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Review Article

# Fermentation of fruit wine and its quality analysis: A review

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**ABSTRACT**

Fruit is an essential part of your diet using essential part of vitamin and minerals that contribute to overall strength for your health. Fruit wines are undistilled alcoholic beverages usually made from grapes or other fruits such as peaches, plums or apricots, banana, elderberry, or black current which are nutritive, more tasty, and mild stimulants. These fruits undergo a period of fermentation and aging. They usually have an alcohol content ranging between 5 and 13%. Wines made from fruits are often named after the fruits. No other drinks, except water and milk, have earned such universal acceptance and esteem throughout the ages as has wine. Wine is a food with a flavor like fresh fruit which could be stored and transported under the existing conditions. Being fruit-based fermented and undistilled product, wine contains most of the nutrients present in the original fruit juice. The nutritive value of wine is increased due to the release of amino acids and other nutrients from yeast during fermentation. Fruit wines contain 8–11% alcohol and 2–3% sugar with energy value ranging between 70 and 90 kcal per 100 ml. The present explained about the fermentation of wine and its quality analysis. In this present review, we discussed about fermentation, history of fermentation, *Saccharomyces cerevisiae* and alcoholic fermentation, fermentation of fruit juice into wine, classification of wine, factors influencing fermentation and wine quality, and Indian wine market.

**Keywords:** Fermentation, fruits, wine, wine quality, yeast

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## INTRODUCTION

Fermentation is a viable technique in the development of new products with modified physicochemical and sensory qualities, especially flavor and nutritional components. Alcohol and acetic and lactic acid fermentation are important for quality in production. Of these, alcoholic fermentation is widely employed for the preparation of beverages in which alcohol is major constituent. Fermented beverages have been known to humankind from time immemorial. An alcoholic beverage is a drink that contains ethanol. These are divided into three general classes for taxation and regulation of production, namely, beers, wines, and spirits distilled beverages such as whisky, rum, gin, and vodka. Beer is made by fermentation of starch combining yeast and malted cereal starch, especially barleycorn, rye, wheat, or blend of several grains and usually flavored with hops. It contains 4–8% alcohol and its energy value ranges between 28 and 73 kcal per 100 ml. Distilled alcoholic beverages are produced by distilling ethanol by fermentation of grains, fruits, or vegetables. They are made from sugarcane juice, molasses, fermented mash of cereals and potatoes, and fermented malt of barley and rye. The alcohol content in distilled alcoholic beverage ranges between 40% and 60%.[1]

Fermentation is a relatively efficient, low energy preservation process which increases the shelf life, and decreases the need for refrigeration or other forms of food preservation technology. It is, therefore, a highly appropriate technique for use in developing countries and remote areas where access to sophisticated equipment is limited. Fermented fruit wines are popular throughout the world, and in some regions, it makes a significant contribution to the diet of millions of individuals. The possibility and the use of pineapple for the production of wine will create employment, income generation for farmers, and address the post-harvest losses associated with the glut on the local market in India.[2]

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Alcoholic fermentation leads to a series of by-products in addition to ethanol. They include carbonyl compounds, alcohols, esters, acids, and acetals, all of them influencing the quality of the finished product. The composition and concentration levels of the by-products can vary widely.[3] There is an abundance of exotic tropical fruits in India with the potential to be used by the food industry. Different new uses and new methods for processing tropical fruits need to be developed to minimize production losses, generate more profits, and promote the sustainable use of biomes. One possible use of these fruits is in the production of wines from various tropical fruits. There are many studies in the literature that demonstrates the feasibility of using fruits to produce alcoholic beverages. There are several Indian fruits with the potential for use in the production of wines.

