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Viticultural and Oenological Research Institute, Stellenbosch, Republic of South Africa

Terpene concentrations and wine quality of *Vitis vinifera* L. cv. Gewürztraminer as affected by grape maturity and cellar practices

by

J. MARAIS

Terpenkonzentration und Weinqualität bei der Rebsorte Gewürztraminer (*Vitis vinifera* L.) in Abhängigkeit von Beerenreife und Kellertechnik

Zusammenfassung: Bei der Rebsorte Gewürztraminer wurde der Einfluß der Beerenreife und der Mostbehandlung — Kontakt des Mostes mit den Beerenhäuten sowie Hitzeeinwirkung — auf die Konzentration einzelner freier Terpene in Most und Wein sowie auf die Weinqualität untersucht. Außerdem wurde der Gesamtgehalt der freien flüchtigen Terpene und der potentiell flüchtigen Terpene im Verlauf der Beerenreife bestimmt. Linalool, Hotrienol, α-Terpineol, Citronellol, Nerol, Geraniol, Diendiol-1, *trans*-Geraniumsäure und aus der Gruppe der Furane die Linalooloxide wurden gaschromatographisch analysiert. Merkmale der Weinqualität wie „fruchtig/esterartig", „würzig/terpenartig" und der Gesamteindruck der Weine wurden sensorisch bewertet. Zunehmender Reifegrad der Beeren äußerte sich in einem deutlichen Konzentrationsanstieg der gebundenen Terpene insgesamt sowie der meisten Einzelkomponenten. Beerenhautkontakt von 4- und 15stündiger Dauer sowie 15stündiger Beerenhautkontakt kombiniert mit Hitzeeinwirkung bewirkten bei der Mehrzahl der analysierten Terpene eine signifikante Konzentrationszunahme. Hitzebehandlung hatte eine Abnahme der Geraniol-, Nerol- und Citronellolkonzentrationen zur Folge. Die kombinierte Beerenhautkontakt-Hitze-Behandlung intensivierte den fruchtig-würzigen Charakter und steigerte die Weinqualität insgesamt.

Key words: variety of vine, berry, maturation, winery, technique, must, wine, flavour, constituent, wine quality, Republic of South Africa.

Introduction

Vitis vinifera L. cv. Gewürztraminer is a well-known, aroma-rich cultivar, widely grown in colder wine-producing regions, such as Alsace in France, West Germany and Northern Italy. This cultivar with its characteristic spicy, rose-like aroma is, however, also becoming increasingly important in warmer wine-producing countries. It is believed that lack of sufficient and characteristic aroma in many white cultivar wines in South Africa is mainly caused by high average temperatures during ripening of the grapes. While this factor undoubtedly contributes to this phenomenon, many other viticultural and oenological factors may also have an effect on wine aroma and quality.

Various researchers have investigated the effect of grape maturity on terpene concentrations in grapes and wines (BAYONOVE and CORDONNIER 1970; HARDY 1970; RAPP *et al.* 1978; VERSINI *et al.* 1981; WILSON *et al.* 1984; GUNATA *et al.* 1985 b; MARAIS and VAN WYK 1986). The effect of juice treatments, such as skin-contact and heat treatment on terpene concentrations was also evaluated (USSEGLIO-TOMASSET and DI STEFANO 1980; VERSINI *et al.* 1981; WILLIAMS *et al.* 1980, 1981; MARAIS and VAN WYK 1986). Some of the most recent studies mentioned above were directly generated by the work on glycosidically bound terpenes (WILLIAMS *et al.* 1982 a, 1982 b, 1982 c).

The present investigation on the effect of grape maturity and juice treatments, namely skin-contact and heat treatment, was aimed at determining optimum grape quality in terms of terpene concentrations and at improving wine quality of the cultivar Gewürztraminer.

Materials and methods

Harvesting of grapes for wine production

Gewürztraminer grapes (1985 and 1986 vintages), from the Tulbagh region, were harvested at three ripening stages using procedures described by MARAIS and VAN WYK (1986). During the 1985 vintage, grapes were harvested between approximately 18 and 21 °B, and during 1986 between 22 and 24 °B.

Juice treatments and fermentation

Juices were treated and fermented as described previously (MARAIS and VAN WYK 1986). Apart from the three treatments, free-run (control), skin-contact for 4 h and heat treatment (70 °C for 15 min), a fourth treatment, 15 h skin-contact, was applied during the 1985 vintage. These treatments were also applied during 1986 and a further treatment of 15 h skin-contact followed by heat treatment of the resultant juice was included. During 1986 the skin-contact treatments were conducted at 10 °C, compared to 18 °C during 1985. This lower skin-contact temperature was obtained by separately cooling each juice and skin/pulp fraction to 10 °C, prior to skin-contact.

Rehydrated dry yeast of *Saccharomyces cerevisiae* strain WE 500 was used during both 1985 and 1986 vintages and fermentations were carried out in duplicate. Dry wines were produced during 1985, whereas during 1986, the wines were sweetened with neutral sterilized juice to approximately 6 g/l. After bottling, the wines were stored at 0 °C until gas chromatographic analysis and sensory evaluation.

Determination of total free and total bound terpenes

This part of the study was carried out in 1986 only. Approximately 5 kg of grapes were collected at 1 week intervals on the same representative basis as in the case of the grapes harvested for wine production. Each grape sample was destemmed and non-settled juice obtained by subjecting the skin/pulp mixture to a pressure of 100 kg/cm^2 for 10 s. Each juice was then analysed for sugar (°B), pH, total titratable acidity (TTA) and individual free terpenes using standard VORI techniques. Total free volatile terpene (FVT) and total potentially volatile terpene (PVT) concentrations were also determined by spectrophotometry (DIMITRIADIS and WILLIAMS 1984).

