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Yeast stability tests on dessert wines

by

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Introduction

The biennual report of the Enological Station at Odessa for the years 1908 and 1909 was not published until 1911[1]). The station was a private enterprise, largely financed by a public-spirited woman. The report runs to over 200 pages but starting on page 118 there begin a series of papers on the influence of the sugar content of the must on the progress of the fermentation. The report is not signed but one of the investigators at the station was P. N. Delle and the experiments have been attributed to him by later Russian workers. Delle's theory on the stability of dessert wines was based on the observation that a must of 78 percent sugar or of 13 percent alcohol (by weight) is biologically stable. For biological stability, according to this theory, the sum of the sugar content and 6 times the alcohol content (by weight) must equal at least 78. On the more familiar percent by volume basis the alcohol is 15.6 percent. Thus, in terms of biological stability, 4.8 grams of sugar equal 1 percent by volume of alcohol. In his paper he refers to these sugar and alcohol values as units of conservation (konserv dieistvie). Later papers call them KED (konserviruiushchikh edenits Delle) or Delle conservation units. The original paper of Delle considered the influence of sugar on yeast multiplication, on the course of fermentation, and on the composition of the end product. A large number of Russian wines using different yeasts were analyzed in reaching the equation: KED = a + 6 c where a is sugar and c is percent alcohol by weight. Of course, other factors, which Delle was well aware of, will also influence the biological stability of a wine: amount and activity of yeasts, temperature, total acidity and pH, nitrogen and growth factor content, oxygen tension and carbon dioxide pressure, etc. Delle published another report in 1915 which we have not seen.

In the Soviet Union there have been a number of investigations of Delle's work, most of which have been reviewed by Deibner (1953). Deibner's report quotes the original paper but apparently from Okhremenko (1950). He, in turn, was referring to Schumakov (1930, 1931, 1934) who worked at the Odessa station in the 1930's. Kotcherga's (1940) report is also quoted by Okhremenko. Deibner believed that Okhremenko's equation was in error but actually it is as given on p. 148 of the original Delle paper. Deibner used the equation DU = a + 5.6 b or a + 4.5 c, where DU are Delle units, a is the percent sugar and b and c the percent alcohol by weight or by volume. The work of Frolov-Bagreev et al. (1933) indicated Delle units of 75 to 78.5 for sugar contents varying from 2 to 30 percent and alcohol contents of 10 to 17 percent (by volume). Similar results were obtained on old wines by Okhremenko (1960).

Okhremenko also makes the point that production of this type of wine results in a great saving in spirits. They are less intoxicating and thus help prevent alcoholism. It is of interest to note that the editor of the journal asked for comments on the ex-

[1]) Actually the station worked on viticultural as well as enological subjects. We are indebted to the Lenin State Library in Moscow for the loan of the original report.

perience of other workers in the production of this type of wine at the end of OKHREMENKO's article.

SCHUMAKOV (1930, 1931) in particular studied DELLE's equation[2]). He reported that DELLE had not taken adequate account of the influence of the concentration of sugar on yeast growth nor of the influence of concentration of sugar on the products of yeast metabolism. Specifically, acids, alcohols (other than ethyl), esters and surface tension were all shown to contribute to the biological stability of wines. Soviet investigators have also noted the depressing effect of carbon dioxide on fermentation, particularly under pressure.

To make the calculation of DELLE units even simpler KOTCHERGA (1940) and OKHREMENKO (1961) prepared nomograms. For the 11 old wines analyzed by him (from an 1898 muscatel to a 1903 sweet wine) the DELLE units varied from 71 to 98. A somewhat more complicated nomogram was published by KOTCHERGA (1940).

Actually much of these data are inherent in many Western European studies, particularly of MÜLLER-THURGAU (1891), ORTLOFF (1900), SCHMITTHENNER (1949) and JENNY (1952). The effect of carbon dioxide had been especially carefully delineated by the BÖHI (1912) process for storage of grape juice.