Wine can be made from a wide array of fruits, so long as there is enough sugar content in the fruit to convert into alcohol during the fermentation process. Fruits that can be made into wine range from the familiar (blackberries and pineapples) to the exotic (durians and mangosteens). One of the most widely produced non-grape fruit wines is cider, or "apple wine," which is made from fermented apples. Apple wines are prolific throughout England and the rest of the UK as well as in Germany, France (Brittany and Normandy), Spain (Asturias, Basque Country, and Galicia), Ireland, Argentina (Patagonia and Mendoza), and Australia (Tasmania). Plum wine is often paired with fruit-based desserts or drizzled over fresh oranges in traditional sushi bars. Plum wines can also be used in cocktails either with soda water in spritzers or as a complement to shochu, which is a spirit made from distilled rice, barley, or sweet potatoes. While apple and plum wines are produced on a commercial scale, the craft of making wines from other fruits and berries is more commonly practised among home winemakers and artisans making small batch libations from locally sourced fruit. When dealing with fruits other than grapes, sugar may need to be added to spur the fermentation process in the event that the fruit does not contain enough natural sugar to ferment on its own in the presence of yeast. Some fruits such as cherries, raspberries, strawberries, and pineapples are also very high in acid, which can translate into a very sour tasting wine. In these cases, sucrose and water can be added to help counter the fruit's tart acidity. Fruit and berry wines are rarely available in traditional wine or liquor stores but can be found at farmer's markets and fairs throughout the country.[4]

Wine is an alcoholic beverage made by fermenting grape juice. Although the juice of other fruit, berries, and vegetables can be fermented to create alcohol, fruit wines are generally qualified by the name of the produce used, such as gooseberry wine and blueberry wine. The word "wine" when used alone refers to an alcoholic beverage made from grapes. Wines come in various colors (red, white, and rose) and many types, which include dry and sweet, still and sparkling, and wines fortified with grape spirit (brandy). There are also many wine-based drinks, such as wine coolers and offering peach, kiwi, and strawberry wines. There are many different styles of wine, allowing wine to satisfy a wide range of individual tastes and occasions and permitting wine to accompany many styles of food. Most table wines are dry in the technical sense that they contain no residual sugar because all the sugar that was in the grapes (or added to the must) has been fermented out. Even so, wines can feel sweet in the mouth because of their fruit flavors, and many varietals such as chardonnay, shiraz, and zinfandel have a sweet fruit dimension to them.[5]

## FERMENTATION

Fermentation is biotechnology in which desirable microorganisms are used in the production of value-added products of commercial importance. Fermentation occurs in nature in any sugar-containing mash from fruit, berries, honey, or sap tapped from palms. If left exposed in a warm atmosphere, airborne yeasts act on the sugar to convert it into alcohol and carbon dioxide. The making of wines and beers uses this biotechnology under controlled conditions. Alcoholic beverages have been produced for centuries in various societies. They are often central to the most valued personal and social ceremonies of both modern and less literate societies. In such traditional ceremonies as child naming, marriage feasts, and funerals, alcoholic beverages are often present. In Africa, maize, millet, bananas, honey, palm and bamboo saps, and many fruits are used to ferment nutrient beers and wines. The best known being kaffir beer and palm wines.[6]

Industrial fermentation processes are conducted with selected microorganisms under specified conditions with carefully adjusted nutrient concentrations. The products of fermentation are as follows: Alcohol, glycerol, and carbon dioxide are obtained from yeast fermentation of various sugars; Butyl alcohol, acetone, lactic acid, monosodium glutamate, and acetic acid are products of bacteria action; and citric acid, gluconic acid, antibiotics, Vitamin $B_{12}$, and riboflavin are some of the products obtained from mold fermentation.

Fermentation is a relatively efficient, low-energy preservation process which increases the shelf life and decreases the need for refrigeration or other form of food preservation technology. It is, therefore, a highly appropriate technique for use in developing countries and remote areas where access to sophisticated equipment is limited. Fermented fruit wines are popular throughout the world, and in some regions, it makes a significant contribution to the diet of millions of individuals. The possibility and the use of pineapple for the production of wine will create employment, income generation for farmers, and address the post-harvest losses associated with the glut on the local market in India.[7]

According to Dickinson,[8] the process of fermenting is basically feeding sugars and nutrients in solution to yeast, which return the favor by producing carbon dioxide gas and alcohol. This process goes on until either all the sugar is gone or the yeast can no longer tolerate the alcoholic percentage of the beverage. Different yeasts produce different results and have different tolerance levels.

