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THE RELATION OF MATURITY OF THE GRAPES TO THE YIELD, COMPOSITION, AND QUALITY OF RAISINS[1]

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THAT THE MATURITY of grapes is related to the yield and quality of the raisins made from them has probably been observed almost as long as grapes have been dried to preserve them. Apparently, however, no one attempted to determine precisely the nature and magnitude of these relationships before the work done by Bioletti (1915),[3] which was begun about 1913. Important contributions have since been made by Lyon (1920, 1924), Cruess and Christie (1921), and Nichols and Christie (1930).

Bioletti (1915) reports on tests made with Muscat of Alexandria and Sultanina (Thompson Seedless) at Kearney Park, near Fresno, and at Davis, during the seasons of 1913 and 1914. With Muscat, the drying ratios reported ranged from 4.8 for grapes of 18° Balling to 3.1 for grapes of 28° Balling. Quality, as measured by the size of the individual raisins, improved notably as maturity advanced. With Sultanina, the drying ratios ranged from 4.6 for grapes of 20° Balling to 3.6 for grapes of 24° Balling. According to Bioletti's calculations, the average increase in crop per Balling degree of sugar in the grapes was about 5.35 per cent with Muscat and 7.4 per cent with Sultanina. In another paper Bioletti (1919) briefly reported, collectively, on the results of several years' tests on the drying of eleven varieties of grapes. He interpreted his results as showing an average increase of 35 pounds of dried grapes per ton of fresh for each added degree of sugar. Actually, his figures show the increase to range from 16 to 104 pounds, the greater increases being obtained from the riper fruit. Although he recognized that the higher sugar content measured in the fresh fruit with advancing maturity is chiefly responsible for the increased yield, he was led by his earlier ex-

[1] Received for publication April 16, 1941.

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[3] See "Literature Cited" for complete data on citations, referred to in the text by author and date of publication.

periments to believe that something other than sugar must be a factor in producing the larger increases as maturity became advanced. Lyon's (1920) figures for "Sultana" and "Zante currant" raisins also fluctuate between rather wide limits, but fail to show any consistent trend toward greater increases in yield of raisins per degree Balling as the maturity of the fresh fruit advanced.

In 1926, Bioletti began a more elaborate investigation in collaboration with Christie[4] and the present author. The work has been continued down to the present time, and this paper will present the principal results.[5]

SOURCES OF THE FRUIT

During the 1926 season, lots of grapes were picked at weekly intervals, August 22 to October 17 inclusive, from about thirty vines in a vineyard near Marysville. For the 1927, 1935, and 1936 series of tests, all fruit was obtained from the University of California vineyards at Davis. Each season, except 1926, two adjacent rows of twenty vines each were chosen as sources of the fruit, one row having been thinned to a light-to-moderate crop, the other being permitted to bear a moderate-to-heavy crop. Pickings were made at approximately weekly intervals, beginning when the fruit was relatively green (for raisins) and extending to the end of the season, when fruit in good physical condition could no longer be obtained. In general, only one large or two medium-sized clusters were harvested from each vine at each picking; and all those from one lot of vines were combined to form a composite sample of 18 kilograms or more.

PREPARATION OF THE SAMPLES FOR DRYING

Except the natural sun-dried lots of 1926 and 1927, all samples were prepared as follows: The individual berries were clipped from the clusters by cutting the pedicels with scissors. All dried, injured, or discolored berries were discarded. The lot was then thoroughly mixed by repeated gentle pouring from one container to another; in this procedure, metal cans of about 3½ cubic feet capacity were found convenient. After the mixing, a small part of the lot was taken out for the observations and measurements on the fresh fruit; and from the remainder, samples of 1,500 or 2,000 grams each were weighed out for the individual drying tests.

For the natural sun-drying tests in 1926 and 1927, entire clusters were used; the individual lots varied in fresh weight from 7 to 15 kilograms.

[4] A. W. Christie, Assistant Professor of Fruit Products and Associate Chemist in the Experiment Station, University of California; resigned 1928.

[5] Some of the data obtained in 1926 were published by Nichols and Christie (1930).

Samples for measurements on the fresh fruit were obtained by clipping off a few berries from the basal, middle, and apical portions of each cluster.

MEASUREMENTS ON THE FRESH FRUIT

Weight of One Hundred Berries.—The berry weight was determined by counting out and weighing single lots of 1,000 berries in 1926; single lots of 500 in 1927; and duplicate, triplicate, or quadruplicate lots of 200 each in 1935 and 1936. This last procedure proved to be the most reliable; if the weights of the duplicate lots failed to agree within reasonable limits, additional lots were counted, weighed, and included in the computation. In each case, the results were calculated to weight per 100 berries.

Balling.—Part of the composite sample was thoroughly macerated in a pan by means of a wooden masher or by passing it through a continuous screw-press, and the juice was extracted from the macerated pulp by squeezing or straining through cheesecloth. The juice was poured into glass jars, where it was allowed to stand for a few minutes to permit the escape of air bubbles and settling of the gross sediment. Balling (or Brix) hydrometers, graduated in $\frac{1}{10}$ degrees, were used in glass cylinders of appropriate size. All determinations were made in duplicate or triplicate, and the readings corrected for temperature differences.

Acidity.—The juice extracted for the Balling test was allowed to stand until part of it had become reasonably clear, but never for more than an hour. Duplicate 10-cc portions of the clear juice were then titrated with standardized NaOH solution, phenolphthalein serving as an indicator. A faint color, lasting 10 seconds or longer with constant shaking, was taken as the end point. The results were calculated and expressed as per cent tartaric acid by weight.

METHODS OF DRYING

During the investigation, standard commercial methods of pretreatment and drying were employed; and, in addition, the standard methods were duplicated with either dehydrated or naturally dried lots. The various methods used are briefly described below; the years in which the method was used are indicated.

(1) Natural sun-drying, in 1926, 1927, 1935, and 1936: The grapes were thinly spread, without pretreatment, on trays and exposed to direct solar radiation until dried to the desired degree. In 1926 and 1927, standard wood raisin trays (2×3 feet) were used, and the raisins dried in the open. Since, however, losses were caused by bees and birds, a large cage of $\frac{3}{16}$-inch mesh hardware cloth was used in 1935 and 1936, and the raisins were dried on paper-covered laboratory-dehydrater trays

inside the cage. The losses were thus practically eliminated. The product was similar to the natural sun-dried raisins of commerce.

(2) Dehydration without pretreatment, in 1926, 1927, 1935, and 1936: The sample was spread on a paper-lined tray, without pretreatment, and dehydrated in a laboratory dehydrater of the recirculating tunnel type, electrically heated and thermostatically controlled to a minimum of 130° F and a maximum of 140°. The rate of air flow exceeded 600 lineal feet per minute between the trays. Humidity, although kept low, was not controlled within close limits. As the desired degree of dryness in the raisins was approached, the trays were weighed at 1- or 2-hour intervals. The end point in drying was determined by assuming a water content of 15 per cent in the dried raisins and by assuming that the Balling reading on the juice of the fresh grapes would indicate the total solids of the grapes. Then the constant 85 (100 minus 15) divided by the Balling of the fresh grapes approximates the drying ratio. The weight of fresh fruit divided by the drying ratio is the calculated weight of the raisins, which was taken as the end point of the drying. The raisins were uniform grayish brown in color, rather tough-textured, and slightly caramelized to the taste.

