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Regional, Varietal, and Type Influences on the Degree Brix and Alcohol Relationship of Grape Musts and Wines

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The varietal, regional, yearly and type (red and white) effects on the degree Brix-alcohol relationship are discussed. It was determined that the degree Brix measurement by hydrometer is a relatively poor indicator of the expected alcohol due to type, regional, yearly and varietal effects. These effects are shown by regression analyses of a large number of varieties over a 3-year period, and by analyses of data of 18 varieties over a 9-year period. Type-region effects are very significant with the red varieties between the two regions discussed and between the red and white types.

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Regional, Varietal, and Type Influences on the Degree Brix and Alcohol Relationship of Grape Musts and Wines[1]

INTRODUCTION

PREDICTING THE EXACT AMOUNT of alcohol that a yeast fermentation of a sugar solution can produce is a matter of routine procedure, but in dealing with a raw product such as grape juice (must) many difficulties may arise to make such prediction difficult. Grape juice consists of many compounds besides sugars, and not all of the sugars are fermentable by the yeast to ethyl alcohol. Amerine (1954)[2] discussed the work done in developing the factors used in estimating alcohol in the finished wine from reducing sugar in the must and also conditions which may cause variations in results. Marsh (1958) gives an average conversion factor of 0.47 grams of alcohol per gram of reducing sugar under normal conditions.

In commercial practice, sampling is of prime importance in estimating alcohol. Methods of obtaining adequate samples from truck loads of field lugs or from gondolas have been worked out by Berg and Marsh (1954), and if their procedure is followed errors are small. In practice, however, when proper sampling is neglected this becomes an important source of error. Methods of crushing the grapes and obtaining the measure of the soluble solids will effect the results. Amerine and Roessler (1958) using four methods of crushing found variations in the soluble solids content of as much as 2.5 to 3.0 grams per 100 grams, depending on the thoroughness of the crushing. Non-soluble solids can also be a factor when the measurement is made by hydrometer. Heavy or light material clinging to the walls and to the hydrometer stem will cause erroneous readings, as will air bubbles in the sample. The primary constituents of grapes which affect the density of the juice are the reducing sugars, glucose and fructose, which occur in about a 1:1 ratio (Amerine and Thoukis, 1958). Other soluble solids which affect the density of musts are acids, tannins, pectins, non-fermentable sugars, and other organic and inorganic constituents. Scott *et al.* (1960, 1961) studied the determination of soluble solids by refractometer in citrus juices and concentrates and found that by applying corrections for various constituents good agreement could be attained when comparison was made to measurements of the vacuum-dried soluble solid content. The prime interest in grape must for fermentation is not the total solids but the reducing sugars which

[1] Received for publication February 25, 1963.
[2] See "Literature Cited" for citations referred to in text by author and date.

provide an estimate of the amount of alcohol that will be produced.

The purpose of this study was to determine how well a measure of the soluble solids content by hydrometer would correlate with the amount of alcohol produced. Varietal, type, yearly, and regional comparisons were made to find if these factors caused differences in the degree Brix-alcohol relationship.

EXPERIMENTAL METHODS

Grapes. Grapes used were grown in the Oakville and Davis vineyards of the University of California. Harvesting dates varied according to regional and yearly climatic conditions, and grape varieties used were those being tested for wine production.

Must sampling. Grapes were stemmed and crushed with a Garolla stemmer-crusher. A minimum of two boxes of each variety was crushed. With white grapes the crushed grapes, juice, and seeds were put directly into a hydraulic basket press and the juice expressed under a maximum face pressure of 40 psi (pounds per square inch). The juice was put into a single container if possible, mixed, and a sample taken for analysis; varieties to be fermented on the skins were crushed directly into the containers in which they were to be fermented. The musts were mixed and a juice sample obtained by plunging a vessel with a screen-covered inlet into the must. Lots too large to be contained in one tank were sampled by taking a proportionate amount of juice from each tank.

Must analysis. The must samples were clarified by settling and decanting or, if appreciable non-soluble solids were present, by centrifugation. One year of testing was done to confirm the fact that the differences in technique between settling and centrifugation were negligible if the amount of non-soluble solids was small in the decanted sample (Ough, 1961). The prepared samples were put into hydrometer cylinders and the degree Brix determined with hydrometers ranging from 9.0 to 21.0, and 19.0 to 31.0, degree Brix. The same hydrometers were used for all determinations and were tested for calibration with sucrose solution and found to be accurate; broken hydrometers were replaced by similar calibrated hydrometers. The temperature of the must was recorded at each reading and corrections made to standardize values to 20° C. Each reading was made twice on each must sample; once by depressing the hydrometer to the bottom of the cylinder and releasing it, and once by raising the hydrometer higher than the float-point and letting it come to level a second time—if a discrepancy between the two readings was found a third reading was made. The same person made all determinations for any one year, but there were different analysts in different years.

Fermentation of musts. All musts were sulfited with 70 to 100 ppm (parts per million) of sulfur dioxide and a standard yeast culture used (*Saccharomyces cerevesiae* var. *ellipsoideus,* Montrachet strain). Fermentations were done in a temperature-controlled room (70° F). Temperature increase during fermentation of the white must was usually no more than 3 to 6° F; however, Ough and Amerine (1961) have shown that temperatures with red varieties may go extremely high in the cap area. After the apparent discontinuation of fermentation of white musts (when degree Brix had remained constant for 2 days) wines were racked to the cellar (53° F) and given standard cellar treatment. Red varieties were pressed from the skins after 2 to 4 days—in most instances the time was 3 days on the skins. The degree Brix at time of press varied, but was usualy between 14° to 8° Brix. Losses in alcohol by entrainment with carbon dioxide, as reported by Warkentin and Nury (1963), were probably small and about the same for all fermentations owing to similarity of environmental conditions under which our fermentations were made.