More recently GAROGLIO (1959) and GAROGLIO and FLORENZANO (1961) have studied the application of the DELLE rule to Italian wines. For finished Asti spumante wines the DELLE units (DU) were found to be as low as 43.6 to 59.8. These low values may be due to the particular method of producing this type of wine, which results in low nitrogen contents, and, of course, to the effect of carbon dioxide pressure. However, OKHREMENKO (1950) found DELLE units of 60 to 66 sufficient for stability of Soviet sparkling wines of high sugar content (12.5 to 13.5 percent sugar).

BERNAZ et al. (1962) also recommended use of DELLE units in the preparation of dessert wines in Roumania. They reported 68—74 DELLE units resulted in stable wines with the 1956 vintage and 69—73 with the 1958 vintage.

JOSLYN and AMERINE (1964) noted the large production of moderate alcohol high sugar wines in the Soviet Union based on this principle (wines of only about 14 to 15 percent alcohol and 20 or more percent sugar).

So far as we know there have been no direct tests of the applicability of the DELLE equation to California musts. The present experiments were designed to test the validity of the equation under pilot plant conditions. It is possible that the greater yeast/wine ratio which exists in small fermentation vessels results in more severe stability conditions than would occur under winery operations.

Experimental

Sauvignon blanc grapes (26.2° Brix, 0.48 percent total acidity [as tartaric] and pH 3.66) from the University Vineyard were harvested on October 13, 1964. They were crushed and pressed, sulfited to 100 ppm, 1 percent yeast culture, *Saccharomyces cerevisiae* var. *ellipsoideus*, Montrachet strain, Enology No. 522) added, and a lot removed when the fermentation had reached 19.1, 13.9 and 7.0° Brix (= 18.8, 14.4 and 7.5 percent sugar by analysis). Each lot was subdivided into several samples of about 2 gal. each. An attempt was made to fortify these aliquots to 12, 13, 14, 15, 16, 17, 18 and 19 percent alcohol, with the use of 188° proof (94 percent) spirits. Following

[2]) No doubt because he also was an investigator at Odessa in the state experiment station (apparently the successor of the station at which DELLE worked).

fortification all lots were stored at 11.7° C. One week following fortification all lots were racked off the lees and analyses made for Brix, alcohol, and sugar by the usual methods of this laboratory (AMERINE 1960). The wines were stored in full containers and examined monthly for yeast growth; presence of either microorganisms or gasiness. The results are shown in table 1. The Delle units are given as calculated by the equation of DEIBNER.

A second experiment was made with Sémillon grapes harvested on October 20, 1964 and handled as previously. The original must was 25.9° Brix, 0.38 percent total acidity and had a pH of 3.72. In this case fermenting juice was removed when the Brix reached 22.3° and 18.9°. Fortifications were made to 11 through 18 percent alcohol.

The data are given in table 2.

A third series was made with Chardonnay grapes harvested on October 27, 1964. The original must was 26.8° Brix, 0.45 percent total acidity and had a pH of 3.91. In this experiment the primary purpose was to compare the stability of wines fermented with three different yeasts when fortified to various percents of alcohol. The yeasts were the Montrachet strain (Enology No. 522), Champagne (Enology No.