Fermentation is a process of deriving energy from the oxidation of organic compounds, such as carbohydrates and using an endogenous electron acceptor, which is usually an organic compound, as opposed to respiration where electrons are donated to an exogenous electron acceptor, such as oxygen through an electron transport chain. The risk of stuck fermentation and the development of several wine faults can also occur during this stage which can last from 5 to 14 days for primary fermentation and potentially another 5–10 days for a secondary fermentation. Fermentation may be done in stainless steel tanks, which is common with many white wines like Riesling, in an open wooden vat, inside a wine barrel and inside the wine bottle itself as in the production of many sparkling wines.[9]

Fermentation is a cheap and energy efficient means of preserving perishable raw materials such as pineapple juice. Harvested fruits may undergo rapid deterioration if proper processing and storage facilities are not provided, especially in the humid tropics where the prevailing environmental conditions accelerate the process of decomposition. Although, there are several options for preserving fresh fruits, which may include drying, freezing, canning, and pickling, and many of these are inappropriate for the product and use on small scale in developing countries. For instance, the canning of fruits at the small-scale has serious food safety implications and contamination, especially botulism.[9]

Freezing of fruits and vegetables is not economically viable at the small scale. Fermentation requires very little sophisticated equipment, either to carry out the fermentation or for subsequent storage of the fermented product. It is a technique that has been employed for generations to preserve fruits in the form of drinks and other food for consumption at a later date and to improve food security. Basically, most fruits can be fermented if not all provided they are well prepared.[10]

## HISTORY OF FERMENTATION

Fermentation is one of the oldest forms of food preservation technologies in the world. Indigenous fermented foods such as bread, cheese, and wine have been prepared and consumed for thousands of years and are strongly linked to culture and tradition, especially in rural households and village communities. The development of fermentation technologies is lost in the midst of history. Anthropologists have postulated that it was the production of alcohol that motivated primitive people to settle down and become agriculturists. Some even think that the consumption of fermented food is pre-human.[11]

The first fermented foods consumed probably were fermented fruits. Hunter-gatherers would have consumed fresh fruits but in times of scarcity would have eaten rotten and fermented fruits. Repeated consumption would have led to the development of the taste for fermented fruits. There is a reliable information that fermented drinks were being produced over 7000 years ago in Babylon, 5000 years ago in Egypt, 4000 years ago in Mexico, and 3500 years ago in Sudan.[12] There is also evidence of fermented meat products being produced for King Nebuchadnezzar of Babylon. China is thought to be the birthplace of fermented vegetables, and the use of *Aspergillus* and *Rhizopus* molds to make food. The book called "Shu-Ching" written in the Chou dynasty in China (1121–256 BC) refers to the use of "chu" a fermented grain product.[13]

Knowledge about traditional fermentation technologies has been handed down from parent to child, for centuries. These fermented products have been adapted over generations; some products and practices no doubt fell by the wayside. Those that remain today have not only survived the test of time but also more importantly are appropriate to the technical, social, and economic conditions of the region. According to Robinson,[14] natural occurrence of fermentation means that it was probably first observed long ago by humans. The earliest uses of the word "Fermentation" in relation to winemaking were in reference to the apparent "boiling" within the must that came from the anaerobic reaction of the yeast to the sugars in the grape juice and the release of carbon dioxide. The Latin "fervere" literally means to boil. In the mid-19$^{th}$ century, Louis Pasteur noted the connection between yeast and the process of the fermentation in which the yeast acts as catalyst through a series of a reaction that converts sugar into alcohol. The discovery of the Embden–Meyerhof–Parnas pathway by Gustav Embden, Otto Fritz Meyerhof, and Jakub Karol Parnas in the early 20$^{th}$ century contributed more to the understanding of the complex chemical processes involved the conversion of sugar to alcohol.

## *SACCHAROMYCES CEREVISIAE* AND ALCOHOLIC FERMENTATION

Yeasts are of great economic importance. Yeasts, especially, different strains of *S. Cerevisiae,* have long been used for the production of alcoholic beverages, solvents, and other chemicals. Yeast is a unicellular fungi or plant-like microorganism that exists in or on all living matter, i.e., water, soil, plants, and air. They are a microbial eukaryote, associated with Ascomycetes, and are rich in protein and Vitamin B.[15] As a living organism, yeast primarily requires sugars, water, and warmth to stay alive. In addition, albumen

or nitrogenous material is also necessary for yeast to thrive. There are hundreds of different species of yeast identified in nature, but the genus and species most commonly used for baking are *S. cerevisiae*. The scientific name *S. cerevisiae* means "a mold which ferments the sugar in cereal to produce alcohol and carbon dioxide."