Gas chromatography and mass spectrometry

Non-settled and settled Gewürztraminer juices and wine samples were gas chromatographically analysed for terpenes and the identities of these terpenes confirmed on a Finnigan 4500 mass spectrometer (MARAIS 1986). Terpenes analysed were *trans*- and *cis*-furan linalool oxide, linalool, hotrienol, α-terpineol, citronellol, nerol, geraniol, diendiol-1 and trans-geranic acid.

Sensory evaluations

Wines were sensorially evaluated by a panel of six specially trained judges. Intensities of fruity/ester-like and spicy/terpene-like characters, as well as overall wine quality were evaluated on a 9-point scale.

Statistical analyses

The statistical significance of the effects of grape maturity and juice treatments on terpene concentrations and wine quality characteristics was determined as described by MARAIS and VAN WYK (1986).

Results and discussion

The results of the 1986 vintage confirmed those of 1985. Only typical examples of the tendencies observed during the 1986 vintage are therefore given in this report.

Effect of grape maturity on terpene concentrations in Gewürztraminer grapes

The effect of grape maturity on FVT and PVT concentrations, as well as on geraniol and linalool concentrations in Gewürztraminer non-settled juices is illustrated in Fig. 1. In this part of the study, an attempt was made to determine optimum grape maturity, which would result in the production of maximum quality wines. The sugar concentrations of the grape samples, collected at 1 week intervals over 7 weeks (Fig. 1 A), varied between 18,6 and 25,3 °B. The maximum sugar concentration of 25,3 °B was obtained at time 7.

The FVT concentration varied slightly with relatively high concentrations at time 1 (18,6 °B), 4 (22,0 °B), 7 (25,3 °B) and 8 (24,0 °B) (Fig. 1 A). On the other hand, the PVT concentration continually increased from the second to the last sampling and was constantly higher than the FVT concentration. It appears as if the biosynthesis of bound terpenes increased with grape maturation. The above-mentioned results correspond with the findings of GÜNATA *et al.* (1985 b), who reported increases in glycosidically bound terpene concentrations during maturation of Muscat d'Alexandrie and Muscat de Frontignan grapes. These authors also found that the bound fraction continued to increase strongly after ripeness was attained, while the free fraction stayed constant or diminished in concentration. Furthermore, the total bound forms were found to be more abundant than the total free forms in skins, pulp and juice (GÜNATA *et al.* 1985 b).

With regard to individual free terpene concentrations, geraniol (Fig. 1 B), citronellol, nerol and trans-geranic acid (data not shown), in general showed the same tendency as the PVT concentration, namely a steady increase over the entire period of 7 weeks. These increases were especially prominent during the last 3 weeks of the investigation. Linalool concentration fluctuated between time 1 and 5 and decreased from time 5 to 8 (Fig. 1 C). Peaks were observed at time 3 (21,3 °B) and 5 (22,6 °B). These results correspond with findings of GÜNATA *et al.* (1985 b), who also found sharp increases in free geraniol, nerol and citronellol concentrations with grape maturation and especially with over-ripeness. Linalool concentration also increased with grape maturation, but decreased during over-ripeness. WILSON *et al.* (1984), however, observed the disappearance of free geraniol and nerol with increasing maturity of Muscat d'Alexandrie grapes. These authors also found an increase in linalool concentration followed by a decrease with increasing maturity. The reasons for differences between the above-mentioned findings are not clear, but could be ascribed to cultivar and climatic differences.

A distinct resemblance between the results of this study (Table 1, free-run juice) and others (GÜNATA *et al.* 1985 a; VERSINI 1985; WILLIAMS *et al.* 1985) is the low concentration in which linalool and the relatively high concentrations in which geraniol, nerol

and citronellol occur in Gewürztraminer grapes. A further result of this study was that the concentrations of α-terpineol, diendiol-1 and *trans*-geranic acid were also relatively high in comparison to linalool.

The following factors should be considered in the final determination of the correct time of harvesting. Geraniol, nerol and citronellol appear to be of importance in the typical character and quality of Gewürztraminer grapes and wines, since these relatively low threshold terpenes occur in relatively high concentrations. Although important, these terpenes do not necessarily cause the typical cultivar character of Gewürztraminer. VERSINI (1985) claimed that the fermentation-formed 4-vinylguaiacol is the main compound responsible for the characteristic aroma of Gewürztraminer, but also speculated that the contribution of this compound is not quite sufficient for Gewürztraminer typicity. If of any importance, the determination of the precursor of 4-vinylguaiacol in grapes would be of great interest. It is important that all compounds which contribute to Gewürztraminer character should be determined and considered in grape quality evaluation.

The PVT concentration should be considered as an important factor in the final determination of the correct time of harvesting, since the possibility of the liberation of terpenes from their bound forms continually exists (WILSON *et al.* 1984; WILLIAMS *et al.* 1985).

Although sugar concentration is generally considered as an important parameter for optimum grape quality assessment, it is, however, not necessarily a reliable parameter. This is illustrated by the fact that terpene concentrations may change significantly over a given period, while sugar concentration shows minor changes (MARAIS and VAN WYK 1986). At a certain sugar concentration and specific climatic conditions, raisin development sets in with the resultant concentration of, amongst others, terpenes in the berries. This factor most probably explains the prominent increases in certain terpene concentrations during the last harvesting stages of this study (Fig. 1). Wines produced from over-ripe grapes, normally have high alcohol and low TTA concentrations, and burnt, bitter and coarse after-tastes are often perceived. Over-ripeness also normally results in lower crop masses and financial considerations may, therefore, also play an important role in the final determination of the time of harvesting.

