, a). It appeared that the fruitiness of the young wines slightly decreased immediately after bottling and that the wines manifested a slightly unstable sensory condition. As soon as the maturation bouquet started developing, the wines stored at higher temperatures tended to show more body and the quality improved. Wines stored at the lower temperatures appeared to recover and stabilize after bottling.

In the case of the Colombar wine (1977 vintage) it is clear that the wines stored at 30 °C for 2 years showed a definite decrease in quality when compared to the wines stored at 0 °C (Table 3). The colour of the wine was a deep yellow and, generally speaking, the judges described the wines as over-aged and oxidized. The wines stored at 20 °C for two years developed an intense, but well-balanced bottle maturation bouquet while those stored at 10 °C showed a reasonably good balance between young wine and maturation bouquets. The wines stored at 0 °C not only in-

creased in quality after 2 years storage for reasons not immediately obvious, but were also as fresh and fruity as the day they were bottled.

Results from this study clearly indicate that different white cultivar wines would age differently with regard to the rate of bottle maturation bouquet formation and its manifestation in the wine. The ageing potential of a white wine should be dependent on different factors of which the inherent composition of the wine with bottling, especially in respect of the concentration of dimethyl sulphide precursor(s), would be most important.

Conclusions

Results obtained in this study indicate that highly significant statistical relationships were found between maturation bouquet and dimethyl sulphide concentration, as well as between young wine bouquet and the concentrations of the acetate esters (cf. Table 2). Maturation and young wine bouquets are wine quality factors and in this respect these findings are of special importance in that objectively determined components can be related to subjective ones.

The finding that, under specific conditions, significant changes could arise in the character of white wines within 2 weeks after bottling, is of practical importance. It seems reasonable to expect that the differences in total wine quality among the wines stored at the different temperatures would become greater as the storage time is increased. Results obtained during this study indicated a remarkably stable young wine bouquet in Colombar over 2 years when the wines were held at 0 °C and it appears logical to assume that the status quo could be retained for even longer periods. In general, it can be stated that the young wine bouquets of the wines stored at 0 and 10 °C were well preserved for the whole storage period. The wines stored at 20 °C developed a well-balanced maturation bouquet, while the wines stored at 30 °C developed faulty flavours within the duration of this experiment.

Although it is not always possible to make definite recommendations from the results of one study, interesting possibilities for practical application nevertheless emerged. In view of the marked effect of temperature on the quality and character of bottled white wines, it is without doubt an aspect of wine marketing which should receive more attention than is the case at present, especially in warmer wine-producing and consuming countries.

Another important aspect which resulted from this investigation was the fact that in the case of dry white wines an imbalance may develop between the heavy maturation bouquet and the less full taste of the dry wines. A semi-sweet wine has more body on the taste and should give a better overall balance between body and the full maturation bouquet. Consequently, the ageing potential of semi-sweet white wines is an aspect which is important and further studies in this respect are at present being undertaken at this institute.

Summary

Dry white wines of the cultivars Chenin blanc, Riesling and Colombar (1978 vintage) were stored at 0, 10, 20 and 30 °C for 12 months. Another Colombar wine (1977 vintage) was stored under similar conditions for 2 years. The 1978 wines were

analysed periodically by gas chromatography for esters, higher alcohols and dimethyl sulphide and sensorily evaluated for young wine bouquet, maturation bouquet and total wine quality. Increases in storage time and temperature caused marked decreases in the concentrations of *i*-amyl acetate, hexyl acetate, 2-phenethyl acetate, ethyl butyrate, ethyl caproate, ethyl caprylate, ethyl caprate, total esters and young wine bouquet and marked increases in the concentrations of dimethyl sulphide, diethyl succinate, ethyl acetate and total aldehydes as well as optical density and maturation bouquet. Highly significant relationships were found between chemical components and the percentage scores of the wines determined by sensory evaluations.

The effect of time and temperature on the ageing of white wines can be utilized in practice either to preserve the young wine bouquet for an extended period of time or to produce a well-aged wine within a short period.

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