Yeasts are usually spherical, oval, or cylindrical in shape and a single cell of *S. cerevisiae* is around 8 μm in diameter. Each cell has a double-layered wall, which is permeable to certain substances, and in this way, food material is taken into the cell and metabolites. Cell division or cell reproduction generally takes place by budding. In the budding process, a new cell forms as a small outgrowth of the old cell, the bud gradually enlarges and then separates. Although, most of the yeasts reproduce only as single cells, under some conditions, some yeasts can form filaments.[3,16] Yeasts flourish in habitats where sugars are present, such as fruits, flowers, and bark of trees. However, commercial yeasts of today are quite different from wild strains due to genetic manipulation, allowing them to grow in previously unsuitable conditions.[17,18]

Yeasts, the main microorganisms involved in alcoholic fermentation, are found throughout the world. More than 8,000 strains of this vegetative microorganism have been classified. About 9–10 pure strains with their subclassifications are used for the fermentation of grain mashes. These belong to the type *S. cerevisiae*. Each strain has its own characteristics and imparts its special properties to a distillate when used in fermentation. A limited number of yeasts in the classification *S. cerevisiae* are used in the fermentation of wines from which brandy is distilled. The strains used in the fermentation of grain mashes are also used in the fermentation of rum from sugarcane extracts and beer production. Since yeasts function best in slightly acid medium, the mash, juice, sap, or extract prepared for fermentation must be checked for adequate acidity. If acidity is insufficient, acid or acid-bearing materials are added. For distilled liquors, fermentation was carried out at 24°C–29°C for 48–96 h, when the mash or must is ready for distillation. The alcohol content of the fermented must is about 7–9%.

## FERMENTATION OF FRUIT JUICE INTO WINE

Wine fermentation is one of the most ancient of human's technologies and is now one of the most commercially prosperous biotechnological processes.[19] The technique of winemaking is known since the dawn of civilization and has followed human and agricultural progress.[20] The earliest biomolecular archaeological evidence for plant additives in fermented beverages dates from the early Neolithic period in China and the Middle East when the first plants and animals were domesticated and provided the basis for a complex society and permanent settlements.[21] In ancient China, fermented beverages were routinely produced from rice, millet, and fruits.[22] However, in earlier years in Egypt, a range of natural products, specifically herbs and tree resins, were served with grape wine to prepare herbal medicinal wines.[21] Many of the polyphenols and other bioactive compounds in the source materials are bonded to insoluble plant compounds. The winemaking process releases many of these bioactive components into aqueous ethanolic solution, thus making them more biologically available for absorption during consumption.[23]

Fruit juices are fermented to produce wine, an alcoholic beverage. Grapes are usually preferred because of the natural chemical balance of the grape juice which aids their fermentation process without the addition of sugars, acids, enzymes, or other nutrients. However, fruits such as banana, cucumber, pineapple, and other fruits are used in wine production.[24-26] Home-made wine production has been practised with various fruits such as apple, pear and strawberry, cherries, plum, banana, pineapple, oranges, cucumber, watermelon, and guava. Using species of *S. cerevisiae* which converts the sugar in the fruit juices into alcohol and organic acids, that later react to form aldehydes, esters, and other chemical compounds which also help to preserve the wine.[27-29] Yeasts from other sources such as palm wine have also been used[30] in the production of fruit wine.

Winemaking involves mainly three categories of operations, namely, pre-fermentation, fermentation, and post-fermentation operations.[31-33] In the case of wines made from grapes, pre-fermentation involves crushing the fruit and releasing juice. In case of white wine, juice is separated from the skin, whereas in red wine, the skins are not separated from the juice. Clarification of juice for white wine is usually achieved by sedimentation or centrifugation. Then, yeast is added to the clarified juice to initiate fermentation. In red winemaking, the pulp, skins, and seeds of grapes are kept together after crushing and during all or part of the fermentation. This is done to extract color and flavor. Yeast is added to mashed pulp (must) in red winemaking.