Climatic conditions, such as rain or heat-waves, could affect the attainment of optimum grape maturity and should therefore be taken into consideration before the harvest is collected. For example, exceptionally high environmental temperatures preceded the 1986 vintage and consequently accelerated the attainment of ripeness and over-ripeness. This most likely had a prominent effect on the development of terpenes in this study.

Taking the above-mentioned factors into consideration, a recommendation for the correct time of harvesting in this particular study would have been at a sugar concentration as high as possible, but before over-ripeness (i.e. time 6, 23,0 °B). Since this prediction is based on the results of one season, the investigation should be repeated before optimum grape maturity could be defined accurately.

Effect of grape maturity on terpene concentrations in Gewürztraminer settled juices and wines

Grapes for the production of wine were collected at time 4 (22,0 °B), 6 (23,0 °B) and 8 (24,0 °B) (Fig. 1 A). The main effect of grape maturity on average terpene concentrations in settled juices and wines is given in Tables 1 and 2. An increase in grape maturity resulted in significant increases in the concentrations of trans-furan linalool oxide, α-terpineol and citronellol in Gewürztraminer settled juices (Table 1), as well as citro-

Table 1

The effect of grape maturity and juice treatments on relative terpene concentrations in Gewürztraminer juice extracts

Der Einfluß der Beerenreife und der Mostbehandlung auf die relative Terpenkonzentration in Extrakten von Gewürztraminermosten

Terpene	Ripening stage			Juice treatment				
	1	2	3	FR	SC(4)	SC(15)	H	SC(15)+H
trans-Furan linalool oxide	0,98 b	1,13 b	1,73 a	0,45 d	0,99 c	1,38 b	1,28 b	2,30 a
Linalool	9,43 a	7,32 b	5,53 b	1,08 c	1,58 c	2,31 c	7,95 b	24,22 a
α-Terpineol	6,00 b	6,31 b	7,42 a	3,32 c	4,79 b	6,31 b	5,70 b	12,77 a
Citronellol	6,06 b	8,23 b	10,41 a	3,28 b	9,99 a	14,45 a	1,84 c	11,61 a
Nerol	30,27 a	29,21 a	18,24 a	3,16 b	30,32 a	47,89 a	3,36 b	44,81 a
Geraniol	120,62 a	122,89 a	113,19 a	39,02 b	144,90 a	213,84 a	21,34 c	175,42 a
Diendiol-1	8,30 a	7,42 a	9,30 a	5,14 c	5,28 c	8,54 b	9,69 b	13,05 a
trans-Geranic acid	60,06 a	52,06 a	47,49 a	17,35 b	63,08 a	89,77 a	11,76 b	84,07 a

Ripening stage 1 = 22,0 °B.
Ripening stage 2 = 23,0 °B.
Ripening stage 3 = 24,0 °B.
FR = Free-run.
SC (4) = Skin-contact for 4 h.
SC (15) = Skin-contact for 15 h.
H = Heat treatment.
SC (15) + H = Combined skin-contact for 15 h and heat treatment.
Figures designated by the same symbol do not differ significantly ($P \leq 0,05$).

nellol and *trans*-geranic acid in the corresponding wines (Table 2). During the 1985 vintage, in which grapes were collected between 18 and 21 °B, significant increases were observed in the concentrations of geraniol, *trans*-geranic acid, linalool, hotrienol and α-terpineol with grape maturation (data not shown). Increases in terpene concentrations with an increase in grape maturity have also been reported previously (BAYONOVE and CORDONNIER 1970; MARAIS and VAN WYK 1986). On the other hand, linalool (Table 1) and diendiol-1 (Table 2) decreased significantly with grape maturation. Several studies showed an increase in linalool with grape maturation, followed by a decrease at a certain ripening stage, usually at over-ripeness (GUNATA *et al.* 1985 b; MARAIS and VAN WYK 1986).

This investigation was done during the last stages of ripeness, namely between 22,0 and 25,3 °B. Variation in sugar concentration was therefore limited and differed from other studies, which normally monitored terpene concentration changes over the whole period of grape maturation. Certain factors causing a relatively gradual increase in sugar concentration over a period of 4 weeks, probably had a similar effect on terpene metabolism. None the less, significant changes in terpene concentrations did occur, which indicate the risk of using sugar concentration as the sole grape quality parameter. Terpene concentrations may be a more reliable indicator of the attainment of optimum grape maturity.

Comparison of geraniol and linalool concentration changes between Gewürztraminer grapes (Fig. 1 B and C) and the corresponding juices (Table 1) is difficult, since gas chromatographic analyses were performed on non-settled juices in the first case and

Table 2

The effect of grape maturity and juice treatments on relative terpene concentrations in Gewürztraminer wine extracts

Der Einfluß der Beerenreife und der Mostbehandlung auf die relative Terpenkonzentration in Extrakten von Gewürztraminerweinen

Terpene	Ripening stage			Juice treatment				
	1	2	3	FR	SC(4)	SC(15)	H	SC(15)+H
trans-Furan linalool oxide	13,20 a	14,87 a	13,27 a	10,91 a	14,52 a	14,57 a	14,61 a	14,27 a
cis-Furan linalool oxide	8,29 a	8,58 a	7,28 a	7,65 a	8,27 a	8,52 a	8,11 a	7,71 a
Linalool	22,65 a	18,93 a	14,87 a	14,40 b	17,13 b	18,82 b	14,04 b	29,69 a
α-Terpineol	12,01 a	11,50 a	9,11 a	7,96 b	11,51 a	12,95 a	6,94 b	15,00 a
Citronellol	13,58 b	13,94 b	27,52 a	11,34 b	31,61 a	33,70 a	4,61 c	10,48 b
Geraniol	13,65 a	15,92 a	11,71 a	11,51 b	14,63 a	17,87 a	9,90 b	14,90 a
Diendiol-1	4,81 a	3,03 b	2,77 b	3,46 a	3,81 a	4,17 a	2,86 a	3,39 a
trans-Geranic acid	55,06 c	80,55 b	199,78 a	51,24 b	130,41 a	170,73 a	43,11 b	163,49 a

Ripening stage 1 = 22,0 °B.
Ripening stage 2 = 23,0 °B.
Ripening stage 3 = 24,0 °B.
FR = Free-run.
SC (4) = Skin-contact for 4 h.
SC (15) = Skin-contact for 15 h.
H = Heat treatment.
SC (15) + H = Combined skin-contact for 15 h and heat treatment.