Wine analyses. Alcohol and extract of the wines was determined by distillation and hydrometer, as described by Amerine (1959). Briefly, the wine sample was brought to volume in a 100 ml volumetric flask at a set temperature, washed into a Kjeldal flask with 3 fifteen ml portions of water and distilled. The distillate (95 ml) was received in a 100 ml volumetric and brought to volume at the set temperature with distilled water. The residual portion of wine was washed into a 100 ml volumetric and brought to 100 ml volume with distilled water at the set temperature. The distilate was brought to 60° F and the alcohol per cent by volume determined with Taylor alcohol hydrometers, with appropriate corrections made for temperature variances from 60° F (no more than ± 1° F). The extract was determined by Reaumur hydrometers with temperature corrections read directly from thermometer and correction scale enclosed inside the hydrometer. The extract was reported as grams per 100 grams of liquid.

The wine analyses were performed from 2 to 6 months after the finish of the fermentations. Again, a single analyst usually did each year's wines but a different analyst was used each year or two.

Statistical analyses. Standard techniques for regression, correlation, and "Student t" comparisons as described by Alder and Roessler (1951), were used. For comparison of slopes and intercepts the methods described by Youden (1951) were used.

Regions. Grape growing areas within the state have been divided into five regions (Amerine and Winkler, 1944). Regions I (Oakville) and IV (Davis) were used for this comparison; region I is the coolest grape-growing region in the state, and region IV is the next to warmest.

Heat summation. Heat summation calculations were based on the California Section Climatological Data Reports of the U. S. Weather Bureau. Degree days were calculated from the monthly mean temperatures reported for St. Helena and Sacramento (city) in this publication. There is no weather station at Oakville where the plantings in region I were grown; therefore, to represent the trends between seasons, data from the St. Helena station were used, even though it is in region II (bordering region III). Absolute values as reported would be high for the Oakville area but because of its close proximity to the St. Helena area the relative changes would be similar. Sacramento (city), while slightly warmer than Davis, fairly represents region IV and trends should be nearly identical to those of Davis.

Table 1 gives the heat summation of degree days in excess of 50° F from

TABLE 1

CLIMATIC DATA FOR THE SEASONS STUDIED*

Weather station	Total degree days in excess of 50° F								
	Year								
	1953	1954	1955	1956	1957	1958	1959	1960	1961
St. Helena	2655	2860	2686	2808	2958	3166	3218	3024	3091
Sacramento	3403	3562	3434	3536	3772	3836	3801	3818	3681

* Data calculated from California Section, Climatological Data Reports, U. S. Weather Bureau and based on monthly mean temperatures, April 1 through September 30.

April 1 through September 30 for nine years in the two stations. Region I should have below 2500 degree days; region II, 2500 to 3000; region III, 3001 to 3500; region IV, 3501 to 4000; and region V in excess of 4000 (Winkler and Amerine 1944). In St. Helena, five years fall into region II and four into region III. For Sacramento, eight years fall into the region IV classification and one into region III. Sacramento data trends will be the same as those for Davis.

RESULTS AND DISCUSSIONS

The degree Brix of the musts and alcohol content of the wines for three years was summarized by types (DW = dry white, and DR = dry red wines) and regions (I and IV). The data for each year for each region-type were plotted on linear paper as the degree Brix of the must versus the alcohol (per cent by volume) in the finished wine. Regression equations, correlation coefficients with the 5 per cent confidence limits, and standard errors of estimate were calculated. Table 2 summarizes the calculations. In most instances the correlation is reasonably good between the initial degree Brix and the final alcohol; however, the regression equations show considerable differences in slope and intercept. Rather large standard errors of estimate are also noted. Figures 1 and 2 show plotted data for one region type with good correlation and low standard error of estimate, and for one with poor correlation and higher standard error of estimate; scatter of the data in figure 2 indicates that more than normal measurement error are present. Errors of measurement of degree Brix of the must and of the alcohol would not be expected to vary from the regression line by more

TABLE 2

STATISTICAL ANALYSIS OF VARIETIES BY REGIONS, TYPES, AND YEARS WITH RESPECT TO INITIAL DEGREE BRIX AND ALCOHOL PRODUCED

Type	Region	Years	Regression equations, yearly and 3-year averages	Correlation coefficient r	df	t*	Standard error of estimate	5 per cent confidence limits for r
Dry White	IV	1959	$Y' = 1.49 + 0.506\,X$	0.761	50	8.29	±0.64	0.86 -0.62
		1960	$Y' = 0.649 + 0.599\,X$	0.917	42	15.28	±0.42	0.95 -0.74
		1961	$Y' = 1.64 + 0.632\,X$	0.838	29	8.30	±0.56	0.92 -0.69
		1959–61	$Y' = 1.18 + 0.620\,X$	0.881	125	20.83	......	0.915-0.835
Dry White	I	1959	$Y' = -4.66 + 0.786\,X$	0.908	29	11.66	±0.51	0.955-0.82
		1960	$Y' = 1.60 + 0.512\,X$	0.809	34	8.09	±0.47	0.895-0.65
		1961	$Y' = -3.61 + 0.735\,X$	0.982	22	24.55	±0.32	0.99 -0.96
		1959–61	$Y' = -1.87 + 0.660\,X$	0.898	89	61.09	......	0.93 -0.85
Dry Red	IV	1959	$Y' = 1.14 + 0.490\,X$	0.739	29	5.91	±0.80	0.865-0.52
		1960	$Y' = -1.77 + 0.591\,X$	0.852	34	9.49	±0 64	0.925-0.73
		1961	$Y' = 4.37 + 0.313\,X$	0.520	39	3.80	±0.66	0.72 -0.26
		1959–61	$Y' = 0.28 + 0.509\,X$	0.743	106	11.43	......	0.82 -0.65
Dry Red	I	1959	$Y' = -4.92 + 0.762\,X$	0.805	30	7.45	±0.97	0.90 -0.64
		1960	$Y' = -1.02 + 0.590\,X$	0.762	29	6.35	±0.66	0.88 -0.56
		1961	$Y' = 0.71 + 0.519\,X$	0.813	23	6.72	±0.66	0.915-0.62
		1959–61	$Y' = -1.16 + 0.602\,X$	0.811	86	12.87	......	0.87 -0.73

* All correlations significant at the 1 per cent level.

than ± 0.20. Other errors could come from the presence of grapes of different degrees of ripeness. The fully ripe berries would be crushed more easily, and if there were raisined (shiveled) berries present these would add to the alcohol but would not be indicated by the Brix reading. Winkler and Amerine (1937) indicated the effect of raisin and overripe fruit on the alcohol yields between two years of different heat summations. Conversely, if unripe grapes were present they would be harder to crush but would detract from the expected alcohol.

