# 30

# Raisin Quality

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Raisin quality is judged in terms of factors related to appearance, texture, flavor, food value, and cleanliness. Characteristics such as seedlessness, size, and distinctive flavor can be variety dependent, notably in 'Zante Currant' ('Black Corinth') and 'Muscat of Alexandria.' Characteristics that are for the most part influenced during harvest are mold and insect damage, mechanical damage (breakage), stickiness (juicing), embedded sand, caramelization, and moisture content. Fruit maturity, the characteristic that usually receives the most attention, is largely determined by the soluble solids content of the grapes from which the raisins are made. Fruit maturity has a direct influence on the first four factors listed above: appearance, texture, flavor, and food value. It affects the packout as well as the marketability of the product. It is also the basis on which the industry has established important quality standards and regulations for delivered raisins.

## IMPORTANCE OF FRUIT MATURITY AND THE ROLE OF THE AIRSTREAM SORTER

Generally speaking, raisins produced from mature fruit are plump, meaty, fine-wrinkled, soft-textured, and of uniform, dark color. Raisins produced from low-maturity fruit are skinny, coarse-wrinkled, hard, light in weight, and tend toward a lighter, more reddish color. Raisins coming into a packinghouse are graded for maturity using an airstream sorter. Minimum industry standards have been established for airstream sorter grades *percentage B and better* (includes USDA A grade "well matured" and B grade "Reasonably well matured") and *percentage substandard* (includes "Substandard" and "Undeveloped" categories). Representative raisins of A, B, C, and substandard grades in a delivered raisin sample are shown in Plate 30.1. After processing, the raisins must be visually graded for maturity. This visual grading is necessary because the changes in the raisins' physical characteristics during processing alter their performance in the airstream sorter.

The airstream sorter was developed by the industry in the 1950s as an objective way to separate raisins on the basis of fruit maturity. Prior to its development, the two methods used for quality evaluation were visual scoring of individual raisins and a weight-per-volume measurement (*can test*). Visual scoring is slow and subject to individual inspector judgment, however, while the can test does not adequately determine the presence of immature (substandard) raisins. With the airstream method, a weighed sample of raisins is belt-fed at a slow, uniform rate into a calibrated, upward air flow that separates individual raisins according to their fruit maturity characteristics (Figure 30.1). Those produced from mature fruit tend to drop directly into a chamber

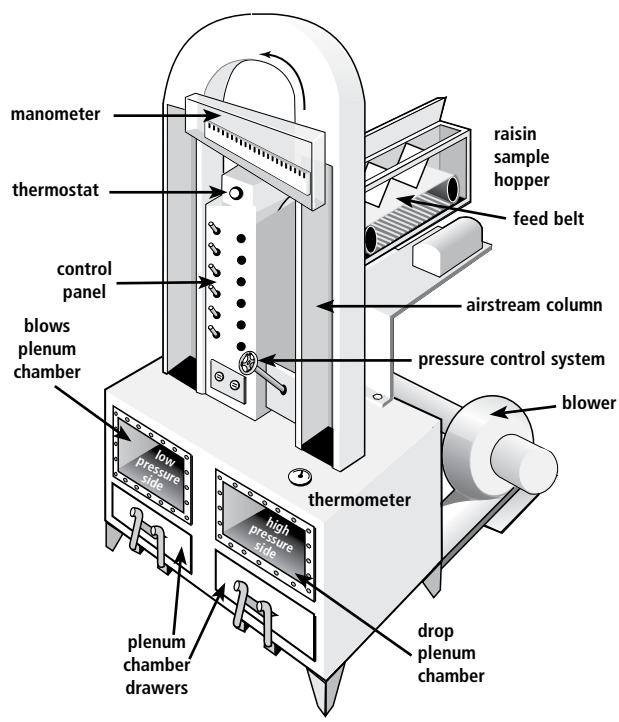


**Figure 30.1** The main features of the airstream sorter

below (the *high-pressure* or *drop* plenum chamber); the lighter, less-mature raisins are lifted in the airstream over an inverted U-tube into an opposite collection chamber (*low-pressure* or *blows* plenum chamber). The pressure differential between the two chambers is set at a specific manometer reading and the air temperature is kept constant. This produces a calibrated, uniform air velocity that separates raisins according to their aerodynamics, which are influenced by their weight and surface characteristics. Heavy, plump, meaty, and smooth (fine-wrinkled) surface characteristics contribute weight and reduced air flow resistance, causing raisins to drop against the airstream. Conversely, light, flat, and coarse-wrinkled raisins rise with the airstream. The weighed proportions of raisins that fall into the two chambers determine the percentage grade of the sample.