Table 1
Composition of Sauvignon blanc Wines

Attempted Alcohol	After fortification			After two weeks			After two months			Delle units
	Alcohol	Sugar	Extract	Alcohol	Sugar	Extract	Alcohol	Sugar	Extract	
%	%	%	gr/100 gr	%	%	gr/100 gr	%	%	gr/100 gr	
Fortified at 19.1° Brix										
13	13.5	17.4	18.4	13.4	16.7	17.8	13.7	16.2	17.8	77.8
14	14.1	16.9	18.2	14.2	16.7	17.7	14.1	16.5	17.6	80.0
15	15.4	16.9	18.0	15.2	16.9	17.6	15.1	16.5	17.6	84.5
16	16.4	16.9	17.9	16.5	16.4	17.5	16.5	16.2	17.5	90.4
17	17.7	16.7	17.6	17.4	15.9	17.1	17.3	15.9	17.3	93.9
18	18.2	16.2	17.4	18.4	16.2	16.9	18.2	15.7	15.7	97.7
Fortified at 13.9° Brix										
12	12.7	12.5	14.5	13.8	11.7	12.8	15.0	10.0	11.4	77.5
13	14.2	12.0	14.6	14.5	12.0	13.1	15.2	11.0	12.6	79.4
14	14.9	12.3	14.7	15.1	12.5	13.7	15.4	11.3	13.5	80.7
15	15.5	12.3	14.9	15.6	13.4	14.4	15.7	12.7	14.5	83.4
16	16.6	12.0	15.0	16.5	13.2	14.2	16.3	12.6	14.4	85.9
17	17.5	12.0	15.1	17.5	13.7	14.3	17.3	12.5	14.4	90.3
Fortified at 7.0° Brix										
14	14.4	7.0	10.5	15.5	6.8	8.1	16.4	3.8	6.8	77.8
15	15.6	6.7	10.4	16.6	7.5	8.5	16.9	4.5	7.6	80.7
16	16.7	6.5	10.2	17.2	7.5	8.8	17.5	5.3	8.2	84.0
17	17.2	7.0	10.2	17.8	7.3	9.2	17.4	6.2	9.1	84.7
18	18.2	6.0	10.0	18.5	8.0	9.3	18.1	6.6	9.4	88.1
19	19.3	5.5	9.6	19.9	8.2	9.3	19.7	6.6	9.3	95.3

505) and Burgundy (Enology No. 51). The fortifications were made at approximately 17° Brix to 10.5, 12, 13.5, 15, 16.5 and 18 percent alcohol. The results are given in table 3.

The data in table 1 indicate that Sauvignon blanc musts fortified at 19.1° Brix to 13, 14, 15, 16, 17, or 18 percent alcohol were essentially stable, *i. e.* they underwent little fermentation following fortification. As criteria for non-stability, either increase in alcohol, or decrease in sugar or extract was used. Usually the former was the more obvious. The calculated DELLE units (DU) at the end varied from 77.8 to 97.7. In other words, at high sugar content alcohol percentages of about 13 percent (77.8 DU) are sufficient for stability. The minor discrepancies in alcohol and sugar are attributed to sampling difficulties with high sugar samples. This is especially true of the samples taken immediately after fortification when considerable carbon dioxide remains.

Table 2
Composition of Sémillon Wines

Attempted Alcohol %	After fortification			After 7 weeks			DELLE units
	Alcohol %	Sugar %	Extract gr/100 gr	Alcohol %	Sugar %	Extract gr/100 gr	
			Fortified at 22.3° Brix				
11	11.6	19.2	20.9	11.9	18.7	20.1	72.3
12	12.7	19.7	20.5	12.5	19.0	20.2	75.2
13	13.2	19.5	20.3	13.2	18.7	20.2	78.2
14	14.5	18.8	19.9	14.3	18.5	20.0	83.0
15	15.4	18.8	19.8	15.5	18.5	20.0	88.5
16	16.9	18.2	19.8	16.7	18.7	19.6	93.8
			Fortified at 18.9° Brix				
11	11.6	16.7	18.3	13.6	13.2	15.5	74.6
12	12.5	16.4	18.0	13.7	15.0	16.5	76.6
13	13.7	16.7	17.8	13.9	16.2	17.6	78.8
14	14.3	16.2	17.7	14.9	16.4	17.5	83.6
15	15.0	16.2	17.5	15.1	16.1	17.5	84.2
16	17.0	16.2	17.4	17.1	15.9	17.2	92.9
17	17.3	15.7	17.1	17.7	15.8	17.5	95.6

When the fortification was made at 13.9° Brix, the usual case in California, stability was not achieved at less than about 15.7 percent alcohol. The final DELLE units ranged from 77.5 to 90.3. Stability was not noted in these lesssweet wines until about 82 DU. Therefore, at sugar percentages of 10 to 12, stability can be secured in wines with about 16 percent alcohol. Storage of the samples at 11.7° C undoubtedly reduced the rate of fermentation and thus helped secure stability.