Figures designated by the same symbol do not differ significantly ($P \leq 0,05$).

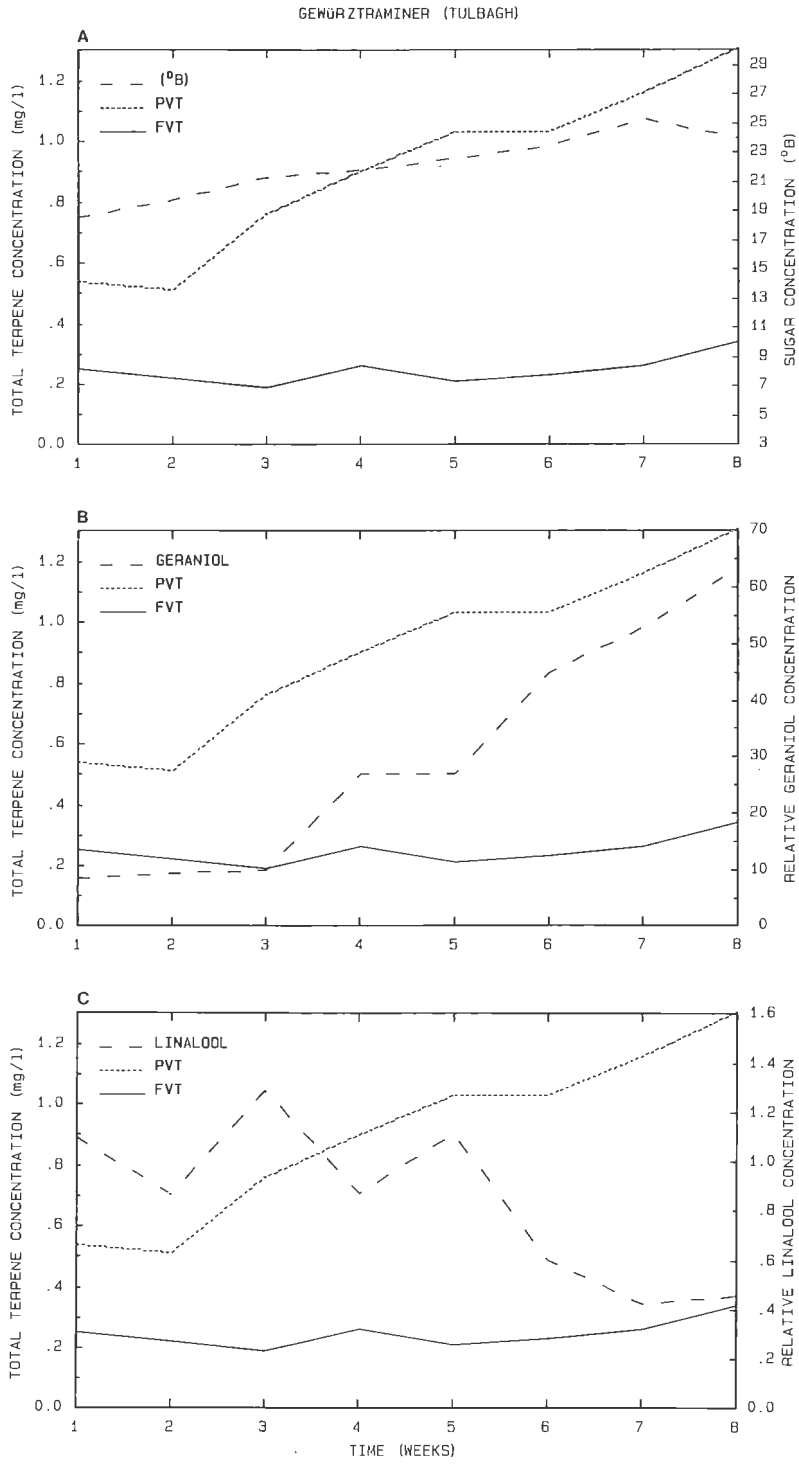
on settled juices in the last. Furthermore, the values for each ripening stage (Table 1) are the rank sums for all five juice treatments. Nevertheless, if the individual free-run values of geraniol (Fig. 2), for instance, are compared with the corresponding values over ripening stages 4, 6 and 8 (Fig. 1 B), increases were observed in both cases.

Effect of juice treatments on terpene concentrations in Gewürztraminer juices and wines

The main effect of juice treatments on average terpene concentrations in settled juices and wines is given in Tables 1 and 2. The effect of juice treatments on individual geraniol and linalool concentrations is also illustrated for juices (Fig. 2) and the corresponding wines (Fig. 3). The free-run treatment was considered as the control in this experiment. Skin-contact for 4 and 15 h resulted in significant increases in the concen-

Fig. 1: Changes in the concentrations of total free volatile terpenes (FVT), total potentially volatile terpenes (PVT) and sugar (° B) (A), geraniol (B) and linalool (C) during maturation of Gewürztraminer grapes.