The airstream sorter settings were established by running visually graded raisin samples at various manometer readings. Once the proper setting for separating the maturity grades was found, many samples were run and the results compared with those of visual grading. The machine results were very reproducible. The industry's current standard uses machine settings with a differential air pressure of 0.67 and 0.48 inch of water column (17.02 and 12.19 kg/m$^2$) to represent B and better and substandard grades, respectively. Two airstream sorter machines—one for each grade setting—are always used during inspection. Those raisins that do not grade as B and better or substandard in a sample are classified as C grade. C grade ("Fairly well matured") raisins can be determined by running the same sample twice: once for B and better and again to remove the substandard. This intermediate C grade is not officially used for incoming inspection. It includes those raisins that are of lower maturity than B and better but still considered marketable, provided that their allowable percentage in a quantity of processed raisins is not exceeded.

## FRUIT CHARACTERISTICS CONTRIBUTING TO RAISIN MATURITY GRADES

Raisin maturity grades are influenced in large part by the characteristics of the grapes from which the raisins are produced. Knowledge of these characteristics can be useful for growers who want to improve raisin quality through cultural practices. In particular, the influence of fruit soluble solids on raisin quality makes the time of harvest an important cultural consideration.

Many studies have evaluated the important characteristics of fresh and dried grapes and how they relate to airstream sorter grades. The main purposes of these studies have been to determine the predictability of raisin grade from fresh fruit characteristics, to determine how these characteristics can be influenced by growing conditions and cultural practices, and to better understand the aerodynamics or behavior of different raisins in the airstream sorter.

Amand Kasimatis and his co-workers conducted the most extensive studies to determine the relationship of fresh fruit indices to airstream sorter grades during the 1960s and 1970s. The first studies in 1962 through 1965 demonstrated a high correlation between fruit soluble solids and percentage B and better (correlation coefficient, $r = 0.867$) and percentage substandard ($r = 0.732$). There was a rapid and almost linear increase in percentage B and better grades with increasing soluble solids, which began to level off as maturity approached 22 °Brix. There was a corresponding decrease in percentage substandard almost opposite that of the percentage B and better increase. The researchers concluded that soluble solids exhibited a strong correlation to airstream grades that was predictable from year to year and through the harvest period when proper sampling was performed.

This conclusion did not always match industry experiences, however, and it was later modified as a result of studies carried on through the 1970s. These studies revealed that other factors, such as fresh berry weight and raisin weight and their range or variability in a sample, can also exert a strong influence on raisin grade. These factors are summarized below.

***Soluble solids (°Brix).*** The soluble solids content (measured in °Brix) has a dominating influence on grades because it contributes to berry and raisin weight as well as the raisins' physical characteristics (meatiness and wrinkling). Most studies have demonstrated that it is the single most important fresh fruit characteristic to correlate with raisin quality. It has an especially high correlative value in high-maturity years when there is a narrow range in individual berry maturities.

***Mean berry weight.*** Large berries make large raisins that grade higher as B and better compared to small raisins made from small berries, even when the °Brix is the same for both sizes of grape. In some years berry weight gives the highest correlative value with percentage B and better, especially in years of low maturity. The relationship of fresh berry weight to percentage substandard is poor.

It is interesting to note that Kasimatis's studies showed that the mean weight of a berry sample tends to characterize the variation between light and heavy berries in that sample. When the mean berry weight is small, the range from light to heavy berries is relatively small. When the mean berry weight is large, the range from light to heavy berries is large.

***Total soluble solids per berry.*** The total soluble solids per berry combines the relationships of soluble solids readings (°Brix) and berry weight by multiplying them together. The result is a calculated value for total grams of soluble solids per berry. For example, a 2 gram, 21 °Brix berry would contain the equivalent of 0.42 grams total soluble solids (2 grams × 0.21 = 0.42 grams). This value often improves the correlation with raisin grades as compared to berry weight or °Brix alone. It can account for least 80 percent of the variability in percentage B and better, but it is not closely related to percentage substandard.