Wine is a distinctive product that influences major life events, from birth to death, victories, auspicious occasions, harvest, and other events, due to its analgesic, disinfectant, and profound mind-altering effects.[21] Fruits produced by many indigenous trees are edible and can ripen within a very short span of time, generating surplus production. Many of these are consumed fresh, but large quantities are wasted during peak harvest periods, due to high temperature, humidity fluctuations, improper handling, inadequate storage facilities, inconvenient transport, and microbial infections. The food industries are using variety of preservation and processing methods to extend the shelf life of fruits and vegetables such

that they can be consumed year round and transported safely to consumers all over the world, not only those living near the growing region.[34] Therefore, utilization of ripe fruits or their juices for wines production is considered to be an attractive means of utilizing surplus sand over ripen fruits. Moreover, fermentation helps to preserve and enhance the nutritional value of foods and beverages. The research underway currently is to assess the potential of fruit species which have been explored by the food industries to meet the growing needs of the ever-increasing consumer market for several fruits by-products including wines.

A wide variety of analytical techniques have been standardized for characterizing various foodstuffs mainly wine, honey, tea, olive oil, and juices. Simultaneously, consumer preferences for wine selection depend on several properties such as pleasant color, taste, aroma, ecological production, guaranteed origin, quality, and sensory perceptions offered by the complex combinations of hundreds of components present in wine.[35] No food or beverage is worth producing, distributing, or marketing without having an approximate idea that its sensory quality is accepted by consumers.[36] Apart from grapes, there are many other fruits available that can be used as substrates for winemaking. Among various fruits, grapes are the most technically and commercially used as substrates for winemaking. The impact of the model plant grape is relevant, and hence, genetic and molecular studies on this plant species have been proved to be very successful in winemaking.[37] According to the routine definition, wine is a fermented beverage produced from grapes only. Otherwise, wine is given the prefix of the fruit from which it originates. Today, a big variety of fruits which differ in shape, color, taste, and nutritive value are available in the market and many are utilized widely for the production of fermented beverages.

Wine consists of a diverse commodity class composed of the yeast fermentation products of must (or fruit juice). Wine is a fruit product, but fermentation produces a variety of chemical changes in the must and so wine is far from being juice with ethanol added. Both clinical and experimental evidence suggest that moderate consumption of red wine offers greater protection to health by reducing cardiovascular morbidity and mortality and this is attributed to antioxidant polyphenolics other than alcohol which is found particularly in red grape wine.[38,39] The phenolic acids can scavenge free radicals and quench reactive oxygen species and therefore provide effective means of preventing and treating free radical-mediated diseases.[40] Furthermore, wine polyphenols can lead to the modulation of both oral and gut microbiota.[41]

According to Robinson,[42] the process of fermentation in wine is the catalyst function that turns fruit juice into an alcoholic beverage. To Walker,[43] this organic process is the "slow decomposition process of organic substances induced by microorganisms or by complex nitrogenous substances (enzymes) of plant or animal origin. During fermentation, yeast interacts with sugars in the juice to create ethanol, commonly known as ethyl alcohol and carbon dioxide as a by-product. In winemaking, the temperature and speed of fermentation are an important consideration as well as the levels of oxygen present in the must at the start of the fermentation.[44] Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to oxidative phosphorylation, as long as sugars are readily available for consumption.[45]

Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, and hydrogen.[46] However, more exotic compounds can be produced by fermentation, such as butyric acid and acetone.[1] Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of carbon dioxide.[47] Fermentation products contain chemical energy but are considered waste products, since they cannot be metabolized further without the use of oxygen or other more highly oxidized electron acceptors. The consequence is that the production of adenosine triphosphate by fermentation is less efficient than oxidative phosphorylation, whereby pyruvate was fully oxidized to carbon dioxide. Juice temperature must be warm for fermentation. However, yeast cells will die if temperature is too hot.[42]

Ethanol fermentation performed by yeast and some types of bacteria break the pyruvate down into ethanol and carbon dioxide. It is an important thing in bread making, brewing, and winemaking. Usually, only one of the products is desired; in bread-making, the alcohol is baked out, and in alcohol production, the carbon dioxide is released into the atmosphere or used for carbonating the beverage. When the ferment has a high concentration of pectin, minute quantities of methanol can be produced.[48]

Hydrogen gas can be produced in many types of fermentation (mixed acid fermentation, butyric acid fermentation, caproate fermentation, butanol fermentation, and glyoxylate fermentation), as a way to regenerate $NAD^+$ from NADH. Electrons are transferred to ferredoxin, which in turn is oxidized by hydrogenase, producing $H_2$. Hydrogen gas is a substrate for methanogens and sulfate reducers, which keep the concentration of hydrogen sufficiently low to allow the production of such an energy-rich compound.[16] However, in the case of some fruit juice, a risk factor involved with fermentation is the development of chemical residue and spoilage, which can be corrected with the addition of sulfur dioxide ($SO_2$), although excess $SO_2$ can lead to a wine fault.[49]