(3) Lye dip with dehydration, in 1926 and 1935: The grapes were dipped in a 0.2 to 0.3 per cent NaOH solution at a temperature of 95° to 100° C for 2 or 3 seconds—until faint checks showed in the skins after the grapes had been cooled by rinsing in cold water. The sample was then dehydrated as for (2). The raisins were uniform medium brown in color, and otherwise resembled the commercial product occasionally made in this manner.

(4) Lye dip with sun-drying, in 1935: The sample was dipped as for (3) and sun-dried as for (1). The raisins were dark brown, tender, meaty, and slightly sticky—generally similar to the commercial product occasionally made by this process.

(5) Golden bleach, in 1935 and 1936: The hot lye dipping as for (3) was followed by exposure at ordinary air temperature to SO_2 gas (diluted to about 1 per cent by weight with air) until the grapes had bleached to a yellowish white, the fruit absorbing 1,200 to 2,000 p.p.m. of SO_2. They were then dehydrated as in (2). In these experiments the procedure differed in two minor respects from the standard commercial process: first, the SO_2 for bleaching the grapes was derived from the commercial liquefied product instead of from burning sulfur; second, the dehydration temperature was lower, since commercial dehydraters usually operate at about 160° F. The product was of brilliant, glossy, greenish-yellow to golden-yellow color.

(6) Sulfur bleach, in 1935 and 1936: The grapes were treated as for

(5), then exposed to direct sunlight until half or two-thirds dried. The drying was finished in the shade. Exposure to direct sunlight was for a longer period than is usual in commercial practice. Except in being a pronounced reddish-yellow, the raisins were similar to the commercial product.

(7) Australian mixed dip with dehydration, in 1935: The dip was composed of 0.3 per cent NaOH, 0.5 per cent K_2CO_3, and 0.4 per cent virgin olive oil, this last being first emulsified in a 5 per cent K_2CO_3 solution. It was used at 80°–82° C, and the grapes were immersed until faint checks showed in the skin after cooling without rinsing—a matter of 2 or 3 seconds. Dehydration was as described for (2). The raisins resembled those of (3) in color, but were more glossy; the texture was more tender than with those of (3). The process is not used commercially.

(8) Australian mixed dip with rack-drying, in 1935 and 1936: The predrying treatment was as for (7). The grapes were dried in the shade on specially constructed wire racks like those commonly used in Australian drying yards. The dip and the drying procedure were essentially the same as described by Lyon (1934). The day after the grapes were placed on the racks, and thereafter at weekly intervals until dry, they were lightly sprayed with a 5 per cent solution of K_2CO_3 in which 0.4 per cent olive oil had been emulsified. The raisins were of soft, tender texture, of characteristic flavor; and the color varied from light to dark brown, the darker colors developing in samples subjected to foggy or rainy weather at some time during the drying period.

(9) Australian cold dip with dehydration, in 1935: The dip was composed of a 5 per cent solution of K_2CO_3 (technical grade) in which was emulsified 0.4 per cent virgin olive oil. It was used at about 35° C, and the grapes were immersed until about three fourths of the bloom had been removed—usually 1 to 4 minutes. The drying was as for (2), and the dried product resembled that of (7). This process is not used commercially.

(10) Australian cold dip with rack-drying, in 1935 and 1936: The predrying treatment was as for (9), and the drying as for (8). The composition of the dip and the drying procedure were essentially the same as that recommended by de Castella (1925). The product varied from light greenish brown to medium brown and in other respects resembled that of (8), but had somewhat better texture. This and (8) are the processes used in making the "Sultana" raisins of Australia and South Africa.

(11) California soda-oil dip with dehydration, in 1935: The dip consisted of a 4 per cent water solution of Wyandotte (soda ash) powder on which was floated a thin film of olive oil. It was used at about 35° C.

The grapes were immersed until about three fourths of the bloom had been removed—usually 30 to 60 seconds. They were dehydrated as for (2). The dried product resembled that of (7). This process is not used commercially.

(12) California soda-oil dip with sun-drying, in 1935: The predrying treatment was as for (11), the drying as for (1). The process was once used extensively in the Sacramento Valley, but now has been largely abandoned. The raisins were medium brown and otherwise resembled the commercial product.

OBSERVATIONS AND DETERMINATIONS ON THE RAISINS[6]

Immediately after the final weighing of the dried raisins, part or all of each lot was packed into a glass preserving jar, sealed, stored for a few days at room temperature, and then held at 1° C until used.

The physical measurements attempted were based largely on the report of Chace and Church (1927) except that moisture was determined by direct vacuum-oven drying. The chemical determinations followed standard practices wherever possible, the methods of the Association of Official Agricultural Chemists (1935) being used as guides.

Drying Ratio.—After the moisture determinations, the dry weight of each lot was adjusted by calculation to a 15 per cent moisture basis. The drying ratio was then calculated by dividing the original fresh weight by the dry weight adjusted to a basis of 15 per cent moisture. Usually, in the tables and discussion following, the quotient only is expressed. The ratio is, however, always implied.

Weight of Raisin Berries.—The sample was loosened up to separate the individual raisin berries from each other, then mixed by slowly rotating the partially filled jar in an end-over-end manner. Duplicate lots of 200 berries each were counted out and weighed. If the weights of the two lots differed by more than 5 per cent, additional lots were taken. The weight of 100 raisin berries was calculated from the total number counted and from their total weight.

Weight per Unit Volume.—The laboratory method of Chace and Church (1927) for this measurement was modified by the use of a home-made mechanical shaker. A calibrated 500-cc wide-mouth Erlenmeyer flask was filled to overflowing with loose raisins. The flask was then placed in a receptacle on the shaker, which was so constructed as to provide an abrupt vertical drop of about 1/4 inch at the rate of 120 times per minute. The shaker was run for 1 1/2 minutes with each sample. The flask was large enough so that when the shaking was finished most of the

[6] Most of the routine work of chemical analysis on the 1935 and 1936 raisin samples was done by Bernard A. Fries.

samples slightly overran the 500-cc volume mark. The volume was adjusted to the mark by removing or adding a few raisins as necessary. All determinations were made in duplicate; and the duplicates checked, in all but occasional instances, within 2 per cent of each other. Where greater differences occurred, the determinations were repeated. Satisfactory checks could not be obtained by hand-shaking nor on the mechanical shaker with less than 1½ minutes' shaking. The weights obtained for 500 cc are heavier than those reported by Chace and Church.

Mold and Fermentation.—The hydrogen peroxide test described by Chace and Church (1927) for mold and fermentation was used on a sample of 100 raisin berries from each lot. Since the amount of mold and decay observed appeared to be correlated only with weather conditions during drying and with the method of drying, not with the maturity of the grapes, the data are not reported; but lots in which more than 10 per cent of the berries showed evidence of mold or yeast growth were discarded.

Moisture in the Raisins.—A portion of 250 grams or more of the original raisin sample was passed four times through a small household-type food chopper with a nut-butter attachment. The ground sample was then sealed in a glass sample jar, and from it portions were withdrawn for all determinations requiring ground material.