***Raisin weight.*** The weight of raisins is highly correlated to the fresh berry weight and the grams of soluble solids per berry (the product of °Brix and berry weight as described above). There is no correlation between the °Brix of fresh grapes and raisin weight. Of interest is the close relationship between raisin weight and airstream sorter grade. This is demonstrated in Figure 30.2, which depicts an example from a raisin quality study by Kasimatis. It shows the normal distribution curves for individual raisin weights expressed as percentages of the number of raisins in a sample and for the B and better and substandard fractions in that sample. While there is some overlap in the weight distribution for the grades, the heavier raisins have a much higher representation in the B and better grades. In this sample the mean raisin weight was 0.28 g; B and better raisins averaged 0.33 g while C and substandard averaged 0.25 g and 0.12 g, respectively.

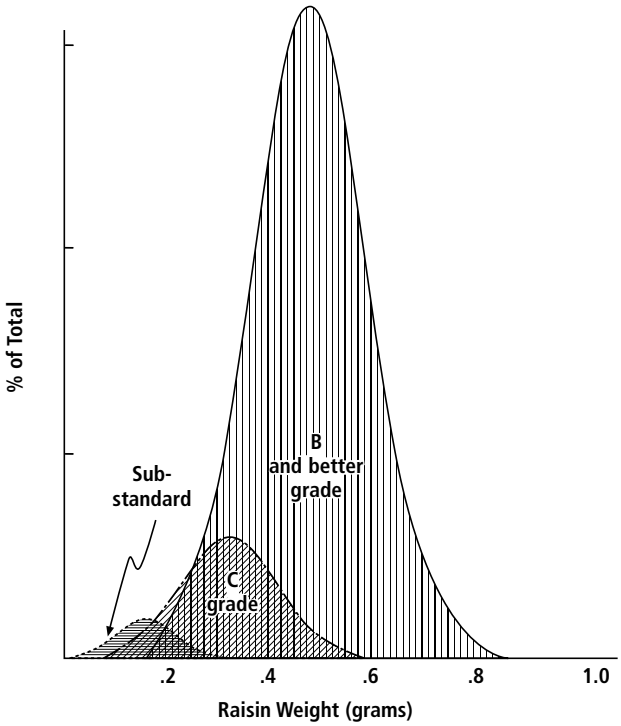


**Figure 30.2** The observed frequency distribution of raisin berry weight, shown as the percentage of the total number of raisins in each grade. The total number of raisins in the 1,000 gram sample was 2,985, with 485, 800, and 1,700 raisins in the substandard, C, and B or better grade fractions, respectively.

Raisin weight is considered the dominant factor affecting an individual raisin's aerodynamics or resistance to the vertical air column in the airstream sorter, accounting for 80 percent of the variability in percentage B and better grades. However, other aerodynamic characteristics (size, shape, surface texture, etc.) will modify the raisin-weight–air-resistance relationship, contributing to the overlapping of raisin weights between grades.

***Range of values or deviation from the mean.*** A grape or raisin sample is made up of many individual berries with different characteristics. A sample analysis is only an average of all of those individuals. Each grape berry, depending on its °Brix, weight, and perhaps other characteristics, will dry to a raisin that will grade as B and better, C, or substandard in the airstream sorter. Only a relatively small percentage of berries will be similar in composition to the average values of the sample. Studies have shown that two raisin samples of identical average berry weight or soluble solids but with different ranges among individual berries will perform differently in the airstream sorter. For example, if the grapes have an average of 20 °Brix and most of the individual berries have °Brix values within a range of 15 to 25 °Brix, the raisin grades from that vineyard will be different than from a vineyard with grapes that average 20 °Brix within a range of 18 to 22 °Brix.

'Thompson Seedless' berry weights tend to fit normal distributions and form a typical bell-shaped curve (see Figure 30.2 for an example). This shows that the mean grape berry weight adequately describes the entire population of berry weights. The distribution for °Brix often does not resemble a normal bell curve, however; instead it is skewed to one side, with a wider range of lower-maturity berries. This skewed distribution is thought to reduce the predictability of the mean °Brix as an indicator of raisin grade.

*Standard deviation* is a statistical measurement of the spread of data from the sample mean. It measures the limits within which two-thirds of the data will fall. Kasimatis has studied the relationships of the standard deviation for °Brix and fresh berry weight to airstream sorter grades. Unfortunately, the use of standard deviation did not improve predictability over the mean values of the samples.

