Proceedings Arkansas State Hort. Soc. 110th Ann. Mtg., 1989, pp. 67-81

# PRODUCING QUALITY GRAPE JUICE

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## INTRODUCTION

The first grape juice known to be processed in the United States was produced by Dr. Thomas B. Welch, a New Jersey dentist, in 1869 with the newly developed pasteurization process. Assisted by his wife and their 17-year-old son, Charles, he extracted juice from 18 kg (40 lb) of grapes (*Vitis labrusca* L.). They filtered and bottled the juice and pasteurized it in hot water to kill the yeasts.

Their product was used for the sacrament on the Communion table of the Vineland New Jersey Methodist Church. Orders for the juice, mainly for Communions, increased after this initial effort until most of the family's time during harvest season was devoted to preparing grape juice (1).

From this relatively small but ambitious beginning, Dr. Welch had established a new industry. The elder Welch turned the endeavor over to Charles in 1872, and before long the young man had a full-time business. In 1896 he moved his operation to Watkins, New York, closer to a large grape-growing area. The following year he built a plant in Westfield, New York, which processed 300 tons of grapes during the first year of operation. Between 1912 and 1926, Welch introduced a number of new supplementary products. Jams and jellies were two of these products; although successful, they were a small part of the early operation (1). However, grape jams and jellies are currently the leading fruit spreads in the United States.

In recent years, consumption of grape juice and grape products has continued to increase. In 1987, each person in the U.S. consumed an average of 887 ml (30 oz) of unfermented grape juice. In 1987, the per capital consumption of grape jams and jellies purchased in U.S. food stores was estimated at 380 g (13.4 oz). This estimate does not take into consideration hone-made spreads or institutional sales. Most of the juice for the grape drink and grape products is made from Concord grapes grown chiefly in Washington, New York, Michigan, Ohio, Pennsylvania, and Arkansas (6).

## COMPOSITION OF GRAPE JUICE

The specific composition of juice from any grape species can never be accurately predicted, since composition varies from year to year and changes continually during the maturation and ripening processes in the field. The composition of a given variety such as Concord will vary from place to place depending upon the soil, and the climatic conditions.

The flavor of grape juice is the result of a combination of sugars, acids, anthranilate, volatile esters, alcohols, and aldehydes. In addition to the mineral elements of sodium, potassium, calcium, phosphorus, iron, copper, and manganese, grapes also contain biotin, niacin, inositol, pantothenic acid, pyridoxine hydrochloride, thiamine, folic acid, ascorbic acid, choline, and trace amounts of riboflavin and vitamin $B_{12.}$

Fruit quality largely depends upon the sugar level, acid content, and flavor constituents including methyl anthranilate and other volatile esters as well as tannins and color substances (17). The major sugar present is glucose, but some of the total sugar may be sucrose. Principal acids in grapes are tartaric, malic, and citric with smaller amounts of other acids present. The tartaric acid can be in the form of free acid or contained in salts. Titratable acidity above 0.85%, expressed as percentage tartaric, produces juice that is too tart. Sugar may be added, but if so, the words sugar added must be placed on the marketing label.

The flavor and aroma of the grapes develop during the ripening process. Aroma is created by the various volatile compounds in the fruit. Methyl anthranilate, which by itself produces an odor similar to that of Concord grapes, was one of the first compounds to be associated with the aroma of that particular grape species. Other varieties of American grapes also contain anthranilic esters but at lower levels than are found in the Concord.

Differences in the anthocyanins present explain why some varieties have greater color stability and are more suitable for juice than others. Muscadine grapes (*Vitis rotundifolia* Michx.) are more susceptible to browning than many other Vitis species because they contain only nonacylated 3,5-diglucosides. Diglucoside anthocyanins are more susceptible to browning than the monoglucosides which are present in varieties that maintain more stable color. Morris (7) has observed that one of the major problems with muscadine products is the instability of the diglucoside anthocyanins. Juice from white grapes also contains minor pigments such as chlorophyll and carotenes that can be very important to stability and quality.