The moisture test was made as follows: Filter papers of 9-cm size were oven-dried at 80° C for 8 hours, cooled in a desiccator over soda lime, and weighed in a tared, closed petri dish. About 5 grams of the ground raisin pulp was quickly and thinly spread by means of a spatula on the paper, which was rested on a glass plate; then the paper, now holding the sample, was again weighed in the petri dish. The operations of placing the sample on the paper and replacing the paper in the petri dish were performed as quickly as possible in order to minimize changes in weight due to moisture absorption or loss. The drying was done in a vacuum oven at 70° C for 12 hours, under a pressure approximating 100 mm mercury, with a slow current of dried air passing through the oven. The dried samples, cooled in a desiccator over soda lime, were finally weighed in the closed petri dish. Determinations were in duplicate. In comparisons made during the preliminary work, the method yielded more consistent results with much less labor than the Association of Official Agricultural Chemists' official method (1935) making use of asbestos. The end point was essentially the same as that obtained by using the official procedure and drying for 10 hours. Consistent results could not be obtained by the official method with only 6 hours' drying.

Sugar Content of the Raisins.—Determinations of sugars on the 1926 samples (by the Fruit Products Laboratory at Berkeley) were made as follows: A 10-gram portion of the ground sample was extracted by boiling in 500 cc water, filtered, then cleared with Horne's basic lead acetate and sodium oxalate. Copper oxide precipitated by the regular Munson and Walker procedure was determined by the Shaeffer-Hartman (1920) method. With the 1927 samples, 5 grams of raisins were extracted with 95 per cent alcohol in Soxhlet apparatus. The extract, brought to sirupy consistency under reduced pressure, was taken up in water, and the determination made thenceforth as with the 1926 samples. The results were less consistent than was desired.

With the 1935 and 1936 samples, the determination of total water-insoluble matter was included, and the following procedure of extraction gave satisfactory results: Filter papers, 15 cm in diameter, were dried and weighed as for the moisture determinations. Before drying, the paper was folded to make a roughly conical receptacle that could be inserted in a Soxhlet extraction tube with the top edge above the high point in the siphon. About 10 grams of the ground raisin pulp was smeared on the inside of the paper cone and weighed, then placed in the extraction tube so that the drip from the condenser fell directly into the paper cone containing the sample. Extraction was with water for 6 to 8 hours, the water in the boiling flask being changed two or three times early in the extraction period to avoid "bumping" and partial caramelization of the sugars on the sides of the flask. The several extract portions were combined and made up to 1-liter volume.

An aliquot portion of the extract to be used for the sugar determination was cleared in the usual manner with lead acetate and sodium oxalate. Copper oxide precipitated by the Quisumbing and Thomas method (Association of Official Agricultural Chemists, 1935) was determined by direct weighing. Very close agreement was obtained from determinations on duplicated samples.

Since preliminary tests showed no sucrose to be present, only reducing sugars were determined.

Water-Insoluble Solids in the Raisins.—The residue in the filter paper, after the extraction described above for the 1935 and 1936 samples, was dried at 80° C for 8 hours, cooled in a desiccator, and weighed in a closed petri dish.

Titratable Acid in the Raisins.—The total titratable acidity was determined by titrating 100-cc portions of the extract (made up to 1-liter volume) with 0.033 N sodium hydroxide, phenolphthalein serving as the indicator. If the end point was obscured by the brown color of the extract, a spot plate was used.

Potassium, Calcium, Magnesium, and Phosphorus Content.—A 10-gram sample of the ground raisins was charred in a porcelain crucible over the free flame of a Bunsen burner. About 1 cc of dilute H_2SO_4 was added to the charred mass, which was then ashed at 580° C. Silica was removed by twice evaporating with 1 to 5 HCl. The ash was then dissolved in additional 1 to 5 HCl and made up to 100 cc. Potassium was determined gravimetrically by the platinic chloride method. Calcium was determined, by the official method of the Association of Official Agricultural Chemists (1935), involving precipitation with $NH_4C_2O_4$, redissolving with H_2SO_4, and finally titration with $KMnO_4$. For magnesium determination the filtrate from the calcium precipitation was evaporated to 10-cc volume. Next, 7 cc of microcosmic salt solution was added, and then 10 cc concentrated NH_4OH. After standing overnight the precipitate was filtered off and washed with dilute NH_4OH and alcohol. The precipitate and the paper were then added to 20 cc of 0.02 *N* H_2SO_4 and digested cold for 3 or 4 hours. The excess acid was titrated with 0.02 *N* NaOH. Phosphorus was determined colorimetrically by the Fiske and Subbarow method as given by Yoe (1928).

RESULTS WITH THOMPSON SEEDLESS

In most of the following tables and discussions, the individual experimental lots are grouped into classes according to the Balling degree of the juice of the fresh grapes. Thus all Thompson Seedless lots testing between 17.5° and 18.4° were grouped into the class designated 18 in the left-hand column of each table. Class 19 includes all lots from 18.5° to 19.4°; class 20 those from 19.5° to 20.4°; and so on to class 29, which includes all lots from 28.5° to 29.7°. The number of lots in each class is shown in the second and third columns of table 1. Dashes in the tables indicate absence of data. All observations and calculations involving the "dry weight" of the raisins are reported on the basis of 15 per cent moisture in the raisins. To aid in analyzing and interpreting the data, standard errors, derived by the formula $\sqrt{\frac{\Sigma d^2}{n(n-1)}}$, are given wherever they appear to have value.

The Relation of the Drying Ratio to the Balling Degree of the Fresh Grapes.—The dry weight of the raisins obtained from a unit quantity of fresh Thompson Seedless grapes increased regularly with advancement in maturity of the grapes. The drying ratios, therefore, vary inversely with the Balling degree of the fresh grapes as shown in table 1. All artificially dehydrated lots, pretreated in various ways as described under "Methods of Drying," have been grouped in the columns of table 1 headed "Dehydrated." Likewise all lots dried without the use of artificial heat, whether dried in direct sunlight or in shade, have been grouped in the "Sun-dried" columns.

The drying ratios of the dehydrated lots were consistently more favorable than those of similar sun-dried lots except in the 28° Balling class, where the difference is negligible but in the opposite direction. The differences between dehydrated and sun-dried lots appear to be slightly greater in the low Balling range than in the high range—that is, 25° Balling and above. The coefficient of correlation of drying ratio with Balling degree of the fresh grapes is –0.962 for the dehydrated and –0.951 for the sun-dried lots (table 5).

TABLE 1

RELATION OF THE DRYING RATIO TO THE BALLING DEGREE OF THE FRESH GRAPES IN THOMPSON SEEDLESS

Degree Balling of fruit	Number of lots		Drying ratio*		Balling × drying ratio†	
	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried
18	14	12	4.79±0.034	4.88±0.052	85.5±0.344	87.3±0.835
19	4	2	4.35	4.45	83.9	85.2
20	11	6	4.35±0.036	4.50±0.053	85.7±0.584	88.3±1.016
21	13	13	4.04±0.018	4.17±0.028	84.9±0.342	87.4±0.595
22	26	31	3.80±0.010	3.88±0.016	83.7±0.176	85.4±0.310
23	23	27	3.63±0.012	3.71±0.027	83.9±0.160	85.8±0.297
24	17	18	3.47±0.016	3.57±0.027	83.7±0.353	83.3±0.841
25	35	35	3.41±0.003	3.46±0.012	84.3±0.216	85.6±0.255
26	5	0	3.18	—‡	83.7	—
27	16	17	3.12±0.005	3.13±0.018	83.9±0.446	83.9±0.485
28	7	8	3.04±0.021	3.03±0.015	84.5±0.276	85.1±0.377
29	3	5	2.79±0.006	2.82±0.015	82.9±0.562	83.8±0.449
Mean					84.21	85.55

* Raisins, 15 per cent moisture.
† Arithmetical means of calculations on individual lots.
‡ Dashes indicate data not available.