Clary's research shows that the greater the standard deviation of berry soluble solids within a vineyard, the greater the percentage substandard grade. By determining the proportion of berries in a sample that float in a

16 °Brix solution, one can more accurately predict the percentage substandard and percentage B and better with mean soluble solids readings. This suggests that the accuracy of raisin grade prediction would improve if there were a way to account for the proportion of individual low-maturity berries.

These studies have shown that berries high in fresh weight and soluble solids produce heavier raisins with high percentage B and better grade and a lower percentage substandard grade. Also, these characteristics tend to be interdependent; a fresh berry that is heavier and has a higher soluble solids concentration tends to grade higher than one that is lower in either characteristic. Greater raisin weight, which is a function of fresh berry weight and soluble solids, also correlates well with higher raisin grades. Unfortunately, these measurements alone cannot always accurately predict airstream sorter grades. This is because variations in the range or spread of specific characteristics in individual raisins in a sample results in more or fewer individual raisins in each grade. Soluble solids (°Brix) is probably most useful index for the grower; it is a reasonably good predictor of raisin grade and is closely related to the drying ratio and raisin yields.

It is easy to see how these factors can affect the external physical characteristics of raisins as well as their weight. Raisins from grapes high in soluble solids tend to be more dense (have higher specific gravity) and show finer wrinkles. Compact, higher-density raisins without large, coarse surface pockets have less air resistance and tend to fall, rather than rise, against the airstream.

Other factors can also affect aerodynamics by changing raisin physical characteristics. They include moisture content, drying method, and degree of handling. Moisture may increase the plumpness of raisins and their ability to fall in the airstream. USDA raisin grades compensate for moisture with a calibrated chart, however. Drying practices that tend to produce fine wrinkling, such as drying-on-the-vine (DOV) and the use of an emulsion dip or spray to speed drying (ethyl oleate + potassium carbonate), can help improve raisin grades. Likewise, handling practices that change the raisin from a coarse, flattened shape into something more smooth and rounded, such as some reconditioning methods, can alter raisin grades. These practices are intended for special products or to address special needs, and are not necessarily used to influence the incoming grade. However, the differences point to the need to develop airstream grades for different products or raisin types. For example, the raisin industry in South Africa has developed different airstream sorter grades for 'Thompson Seedless' raisins that are classified as either natural sun-dried, golden seedless (dipped and $SO_2$-treated), or 'Sultana'-type (emulsion-dipped and rack-dried).

## CURRENT DATA: FRUIT RELATIONSHIPS TO AIRSTREAM SORTER GRADES

The characteristics described above vary from year to year and from vineyard to vineyard. Therefore, data have been generated to represent a variety of vineyard conditions and growing seasons. Figures 30.3 though 30.9 were developed from measurements taken in a uniform manner from 'Thompson Seedless' vineyard trials in Fresno, Madera, and Tulare Counties over an 11-year period (1983–1993). All of the locations involved studies evaluating the effects of cultural practices on raisin grades.

***Soluble solids.*** The curvilinear relationship between increased soluble solids and improved grade (increased percentage B and better and lowered percentage substandard) shown in Figures 30.3 and 30.4 is typical of numerous studies. The coefficient of determination ($r^2$ value) is a calculation that shows how much of the variability in the comparison can be accounted for by soluble solids alone. An $r^2$ value of 0.4667 in Figure 30.3 indicates that about 47 percent of the change in the percentage B and better curve can be attributed to

