

Composition of Grapes

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Grapes are the most important raw material for making wine. A good understanding of grape composition is essential to understanding the process of winemaking and making better quality wine.

Physical Composition

The fruit of the grape is a berry. Berries are attached to the stem. Many berries make up the cluster or bunch of grapes. The essential parts of the berry include the skin, pulp, and seeds.

The skin consists of an outer layer covering the berry. It is made up of six to ten layers of thick walled cells. The outer surface of the skin is covered with a wax-like coating called the cuticle, which renders the berry waterproof. The main components in the skin are: coloring matter (red and yellow pigments), tannins, aromatic substances, and potassium and other minerals.

Below the skin layer lies flesh or pulp which makes up most of the berry volume. Cells in the pulp have large vacuoles containing the cell sap or juice. When the berry is gently crushed, the fragile cells in the pulp are broken and the juice is released. This juice is commonly referred to as the free run.

The seeds are localized in the center of the flesh. The berry contains two to four seeds. They are rich in tannin which is extracted during fermentation (in red wines).

Chemical Composition

Freshly expressed grape juice consists of 70 to 80% water and many dissolved solids. These soluble solids include numerous organic and inorganic compounds. The important group of compounds, from the winemaking point of view, include the following:

1. sugars
2. organic acids
3. phenolic compounds
4. nitrogenous compounds
5. aroma compounds
6. minerals
7. pectic substances

Sugars

In grapes, a large portion of the soluble solid is sugars. Glucose and fructose are the main sugars in the juice. The sugar content of the juice of ripe grapes varies between 150 to 250 g/L. In unripe berries, glucose is the predominant sugar. At the ripening stage, glucose and fructose are usually present in equal amounts (1:1 ratio). In overripe grapes, the concentration of fructose exceeds that of glucose. In ripe grapes, there is some variation in the glucose to fructose ratio among the grape varieties. For example, Chardonnay and Pinot blanc are classified as high fructose varieties, while Chenin blanc

and Zinfandel are regarded as high glucose varieties.

Fructose, glucose, and sucrose differ significantly in sweetness. The order of sweetness is: fructose is sweeter than sucrose, which is sweeter than glucose. In other words, on a sweetness scale, if fructose is considered to be 100, then sucrose is 84 and glucose is 66. That is quite a difference. This information is important to a winemaker. For example, if a winemaker wishes to sweeten a wine, he will need less fructose than sucrose to reach the same degree of sweetness.

Glucose and fructose are fermentable sugars. During the course of fermentation, the yeast converts these sugars to alcohol and carbon dioxide. The amount of alcohol produced is related to the amount of sugar initially present in the juice; thus, by controlling the amount of sugar in the juice, one can control the amount of alcohol in the resulting wine. It should be noted that the relationship between sugar content and alcohol formed is not precise. Roughly speaking, the conversion of sugar to alcohol is $^{\circ}\text{Brix} \times .55 = \% \text{ of alcohol in wine}$.

The sugar content of the juice is often expressed in terms of $^{\circ}\text{Brix}$. The unit $^{\circ}\text{Brix}$ represents grams of sugar per 100 grams of juice. Commonly, it is interpreted as grams of sugar per 100 ml of juice. The sugar content of the juice in terms of $^{\circ}\text{Brix}$ can be measured by a refractometer or a $^{\circ}\text{Brix}$ hydrometer. Sugar in the juice can also be measured by determining specific gravity. Hydrometers calibrated to specific gravity scale are often used. The relationship between $^{\circ}\text{Brix}$ and the specific gravity value is in the range of 15 to 25 $^{\circ}\text{Brix}$ and is given in Table 1.

| Table 1. The relationship between $^{\circ}\text{Brix}$ and specific gravity value in grape juice. | |
|---|------------------|
| Degrees Brix | Specific Gravity |
| 15.0 | 1.06103 |
| 15.5 | 1.06318 |
| 16.0 | 1.06534 |
| 16.5 | 1.06750 |
| 17.0 | 1.06967 |
| 17.5 | 1.07185 |
| 18.0 | 1.07404 |
| 18.5 | 1.07624 |
| 19.0 | 1.07844 |
| 19.5 | 1.08066 |
| 20.0 | 1.08288 |
| 20.5 | 1.08510 |
| 21.0 | 1.08733 |
| 21.5 | 1.08957 |
| 22.0 | 1.09182 |
| 22.5 | 1.09408 |

| | |
|------|---------|
| 23.0 | 1.09634 |
| 23.5 | 1.09862 |
| 24.0 | 1.10090 |
| 24.5 | 1.10320 |
| 25.0 | 1.10550 |

Organic Acids

Next to sugars, organic acids are the most abundant solids present in grape juice. They are a very important component of juice and wine. They are responsible for the tart taste and have a marked influence on wine stability, color, and pH. The principal organic acids found in grapes are tartaric, malic, and to a small extent, citric. Many other organic acids, including amino acids, are also found in juice and wines, but tartaric and malic acid account for over 90% of the total acids present. During the early period of berry growth, concentration of both acids increases in the fruit. With the onset of ripening, as the sugar accumulates in the fruit, the acid concentration decreases. Generally the reduction in malic acid is greater, and consequently, at maturity, the fruit contains more tartaric acid than malic.

Grapes are one of the rare fruits that contain tartaric acid. It is present as free acid and a salt, such as potassium bitartrate. Bitartrate is an important constituent since it affects pH and the cold stability of the wine.