In the last two columns of table 1 appear the products of the Balling degree multiplied by the respective drying ratios. The figures given are the arithmetical means of calculations on the individual lots in each class. The mean of these products for all dehydrated lots is 84.21; for all sun-dried lots, 85.55. The figures exhibit no appreciable correlation with maturity. They fall so closely around the mean as to indicate that the relation of the drying ratio to the Balling degree (maturity) of the fresh grapes approximates that of a straight-line function, the value of the constant differing, of course, with the method of drying employed.

The fluctuations were greater in the data on the sun-dried lots than in those on the dehydrated lots, probably because of the lesser degree of control that could be exercised over drying conditions and over sources of minor losses. Direct losses of entire berries were not, however, entirely responsible for the differences shown between the dehydrated and sun-dried lots, for the raisin berries were slightly heavier in most dehydrated lots than in equivalent sun-dried lots (table 2).

The Relation of the Weight of Berry and the Weight per Unit Volume of the Raisins to the Balling Degree of the Fresh Grapes.—Table 2 gives the weight per 100 raisin berries and the weight per 500-cc volume measurements on the experimental lots, grouped into Balling-degree classes. The figures show, with some irregularities, a gradual and steady increase in the weight of raisin berries and in weight per unit volume as the total soluble-solids content of the fresh grape berries increases. The

TABLE 2

RELATION OF THE BALLING DEGREE OF FRESH GRAPES TO THE WEIGHT OF BERRY AND THE WEIGHT PER UNIT VOLUME OF THE RAISINS, IN THOMPSON SEEDLESS

Degree Balling of fruit	Weight per 100 raisin berries, grams*		Weight per 500 cc volume of raisins, grams	
	Dehydrated	Sun-dried	Dehydrated	Sun-dried
18	26.1±0.522	26.0±0.507	316±4.15	310±5.28
19	—†	—	—	—
20	31.8±0.325	31.0±0.294	324±8.15	329±8.23
21	35.8±0.946	35.4±1.153	345±5.03	341±3.71
22	38.6±0.771	37.7±0.756	346±4.85	346±3.37
23	40.5±0.747	38.9±0.540	344±4.80	356±4.33
24	39.6±0.740	38.3±0.866	353±5.63	354±3.19
25	43.6±0.638	42.2±0.682	351±4.11	361±3.08
26	—	—	—	—
27	47.7±1.220	46.7±1.033	360±5.68	365±5.23
28	48.1±1.277	44.3±1.179	351±4.43	377±7.09
29	44.3±0.537	45.3±1.005	367±6.75	378±7.15

* Data adjusted to the basis of 15 per cent moisture in the raisins.
† Dashes indicate data not available.

increase in weight of raisin berry from 18° to 29° Balling in the fresh fruit was roughly 70 per cent; the increase in weight per unit volume over the same range of maturity, about 18 per cent. The figures of table 2 show small differences in raisin-berry weights between the dehydrated and sun-dried lots in favor of the dehydrated lots by odds of about 150 to 1 when the data are analyzed by Student's (1908, 1917) method. Most of the sun-dried lots appear to have had a higher weight per unit volume than did similar dehydrated lots. Since, however, the figures for dehydrated lots in table 2 lack consistency in respect to this measurement, the odds by Student's method are only 26 to 1 in favor of the sun-dried.

The rather positive, although small, differences in berry weights in favor of the dehydrated lots indicate that respiration, and perhaps fermentation in some lots, used up some of the grape solids in the sun-dried fruit. The data on the sugar content of the raisins (table 3) tend to substantiate this hypothesis, showing a higher percentage of sugar in the dehydrated than in the sun-dried lots.

The coefficient of correlation of raisin-berry weight with Balling degree of the fresh fruit was 0.860 for the dehydrated lots, and 0.699 for the sun-dried. The coefficient of correlation of the weight per unit volume measurements on the raisins with the Balling degree of the fresh fruit was 0.454 for the dehydrated, 0.625 for the sun-dried lots (table 5).

The Relation of the Composition of the Raisins to the Balling Degree of the Fresh Grapes.—The sugar content of the raisins increased with

TABLE 3

RELATION OF BALLING DEGREE OF THE FRESH GRAPES TO THE SUGARS AND INSOLUBLE SOLIDS OF THE RAISINS, IN THOMPSON SEEDLESS*

Degree Balling of fruit	Per cent sugars†		Per cent insoluble solids‡	
	Dehydrated	Sun-dried	Dehydrated	Sun-dried
18	69.5±0.246	68.7±0.313	6.38±0.166	7.06±0.233
19	—§	—	—	—
20	70.4±0.829	69.6±0.584	7.05±0.403	6.66±0.178
21	70.9±0.295	71.0±0.246	6.23±0.254	6.12±0.132
22	72.0±0.218	71.2±0.360	5.60±0.141	5.91±0.064
23	72.3±0.173	71.4±0.282	5.70±0.135	5.65±0.062
24	72.8±0.347	71.5±0.520	5.83±0.259	5.69±0.074
25	72.7±0.169	71.9±0.363	5.26±0.107	5.29±0.070
26	—	—	—	—
27	72.9±0.233	71.5±0.273	4.87±0.086	5.29±0.083
28	72.2±0.541	71.0±0.313	5.15±0.322	5.08±0.129
29	73.0±0.276	71.7±0.458	4.52±0.076	4.98±0.172

* Data adjusted to the basis of 15 per cent moisture in the raisins.
† Reducing sugars calculated as invert sugars.
‡ Insoluble residue from water extraction in the Soxhlet apparatus.
§ Dashes indicate data not available.

the maturity of the grapes during the early part of the maturation period—from 18° to 23° or 24° Balling (table 3). After the grapes had reached 24° Balling, the sugar content of the raisins apparently increased but little, if at all. At 18° Balling the sugar content of the raisins was 69.5 per cent and 68.7 per cent, respectively, for dehydrated and sun-dried lots; whereas at 24° Balling it was 72.8 per cent and 71.5 per cent, respectively, calculated as invert sugars and based on raisins of 15 per cent moisture content.

The dehydrated lots had higher sugar content than the sun-dried by 1.3 per cent of the sun-dried.

The coefficient of correlation of sugar content of the raisins with the Balling degree of the fresh grapes over the entire range of maturity studied was 0.474 in the dehydrated, 0.394 in the sun-dried lots (table 5).

The water-insoluble solids of the raisins varied inversely with the sugars, decreasing, as maturity advanced, from about 7.0 per cent in the raisins made from grapes of 18° or 19° Balling to about 5.7 per cent at 23° or 24° Balling and to about 5.0 per cent in the raisins made from the ripest grapes. The differences in insoluble-solids content shown in table 3 between the dehydrated and sun-dried lots are not significant.