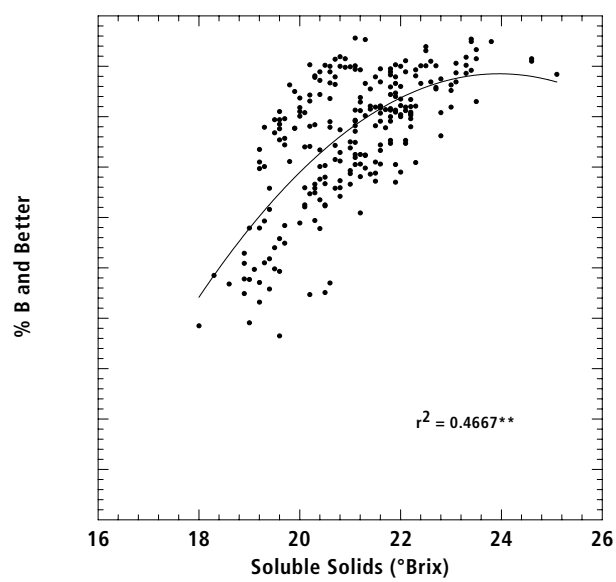


**Figure 30.3** The influence of berry soluble solids (°Brix) on percentage B and better raisin grades

soluble solids. The predictive value of $r^2 = 0.1978$ (Figure 30.4) for percentage substandard is much lower; it indicates that only about 20 percent of the change in percentage substandard can be attributed to soluble solids.

***Fresh berry weight.*** Berry weight in Figures 30.5 and 30.6 shows a curvilinear relationship to the percentage B and better grades, but with a lower predictive value or coefficient of determination ($r^2 = 0.4092$ for percentage B and better) than was shown for soluble solids. It is interesting to note that berry weight has its maximum influence on the percentage B and better as fresh berries approach 2.75 g. It is possible that the greater surface area of large berries may contribute to a higher air resistance, lifting the raisins in the airstream column. This would explain the industry experience that "jumbo" raisins made from 'Thompson Seedless' table grapes are not accurately measured for percentage B and better by the airstream sorter. Also, percentage substandard has a low predictive value of $r^2 = 0.0920$, indicating that berry weight has a minor role in the determination of percentage substandard grade.

***Total soluble solids per berry.*** To determine the total soluble solids per berry, you multiply the berry weight in grams by the percentage soluble solids (measured as °Brix). This is nearly equivalent to the grams of sugar per berry, since sugar makes up most of the soluble solids. Total soluble solids per berry is a better predictor of percentage B and better and percentage substandard grades than either soluble solids or berry weight alone (Figures 30.7 and 30.8). This is not surprising: both fresh berry weight and soluble solids concentration influence raisin weight. Additionally, higher soluble solids concentrations can contribute to a greater pro-