Gross errors are probably due to poor sampling, cellar handling errors, or carelessness during analysis, but would be expected to balance out between region-types, years, and varieties over a large number of samples. Figure 3 shows the combined regressions lines for the three years for each region-type. Again there are differences which appear to be due to more than normal error. Table 3 shows a comparison of the intercepts and slopes by region-type and years and by region-types. Regression equations calculated for several years show significantly different intercepts and slopes for the same region-types. On the region-type comparison, one of the slopes, the DR region IV is significantly different from DW region I and DW region IV. There is a strong trend for the regression coefficient of DR region I to differ also from DR region IV.

These data indicate that real differences exist in the degree Brix-alcohol relationship due to regions and types. To find if these effects were truly due to region-type differences or due to varietal differences, the Brix-alcohol data

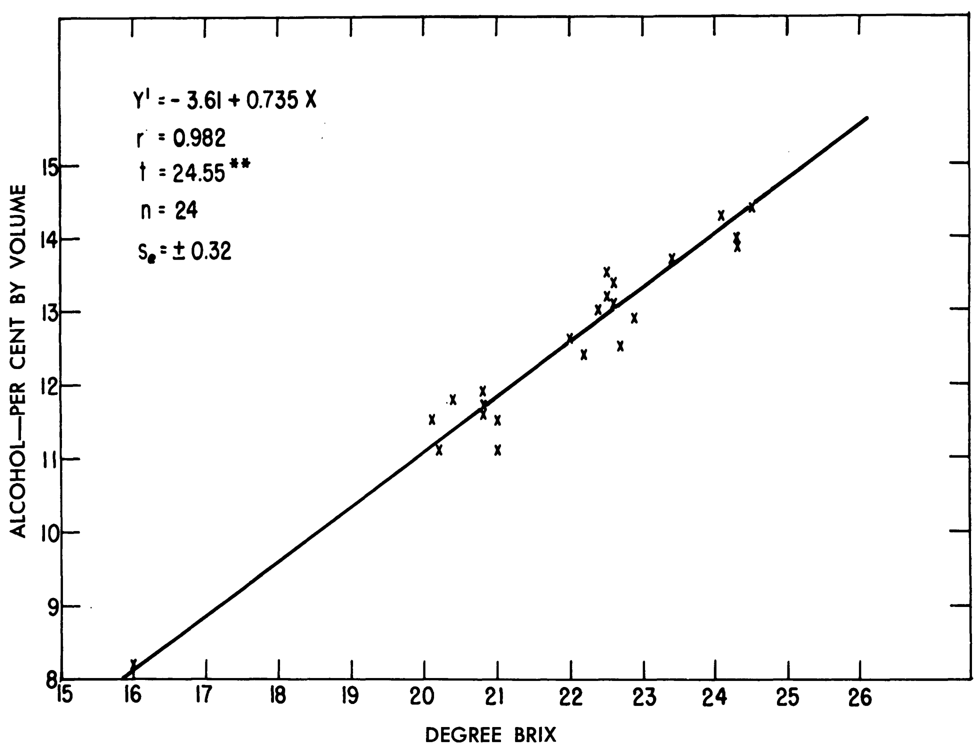

Fig. 1. Correlation of degree Brix of must to per cent alcohol, by volume, in the resulting wine. (Dry white varieties, region I, 1961.)

were summarized for nine white varieties and nine red varieties. These varieties were grown in both regions. There were some yearly variations in the number of samples from each region, but over the 9-year period annual variation between regions would be somewhat compensated. A point slope was calculated for each sample of each variety, and were summarized in histogram form, with a one degree Brix range used to form the divisions of the histogram base. The total range represented was 19° to 26° Brix. A total summary by region-types was made, and from the resultant mean point slopes the mean alcohol produced was calculated for each degree Brix. These data were plotted (figure 4) and the regression equations calculated using the method of least squares with the mean values weighted by the number associated with each mean; they were found to give very good fits.

Table 4 shows the analysis of the regression data and indicates, by the insignificant residual term, that the divergence from linearity is negligible. The regression equations given in figure 4 were compared for slope and intercept differences (table 5). The equation of DW region I did not differ significantly from DW region IV in slope or intercept. The equation of DR region I differed in intercept but not in slope from DR region IV. The equations of DR region I differed significantly in slope and intercept from those of DW region I or DW region IV. Calculations were not made, but it is obvious that the regression equation of DR region IV would also differ significantly in slope and intercept from DW region I and DW region IV.