The coefficient of correlation of insoluble solids in the raisins with the Balling degree of the fresh fruit was –0.460 in the dehydrated lots, –0.693 in the sun-dried (table 5).

The total titratable acidity of the raisins decreased markedly with increased maturity of the fresh grapes in the early part of the ripening

TABLE 4

RELATION OF BALLING DEGREE AND TITRATABLE ACID IN THE FRESH GRAPES TO THE TITRATABLE ACID IN THE RAISINS, IN THOMPSON SEEDLESS

Degree Balling of fruit	Per cent acid in fresh fruit*	Percentage of acid in fresh fruit × drying ratio†		Per cent acid in raisins*‡	
		Dehydrated	Sun-dried	Dehydrated	Sun-dried
18	0.79	3.82±0.027	3.92±0.041	3.47±0.111	3.37±0.123
19	—§	—	—	—	—
20	0.69	3.06±0.025	3.13±0.037	2.81±0.133	2.88±0.261
21	0.66	2.69±0.012	2.76±0.018	2.45±0.077	2.47±0.084
22	0.59	2.16±0.006	2.26±0.009	2.16±0.070	2.11±0.052
23	0.54	1.85±0.007	1.94±0.015	1.91±0.083	1.93±0.050
24	0.51	1.71±0.008	1.88±0.014	1.83±0.098	1.92±0.095
25	0.46	1.52±0.002	1.61±0.006	1.70±0.043	1.70±0.040
26	—	—	—	—	—
27	0.42	1.26±0.002	1.37±0.008	1.59±0.061	1.55±0.050
28	0.42	1.24±0.009	1.30±0.006	1.68±0.098	1.49±0.092
29	0.44	1.24±0.003	1.26±0.007	1.62±0.163	1.47±0.056

* Per cent acid by weight calculated as tartaric acid.
† Means of computations on individual lots.
‡ Water extract titrated with 0.033 normal NaOH to phenolphthalein indicator and calculated as tartaric acid.
§ Dashes indicate data not available.

period (table 4). As the grapes became more mature, the decrease in acidity of the raisins became less. Titration figures on the fresh grape juice (table 4, second column) show a similar trend. The total acid content of the fresh grapes appears to decrease rapidly early in the ripening period, but more slowly or not at all later on.

To judge from the rather rapid decrease in the total titratable acid content of the raisins in the early part of the ripening period of the grapes, a method of grading raisins for quality on the basis of acid determination on the raisin pulp may have considerable practical value.[7] It apparently provides an index of the approximate maturity of the grapes within the range of its application, which is indicated in this investigation to be between 18° and 23° Balling.

[7] Such a method has been proposed by Mr. Charles D. Fisher of the Dried Fruit Association of California (unpublished).

The coefficient of correlation of the total titratable acidity of the raisins with the Balling degree of the fresh grapes was –0.741 for the dehydrated, –0.777 for the sun-dried lots (table 5).

Table 4 shows no consistent differences in acid content between the dehydrated and sun-dried raisins. (The odds are only 8.9 to 1, by Student's method, that the dehydrated lots as a group are higher.)

Table 4 gives also the titratable acidity of the fresh grapes multiplied by the drying ratio (from table 1) in order that these calculated quantities may be compared with the total titratable acid content as determined on the raisins. As the figures show, in the early part of the ripening period—until the fresh grapes reach 22° or 23° Balling—the

TABLE 5

COEFFICIENTS OF CORRELATION BETWEEN BALLING DEGREE OF THE FRESH GRAPES AND VARIOUS DETERMINATIONS ON THE RAISINS, IN THOMPSON SEEDLESS

Determinations	Dehydrated lots	Sun-dried lots
Drying ratio	−0.962	−0.951
Sugars	0.474	0.394
Titratable acids	−0.741	−0.777
Insoluble solids	−0.460	−0.693
Weight per 100 raisin berries	0.860	0.699
Weight per unit volume	0.454	0.625

titratable acid in the raisins is less than the calculated amount, assuming that there was no change in the nature of the acids of the fresh grapes as a result of drying. In the later part of the ripening range—above 22° or 23° Balling—the total acid content of the raisins is consistently greater than the calculated amount. The data are very consistent in both the dehydrated and sun-dried lots, and the reversal of trend in the figures is probably not due to any errors in the empirical procedures followed in titrating either the fresh grape juice or the water extracts of the raisins. The phenomenon may be explained, conceivably, by changes in the composition of the grapes, perhaps precipitation of potassium bitartrate in the grape tissues, part of the precipitate being lost in the discarded fresh grape pulp but redissolved in the prolonged water extraction of the raisin pulp. It has not, however, been possible to make the necessary investigations to verify or disprove this hypothesis.

The content (percentage) of potassium, calcium, and magnesium of the Thompson Seedless raisins appears to remain nearly constant over the entire range of maturity of the grapes used in the investigations (table 6). The data of table 6 appear to indicate that phosphorus may decrease slightly in the raisins as the maturity of the grapes advances; but the consistency in the figures is not sufficient to establish the apparent decrease as a fact.

The potassium content of the raisins averaged 0.905 per cent, the calcium 0.058 per cent, the magnesium 0.027 per cent, and the phosphorus 0.105 per cent.

TABLE 6

RELATION OF BALLING DEGREE OF THE FRESH GRAPES TO THE POTASSIUM, CALCIUM, MAGNESIUM, AND PHOSPHORUS CONTENT OF THE RAISINS, IN THOMPSON SEEDLESS*

Degree Balling of fruit	Potassium (per cent K)		Calcium (per cent Ca)		Magnesium (per cent Mg)		Phosphorus (per cent P)	
	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried
18	0.862	0.891	0.061	—†	0.026	—	0.115	0.114
19	—	—	—	—	—	—	—	—
20	0.946	0.935	0.057	0.072	0.029	0.029	0.107	0.108
21	0.865	0.864	0.056	—	0.022	—	0.105	0.104
22	0.914	0.938	0.052	0.050	0.021	0.029	0.110	0.111
23	0.852	0.909	0.059	—	0.020	—	0.107	0.104
24	0.935	0.973	0.057	0.051	0.032	0.033	0.107	0.106
25	0.871	0.909	0.063	0.066	0.018	0.021	0.106	0.103
26	—	—	—	—	—	—	—	—
27	0.880	0.898	0.060	0.051	0.030	0.035	0.104	0.106
28	0.935	0.966	0.057	—	0.033	—	0.100	0.095
29	0.891	0.874	0.050	—	0.020	—	0.097	0.097

* Data adjusted to the basis of 15 per cent moisture in the raisins.
† Dashes indicate data not available.

The Relation of the Balling Degree of the Grapes to Quality in the Raisins.—The weight of the raisin berries and the weight per unit volume[8] are accepted factors in the measurement of quality in raisins.

The data on weight of berry, weight per unit volume, sugar content, acidity, and insoluble-solids content indicate a continued improvement in the quality of the raisins as the grapes mature, the improvement proceeding rapidly during the early part of the ripening period, slowing in its middle part, and almost ceasing as the grapes become very ripe.

Representative samples from the experimental lots of "naturals" and golden-bleached raisins were submitted to a group representing the principal commercial raisin packers of the state. Tabulation of their grading of the samples showed continuous improvement in quality over the entire ripening range.