There are many fermented drinks made from fruit in Africa, Asia, and Latin America. These include drinks made from bananas, grapes, and other fruits. Grape wine is perhaps the most economically important fruit juice alcohol.[50] It is of major economic importance in Chile, Argentina, South Africa, Georgia, Morocco, and Algeria. Due to the commercialization of the product for industry, the process has received most research attention and is documented in detail. Banana beer is probably the most widespread alcoholic fruit drink in Africa and is of cultural importance in certain areas. Alcoholic fruit drinks are made from many other fruits including dates in North Africa, pineapples in Latin America, and jack fruits in Asia.[51]

White grape wine is an alcoholic fruit drink between 10% and 14% alcoholic strength. This prepared from the fruit of the grape plant and is pale yellow in color.[52] There are many varieties used including Airen, Chardonnay, Palomino, Sauvignon Blanc, and Ugni Blanc. The main difference between red and white wines is the early removal of grape skins in white wine production. The distinctive flavor of grape wine originates from the grapes as raw material and subsequent processing operations. The grapes contribute trace elements of many volatile substances which give the final product the distinctive fruity character.

In the case of cashew, the apples are cut into slices to ensure a rapid rate of juice extraction when crushed in a juice press. The fruit juice is sterilized in stainless steel pans at a temperature of 85°C to eliminate wild yeast.[53] The juice is filtered and treated with either sodium or potassium metabisulfite to destroy or inhibit the growth of any undesirable types of microorganisms acetic acid bacteria, wild yeasts, and molds. Wine yeast (*S. cerevisiae* var *ellipsoideus*) was added. Once the yeast was added, the contents are stirred well and allowed to ferment for about 2 weeks.[54]

After fermentation was completed, the wine is separated from the sediment by racking. It can also be clarified further using fining agents such as gelatin, pectin, or casein which are mixed with the wine. Filtration can be carried out with filter aids such as fuller's earth after racking. The wine was then pasteurized at 50°C–60°C. The temperature should be controlled, so as not to heat it to about 70°C, since its alcohol content would vaporize at a temperature of 75°C–78°C.[55] It is then stored in wooden vats and subjected to aging. At least 6 months should be allowed for aging. If necessary, wine is again clarified before bottling. During aging and subsequent maturing in bottles, many reactions, including oxidation, occur with the formation of traces of esters and aldehydes, which together with the tannin and acids already present to enhance the taste, aroma, and preservative properties of the wine.[56]

Date wines are popular in Sudan and North Africa.[57] They are made using a variety of methodologies. "Dakhai" is produced by placing dates in a clean earthenware pot. For every 1 volume of dates, between 2 and 4 volumes of boiling water are added. This is allowed to cool and is then sealed for 3 days. More warm water is then added and the container sealed again for 7–10 days. Many variations of date wine exist: "El madfuna" is produced by burying the earthenware pots underground. "Benti merse" is produced from a mixture of sorghum and dates. "Nebit" is produced from date syrup.[57]

Sparkling grape wines are made in the Republic of South Africa.[58] Sparkling wines can be made in one of three ways. The cheapest method is to carbonate wines under pressure. Unfortunately, the sparkle of these wines quickly disappears, and the product was considered inferior to the sparkling wines produced by the traditional method of secondary fermentation. This involves adding a special strain of wine yeast (*S. cerevisiae* var *ellipsoideus*) - a champagne yeast to wine that has been artificially sweetened. Carbon dioxide produced by fermentation of the added sugar gives the wine its sparkle. In the original champagne method, which is still widely used today, this secondary fermentation is carried out in strong bottles, capable of withstanding pressure, but early in the 19$^{th}$ century, a method of fermenting the wine in closed tanks was devised, this being considerably cheaper than using bottles.[58]

Jackfruit wine is an alcoholic beverage made by ethnic groups in the eastern hilly areas of India.[59] As its name suggests, it is produced from the pulp of jackfruit (*Artocarpus heterophyllus* L.). Ripe fruit is peeled and the skin discarded. The seeds are removed and the pulp soaked in water. Using bamboo baskets, the pulp is ground to extract the juice, which is collected in earthenware pots. A little water is added to the pots along with fermented wine inoculums from a previous fermentation. The pots are covered with banana leaves and allowed to ferment at 18°C–30°C for about 1 week. The liquid is then decanted and drunk.[59]