The acid composition of grapes is influenced by many factors such as variety, climatic region, and cultural practices. Generally in ripe grapes, the acid levels are lower in a warmer climatic region than in a cooler region. The acidity is expressed as titratable acidity (TA). It is an important parameter used in quality evaluation of juice and wine.

Acid content of the juice has an important bearing on juice and wine pH. Acids upon dissociation liberate H⁺ ions, which are measured and expressed in terms of pH. Thus acidity and pH are related. However, the relationship is neither direct nor predictable. Due to the presence of various kinds of acids and their salts, the relationship between acidity and pH is a complex one. Understanding the role of pH in winemaking is crucial to making good wines.

Phenolic Compounds

Phenolic compounds are important constituents of grapes and wine. Following sugars and acids, they are the most abundant constituents present in grapes. Phenolic compounds are a group of substances that are structurally diverse and are present in various amounts. They play a vital role in determining the wine's color and flavor. They are involved in browning reactions in grapes and wines and also play a key role in the aging and maturation of wines.

The phenolic substances are primarily located in the seeds and skins of the berry. The juice contains a very small amount (3 to 5% of total phenols). White wines are usually produced from juice with little skin and seed contact. Their phenolic content is low, in the range of 100 to 250 mg/L gallic acid equivalent (GAE). Red wines, on the other hand, are customarily produced with skin and seed contact. Depending on the length of contact time, the phenolic content of a red wine generally varies between 1000 to 3500 mg/L GAE.

The two main substances included in this group of compounds are anthocyanins and tannins. Anthocyanins are pigments and they are responsible for the red and purple color of the grapes and wines. They exist in both colored and colorless forms. In young red wines, most of the colored anthocyanins are present in free (uncombined) forms. As the red wine ages, the anthocyanins combine with other phenolic compounds. In a combined state, the pigment contributes to color stability in red wines.

Tannins are very complex compounds. They are large molecules with a molecular weight over 500. They are yellow, brown, and red colored. They are astringent and bitter. During processing and aging, the tannins polymerize. Polymerization leads to increased molecular size.

Generally smaller molecules are more bitter than astringent. As the molecular size increases (due to polymerization), the astringency is perceived more than the bitterness. Increase in molecular size makes these compounds insoluble and, consequently, they precipitate, and the wine's astringency decreases.

Nitrogenous Compounds

Grapes contain various nitrogenous compounds. These include ammonium cations and organic nitrogenous compounds: such as amino acids, peptides, and proteins. The nitrogen content of the grape varies with variety, climate, soil, fertilization, and other cultural practices. The total nitrogen concentration of the fruit increases during the maturation period.

Nitrogen containing compounds are important because they serve as the nutrient for yeast and lactic acid bacteria. Nitrogen influences biomass formation (cell population or cell yield), rate of fermentation, and production of various byproducts, which in turn affects the sensory attributes of wine. Proteins (nitrogenous compounds) are involved in wine stability. Insufficient nitrogen in must can cause a sluggish or stuck fermentation and the formation of a "rotten egg" (H₂S) odor. To avoid such a problem, the must is often supplemented with Diammonium phosphate (DAP). The maximum amount of DAP addition legally allowed is 8 lbs/1000 gal or 958.7 mg/L.

Aroma Compounds

Many volatile odorous compounds are found in wine. These aromatic substances are derived from three major sources:

1. Grapes (fruits)
2. Fermentation
3. Aging and maturation

Grapes contain numerous flavor compounds. Some of these compounds have been reported to give a variety their distinct varietal character. Examples of these include:

- a. 2-methoxy-3-isobutyl pyrazine - Predominant compound giving bell pepper-like odors to varieties like Cabernet Sauvignon and Sauvignon blanc.
- b. 4-vinylguaiacol and 4-vinylphenol - giving spicy, clove-like and medicinal odors

to some Gewürtztraminer wines.

c. Terpenes - in muscats and Riesling grapes.

Many varieties such as Chardonnay or Seyval blanc do not appear to have distinct varietal odors that can be attributed to one or two compounds. It is possible that in such varieties, many compounds contribute to the flavor.

The odorous compounds in grapes are largely present in the skin and the layers of cells immediately beneath it. Their concentration (flavor compounds) tends to increase during ripening. It is important that the grapes be harvested when the flavor is at its peak. Many factors affect the concentration of aroma compounds in grapes. Manipulation and control of these factors is necessary for attaining the desired flavor level at harvest.

Minerals

Minerals are taken up by the vine from the soil. They usually make up approximately 0.2 to 0.6% of the fresh weight of the fruit. The important mineral compounds include: potassium, sodium, iron, phosphates, sulfate, and chloride. Of the mineral compounds mentioned above, potassium is the most important mineral. It accounts for 50 to 70% of the cations in the juice. During ripening, the potassium content of the grape increases. Its movement into fruit leads to the formation of potassium bitartrate, which reduces the acidity and increases the juice pH. It should be noted that the tartaric acid salt of potassium is involved in wine instability problems.

Pectic Substances

Pectin substances are cementing agents present in the cell wall. Chemically, they are complex polysaccharides made of galacturonic acid molecules linked together. During ripening, pectin is hydrolyzed by naturally occurring pectolytic enzymes, which renders the berry softer as it ripens. In juice, the pectin causes cloudiness by holding the particles of fruit pulp in suspension. To allow the suspended solids to settle and clarify the juice, commercial preparations of pectolytic enzymes are often used.