Konzentrationsveränderungen während der Reifung von Gewürztraminertrauben: A) Gesamte freie flüchtige Terpene (FVT), gesamte potentiell flüchtige Terpene (PVT) und Zucker (° B), B) Geraniol, C) Linalool.


GEWÜRZTRAMINER (TULBAGH)
A
(°B)
PVT
FVT
TOTAL TERPENE CONCENTRATION (mg/l)
SUGAR CONCENTRATION (°B)
B
GERANIOL
PVT
FVT
TOTAL TERPENE CONCENTRATION (mg/l)
RELATIVE GERANIOL CONCENTRATION
C
LINALOOL
PVT
FVT
TOTAL TERPENE CONCENTRATION (mg/l)
RELATIVE LINALOOL CONCENTRATION
TIME (WEEKS)

trations of *trans*-furan linalool oxide, α-terpineol, citronellol, nerol, geraniol, diendiol-1 and trans-geranic acid in Gewürztraminer juices (Table 1), as well as α-terpineol, citronellol, geraniol and *trans*-geranic acid in the corresponding wines (Table 2). Figs. 2 and 3 also illustrate marked increases in individual geraniol concentrations in Gewürztraminer juices and wines. In contrast to the results obtained for Weisser Riesling and

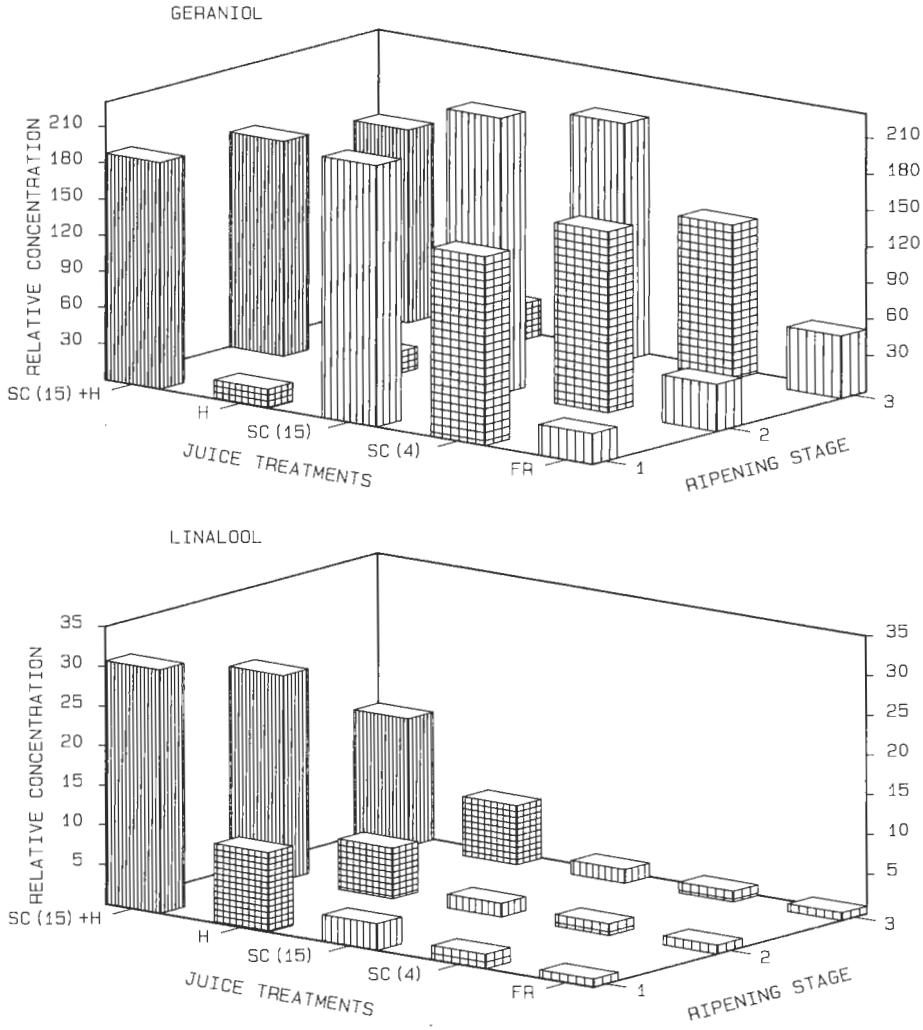


Fig. 2: The effect of grape maturity and juice treatments on the relative concentrations of geraniol and linalool in Gewürztraminer juices. — Ripening stage 1 =22,0 °B, 2 = 23,0 °B and 3 = 24,0 °B. FR = Free-run, SC(4) = Skin-contact for 4 h, SC(15) = Skin-contact for 15 h, H = Heat treatment and SC(15)+H = Combined skin-contact for 15 h and heat treatment.

Der Einfluß von Beerenreife und Mostbehandlung auf die relative Konzentration von Geraniol und Linalool in Gewürztraminermost. — Reifestadium 1 = 22,0 °B, 2 = 23,0 °B, 3 = 24,0 °B. FR = Seihmost, SC(4) = 4stündiger Kontakt mit der Beerenhaut, SC(15) = 15stündiger Kontakt mit der Beerenhaut, H = Hitzebehandlung, SC(15)+H = 15stündiger Kontakt mit der Beerenhaut kombiniert mit Hitzebehandlung.