Comparisons were made of the point slope values by varieties and regions, and table 6 shows that data for white

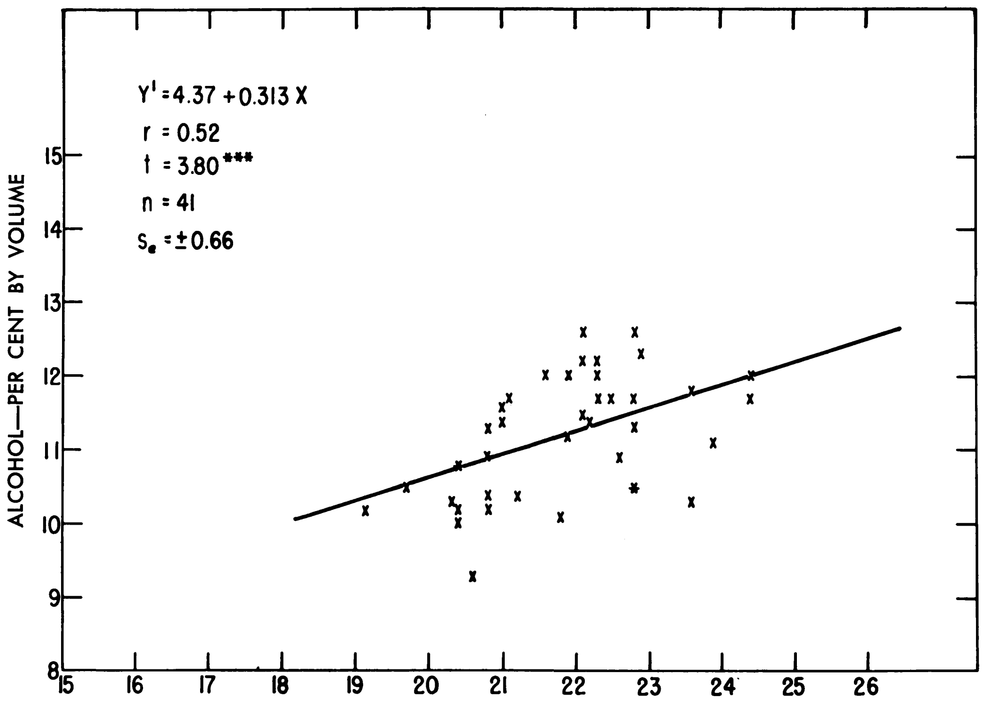

Fig. 2. Correlation of degree Brix of must to per cent alcohol, by volume, in the resulting wine. (Dry red varieties, region IV, 1961.)

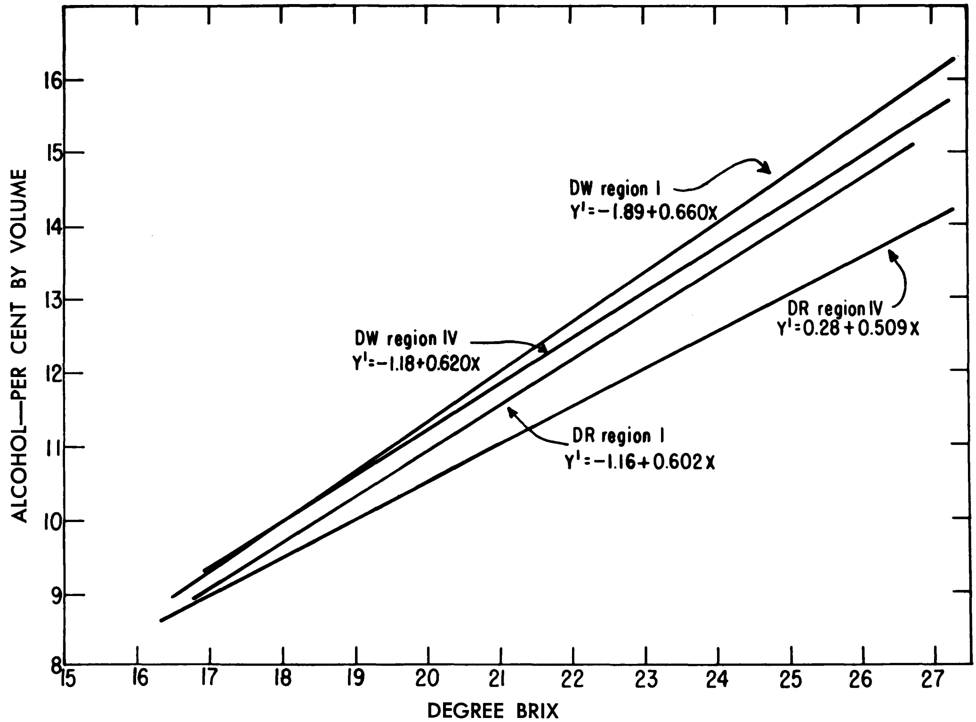

Fig. 3. Regression lines for degree Brix of must plotted against the resulting per cent alcohol, by volume, for four region-types, 1959–1961.

TABLE 3

COMPARISON OF SLOPES AND INTERCEPTS OF REGRESSION LINES

Comparison	Difference		Combined standard deviations		Test of significance		Degrees of freedom
	Intercept a	Slope b	s_a	s_b	t_a	t_b	
DW* region I 1959 to 1960......	6.26	0.274	2.11	0.093	2.97‡	2.95‡	63
DW* region I 1959 to 1961......	1.05	0.051	1.58	0.072	0.66	0.71	51
DW* region I 1960 to 1961......	5.21	0.223	1.61	0.070	3.24‡	3.17‡	56
DW region IV 1959 to 1960.....	2.14	0.093	1.68	0.073	1.27	1.27	92
DW region IV 1959 to 1961.....	3.13	0.126	2.29	0.102	1.37	1.24	78
DW region IV 1960 to 1961.....	0.99	0.033	3.33	0.141	0.30	0.23	70
DR† region I 1959 to 1960......	3.90	0.171	3.48	0.127	1.12	1.35	59
DR† region I 1959 to 1961......	5.63	0.243	3.00	0.150	1.88	1.62	53
DR† region I 1960 to 1961......	1.73	0.071	2.80	0.121	0.62	0.57	52
DR region IV 1959 to 1960......	3.18	0.101	2.35	0.102	1.35	0.98	63
DR region IV 1959 to 1961......	2.96	0.167	2.69	0.117	1.10	1.43	68
DR region IV 1960 to 1961......	6.14	0.278	2.37	0.103	2.59¶	2.70‡	72
RW region I-DW region IV 1959 to 1961..................	0.69	0.040	1.09	0.048	0.63	0.83	214
DR region I-DR region IV 1959 to 1961..................	1.44	0.083	1.47	0.064	0.98	1.30	192
DW region I-DR region IV 1959 to 1961..................	2.15	0.151	1.36	0.060	1.58	2.50‡	195
DW region IV-DR region IV 1959 to 1961..................	1.46	0.111	1.17	0.052	1.25	2.13¶	231

* Dry white. ‡ Significant at 1 per cent level.
† Dry red. ¶ Significant at 5 per cent level.

and red varieties. No significant regional effects could be shown for the dry white wines, although the common trend was for point slope values to be the same or greater for region I. Cabernet Sauvignon, Ruby Cabernet, Zinfandel, Gamay Beaujolais and Pinot noir showed significantly different point slope values between regions, with the higher value associated with region I. The trend in the other varieties was also for higher point slope values for region I, with the exception of Grenache.