[8] The weight per unit volume measurement, based on the work of Chace and Church (1927), has been used by a large coöperative organization for many years to grade growers' lots of raisins when received at the warehouse. Differential payments have been made upon the basis of this measurement.

The Influence of the Method of Drying on the Drying Ratio, Sugar Content, and Acid Content of Thompson Seedless Raisins.—In tables 1 to 4, inclusive, all dehydrated lots and all sun- or shade-dried lots were grouped together to show the relations existing between the maturity of the fresh grapes and the several factors measured in the raisins. The predrying treatments—dipping and sulfuring—as well as the manner of drying did, however, materially influence the yield and composition of the raisins.

TABLE 7

THE INFLUENCE OF METHOD OF DRYING ON DRYING RATIO, SUGAR CONTENT OF THE RAISINS, AND TOTAL TITRATABLE ACIDITY OF THE RAISINS, IN THOMPSON SEEDLESS

Method of drying	Balling degree × drying ratio*	Percentage sugar (as invert) in raisins from grapes of 23° Balling	Percentage acid (as tartaric) in raisins from grapes of 23° Balling
(1) Natural sun-drying	87.8	70.4	1.88
(2) Dehydration without pretreatment	84.5	72.2	2.01
(3) Lye dip with dehydration	84.1	72.2	1.86
(4) Lye dip with sun-drying	85.5	71.9	1.77
(5) Golden bleach	83.6	72.5	2.41
(6) Sulfur bleach	85.0	72.3	2.34
(7) Australian mixed dip with dehydration	84.3	72.2	1.83
(8) Australian mixed dip with rack-drying	85.0	71.7	1.80
(9) Australian cold dip with dehydration	84.1	72.3	1.61
(10) Australian cold dip with rack-drying	85.0	70.7	1.77
(11) California soda-oil dip with dehydration	84.5	72.3	1.56
(12) California soda-oil dip with sun-drying	86.4	71.3	1.86

* Means of the products calculated individually for each lot by multiplying the Balling degree by the drying ratio. Dividing the quantities given in this column by any Balling degree, from 18° to 29°, gives the approximate drying ratio obtained with Thompson Seedless grapes at that degree Balling for the respective method of drying.

Table 7 shows how the several treatments used and the manner of drying affected the product of the Balling degree multiplied by the drying ratio, the sugar content of the raisins, and their total titratable acidity. The Balling degree × drying ratio figures are averages of the quantities obtained by calculating this product separately for each lot dried by the respective methods. It is a convenient expression since the drying ratio obtained with Thompson Seedless grapes at any given Balling degree between 18° and 29° can be very closely approximated by simply dividing it by the Balling degree. The percentages of sugar and acid are given in table 7 only for raisins made from grapes of 23° Balling. The differences obtained in sugar and acid among the various methods of drying, increased slightly with grapes of lower degree Balling but remained fairly constant above 23° Balling. Means calculated from the figures given in table 7 for methods of drying involving artificial dehydration and for methods involving sun- or shade-drying will be found to differ slightly from the figures given in tables 1, 3, and 4. The apparent inconsistencies do not indicate discrepancies in the data nor in their interpretation but are the result of not having the same number of lots represented in each method of drying. Methods 4, 7, 9, 11, and 12 were used only during the 1935 season, hence fewer lots dried by these methods than by the other methods are represented in tables 1, 3, and 4.

The dehydrated lots all yielded better drying ratios, as indicated by lower values for Balling degree $\times$ drying ratio, than equivalent sun- or rack-dried lots. All methods involving a predrying treatment gave better ratios than natural sun-drying. The most favorable ratios were obtained with the golden bleach (method 5), but the advantage of this method over others involving dehydration is small. Hot lye dipping improved the drying ratio in the sun-dried lots, and the sulfured lots (methods 5 and 6) came out slightly more favorably than those lye dipped but not sulfured (methods 3 and 4). The potassium carbonate and oil dips (methods 7 to 10) were roughly equal to the hot lye dip in their effect on drying ratio. Differences of less than 0.5 in the Balling degree $\times$ drying ratio are not significant.

The golden-bleached raisins (method 5) had the highest apparent sugar content. In the percentage-sugar column of table 7, differences of less than 0.5 are not significant. No differences may be assumed to exist, therefore, among equivalent lots dried according to methods 2, 3, 4, 6, 7, 9, and 11; all of these are, however, definitely higher than the natural sun-dried, but the differences between any of these methods and method 5 are of doubtful significance. The raisins made by methods 8 and 12 (table 7) are intermediate in sugar content, higher than the natural sun-dried, and lower than the golden bleached. Method 10 produced raisins of about the same sugar content as the "naturals" (method 1).

The sulfured lots (methods 5 and 6) are clearly higher in titratable acid than any others. No determinations for SO_2 were made; but, assuming the raisins to be analogous to similar commercial samples, a reasonable estimate of the SO_2 in them would approximate 1,000 parts per million (0.1 per cent). If the SO_2 present was all titratable, which it probably is not, and was expressed in terms of tartaric acid, it would account for about 0.23 per cent acid or slightly less than half of the difference found between the golden-bleached raisins (method 5) and those of method 3, which had no sulfur dioxide but which were otherwise treated similarly. The remainder of the apparent differences shown between methods 5 and 3 and methods 6 and 4 are unaccounted for. Differences of 0.12 or greater in the total-acid column of table 7 are required for significance (20 to 1 odds). The strong carbonate dips of methods 9 and 11 reduced the apparent acid content of the raisins, probably as a result of surface adherence of some of the dipping solution. These raisins were not washed after drying. The raisins of methods 10

TABLE 8

THE RELATION BETWEEN THE SIZE OF CROP, MATURITY, AND SIZE OF BERRY IN THOMPSON SEEDLESS GRAPES, AT DAVIS

Picking date	Degree Balling	Weight per 100 berries, grams	Degree Balling	Weight per 100 berries, grams
1927	Vines of moderate crop (6 tons per acre)		Vines of heavy crop (9 tons per acre)	
September 6,	22.5	128	20.3	119
September 10	23.0	131	21.4	120
September 17	23.0	130	22.3	118
September 24	24.3	135	22.2	121
October 1	25.0	133	23.4	120
October 8	26.1	139	23.7	122
October 15	27.0	137	24.5	122
October 22	26.5	140	—*	120
1935	Vines of moderate crop (7 tons per acre)		Vines of heavy crop (12 tons per acre)	
August 31,	21.0	129	18.2	127
September 7	19.6	130	17.4	120
September 13	22.1	136	21.0	136
September 20	23.8	142	21.9	161
September 27	23.4	138	22.4	152
October 4	24.6	144	23.0	169
October 11	24.4	143	24.8	157
October 18	24.3	144	24.6	167
1936	Vines of light crop† (3 tons per acre)		Vines of moderate crop (6 tons per acre)	
August 22,	21.9	130	21.6	134
August 29	24.4	140	22.9	137
September 4	24.5	144	23.3	137
September 11†	26.8	136	24.8	136
September 18	28.0	136	25.1	134
September 25	29.7	137	26.5	138
October 2	—	—	27.0	139

* Dashes indicate data not available.