Ideal flavor, acid, and color usually occur in Concord grapes with soluble solids values of about 16 to 17%. The grape juice industry considers that as the percentage soluble solids of Concord grapes increases above 18%, the flavor and acid decrease thereby reducing the quality of the juice. Concord grapes harvested at 14 to 15% soluble solids have excessive acid, inadequate levels of flavor-aroma components, and, perhaps, insufficient color. The Concord juice industry generally uses 15% soluble solids as the lower level of acceptability for grapes and will pay a premium for grapes with increased levels up to 18% (3). The final and complete criteria for determining fruit quality is established by the Federal State Inspection Service. Based upon grades and standards of this agency, each load of grapes is inspected and judged as it is received at the processing plant.

## GRAPE QUALITY STANDARDS

The latest U.S.D.A. grades and grading procedures for grapes became effective on September 1, 1977. These standards apply to all types of grapes to be processed, whether the fruit is hand or machine harvested. As with standards for all other fruits and vegetables, these standards are enforced on a voluntary basis.

The grade U.S. No. 1 consists of grapes and juice that are (1) mature (not less than 15.5% soluble solids as determined by an approved refractometer); (2) of similar varietal characteristics (having the same skin and pulp characteristics); and (3) free from damage by visible mold, immature berries, foreign materials, sunburn, freeze injury, attached insects or insect injury, or any other cause. The word damage means any defect or combination of defects that materially detract from the processing quality of the grapes.

The grade U.S. No. 2 consists of grapes and juice that meet all the requirements of grade U.S. No. 1 except that berries (1) shall be at least fairly well matured (not less than 14.5% soluble solids) and (2) are allowed a higher tolerance for certain defects and foreign materials (6).

To ensure that an accurate grade can be given to a lot of grapes, proper sampling procedures must be followed. Each bin on a load of grapes is probe sampled by or under the direct supervision of the U.S. Department of Agriculture (USDA) inspection service. The sample must be collected as follows: the closed probe is inserted in a vertical position to the full depth of the contents in the bin. The handler opens the probe and assures himself that it is filled to the height of grapes and juice within the bin. The probe is properly closed and removed, and the sample emptied into a clean bucket.

When all of the bins have been sampled, the composite is emptied into a sample splitter. The sample splitter is a device that divides from the composite sample a subsample small enough to analyze. The workable subsample (no more than 550 g or less than 300 g) is blended for a period of 1 to 2 min. A tablespoon of the macerated material is filtered through filter paper. After the first four or five drops of filtrate are discarded, two drops of filtrate are placed on the rear edge of the measuring prism of a refractometer, and the soluble solids reading is taken immediately on a scale to the nearest 0.1%. A second reading is taken in the same manner after the sample is blended for an additional 15 sec. If a third reading is to be taken, it is taken following the same procedure as the second reading.

Percentage by weight of foreign material and other discernible or measurable defects of the grapes are determined using the material collected in the sample tray section of the sample splitter. Once grading is completed, the official certification is issued. Appeals may be made by either the processor or the grower (6).

## INFLUENCES ON GRAPE JUICE QUALITY

Grape cultivar and fruit maturity are important to the quality of juice produced, but environmental conditions such as climate and soil as well as vineyard management and harvesting methods are equally important. The influence of each of these factors and complex interactions among them result in the final composition and quality of the grapes to be processed.

### Cultivar

Concord is the cultivar most widely used for juice as well as jam and jelly processing. The balance of sugars, acids, flavoring substances, astringent characteristics, and aroma make the palatability of Concord grape juice superior to almost all other varieties. Even with dilution and sweetening, the Concord grape juice will still impart a rich aroma and flavor. Concord grapes are deep red by transmitted light and reddish purple by reflected light when hotpressed. The juice flavor and aroma are distinctive, mainly due to relatively high levels of methyl anthranilate. Concord grapes are easily grown and generally produce adequate yields in the cooler sections of the United States. Concord juice, used alone or in blends, is the standard for unfermented grape products across the United States. However, the use of cultivars which mature earlier, or even later, could extend the processing season and allow harvest of more grapes at optimum maturity.