Buketttraube (MARAIS and VAN WYK 1986), the effect of skin-contact, especially for 15 h, was much more prominent in the present study. The above-mentioned results correspond with studies on Weisser Riesling (VERSINI *et al.* 1981), as well as with the results obtained for Gewürztraminer during the 1985 vintage. In the same context, GUNATA *et al.* (1985 b) reported the abundance of free terpenols, especially citronellol, nerol and

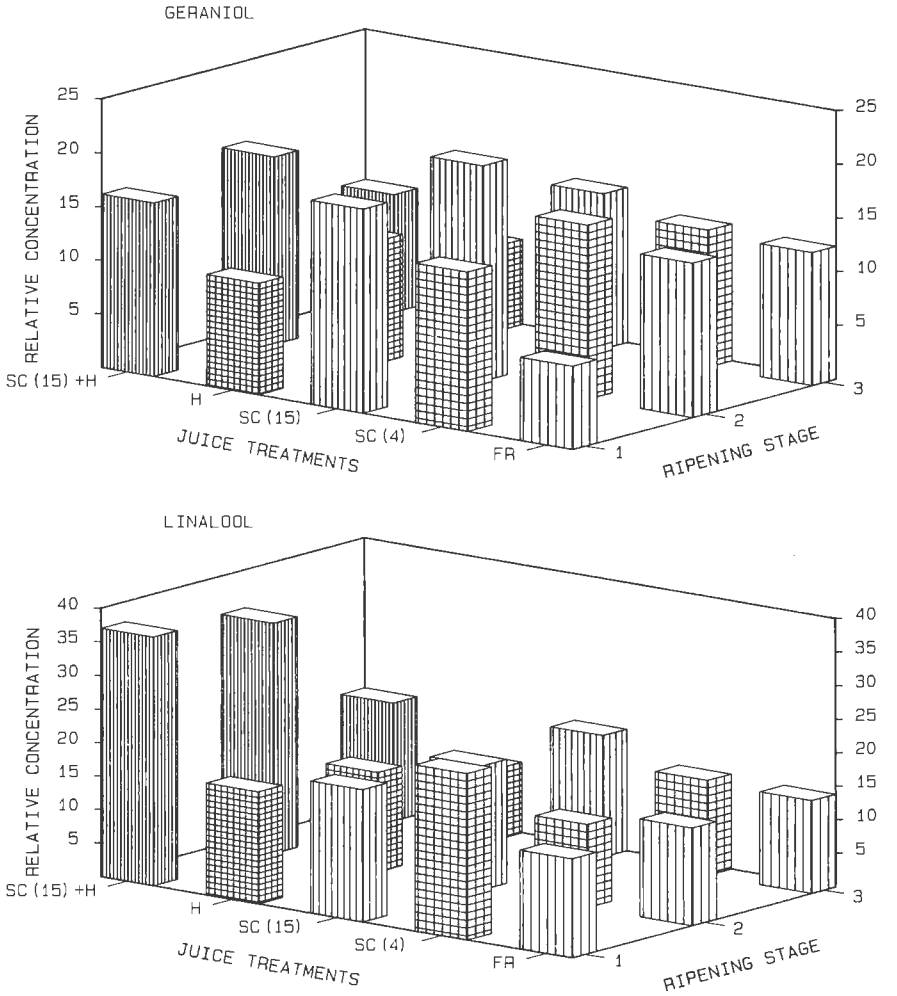


Fig. 3: The effect of grape maturity and juice treatments on the relative concentrations of geraniol and linalool in Gewürztraminer wines. — Ripening stage 1 = 22,0 °B, 2 = 23,0 °B and 3 = 24,0 °B. FR = Free-run, SC(4) = Skin-contact for 4 h, SC(15) = Skin-contact for 15 h, H = Heat treatment and SC(15)+H = Combined skin-contact for 15 h and heat treatment.

Der Einfluß von Beerenreife und Mostbehandlung auf die relative Konzentration von Geraniol and Linalool in Gewürztraminerwein. — Reifestadium 1 = 22,0 °B, 2 = 23,0 °B, 3 = 24,0 °B. FR = Seihmost, SC(4) = 4stündiger Kontakt mit der Beerenhaut, SC(15) = 15stündiger Kontakt mit der Beerenhaut, H = Hitzebehandlung, SC(15)+H = 15stündiger Kontakt mit der Beerenhaut kombiniert mit Hitzebehandlung.

geraniol, in the skins of Muscat d'Alexandrie and nerol and geraniol in the skins of Muscat de Frontignan. WILLIAMS *et al.* (1985) also reported relatively high concentrations of free and bound geraniol in the skins of Gewürztraminer grapes and suggested that the hypodermal cells of the berry are the sites of geraniol biosynthesis and storage.

As mentioned earlier, a skin-contact temperature of 10 °C was applied in 1986, in contrast with 18 °C in 1985. This adaptation was made, since RAMEY (1982) found an increase in the combined concentration of 24 volatiles, a decrease in total phenol concentration and higher wine quality of Chardonnay cultivar wines when skin-contact was applied at 10 °C, in contrast with higher skin-contact temperatures.

In the case of Gewürztraminer juices, heat treatment resulted in significant increases in the concentrations of *trans*-furan linalool oxide, linalool, α-terpineol and diendiol-1 (Table 1), as well as significant decreases in the concentrations of citronellol and geraniol. In the corresponding wines (Table 2), a significant decrease was observed in the case of citronellol concentration only. Although not significant, marked changes were also observed in other terpene concentrations as a result of heat treatment. The above-mentioned effect of heat treatment on geraniol and linalool concentrations is also illustrated in Figs. 2 and 3.