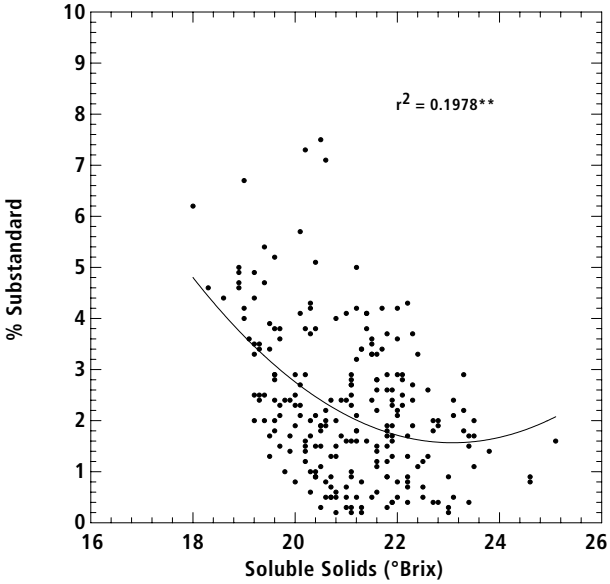


**Figure 30.4** The influence of berry soluble solids (°Brix) on percentage substandard raisin grades

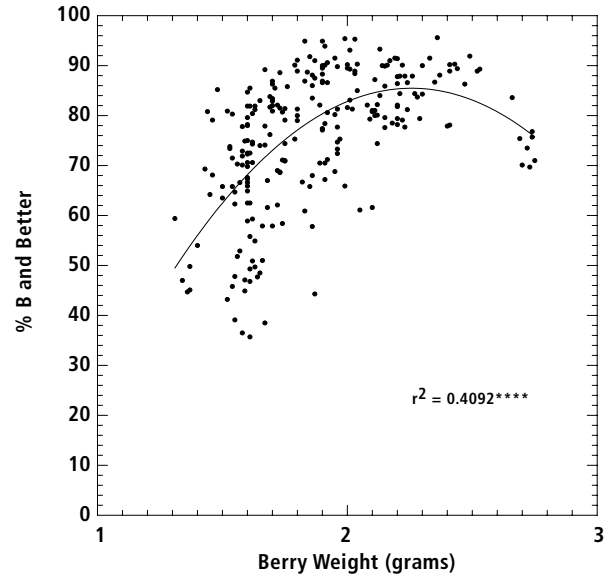


**Figure 30.5** The influence of berry weight on percentage B and better raisin grades

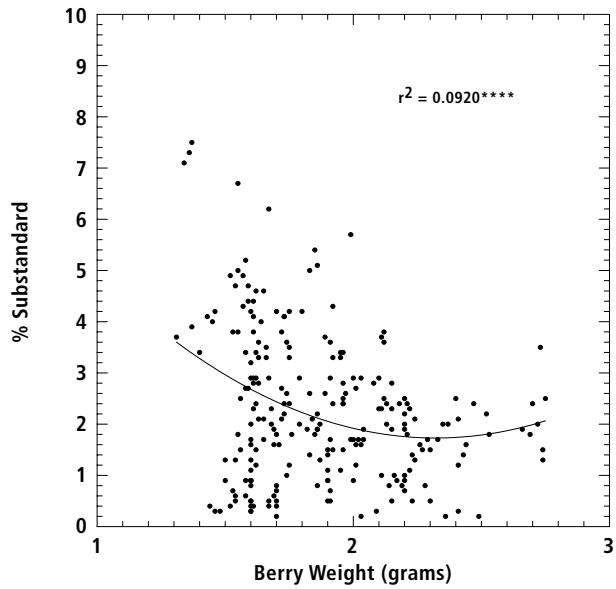


**Figure 30.6** The influence of berry weight on percentage substandard raisin grades

portion of meaty, fine-wrinkled raisins that have less air resistance in the airstream sorter.

***Grape acid.*** Acidity is sometimes promoted as a good predictor of raisin grades (Figure 30.9). Grape acid, which is mostly tartaric and to a lesser extent malic, is measured by titration of the extracted juice with a known concentration of base (0.133 normal sodium hydroxide). The result is expressed as *titratable acidity* in grams per 100 ml (sometimes expressed as grams tartaric acid per 100 ml) of juice. If you carry out the procedure as prescribed, you can divide the number of milliliters of sodium hydroxide solution used by 10 to get the value for titratable acidity. Grape acid gradually declines during ripening while sugars increase, ultimately reaching a value of less than 0.5 g per 100 ml when the grapes are fully ripe (above 22 °Brix). Thus, sugar and acid content are inversely related as time approaches harvest.

Comparisons of these two indices—soluble solids and titratable acidity—in predicting airstream sorter grades have always shown a more positive relationship with soluble solids. This is not surprising when one considers that, because of the sugar component, soluble solids content has a direct effect on raisin berry weight and plumpness while acid is not directly involved in these characteristics.

Samples with a narrower range of variability, such as those collected from individual vineyards or in individual years, may have a closer relationship than is shown here. When we look at grape acid across a variety of growing conditions, however, it has a low correlation with airstream sorter grades. There are also more potential problems in performing acid titration than in taking readings of soluble solids. Titratable acidity requires more equipment and reagents, an accurately standardized sodium hydroxide solution, and human skill in judging phenolphthalein pH endpoints. It is