Table 6 includes a varietal comparison of the white varieties. Only French Colombard in the region IV comparison differed, and then only from Pinot blanc and White Reisling. An intra-region (region I) comparison of the red varieties (table 7) shows Malbec as differing from Cabernet Sauvignon and Pinot noir, and Zinfandel differing from all others. Zinfandel samples were taken mainly from region I in 1958–61 and from region IV in 1953–54. The per cent alcohol-degree Brix ratios determined from region I were notably higher during those years and this contributes much to the differences indicated in table 7, region I, for Zinfandel—and also to the inter-regional comparison of Zinfandel in table 6. In region IV (table 8) significant difference were found between the heavily pigmented Cabernet type varieties (Cabernet Sauvignon, Ruby Cabernet, Malbec) and Zinfandel, Grenache, Barbera, and Petite Sirah. Grenache also differed from Gamay Beaujolais, and Barbera.

Cabernet Sauvignon showed large regional differences and data were investigated further to see if date of harvest or time on the skins could be a contributing factor. No correlation could be found between the time of harvest or the time on the skins with the ratio of

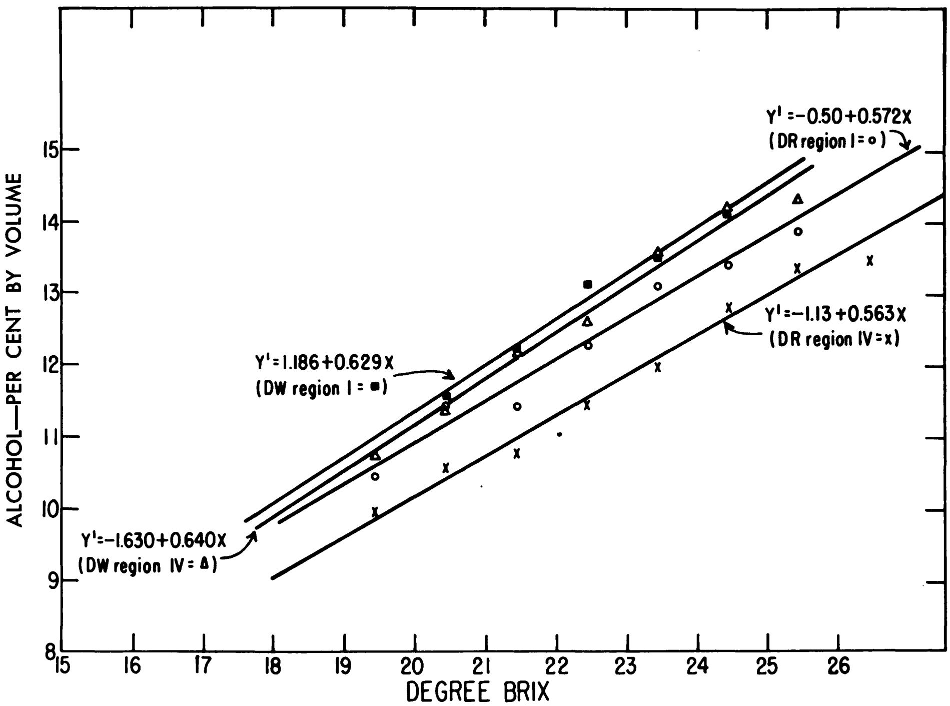

Fig. 4. Regression lines for degree Brix of must plotted against the resulting per cent alcohol, by volume, for nine dry white and nine dry red varieties, regions I and IV, 1953–1961.

TABLE 4

ANALYSIS OF THE FOUR TYPE-REGION GROUPS WITH EIGHTEEN SELECTED VARIETIES FOR REGRESSION AND FOR DIVERGENCE FROM LINEAR FIT

Source of χ^2	df	χ^2	Probability
DW region I			
Regression	1	62.04	$p < .001$
Residual	3	1.59	$0.70 > p > 0.50$
Total	4	63.63	
DW region IV			
Regression	1	128.27	$p < .001$
Residual	5	2.17	$0.90 > p > 0.80$
Total	6	130.44	
DR region I			
Regression	1	117.83	$p < 0.001$
Residual	5	3.79	$0.50 > p > 0.30$
Total	6	121.62	
DR region IV			
Regression	1	124.95	$p < 0.001$
Residual	6	2.86	$0.90 > p > 0.80$
Total	7	127.81	

TABLE 5

COMPARISON OF SLOPE AND INTERCEPTS OF REGRESSION EQUATIONS FOR DW REGION I, DW REGION IV, DR REGION I, AND DR REGION IV FOR NINE WHITE AND NINE RED VARIETIES FOR A 9-YEAR PERIOD

Comparison	Degrees of freedom	Intercepts				Slopes			
		Difference	Combined standard deviation	t	Significance level	Difference	Combined standard deviation	t	Significance level
DW region I to DW region IV	8	0.444	0.282	1.57	N.S.	0.0113	0.0126	0.90	N.S.
DR region I to DR region IV	8	0.686	0.298	2.30	5%	0.009	0.0128	0.70	N.S.
DW region I to DR region I	10	1.130	0.267	4.23	1%	0.0683	0.0119	5.74	0.1%
DW region IV to DR region I	11	0.631	0.246	2.56	2%	0.068	0.0116	5.86	0.1%