The effect of heat treatment on the liberation of glycosidically bound terpenes was demonstrated and explained by the studies of WILLIAMS *et al.* (1982 a, 1982 b, 1982 c). The studies of WILLIAMS *et al.* (1980), USSEGLIO-TOMASSET and DI STEFANO (1980), VERSINI *et al.* (1981) and MARAIS and VAN WYK (1986) on Muscat d'Alexandrie, White Muscat of Piemonte, Weisser Riesling and Buketttraube cultivars, illustrated prominent increases in most terpene concentrations as a result of heat treatment. Therefore, the above-mentioned decreases in citronellol, and geraniol concentrations in Gewürztraminer juices (Table 1, Fig. 2) are contradictory and probably suggest a distinct difference between Gewürztraminer and other cultivars, such as Weisser Riesling and Buketttraube. These decreases in citronellol and geraniol concentrations also confirm the findings of the 1985 vintage. The reasons for these decreases could be the absence of the corresponding bound forms of geraniol and citronellol in the grapes. GUNATA *et al.* (1985 a), however, observed the occurrence of geraniol, citronellol, nerol, linalool and α-terpineol in much higher concentrations in bound than in free forms in Gewürztraminer, as well as other muscat cultivars. These results suggest that in the case of Gewürztraminer grapes, specifically, heat treatment should result in increases in the concentrations of these terpenes. Another reason for the decreases in geraniol and citronellol concentrations in Gewürztraminer juices could be the immediate transformation of liberated geraniol and citronellol to other terpenes during heat treatment, such as linalool and α-terpineol for instance (USSEGLIO-TOMASSET and DI STEFANO 1980). Climatic and clonal differences may also have an important effect on the results of the same cultivar from different regions.

The combined effect of 15 h skin-contact and heat treatment caused significant increases in the concentrations of all the relevant terpenes in Gewürztraminer juices (Table 1, Fig. 2), as well as in the case of linalool, α-terpineol, geraniol and *trans*-geranic acid in the corresponding wines (Table 2, Fig. 3). Since skin-contact may enhance important terpene concentrations and the typical Gewürztraminer character, and heat treatment may enhance the concentrations of important terpenes in general, these two treatments were applied together. From the above-mentioned results it is clear that the combined treatment was quite effective in this investigation. The combined effect, however, is not necessarily merely the sum of the two individual treatments. For example, linalool (Table 1, Fig. 2) was much higher in concentration than the total concentration of the two individual treatments. This finding could be ascribed to the addi-

Table 3

The effect of grape maturity on quality characteristics of Gewürztraminer wines

Der Einfluß der Beerenreife auf die sensorischen Merkmale von Gewürztraminerweinen

Quality characteristic	Ripening stage [1]	
	1	2
Fruitiness/ester-like (Intensity)	13,00 a	23,00 b
Spiciness/terpene-like (Intensity)	17,50 a	18,50 a
Overall wine quality	14,50 a	21,50 b

[1] The values for each ripening stage are the rank sums for all five juice treatments.

Ripening stage 1 = 22,0 °B.
Ripening stage 2 = 23,0 °B.

Figures in rows designated by the same symbol do not differ significantly ($P \leq 0,05$).

tional enrichment of bound linalool from the skins and the resultant liberation of additional free linalool during heat treatment. The reversed tendency, namely a lower combined treatment value than the sum of the two individual treatments was, however, also observed for some terpenes, such as geraniol and citronellol in the case of both Gewürztraminer juices and wines (Tables 1 and 2, Figs. 2 and 3). Complex terpene transformations during heat treatment, as well as during fermentation, could be the reason for these contradicting findings.

Comparison between individual terpene concentrations in juices and their corresponding wines was difficult, since terpenes were calibrated as relative concentrations in both juice and wine media. Nevertheless, if the effect of juice treatments on terpene concentrations, for instance geraniol and linalool (Figs. 2 and 3), is compared, similarities between juices and wines were observed. Where differences or an equalizing effect on terpene concentrations occurred, the reasons are not clear but may probably be ascribed to terpene transformations during fermentation (MARAIS and VAN WYK 1986).

Sensory evaluation

Effect of grape maturity on wine quality

With regard to significant changes in terpene concentrations, the gas chromatographic results of the 1985 vintage corresponded to a great extent with those of 1986. The significant changes in terpene concentrations in juices of the 1985 vintage were, however, not always reflected in the corresponding wine characters. These wines, produced at between 18 and 21 °B, tended to lack sufficient and characteristic aroma. Therefore, it was decided to harvest grapes at higher sugar concentrations during the 1986 vintage. Unfortunately, the wines produced at 24,0 °B had sensory characteristics associated with over-ripe grapes and were therefore excluded from the sensory evaluation.

Sensory evaluation results for the effect of grape maturity on wine quality characteristics are given in Table 3. Gewürztraminer wines, made from grapes at the second ripening stage, had a significantly higher intensity of fruitiness/ester-like character and higher overall wine quality when compared to those produced from grapes of the first stage (Table 3). With regard to terpene-like/spicy character, no significant differences were observed between the two relevant ripening stages. To a certain extent, this

Table 4

The effect of juice treatments on quality characteristics of Gewürztraminer wines

Der Einfluß der Mostbehandlung auf die sensorischen Merkmale von Gewürztraminerweinen

Quality characteristic	Juice treatments [1]				
	FR	SC (4)	SC (15)	H	SC (15) + H
Fruitiness/ester-like (Intensity)	29,00 ab	32,50 ab	21,50 a	49,00 b	48,00 b
Spiciness/terpene-like (Intensity)	23,50 a	32,00 ab	30,50 ab	47,00 b	47,00 b
Overall wine quality	29,50 ab	27,00 ab	25,00 a	46,50 bc	52,00 c

[1] The values for each juice treatment are the rank sums for both ripening stages.

FR = Free-run.
SC (4) = Skin-contact for 4 h.
SC (15) = Skin-contact for 15 h.
H = Heat treatment.
SC (15) + H = Combined skin-contact for 15 h and heat treatment.