Other cultivars of the *V. labrusca* L. species, such as Fredonia and Van Buren yield as well as Concord and ripen as much as 2 to 3 weeks earlier. Sheridan, which ripens later than Concord, could also extend the processing season. These cultivars are similar to Concord in many ways, but their lack of typical flavor and methyl anthranilate can decrease their acceptance for juice (17). Juices from Ives and Clinton, also *V. labrusca* cultivars, have unusual flavor and excellent color. fee -Catawba and Isabella juices have distinctive fragrances also. Hot-pressed juices of Catawba and Delaware are light red; whereas, the cold-pressed varieties are almost colorless. During the time of federal prohibition of alcohol in the United States, Catawba and other cultivars were prepared as unfermented juices in the eastern part of the country. Most Catawba grapes are now processed into wine (15). A few wineries still successfully market sane unfermented Catawba juice in wine bottles.

An opalescent juice with excellent flavor can be acquired by cold-pressing white and green cultivars such as Niagara, Ontario, or Seneca. Niagara has become the standard for juice from white grapes because of its unique aroma and flavor. Although use of 100% Niagara is not essential, this cultivar is still considered a necessary ingredient for a successful white juice blend.

California produces more grapes than all other states combined, but relatively few of those grapes are used for unfermented juice. The *Vitis vinifera* cultivars produced in California are generally higher in sugar and lower in acidity (in warm production areas) than cultivars grown in other areas of the United States. Except for Muscat, the *V. vinifera* cultivars do not produce the flavor expected for juice. This lack of characteristic flavor and tartness is probably one reason for the failure of most California grape juices to compete favorably with Concord juices. Juices of Concord blended with *V. vinifera* juices have proven successful. Excellent white grape juice can be made from a blend of Thompson Seedless and Niagara. A few wineries are producing unfermented juices prepared from *V. vinifera* grapes.

Wine cultivars in other areas of the United States may also be suited for production of unfermented juices. Currently, the University of Arkansas has a program underway to determine which of the wine grapes produced in that state are suitable for unfermented juices. Huckleberry (4) conducted an extensive survey of processing methods and varieties. She found that typically less heat or no heat in processing produced more acceptable flavor, but the color of the heat-processed juice was preferred especially in the red cultivars. Sims and Morris (19) reported on the effects that maturity level at harvest and processing methods have on the acceptability of juice from French-American hybrids. They showed that more mature grapes produce more acceptable juice. Both studies emphasized the importance of a sugar/ acid balance between 20 and 30. Recent unpublished work by Rathburn and Morris (16) has shown that adjusting sugar and acid levels of juice can improve the acceptability of juice from cultivars typically used for wines. The addition of carbonation has also shown improvement of the sensory quality of these juices. The addition of carbonation to juices offers potential for product differentiation and could prove to increase marketability of unfermented varietal juices. More work needs to be done to investigate the effects of sugar/acid adjustments and carbonation on the storage stability of juices.

In the south and southeastern United States, muscadine grapes (*V. rotundifolia* Michx.) are grown commercially. Muscadine juice a has a unique bouquet. Cultivars vary from almost white to nearly black with pink, red, blue, and purple varieties common. Scuppernong, a white muscadine grape, and Hunt, a red cultivar, are two of the original varieties that have been used for processing juice for local consumption. High quality juices have also been produced from Creek, Dulcet, Yuga (14), Noble, and Carlos (22) cultivars. Blends from these cultivars can have beautiful color and a refreshing taste. Blending of juices from different varieties can increase market potential for some grape varieties.

Work has been done by Sistrunk and Morris (21) in Arkansas to determine acceptable muscadine juice blends with traditional Concord and Niagara juices as well as other fruit juices. Two varieties of muscadine grapes, Noble (black-skinned) and Carlos (bronze-skinned) were each blended at three levels with apple juice, cranberry juice, Concord and Niagara grape juice, and with each other. The Noble-Concord blends were found to be the most acceptable while the Noble with Carlos were the poorest in sensory quality. In general, the Noble-Concord blends were also the most stable over the 12 month storage period. The apple and Niagara were the most acceptable of the Carlos blends.