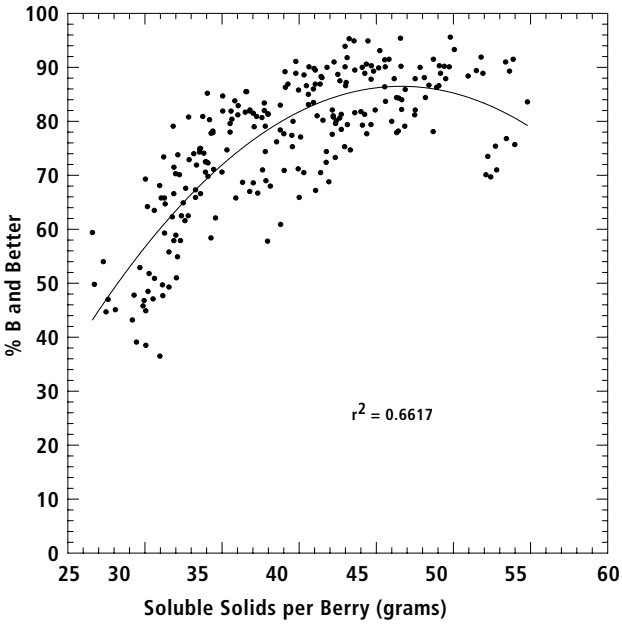


**Figure 30.7** The influence of grams soluble solids per berry on percentage B and better raisin grades

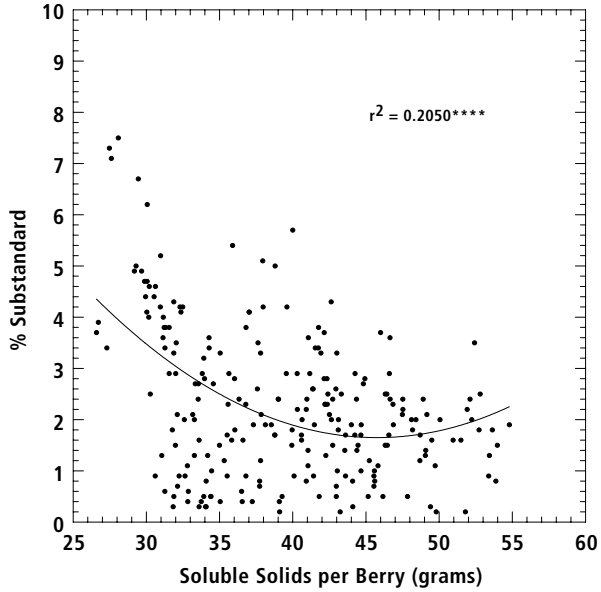


**Figure 30.8** The influence of grams soluble solids per berry on percentage substandard raisin grades

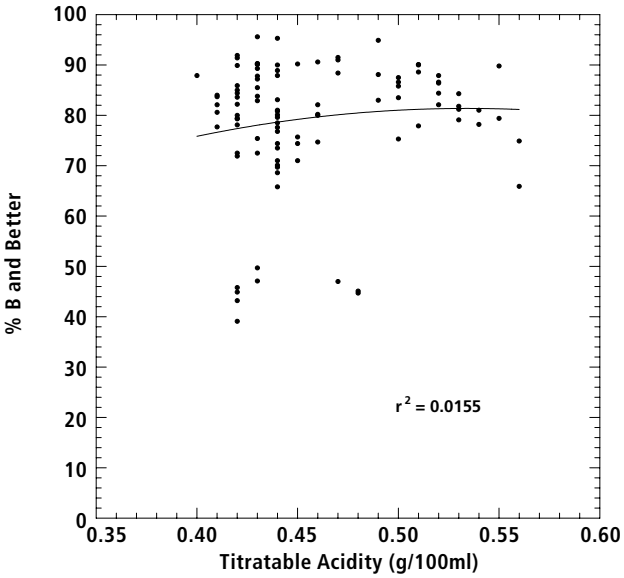


**Figure 30.9** The relationship between berry titratable acidity and percentage B and better raisin grades

far better to depend on soluble solids values: they are easier to measure and they have a higher correlation with airstream sorter grades.

## OTHER WAYS TO JUDGE MATURITY

There is always interest in the pursuit of alternatives to the airstream sorter after a year when raisin quality falls below expectations, and many studies have evaluated other methods for measuring raisin quality. While some of the methods show promise, none has proven superior to the airstream sorter in terms of practicability combined with accuracy. Some of these alternatives are described below.

***Can test.*** For many years, Sun Maid Raisin Growers used the can test to judge raisin maturity and quality. In the can test, the raisin sample is vibrated and settled in a 5 gallon (19 L) can and weighed. Greater raisin maturity is indicated by a higher sample density or weight per volume. Can test results correlate well with fresh fruit soluble solids and airstream sorter percentage B and better grades. Accuracy is influenced by temperature, raisin moisture content, presence of foreign material, and degree of cleaning or reconditioning. The can test is a poor predictor of percentage substandard grade.

***Specific gravity.*** The liquid specific gravity (LSG) method separates raisins based on their ability to float or sink in a solution of known specific gravity. The specific gravity of water, in which most raisins will sink, is expressed as 1.000. By adding salt or sugar, you can increase the specific gravity higher (e.g., to 1.270) so that higher-maturity B and better raisins will sink and less-mature raisins will float. In this way, you can separate raisins according to their density regardless of berry shape or other aerodynamic effects. There is a tendency, however, for the LSG method to overestimate the percentage of B and better raisins, especially in a sample with a low proportion of high-quality raisins. The procedure is also wet and messy and requires that large volumes of standardized liquid material be handled and that the sample be rinsed and drained before weighing.