† The first three pickings exhausted the supply of fruit on the vines used August 22 to September 4, inclusive. Another group of vines was used to supply the fruit for the September 11 to September 25 tests from the light-crop vines.

and 12, which received predrying treatments identical with those of methods 9 and 11 respectively, were washed after drying. They show no considerable decrease in acidity resulting from the treatment. The differences in acid content between dehydrated and equivalent sun-dried lots is small except in the lots dried by method 9 as compared with 10 and those of method 11 as compared with 12. The probable reason for these differences has already been explained.

The Relation Between Size of Crop, Maturity, and Size of Berry.— Table 8 shows the picking dates and Balling degree of the fresh grapes, and the weight per 100 berries for each series of experimental lots obtained from the vineyards at Davis. The crop weights given in the table were arrived at by adding together all quantities removed from the vines, plus the estimated amount of fruit remaining unharvested at the end of the season, and then calculating to the acre basis.

The data are inconclusive. The figures show that in 1927 the vines carrying the heavy crop were a little slower in ripening their fruit and produced somewhat smaller berries than did the vines having only a moderate crop. Also, the berries from the moderately loaded vines apparently increased in size, at least during the early part of the ripening period, whereas those from the heavily loaded vines did not.

In 1935, the fruit from the heavily loaded vines was a little greener early in the season, but caught up with that from the moderately loaded vines before the season was over. The berries from both lots of vines increased in size during the early part of the ripening season, and after the third picking those from the heavily loaded vines were larger than those from the moderately loaded vines.

In 1936, two different sets of lightly loaded vines were required to supply the needed quantity of fruit. The two groups of vines were very similar, but not identical in their characteristics, as is indicated by the break in berry-size increase when the change to the second set of vines was made on September 11. The fruit on the lightly loaded vines ripened slightly ahead of that from the moderately loaded vines. Some increase in berry size is indicated as ripening progressed in the fruit from the first set of lightly loaded vines, but none is indicated in the second set of lightly loaded vines nor in the moderately loaded vines.

RESULTS WITH MUSCAT OF ALEXANDRIA

The work with the Muscat paralleled that with Thompson Seedless during the 1935 and 1936 seasons, but involved a total of only 76 individual lots as against a total of 348 (in four years) for Thompson Seedless. The data obtained are therefore less extensive and not so consistent when summarized. The methods of drying used were those described for Thompson Seedless as (1) natural sun-drying; (2) dehydration without pretreatment; (3) lye dip with dehydration; (4) lye dip with sun-drying; (9) Australian cold dip with dehydration; and (10) Australian cold dip with rack-drying. The complete series was carried through 1935; but in 1936 it was impossible to follow the entire program, and

TABLE 9

RELATION OF BALLING DEGREE TO CERTAIN DETERMINATIONS ON THE FRESH GRAPES AND RAISINS, IN MUSCAT OF ALEXANDRIA*

Degree Balling of fruit	Fresh fruit			Raisins									
	Per cent acid, as tartaric	Weight per 100 berries, grams		Number of lots		Drying ratio		Drying ratio × Balling degrees		Weight per 100 raisin berries, grams		Weight per 500 cc raisins, grams	
		1935	1936	Dehy-drated	Sun-dried	Dehy-drated	Sun-dried	Dehy-drated	Sun-dried	Dehy-drated	Sun-dried	Dehy-drated	Sun-dried
16.0	0.69	423	—†	3	2	4.95	4.92	79.0	78.7	84	83	284	297
17.1	0.66	407	—	3	2	4.68	4.70	79.9	80.4	90	86	310	305
18.6 and 18.7	0.59	400	382	5	4	4.28	4.45	79.9	83.0	91	90	323	297
19.1 and 19.2	0.45	435	—	6	3	4.16	4.30	78.9	82.5	109	107	298	306
19.7 and 20.6	0.48	491	390	5	3	3.89	4.08	78.7	81.6	112	104	306	304
21.3 and 21.4	0.44	480	405	5	3	3.78	3.86	80.7	82.4	120	111	309	309
22.4 and 22.7	0.36	484	—	5	1	3.61	3.83	81.6	86.9	132	120	317	322
23.1 and 23.3	0.38	—	403	4	2	3.51	3.60	81.3	83.8	116	113	315	321
24.7 and 25.4	0.39	—	405	8	2	3.27	3.37	82.0	84.5	123	119	316	330
27.0 and 27.5	0.37	—	393	6	4	3.00	3.06	81.9	84.1	130	129	323	331

* Data adjusted to the basis of 15 per cent moisture in the raisins.
† Dashes indicate data not available.

methods 9 and 10 were dropped. A considerable number of the sun-dried lots were discarded in which 10 per cent or more of the berries showed a positive reaction to the yeast and mold test with hydrogen peroxide.

Tables 9 and 10 summarize the results. The individual lots are grouped according to the Balling degree of the fresh fruit; but, since each class represents only one or two series, the actual Balling hydrometer readings are given in the left-hand column of each table. The acid titrations, calculated to per cent by weight as tartaric, are averaged in the second column of table 9. A marked decrease in the acidity of the fresh fruit is apparent until the fruit reached about 22° Balling, after which no further decrease was observed. Also, the acid content of the grapes in 1936 was slightly higher than in 1935, a fact which accounts for the minor discrepancies in the continuity of the decrease in acid as shown in table 9.

The size of the fresh berries (table 9, third and fourth columns) was appreciably greater in 1935 than in 1936. An increase in size during the early part of the ripening period is, furthermore, indicated.

The drying ratios for both dehydrated and sun-dried lots decreased without a break in continuity from the greenest to the ripest lots. When the drying ratio of the Muscat is multiplied by the Balling degree, the product shows a definite trend to increase as the fruit becomes riper, in contrast to the results with Thompson Seedless (table 1), with which the product of Balling $\times$ drying ratio shows no tendency to drift with the Balling. The difference in behavior of the two varieties in this respect is logically attributed to the presence of seeds in the Muscat and their absence in the Thompson Seedless. If the seeds in the Muscat are assumed to be nearly mature in the greenest fruit used and to change but little as the sugar content of the grapes increases, then the effect on the relation of the drying ratio to the Balling degree would be as observed in these tests.

The weight per 100 raisin berries is influenced both by the size of the fresh berries and by the drying ratio. Since the fresh berries were larger in 1935 than in 1936, and since the lots in the lower Balling classes are preponderantly from the 1935 experiments, whereas the higher Balling classes were mostly obtained in 1936, the size of raisin berries as the fruit becomes more mature progresses upward less regularly than if the tests could have covered the entire range of maturity in both years. Nevertheless, the figures of table 9 show a 50 per cent increase in size of the raisin berries from the greenest to the ripest fruit used. Since commercial grading with Muscat raisins is largely based on size, obviously the commercial quality improved gradually over the entire range of maturity studied.