Finally, when the fortification was delayed until 7.0° Brix, fermentation continued in samples up to about 17 percent alcohol. The final DELLE units ranged from 77.8 to 95.3. If 17 is taken as the percent alcohol for stability, the DELLE units are 84.7.

The results with Sémillon musts were essentially the same as those with Sauvignon blanc. The fortifications at 22.3° Brix were made to 11 to 16 percent alcohol.

Table 3

Composition of Chardonnay Wines Fermented with Three Yeast Strains

Attempted Alcohol %	After fortification Alcohol %	Sugar %	Extract gr/100 gr	After 7 weeks Alcohol %	Sugar %	Extract gr/100 gr	DELLE units
Montrachet strain, Fortified at 17.0° Brix							
10.5	12.0	15.0	17.0	17.6	6.5	9.4	85.7
12.0	12.7	14.7	17.0	17.3	7.6	10.4	85.4
13.5	14.1	14.7	17.1	16.4	11.0	13.4	84.8
15.0	15.8	14.4	16.7	16.0	13.7	16.0	85.7
16.5	17.1	14.1	16.6	17.2	13.9	16.0	91.3
18.0	18.3	14.7	16.3	18.5	13.9	15.8	97.2
Champagne strain, Fortified at 16.8° Brix							
10.5	10.4	15.7	17.4	16.5	6.5	8.5	80.8
12.0	12.0	15.5	17.3	14.3	10.7	13.5	75.0
13.5	13.3	15.5	17.0	14.2	13.7	15.7	77.6
15.0	15.0	14.7	16.9	15.3	13.9	16.2	82.7
16.5	16.4	14.4	16.7	16.3	14.4	16.3	87.8
18.0	17.8	14.5	16.4	17.8	14.2	16.0	94.3
Burgundy strain, Fortified at 17.1° Brix							
10.5	11.3	15.7	17.6	13.9	11.8	13.8	74.4
12.0	13.7	15.7	17.5	14.6	12.2	14.5	77.9
13.5	12.5	15.5	17.7	15.4	13.0	15.5	82.3
15.0	15.3	15.7	17.2	15.8	14.0	16.6	85.1
16.5	16.4	15.5	17.0	16.9	14.6	16.7	90.7
18.0	19.0	15.2	16.8	19.0	14.2	16.4	99.7

The final DELLE units ranged from 72. 3 to 93.8. There was hardly any fermentation in the lot at 11 percent alcohol. When fortification was made at this very high sugar content, stability was reached at less than 12 percent alcohol, giving DELLE units less than 75.2.

When the fortification was made at 18.9° Brix the percent alcohol was 11 to 17 and the DU was 74.6 to 95.6. The lots fortified to 11 and 12 percent alcohol were not stable. Stability was reached with the lots where an attempt was made to fortify to 13 and 14 percent alcohol or more. Thus, when fortification of fermenting musts which were originally very sweet is made at about 19° Brix, stability is achieved at about 14 percent alcohol with about 78.8 DELLE units.

Thus, at high sugar contents stability may be expected at about 78 DU or below, whereas at moderate and low sugars it is not reached until about 82 and 85 DU, respectively. The corresponding alcohol percentages are 12—13, 14—16, and 17.

A comparison of the three yeast strains was made by fortification of fermenting Chardonnay musts at 17° Brix. With the Montrachet yeast, fortification to 15.8 percent alcohol (85.7 DU) resulted in stability. With the Champagne yeast there was some fermentation when fortification was made to 15 percent alcohol but very little when made to 16.5. The calculated DELLE units at 15.8 percent alcohol were

very close to that with the Montrachet (85.6 DU). With the Burgundy yeast, the degree of fermentation at the lower alcohol levels was much less than with the other two strains, but a higher alcohol concentration was required finally to inhibit fermentation. Between 15.3 and 16.4 percent alcohol was required for stability. The DELLE units based on final alcohol of 16.3 were 87.9.