An increasing popularity of muscadine wines and limited commercial acreage restricts the availability of muscadine grapes for juice production. Consequently, muscadine juice has not been tested extensively for quality and marketability. Instability of the pigments in commercially produced muscadine juice during storage is another problem not yet solved (7).

Climate and Soil

For palatable juice from any cultivar, environmental conditions, especially climate and soil, play an important role. The interactions of all characteristics of the environment can alter the composition and quality of the grapes and, consequently, the aroma and taste of the juice.

In the overall climatic effects, not only the maximum, minimum, and average temperatures, but also the daily pattern of heat accumulation and solar energy levels have to be considered. Rainfall, clouds, and fog along with their distribution throughout the season are important. All of these features contribute to the amount of solar energy available for crop production and maturity. Even when the grape vines are not in the process of actively growing and producing grapes, weather conditions can affect their readiness for the next season's growth. Also, differences in latitudes of the grape-producing regions alter the solar energy available and dictate pruning and training methods required. In areas of low solar energy, shoot positioning is important in order to use the sun's energy most effectively.

Soil characteristics are also very important to viticulture. Loose soils having moderate fertility are best for grapes. Good drainage conditions are essential to prevent the vine's roots from staying wet too long. If soil fertility is low, the grape vines will produce less foliage thereby totally exposing the fruit to sunlight. This situation will cause early development of high levels of percentage soluble solids. Grapes produced from deep fertile soils grow vigorously and can produce high yields, but the fruit may be lower in percentage soluble solids, color, and tannins (15). Each fertility situation can require a different vineyard management system for grapes that will produce maximum juice quality.

The depth of the soil can determine the number of vines that a given area can support. Morris and Cawthon (g) investigated the effect of soil depth and in-row vine spacing on yield and juice quality in a mature Concord vineyard in Arkansas. To simulate the extremes in soil depths found in commercial vineyards, they used two different soil depths at the same vineyard site. They tested five row spacings of 1.52, 1.83, 2.13, 2.44, and 3.05 meters between plants. Although yield per hectare was decreased at the widest spacing on the shallow soil, neither soil depth nor vine spacing had any effect on the percentage soluble solids of the grapes, and these treatments had only a slight effect on the titratable acidity, juice color, and percentage green fruit. Widely spaced vines in deep soil tended to produce grapes with slightly lower titratable acidity and a lower percentage of green fruit.

## VINEYARD MANAGEMENT

The grape cultivar is the primary determinant of the taste, color, aroma, and specific composition of processed unfermented juice. Conditions at the location where the grapes are grown, especially the climate and soil, can alter the quality characteristics of any cultivar. Additional influences can be imposed by the viticulturist himself with his vineyard management.

Pruning and Training Systems

There has probably been more work done on the effect of pruning on yield and quality of Concord grapes than any other aspect of their production. The different climates and microclimates of major grape-producing regions can affect the results obtained and the recommendations given for pruning.

The criterion for success of a pruning treatment is the maintenance of vine size and wood quality for subsequent crops and continued high yields with a desirable level of fruit quality. The Geneva Double-Curtain training system is used in vigorous New York vineyards to increase the number of grape leaves that can be exposed effectively to sunlight (18). Also, this system has proven to be the best method of training vigorous vineyards in Arkansas and other grape regions in the eastern United States.

Recently, there has been considerable interest and research in the area of mechanical pruning as a means of reducing the cost of pruning. The influence of mechanical pruning on juice quality is a major concern of the juice industry.

Fertilization

The grape has the ability to obtain all necessary nutrients from poor, gravelly soils unfit for other crops. The grape's roots can extend 1.5 to 3 m in some soils.

Of the major nutrients necessary for growth and maturation of grapes, nitrogen (N) is the most beneficial followed in order by, potassium (K) and phosphorus (P). Vineyards differ in their response to fertilization depending especially on location and soils. A balanced, moderate fertilization program, based upon the soil's fertility, is adequate for grape production. Fertilizer recommendations can be based upon petiole analysis and visual observations of vine vigor as well as annual yields. Excessive amounts of fertilizer, especially N and K, can have adverse effects on quality, and a balance of all nutrients is critical to obtain optimum response. Recommendations must be made for each soil type and location used (11).