TABLE 6

REGIONAL EFFECTS, BY VARIETIES, ON THE PER CENT ALCOHOL PRODUCED PER DEGREE BRIX

Variety	Region I			Region IV		
	Mean degree Brix	Number of samples	Per cent alcohol/ degree Brix	Mean degree Brix	Number of samples	Per cent alcohol/ degree Brix
dry white						
Sauvignon blanc	24.75	19	0.577	22.01	8	0.572
Pinot blanc	22.16	12	0.583	21.26	19	0.574‡
Chardonnay	23.73	13	0.571	23.44	15	0.561
White Riesling	22.63	32	0.571	21.61	23	0.571‡
Aligote	21.63	9	0.590	21.80	9	0.571
Emerald Riesling	22.16	10	0.581	22.78	13	0.559
French Colombard	22.46	13	0.568	20.94	12	0.553‡
Gewürztraminer	22.60	22	0.580	22.71	11	0.569
Sylvaner	22.37	10	0.576	22.06	8	0.564
dry red						
Cabernet Sauvignon*	23.40	30	0.551	22.14	16	0.482
Grenache	21.64	17	0.539	23.59	26	0.541
Ruby Cabernet*	22.01	30	0.539	23.15	19	0.499
Zinfandel*	22.70	23	0.589	22.29	14	0.529
Barbera	22.28	8	0.535	22.88	18	0.514
Gamay Beaujolias*	23.10	10	0.543	21.21	10	0.505
Malbec	22.85	8	0.514	22.59	10	0.487
Petite Sirah†	21.20	11	0.545	22.24	11	0.529
Pinot noir*	22.78	19	0.557	23.50	9	0.502

* Mean ratios of per cent alcohol/degree Brix significantly different between regions.
† The California strain.
‡ Intervarietal comparison indicates French Colombard per cent Alcohol/degree Brix mean ratio is significantly lower at the 5 per cent level than the ratios of Pinot blanc or White Riesling for region IV.

TABLE 7

VARIETAL EFFECTS ON PER CENT ALCOHOL PRODUCED PER DEGREE BRIX (RED VARIETIES, REGION I)

Variety	Difference in per cent alcohol per degree Brix between varieties								
	Cabernet Sauvignon	Ruby Cabernet	Malbec	Pinot noir	Gamay Beaujolais	Zinfandel	Barbera	Petite Sirah	Grenache
Cabernet Sauvignon	.....	0.012	0.037†	0.006	0.008	0.038‡	0.016	0.006	0.012
Ruby Cabernet	.....	.....	0.025	0.018	0.004	0.050¶	0.004	0.006	0.000
Malbec	.....	.....	.....	0.043‡	0.029	0.075¶	0.021	0.031	0.025
Pinot noir	.....	.....	.....	.....	0.014	0.032†	0.022	0.012	0.018
Gamay Beaujolais	.....	.....	.....	.....	.....	0.046‡	0.008	0.002	0.004
Zinfandel	.....	.....	.....	.....	.....	.....	0.054‡	0.044†	0.050‡
Barbera	.....	.....	.....	.....	.....	.....	.....	0.010	0.004
Petite Sirah*	.....	.....	.....	.....	.....	.....	.....	.....	0.006
Grenache	.....	.....	.....	.....	.....	.....	.....	.....	.....

* The Califoria strain.
† Significant difference at 5 per cent level.
‡ Significant difference at 1.0 per cent level.
¶ Significant difference at 0.1 per cent level.

TABLE 8

VARIETAL EFFECTS ON PER CENT ALCOHOL PRODUCED PER DEGREE BRIX (RED VARIETIES, REGION IV)

Variety	Difference in per cent alcohol per degree Brix between varieties								
	Cabernet Sauvignon	Ruby Cabernet	Malbec	Pinot noir	Gamay Beaujolais	Zinfandel	Barbera	Petite Sirah	Grenache
Cabernet Sauvignon..	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ruby Cabernet	0.017	.....	.....	.....	.....	.....	.....	.....	.....
Malbec........	0.005	0.012	.....	.....	.....	.....	.....	.....	.....
Pinot noir.....	0.020	0.003	0.015	.....	.....	.....	.....	.....	.....
Gamay Beaujolais...	0.023	0.006	0.018	0.003	.....	.....	.....	.....	.....
Zinfandel.....	0.047†	0.030‡	0.042‡	0.027	0.024	.....	.....	.....	.....
Barbera.......	0.032‡	0.015	0.027	0.012	0.009	0.015	.....	.....	.....
Petite Sirah*..	0.038‡	0.030‡	0.042‡	0.027	0.024	0.000	0.015	.....	.....
Grenache......	0.059†	0.042¶	0.053¶	0.039	0.036‡	0.012	0.027†	0.012	.....

* The California strain.
† Significant difference at 0.1 per cent level.
‡ Significant difference at 5 per cent level.
¶ Significant difference at 1.0 per cent level.