The wines were tested for possible sensory differences. For this each of the 8 sets of fortified wines was judged by an experienced panel of 10 members. Each of the wines within a set was ranked by the judges in order of preference and the results were analyzed statistically (KENDALL, 1955; AMERINE et al., 1959) The "F" values (variance ratios) for the wines showed that in only 2 sets (Sauvignon blanc and Sémillion fermentations fortified at 19° Brix) of the 8 could the panel as a whole significantly differentiate the wines within a set.

Discussion

In figure 1 are plotted final DELLE units at stability versus percent sugar at time of fortification. It is obvious from these data that dessert wine stability is not achieved at any particular DELLE unit value. Rather the DELLE units for stability increases as the sugar content at fortification decreases.

Furthermore, there are differences between varieties of grapes and strains of yeast. The DELLE units for stability with Chardonnay grapes was much higher than with Sauvignon blanc or Sémillon. While we would not wish to emphasize the effect of yeast based on this single experiment, it does appear that a higher DU value is required finally for stability with Burgundy yeast as compared to the Montrachet

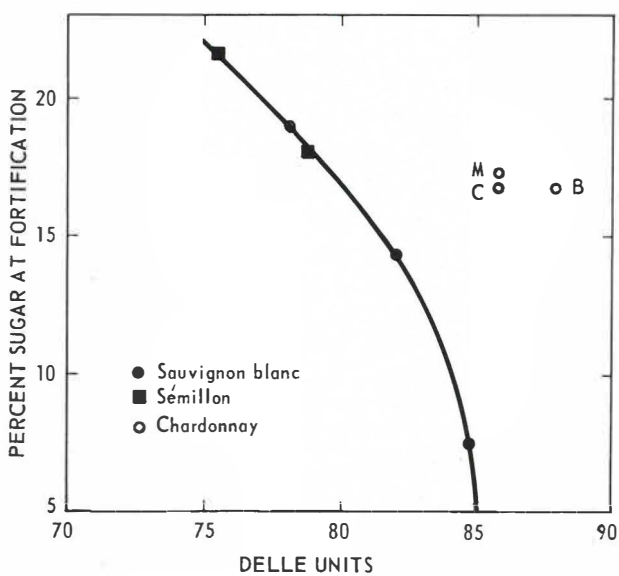

Figure 1: DELLE units (percent sugar plus 4.5 times percent alcohol, by volume) required to inhibit fermentation of musts fortified at the indicated percentages of sugar. Sauvignon blanc and Sémillon musts fermented with Montrachet (M) strain. C = Champagne yeast strain and B = Burgundy yeast strain.

or Champagne strains, even though at lower (non-stable) DU units, there was greater inhibition of fermentation of the Burgundy strain than of the other two.

In practice, the use of sulfur dioxide and the large yeast/volume relationship may tend to result in lower DELLE unit values at stability. The susceptability of these wines to various types of bacterial spoilage also needs to be considered.

In spite of the varying DELLE unit value for stability, the concept that sugar content is an important factor in achieving fermentation stability of dessert wines is a useful one. It opens up, for example, the possibility of producing stable California dessert wine with alcohol percentages considerably below the present California legal limit of 19.5 percent alcohol. This is all the more possible with the equipment and stability processing which is available in our larger California wineries.

Summary

California musts were fortified at various stages of fermentation to test the applicability of the DELLE equation, *i. e.*, dependency of inhibition of fermentation on the sum (DELLE units) of the percentage of sugar plus 4.5 times the percentage of alcohol, by volume. For fortification, alcohol was added to fermenting musts to give final concentrations from 11 to 19 percent. The resultant DELLE units, calculated from chemical analyses of lots in which fermentation was inhibited, were dependent upon stage of fermentation at which fortified, variety of must, and strain of wine yeast. Higher DELLE units were required for stability when the fortification was made in the late stages of fermentation, compared to early stages, and Chardonnay must required higher DELLE units for stability than did Sauvignon blanc or Sémillon musts. Montrachet and Champagne strains of *Saccharomyces cerevisiae* var. *ellipsoideus* required lower DELLE units to give complete inhibition of fermentation than did Burgundy strain.