Irrigation

Major Concord-producing regions in the northeastern United States produce acceptable grape yields without irrigation; few studies on the effects of supplemental irrigation on juice quality have been conducted. However, supplemental irrigation can increase yield and should be recommended for regions with dry climate and shallow soils. Irrigation delays fruit maturity as indicated by lower percentage soluble solids, higher acidity, and poorer color of the juice at the time of traditional commercial harvest. Delaying harvest will help to overcome this problem (8,18, 23) and may be justified by the additional yields.

Predicting Harvest Date

The quality of the grapes will not be at their best unless the proper harvest time is determined by fruit maturity.

Degree day accumulations have been an effective method of predicting harvest date in California vineyards. However, methods for using degree-day accumulations and effective heat-unit summations in Arkansas have not proven superior to the use of calendar days for predicting grape maturation (12). Predictions of days from 8 to 16% soluble solids in Concord grapes were more accurate than predicting from peak bloom. Between years and between vineyard locations, within a given year, maturity may vary enough to prevent accurate predictions from any of the methods. Predictions based upon development of soluble solids can be influenced by fruit load and soil moisture. Initial fruit sampling may be determined from prediction models based upon long-range estimates, but continuous monitoring of maturation from that time is necessary to determine actual harvest dates and to schedule processing operations.

Mechanical Harvesting

Like mechanical pruning, mechanical harvest could prove economically important in large-scale commercial grape production. Due to the potential ability to control variables such as time, temperature, and chemical stability, the machine-harvested grapes can be of higher quality than hand-harvested fruit for processed products. The quality of machine-harvested grapes is influenced by five major causes: (1) the machine, (2) the cultivar, (3) the production system, (4) the temperature and time between harvesting and processing, and (5) postharvest handling.

Although mechanically harvested grapes can have better quality than hand-harvested fruit, quality loss is still associated with several problems in the machine harvest. As in hand-harvest time delay between harvest and delivery to the processing plant can promote the development of off-flavors, wild yeast fermentations, oxidation, and other signs of quality loss (10,13). Harvesting, handling, and field crushing by the machine can rupture fruit cells that release and combine enzymes with various cellular components. As a result, an increase occurs in enzymatic activity. Subsequent browning, oxidation, and development of off-flavors and microbial growth can result.

Several guidelines have been developed from research in Arkansas in cooperation with the grape industry to maintain or improve the quality of machine-harvested grapes (6):

1. Select the proper rpm of the shaking mechanism or strikers and the proper ground speed for the harvester for each cultivar and crop load situation. The importance of proper machine adjustments and operation cannot be overemphasized.

2. Establish a time limit from harvesting to delivery at the processing plant. The time can vary with cultivar (2 to 4 hr for grapes used for premium white wines and 8 to 14 hr for red wine and juice grapes). In establishing time limitations, fruit temperature, use of $SO_2$, and quality standards required for the final product must also be considered.

3. Apply $SO_2$ at the rate of 100 ppm as the grapes pass over the final delivery conveyer if they are harvested under high-temperature conditions.

4. Prepare vineyard to eliminate extraneous materials. Preparation will involve mechanical trimming of low-hanging canes that interfere with harvest, removal of bird nests and tall weeds with seed heads or pods, providing a smooth surface to the vineyard floor, and stopping all cultivation early enough before harvest to minimize dusty conditions.

5. Inspect the vineyard for insects and, if necessary, apply the required sprays well in advance of harvest.

6. Provide an inspector as part of the harvest crew. This individual would remove extraneous materials; watch for plugging of cleaning fans, hydraulic leaks, and mechanical failures; monitor the application of SO,; and watch for any other problems that may ari~e.

7. Keep harvested grapes covered at all times and require complete washing of delivery bins or containers after they have been emptied at the processing plant.