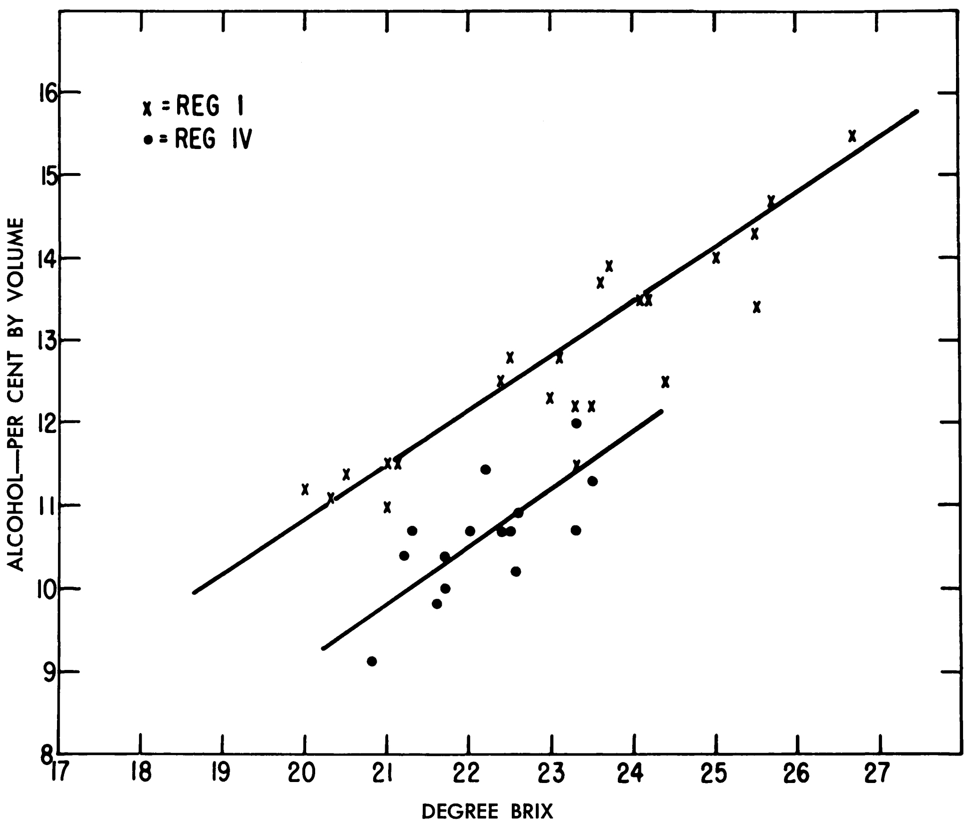

Fig. 5. Degree Brix in must plotted against resulting alcohol in the wine for Cabernet Sauvignon, regions I and IV, 1953–1961.

the present alcohol to the degree Brix for this variety in either region. Figure 5 shows a plot of the alcohol versus the degree Brix for both region I and region IV over the 9-year period studied. The estimated regression lines indicates the gross differences found between regions for this variety. Figure 6 shows a plot of the heat summation from April 1 to the average date of harvest against the per cent alcohol/degree Brix ratio for Cabernet Sauvignon in both regions. Region I shows a definite correlation, but region IV does not. No sound explanation can be offered for the lack of correlation in region IV, though differences in crop level, seasonal variations (such as rain or sunburn), pruning practices, etc., might be the cause.

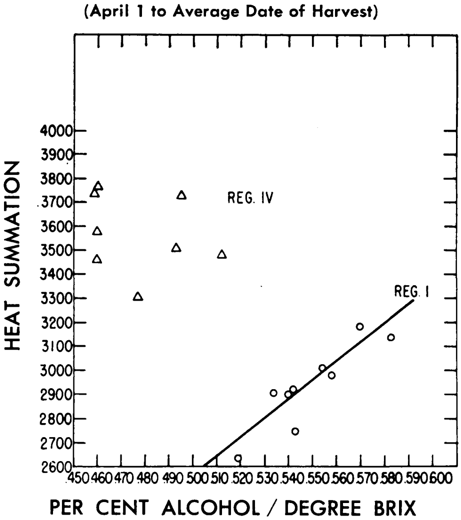

Fig. 6. Per cent alcohol by volume in the wine to degree Brix in the must, plotted against the heat summation(degree days above 50°F from April 1 to average data of harvest) for Cabernet Sauvignon, regions I and IV, 1953–1961.

The data for all the selected varieties were grouped by region-types and years and the mean per cent alcohol/degree Brix ratio found. Table 9 gives the results and indicates significant differences between years for all the region-types. These data were plotted against the heat summation (from April 1 to average date of harvest) in degree days above 50° F (figure 7). This partially explains the differences between years. The explanation of Winkler and Amerine (1937) for differences in the per cent alcohol produced for a given degree Brix was, mainly, that in warmer years a greater per cent of fruit was raisined and this sugar was not reflected in the must sugar or degree Brix reading; this seems valid. Other factors are also involved, as evidenced by the poor correlation with DR region IV data. One explanation of the poor correlation is crop level, due to either natural thinning (such as frost) or to pruning differences. The distribution of the varieties between years was not equal. Humidity and early rains or lack of early rains would certainly influence the degree of raisining and also the amount of rotten fruit, which in turn would be reflected in the alcohol/degree Brix ratio.

In general, these varietal as well as regional differences cannot be accounted for by residual extract differences. The

TABLE 9

EFFECT OF YEARS ON ALCOHOL TO DEGREE BRIX RATIO (BY TYPE-REGION GROUPS)*

Type	Region	Year									Total number of samples	F ratio (years)	Level of significance
		1953	1954	1955	1956	1957	1958	1959	1960	1961			
DW	I	0.588	0.593	0.557	0.568	0.570	0.591	0.569	0.581	0.570	140	4.54	1%
DW	IV	0.559	0.577	0.548	0.571	0.568	0.584	0.569	0.570	0.559	118	3.15	1%
DR	I	0.536	0.539	0.529	0.543	0.549	0.568	0.557	0.556	0.557	156	2.08	5%
DR	IV	0.509	0.535	0.507	0.486	0.490	0.544	0.532	0.521	0.481	133	8.66	1%

* Using nine each of selected white and red varieties.

differences (table 10) are significant in many instances and usually in the proper direction, but are too small to account for more than a fraction of the differences found.