***Raisin sugar concentration.*** Raisins typically contain 75 to 85 percent the reducing sugars fructose and glucose. The sugar concentration tends to increase with raisin maturity, but correlations with raisin grades have been too inconsistent to be of predictive value. This is because of the narrow possible range for sugar concentration relative to the spread of airstream sorter grades in raisins. Also, there are other factors beyond sugar concentration that affect raisin aerodynamics and physical characteristics.

***Raisin acid concentration.*** To measure the acid concentration of raisins, you must boil a ground raisin sample in water for 1 hour to dissolve the acid, including acid precipitated in the fruit. You then titrate the filtered extract using a standardized NaOH solution and calculate it in terms of grams tartaric or titratable acidity per 100 ml. Raisin acid concentration correlates much more closely to raisin grade than does the titratable acidity of fresh grapes. This is probably because the precipitated tartrates, which are dissolved during hot-water extraction, are included in the titration. These tartrates are not included in titrations of fresh grape samples. However, raisin acid content has been ruled out as a raisin grading index because of the more tedious analysis it requires.

***Near-infrared analysis.*** Near-Infrared Transmittance (NIT) spectroscopy is a technique for determining the chemical properties of a sample by measuring its transmission of energy at various wavelengths. NIT correlates well with raisin bulk density, visual grading, and moisture content. Considerably more work is needed to determine the correlation between variations in the chemical composition of raisins and variations in their visual grades. With that sort of information, near-infrared analysis could be used to quantify relevant chemical components, and in turn quality grades could be predicted. The resulting analysis should be more precise and complete than an NIT prediction based on subjective visual grades.

## REFERENCES

Andris, H., L. P. Christensen, W. M. Miller, and R. Smith. 1986. Influence of grape maturity and drying method on raisin quality and susceptibility to sugaring. Raisin research reports, 1986. Fresno: California Raisin Advisory Board.

Baranek, P., M. W. Miller, A. N Kasimatis, and C. D. Lynn. 1970. Influence of soluble solids in 'Thompson Seedless' grapes on airstream grading for raisin quality. Amer. J. Enol. Vitic. 21:19–25.

Christensen, L. P., M. L. Bianchi, M. W. Miller, A. N. Kasimatis, and C. D. Lynn. 1995. The effects of harvest date on 'Thompson Seedless' grapes and raisins. II. Relationships of fruit quality factors. Amer. J. Enol. Vitic. 46:493–98.

Clary, C. D., and G. A. Sawyer Ostrom. 1990–1991. Effect of fresh fruit maturity on raisin quality. Raisin research reports, 1990 and 1991. Fresno: California Raisin Advisory Board.

Fisher, C. D., A. P. Sidwell, and C. Columbie. 1961. Sorting raisins by the airstream method. Washington, D.C.: USDA Mktg. Res. Rept. 451. 1–16.

Gunnerson, R. E. 1989. Study of low maturity raisins "reconditioned" as related to the maturity grade before "reconditioning." Raisin research reports, 1989. Fresno: California Raisin Advisory Board.

Jensen, F. L., H. Andris, and L. Bettiga. 1982. The effects of drying method and fruit maturity in the range of 15 to 24 °Brix on airstream grades and raisin characteristics of 'Thompson Seedless.' Raisin research reports, 1982. Fresno: California Raisin Advisory Board.

Kasimatis, A. N., E. P. Vilas, F. H. Swanson, and P. P. Baranek. 1975. A study of the variability of 'Thompson Seedless' berries for soluble solids and weight. Amer. J. Enol. Vitic. 26:37–42.

Kasimatis, A. N., E. P. Vilas, F. H. Swanson, and P. P. Baranek. 1977. Relationship of soluble solids and berry weight to airstream grades of natural 'Thompson Seedless' raisins. Amer. J. Enol. Vitic. 28:8–15.

Kasimatis, A. N., E. P. Vilas, F. H. Swanson, and P. P. Baranek. 1980. Raisin Quality Studies. Raisin Research, Late 60s – 1980, Vol. III. Fresno: California Raisin Advisory Board. 1,004–1,040.