TABLE 10

THE RELATION BETWEEN BALLING DEGREE OF THE FRESH GRAPES AND COMPOSITION OF THE RAISINS, IN MUSCAT OF ALEXANDRIA*

Degree Balling of fruit	Sugars (per cent, as invert)		Acid (per cent, as tartaric)		Insoluble solids, (per cent)		Potassium (per cent K)		Phosphorus (per cent P)		Calcium (per cent Ca)		Magnesium (per cent Mg)	
	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried	Dehydrated	Sun-dried
16.0	62.8	62.2	3.16	2.67	13.8	15.3	0.796	0.794	0.101	0.100	—†	—	—	—
17.1	64.7	63.8	2.93	2.21	11.8	13.6	0.773	0.784	0.098	0.099	0.074	0.076	0.030	0.033
18.6 and 18.7	64.8	64.2	2.60	2.02	12.8	13.1	—	—	—	—	—	—	—	—
19.1 and 19.2	66.5	65.9	2.18	1.82	11.5	12.0	0.700	0.771	0.094	0.098	0.062	0.073	0.024	0.026
19.7 and 20.6	67.2	65.5	1.83	1.66	11.3	11.7	0.701	0.774	0.089	0.097	—	—	—	—
21.3 and 21.4	68.0	66.9	1.65	1.50	10.6	11.7	0.652	0.670	0.090	0.095	0.059	0.070	0.019	0.026
22.4 and 22.7	69.4	68.0	1.60	1.44	9.5	11.2	—	—	—	—	—	—	—	—
23.1 and 23.3	68.2	67.4	1.53	1.34	10.9	10.5	0.665	0.706	0.082	0.087	0.072	0.072	0.017	0.020
24.7 and 25.4	68.8	67.2	1.43	1.28	10.1	10.1	0.668	0.713	0.086	0.097	0.067	0.061	—	0.019
27.0 and 27.5	68.7	68.0	1.24	1.18	10.0	10.6	0.665	0.694	0.086	0.088	0.077	0.073	0.024	0.024

* Data adjusted to the basis of 15 per cent moisture in the raisins.
† Dashes indicate data not available.

The weight per unit volume of the Muscat raisins (table 9) shows a clear increase in this measurement as the grapes became riper, but an increase neither so regular nor so great as in Thompson Seedless (table 2).

In the early part of the ripening range the Muscat raisins showed a marked increase in sugar as the grapes became riper. Grapes of 16.0° Balling produced raisins having 62.8 per cent and 62.2 per cent sugar respectively for the dehydrated and sun-dried lots, whereas raisins made from grapes of 23.1°–23.3° Balling had 68.2 and 67.4 per cent sugar (table 10). Beyond the 23° Balling stage of maturity the sugar content of the raisins did not increase further with more advanced maturity of the grapes.

The total titratable acid content of the raisins decreased with advancing maturity, rapidly at first, then more slowly, but continued over the entire range of maturity. Raisins made from grapes at 16.0° Balling had 3.16 and 2.67 per cent total acid as tartaric in the dehydrated and sun-dried lots respectively, those from grapes of 23.1°–23.3° Balling had 1.53 and 1.34 per cent acid, and those from grapes of 27.0°–27.5° Balling had 1.24 and 1.18 per cent. The acid content of the sun-dried lots was consistently lower than that of equivalent dehydrated lots.

The water-insoluble solids content of the Muscat raisins, which included much of the seed materials, decreased from 13.8 and 15.3 respectively in dehydrated and sun-dried lots made from grapes of 16.0° Balling to between 10 and 11 per cent from grapes of 23.1°–23.3° Balling; thereafter it decreased but little, if at all.

Potassium and phosphorus in the raisins (table 10) decreased slightly in percentage as the maturity of the fresh grapes advanced. The decrease is small but too consistent to be ignored. Calcium and magnesium in the raisins seem to remain about the same over the entire range of maturity of the fresh grapes.

When compared with Thompson Seedless (table 6) the Muscat raisins were slightly lower in potassium and phosphorus content, slightly higher in calcium, and about the same in magnesium.

SUMMARY

Experiments were conducted to determine how the maturity of the fresh grapes influences the drying ratio, the size of the raisin berries, the weight per unit volume, the titratable acidity, and the content of sugar, potassium, calcium, magnesium, and phosphorus in the raisins. Thompson Seedless (Sultanina) and Muscat of Alexandria grapes, picked at about weekly intervals, were dried by several methods, including most of the standard commercial procedures and certain others that are not

commercial. The stage of maturity is represented by degree Balling of the juice from the fresh grapes. The tests with Thompson Seedless covered a range of 18° to 29° Balling and with Muscat 16° to 27°.

As the maturity of the fresh Thompson Seedless grapes advanced, the drying ratio decreased regularly with the increase in Balling degree, so that the product of Balling degree × drying ratio remained nearly constant. With the Muscat of Alexandria, the drying ratio decreased with advancing maturity of the grapes, but not proportionally, and the product of Balling degree × drying ratio drifted upward with the Balling. The size of the raisin berries and the weight per unit volume of raisins in both varieties increased along with the maturity of the grapes.

During the early part of the range of maturity studied, the sugar content of the raisins increased, whereas the total titratable acidity and insoluble-solids content decreased. The rate of these changes lessened as maturity advanced. Changes in the sugar and insoluble-solids content of the raisins nearly or quite ceased after the midpoint in the range of maturity of the grapes was reached, although the acidity of the raisins continued to decrease slowly.

The potassium, calcium, and magnesium content of the Thompson Seedless raisins remained fairly constant, whereas the phosphorus content appears to have decreased somewhat with advancing maturity. In the Muscat raisins both the potassium and phosphorus decreased, with the calcium and magnesium content remaining about the same.

LITERATURE CITED

ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS.
1935. Official and tentative methods of analysis. 710 p. Published by the Association, Washington, D. C.

BIOLETTI, FREDERIC T.
1915. Relation of the maturity of the grapes to the quantity and quality of the raisins. International Congress of Viticulture, Panama Pacific International Exposition, San Francisco, California. Official Rept. p. 307–14.
1919. Dried wine grapes: Methods and returns. State Board of Viticultural Commissioners, Sacramento, California. Bul. **15**:6–9.

CHACE, E. M., and C. G. CHURCH.
1927. Tests of methods for the commercial standardization of raisins. U. S. Dept. Agr. Tech. Bul. **1**:1–23.

CHRISTIE, A. W., and L. C. BARNARD.
1925. The principles and practice of sun-drying fruit. California Agr. Exp. Sta. Bul. 388:1–60.

CRUESS, W. V., and A. W. CHRISTIE.
1921. Dehydration of fruits. California Agr. Exp. Sta. Bul. 330:53–54.

CASTELLA, F. DE.
1925. Sultana drying by the cold-dip process. Victoria (Australia) Dept. Agr. Jour. **23** (12):716–31.

LYON, A. V.
1920. Mildura Research Committee experiments with the drying of vine fruits. Sci. and Indus. (Australia) **2**:625–29.
1924. Problems of the viticultural industry. Australian Inst. Sci. and Ind. Bul. **28**:1–84.
1934. The mixed dip for Sultanas. Australian Dried Fruit News **9**(2):1, 11. March 7, 1934.

NICHOLS, P. F., and A. W. CHRISTIE.
1930. Dehydration of grapes. California Agr. Exp. Sta. Bul. **500**:1–31.

SHAEFFER, P. A., and A. F. HARTMAN.
1920. The iodometric determination and its use in sugar analysis. Jour. Biol. Chem. **45**:349–90.

STUDENT.
1908. The probable error of a mean. Biometrika **6**:1–25.
1917. Tables for estimating the probability that the mean of a unique sample of observations lies between $-\infty$ and any given distance of the mean of the population from which the sample is drawn. Biometrika **11**:414–17.

YOE, JOHN H.
1928. Photometric chemical analysis. Vol. 1. Colorimetry. 771 p. John Wiley and Sons, Inc., New York, N. Y.