Literature Cited

AMERINE, M. A.: Laboratory procedures for enologists. Davis, Department of Viticulture and Enology. 124 (1960).

— —, E. B. ROESSLER and F. FILIPELLO: Modern sensory methods of evaluating wines. Hilgardia 28, 477—567 (1959).

BERNAZ, D., I. DUMITRESCU, GH. BERNAZ and M. MARTIN: Teknologia vinului. Bucuresti, Editura Agro-Silvica. 392 p. (see p. 317) (1962).

BÖHI, A.: Ein neues Verfahren zur Herstellung alkoholfreier Obst- und Traubenweine (Kohlensäureverfahren). Frauenfeld, Huber & Co. (1912).

DEIBNER, L.: Principales données actuelles sur les facteurs de la stabilité biologique des vins sucrés ou des vins spéciaux et sur la régulation de cette dernière. Rev. ferment. ind. aliment. 8, 211—222 (1953).

DELLE, P. N.: The influence of must concentration on the fermentation and composition of wine and its stability. Odessa, Otchet" vinodiel'cheskoi stantsii russkikh" vinogradarei i vinodielov" za 1908 i 1909 g., 118—160 (1911).

FROLOV-BAGREEV, A. M., I. M. RIABCHENKO and E. IA. KLOTS: Microorganisms of grapes and fruits and their wines. Moskva, Snabtekhizdat. 304 p. (1933).

GAROGLIO, P. G.: La nuova enologia. Firenze, Ist. di Industr. Agrarie. 1357 p. (see pp. 776—777) (1959).

— — and G. FLORENZANO: Tecniche e processi di stabilizzazione dei vini con particolare riguardo a quelli dolci. Vini d'Italia 3, 307—314 (1961).

JENNY, J.: Les bases scientifiques de la conservation des jus sans alcool de raisin et de fruits à pépins sous pression d'acide carbonique. Industr. agr. aliment. 69, 687—700 (1952).

JOSLYN, M. A. and M. A. AMERINE: Dessert, appetizer and related flavored wines; the technology of their production. Berkeley, University of California, Division of Agricultural Sciences, 483 p. (1964).

Kendall, M. G.: Rank correlation methods. New York, Hafner Publishing Co., 2nd Ed., 196 p. (1955).

Kotcherga, P.: Nomogram of stability of wine. Vinod. i Vinograd. SSSR 1 (2), 10 (1940).

Müller-Thurgau, H.: Ergebnisse neuer Untersuchungen auf dem Gebiete der Weinbereitung. Ber. Dt. Weinbau-Congresses Worms 12, 128—152 (1890) (Mainz, Druck von P. von Zabern, 1891).

Okhremenko, N. S.: Method of bottling sparkling wines with high sugar content. Biokhim. Vinodel. 3, 236—246 (1950).

— — : Change in specification for dessert wines. Vinodel. i Vinograd. SSSR 20 (7), 13—15 (1960).

— — : Nomogram of wine stability. Vinodel. i Vinograd. SSSR 21 (2), 14—16 (1961).

Ortloff, H.: Der Einfluß der Kohlensäure auf die Gärung. Centralbl. für Bakt. 2. Abt. 6: 676—682, 721—733, 753—763 (1900).

Schumakov, A. M.: Yeast yield in relation to change in concentration factors. Trudy Tsentr. nauchno-opytnoi vinodel. stantsii im. Timiriazeva (Odessa) 2, 3—21 (1930).

— — : Factors determining the life processes of yeast. Trudy zonal'n. nauchno-opytnoi vinogrado-vinodel. stantsii im. Timiriazeva (Odessa) 4, 9—54 (1931).

— — : Methods of regulating the adding of spirits to wine. Trudy tekhn. vinograda Ukrain. nauchno-issledov. inst. vinograd. i vinotekh. (Odessa) 5, 5—32 (1934).

Schmitthenner, F.: Die Wirkung der Kohlensäure auf Hefen und Bakterien. Der Weinbau, Wiss. Beih. 3, 147—187 (1949).

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