Figures in rows designated by the same symbol do not differ significantly ($P \leq 0,05$).

corresponded with minor changes in some terpene concentrations (Table 2), as well as with FVT and PVT concentrations (Fig. 1, time 4 to 6). Minor changes in terpene-like/spicy character intensity between ripening stages 1 and 2 could have been expected, since ripeness proceeded with only 1,0 °B over 2 weeks. Therefore, factors affecting wine quality could have similarly affected the biosynthesis of terpenes. Nevertheless, in this specific study, ripening stage 2 (23,0 °B) appeared to be optimal with regard to optimum wine quality, which agreed with the deductions made earlier from the FVT and PVT results.

Effect of juice treatments on wine quality

Sensory evaluation results for the effect of juice treatments on wine quality characteristics are given in Table 4. Heat treatment resulted in wines with significantly higher intensities of terpene-like/spicy character than the free-run control, as well as significantly higher overall wine quality than the 15 h skin-contact treatment (Table 4). Wines with significantly higher intensity of fruitiness/ester-like characters were also produced by heat treatment when compared to those produced by 15 h skin-contact. Wines produced from the juices subjected to the combined 15 h skin-contact and heat treatment showed significantly higher intensities of terpene-like/spicy character when compared to those produced from free-run juices, as well as significantly higher overall wine quality when compared to those produced from free-run and 4 h skin-contact treatments. The combined treatment also resulted in wines with significantly higher intensities of fruitiness/ester-like character and overall wine quality than the 15 h skin-contact treatment.

From the above-mentioned findings, it is evident that heat treatment to some extent, and more specifically the combined 15 h skin-contact and heat treatment produced the highest quality wines. In general, the wines of the 1986 vintage were, most probably due to TTA adjustment of juices, lower skin-contact temperature of 10 °C and sugar concentration adjustment of the wines, much less coarse and bitter and presented a better overall balance than those of the 1985 vintage.

If the gas chromatographic results of the Gewürztraminer wines (Table 2) are compared with the corresponding sensory evaluation results in general (Table 4), the following is evident. Significant increases in the relevant terpene concentrations as a result of 4 and 15 h skin-contact corresponded with slight increases in terpene-like/spicy intensities of the wines, but were not reflected in the corresponding overall wine qualities. Heat treatment had a prominent effect on the enhancement of wine quality, but failed to liberate substantial amounts of the terpenes analysed. On the other hand, the combined 15 h skin-contact and heat treatment resulted in significantly higher concentrations of most terpenes analysed (Table 2), as well as the corresponding wine qualities (Table 4).

Conclusions

The development of the typical Gewürztraminer aroma in wine should never be taken for granted. In order to attain this goal it could become necessary to adapt viticultural and cellar practices in warm wine-producing countries. An increase in grape maturity (time 4 to 8) did not have a prominent effect on free terpene concentrations in juices and wines. This could be ascribed to the relatively limited °B intervals between harvests. An increase in grape maturity (time 1 to 8), however, resulted in marked increases in PVT and some individual free terpene concentrations in grapes, collected over a wider range of sugar concentrations (18,6—25,3 °B). The continual liberation of terpenes from their bound forms during ripening, cellar manipulations and fermentation is a distinct possibility, which should be thoroughly considered in the determination of the optimum time of grape harvesting. From the results of this study, a prediction of 23 °B was made. Further studies on the effects of other viticultural factors, such as aroma-rich clones, different crop levels and irrigation would, however, be necessary before optimum grape maturity could be defined accurately.

With respect to juice treatments, skin-contact and the combined skin-contact/heat treatment resulted in significant increases in most terpene concentrations. Heat treatment, however, caused decreases in geraniol and citronellol concentrations, which is in contrast to previous findings in studies on other cultivars. The combined skin-contact/heat treatment resulted in increases in the intensities of fruitiness/ester-like, spicy/terpene-like characters, as well as overall wine quality, which correlated with the gas chromatographically analysed terpene results. It is recommended that skin-contact at temperatures below 10 °C, or skin-contact followed by a certain degree of heat treatment of the juice, would produce typical Gewürztraminer wines. Different procedures would, however, apply to different aroma-rich cultivars. If a mere enhancement of aroma is required, heat treatment as such would probably have a desirable effect on wine quality. It must be noted that all deductions made in this study, were based on young wine bouquet or quality. No prediction of the ageing potential of wines was attempted and further studies in this regard should be undertaken.

Summary

The effect of grape maturity and juice treatments, namely skin-contact and heat treatment, on individual free terpene concentrations in Gewürztraminer juices and wines, as well as on wine quality, was investigated. Total free volatile terpenes and

total potentially volatile terpenes were also monitored during ripening of the grapes. Linalool, hotrienol, α-terpineol, citronellol, nerol, geraniol, diendiol-1, *trans*-geranic acid and the furan linalool oxides were analysed gas chromatographically. Wine quality characteristics, such as fruitiness/ester-like, spiciness/terpene-like and overall wine quality of the wines were evaluated sensorially. An increase in grape maturity caused marked increases in total bound terpene, as well as in most individual terpene concentrations. Skin-contact for 4 and 15 h, respectively, and a combined treatment of 15 h skin-contact and heat treatment caused significant increases in the concentrations of the majority of terpenes analysed. Heat treatment resulted in decreases in geraniol, nerol and citronellol concentrations. The combined skin-contact and heat treatment resulted in higher intensities of fruitiness and spiciness, as well as overall wine quality.

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J. MARAIS
Viticultural and Oenological
Research Institute
Private Bag X5026
7600 Stellenbosch
Republic of South Africa