If we make reasonable estimates of the non-sugar soluble solids in the must it is possible to calculate the conversion factors for each region-type. Estimating the non-sugar soluble solids, as 2.5

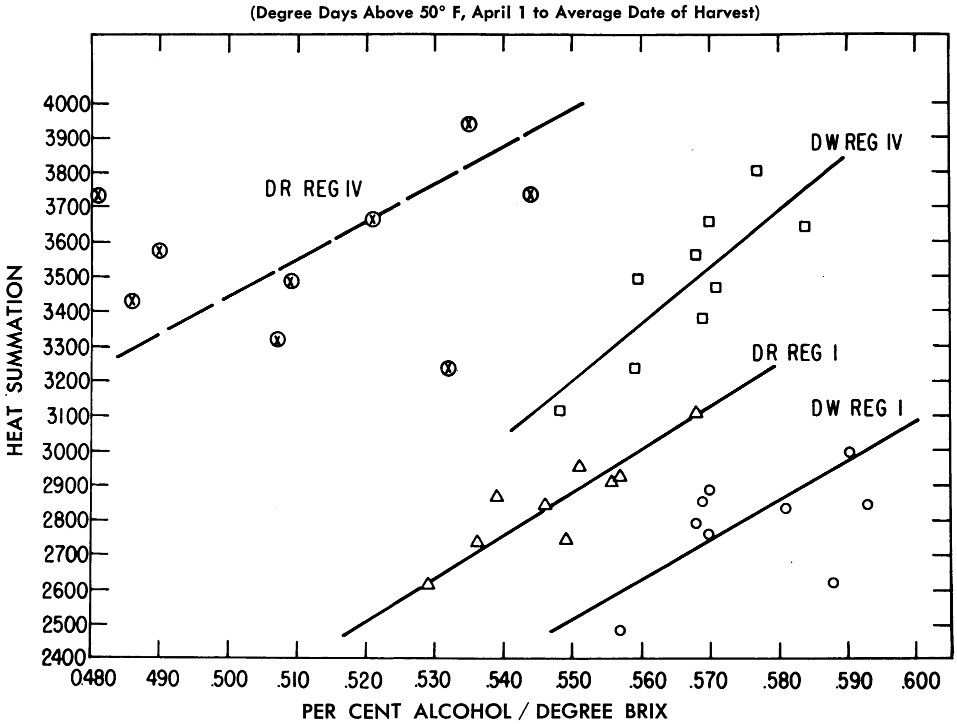

Fig. 7. Per cent alcohol/degree Brix ratio plotted against the heat summation (April 1 to average date of harvest) using nine selected dry white and nine selected dry red varieties, 1953–1961.

TABLE 10

REGIONAL EFFECTS ON THE SOLUBLE SOLIDS CONTENT OF VARIOUS RED VARIETIES

Variety	Extract*			Statistical test	
	Region I	Region IV	Difference	Degrees of freedom	t
Cabernet Sauvignon	3.0666	3.3294	0.2628	45	2.30†
Grenache	2.8722	2.8250	0.0472	44	0.37
Ruby Cabernet	3.1676	3.4700	0.3024	52	3.27‡
Zinfandel	3.1384	3.0285	0.1099	18	0.98
Barbera	3.086	3.155	0.0690	25	0.42
Gamay Beaujolais	2.940	2.909	0.0310	19	0.15
Malbec	3.1125	3.4300	0.3175	16	1.39
Petite Sirah (Calif.)	2.9916	3.3333	0.3417	19	2.29†
Pinot noir	2.9380	3.2500	0.3120	31	2.07†
Total	3.044	3.1529	0.1089	287	2.2†

* Extract grams per 100 grams.
† Significant at 5 per cent level.
‡ Significant at 1 per cent level

grams per 100 grams for the DW region I and IV musts and 3.0 and 3.5 grams per 100 grams for the DR region I and IV musts, respectively, conversion factors found are DW I, 0.472; DW IV, 0.465; DR I, 0.461; and DR IV, 0.442 grams alcohol per gram reducing sugar. With the exception of DR IV these values are consistent with the accepted conversion factor of 0.47.

INTERPRETATION OF RESULTS

Variety, year, type (red or white) and region, all have a definite effect on the amount of acohol which can be predicted from a hydrometer measurement of the degree Brix.

The effect of years appears to be due primarily to the cumulative heat and the percentage of raisined or green fruit associated with seasonal climatic differences.

Differences between regions cannot be explained directly by the heat summations. Region I is much cooler than region IV, and in general a more favorable ratio exists between the degree Brix and the per cent alcohol for region I. Crop level is generally less for region I and this could be a compensating factor. Degree of maturity at time of harvest might be an influence but the data do not indicate this.

Varietal differences, especially within region IV for the red types, are not readily explainable on the basis of heat summation. The early varieties (Pinot) and the late varieties (Cabernet) both show a lower yield of alcohol per degree Brix than other varieties.

The dry white varieties are less influenced by region than are the dry red varieties. Inter-varietal effects within region are also less with the white varieties. Differences between the white and red varieties are definite and cannot be readily explained by the differences in contact time with the skins. However, explanations for the type differences must be associated with the time on the skins, since this is the only real difference between the types. The non-sugar soluble solids existing in the wine are greater for the red varieties, and in the proper direction for the indicated regional differences, but are too minor to account for more than a fraction of the differences found. Non-sugar soluble solids such as color, acid, and pectin materials which partially or completely disappear during fermentation might account for some of the regional, type, and varietal differences noted, and should be investigated further.

CONCLUSIONS

1. The degree Brix measurement, if interpreted as a relative measure of the reducing sugar, is subject to gross variations due to variety, region, year, and type.

2. The effect of region, variety, year and type are not explainable on the basis of the residual extract in the wine.

3. Accurate predictability of alcohol can be made only if careful sampling and sample preparation procedures are followed, and unless a sound basis for refractometer or hydrometer Brix interpretation has been formulated the chemical reducing sugar determination seems most valid.

4. Accumulation of sufficient data based on soluble solids measurements (hydrometer or refractive index) could be the basis for a statistically sound estimate of the expected alcohol. However, data would have to represent the proper proportion of grapes from each region, type, and variety. The alcohol produced from each lot for which a soluble solids measurements was taken should be accurately determined. If the basis of pay was expected alcohol, even this procedure (if divisions into region-types were not made) would penalize some regions and varieties—especially the cooler regions and the white varieties.

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