8. Wash and clean the mechanical harvester thoroughly with an approved detergent sanitizes at the end of each 8- to 10-hr operating shift. Under some conditions a complete high-pressure water rinse may be required during the operating shift.

**JUICE PRODUCTION**

<u>Juice</u>

Methods for commercial preparation of juice from Concord grapes have undergone considerable change in the past two decades. The hydraulic press has been replaced by a continuous pressing method which is not only more efficient but also more sanitary and leaves less chance for fermentation before pasteurization. The continuous pressing involves destruction of naturally occurring pectins with an enzyme preparation and the addition of wood fiber to facilitate extraction of juice. A hot-pressing method which yields juice with higher total solids, nonsugar solids, tannins, pigments, and other substances is considered necessary in Concord juice production (15). Temperature and time in processing can vary within a range to produce juice with uniform color from grapes throughout the harvest season. Excessive extraction temperatures must be avoided to preserve the juice quality (20,22). Commercially, temperatures exceeding 65 C (150°F) are to be avoided (15).

The grapes are dumped into a hopper then transported by augers or pumps to a rotary stemmer-crusher which separates the fruit from the stem. The stems are discharged, and the crushed berries are pumped through a steam-jacketed, vacuum preheater where the pulp is heated to 60-63 C (140 to 145 F) and then passed into holding tanks. At this point slow-moving agitators in the tank mix approximately 91 g (0.2 lb) of pectic enzyme and 6.8 Kg (15 lb) of purified paper pulp into each ton of grapes. Within 30 min to 1 hr the enzyme will break down the pectin to make the grape pulp ready for pressing.

In the next step, a dejuicer removes approximately 30 to 35% of the free-run juice through a 40-mesh screen. The remaining pulp is poured into a continuous screw press. The free-run juice may have as much as 20 to 40% suspended solids while the pressed juice may only have 5 to 6% suspended solids. The two juices are combined and a majority of the insoluble solids are removed by either rotary vacuum filtration, pressure leaf filtration, or centrifugation. This hot pressing process yields approximately 738 L (195 gal) of juice per U.S. ton of grapes. An additional 37.8 L (10 gal) of juice (after concentration) may be obtained by breaking up the press cake from the continuous screw press and spraying it with hot water.

After juice extraction the crude argols must be precipitated. Until recently, this precipitation required several months of settling time for the juice. Anew rapid method has been developed in which the filtered juice is flash-heated at (80-85 C) (175 to 185 F) in a tubular or plate-type heat exchanger and then cooled in the heat exchanger to -2.2 C (28 F). The cooled juice is then pumped to storage tanks and held at -2.2 C (28 F) for rapid settling of argols. The final processing of the grape juice into single-strength juice or concentrate can occur anytime the argols have settled and the juice can be racked off. The tank bottoms (settlement) can be filtered, resterilized and stored to allow argols to again settle for optimal recovery of juice (15).

The juice is passed through a heat exchanger to bring the temperature to 77 C (170 F), into an automatic filler, and then into preheated bottles. The full bottles are capped and pasteurized at 85 C (185 F) for 3 min. The bottles are then cooled and labeled.

Grape juice concentrate is made in much the same manner as any juice concentrate. Concentration of Depectinized juice can be made to 72° Brix, but most grape juice is concentrated to 65 or 68 Brix. The principles of distillation are applied to the design of the essence rectification column for Concord grape juice. However, there has been a renewed interest in concentration by freezing.

**CONCLUSION**

The popularity of unfermented grape juice and other processed products has motivated a great deal of research into the influences on these consumer goods. The final product is the result not only of the process itself, but also of vineyard management, cultivar selection, climate and soil on which the grapes are grown, and the understanding of the combined effects of all influences. As research continues, we will be able to incorporate more efficiency and quality into growing, harvesting, and processing these grape products. Currently, important areas for pre and postharvest research include better use of present cultivars, mechanizing pruning and harvesting operations, and postharvest handling. Also, additional research is needed in developing juice blends and improving styles of jams, jellies and preserves, especially the all grape products (no sugar added) and "lite" spreads.

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