## FACTORS INFLUENCING FERMENTATION AND WINE QUALITY

### Effect of Temperature on Fermentation

To avoid contamination and unpleasant odors in wine, everything that comes in contact with the wine must be very clean. This is, especially, critical when cleaning the fermenting vessel. Just as, there are weeds in the garden, so there are weeds in wines. There are microorganisms that feed on alcohol and cause a poor flavor.[60] Vinegar bacilli will change the sugar to vinegar. Molds give a stale flavor. To prevent these unwelcome intruders, cleanliness is the only answer. An effective agent is sal soda (sodium carbonate).

Baking soda is fairly effective if given time to work. Either of these agents will remove odors and flavors from the

containers.[56] All these chemicals may reduce the wine quality if the right quantities are not added. To avoid this situation, fruit juice for fermentation can be sterilized in stainless steel pans at a temperature of 85°C to eliminate wild yeast after extraction. The juice is filtered and treated with either sodium or potassium metabisulfite to destroy or inhibit the growth of any undesirable types of microorganisms acetic acid bacteria; wild yeasts and molds.[42] Furthermore, increasing temperatures above 60°C may kill wild yeast and other microorganisms.[61]

During fermentation, there are several factors that winemakers take into consideration. The most notable is that of the internal temperature of the must.[44] The biochemical process of fermentation itself creates a lot of residual heat which can take the must out of the ideal temperature range for the wine.[54] Thus, fermentation is an exothermic process. However, in winemaking, the temperature must not exceed 29.4°C for red wines or 15.3°C for white wines. Otherwise, the growth of yeast cells will stop. Therefore, a lower temperature is desirable because it increases the production of esters, other aromatic compounds, and alcohol itself. This makes the wine easier to clear and less susceptible to bacterial infection.[60] In general, temperature control during alcoholic fermentation is necessary to facilitate yeast growth, extract flavors and colors from the skins, permit accumulation of desirable by-products, and prevent undue rise in temperature that might kill the yeast cells. The low temperature and slow fermentation favor the retention of volatile compounds.[27]

Typically, white wine is fermented between 64°F and 68°F (18°C–20°C) though a winemaker may choose to use a higher temperature to bring out some of the complexity of the wine.[62] Red wine is typically fermented at higher temperatures up to 85°F (29°C). In most cases, fermentation at higher temperatures may have adverse effect on the wine in stunning the yeast to inactivity and even "boiling off" some of the flavors of the wines. Some winemakers may ferment their red wines at cooler temperatures more typical of white wines to bring out more fruit flavors.[63]

Yeasts are active in a very broad temperature rangeing from 0°C to 50°C, with an optimum temperature range of 20°C–30°C.[50] The temperature of fermentation is usually from 25°C to 30°C, this makes yeast an important microorganism for fermentation. White wines are fermented at 10°C–18°C for about 7–14 days. The low temperature and slow fermentation favor the retention of volatile compounds. Red wines are fermented at 20°C–30°C for about 7–14 days. This higher temperature is necessary to extract the pigment from the grape skins.[64] With reference to other organisms, different bacteria can tolerate different temperature which provides enormous scope for a range of fermentation. While most bacteria have a temperature optimum of between 20°C and 30°C, there are some thermophiles which prefer higher temperatures (50°C–55°C) and those with colder temperature optima (15–20°C). Most lactic acid bacteria work best at temperatures of 18°C–22°C. The *Leuconostoc* sp. which initiate fermentation has an optimum temperature of 18°°C–22°C. The temperatures above 22°C favor the *Lactobacillus* sp.[8] As soon as the desired degree of sugar disappearance and alcohol production has been attained, the microbiological phase of winemaking is over.[65] The wine was then pasteurized at 50°C–60°C. The temperature should be controlled so as not to heat it to about 70°C, since its alcohol content would vaporize at a temperature of 75°C–78°C.[66]

## Effect of pH on Fermentation

According to Fleet,[27] pH directly affects wine stability. This may be as a result of the fact that at a pH close to neutral (7.0), most microorganisms such as bacterial and molds including some yeasts become more active for fermentation and subsequent spoilage of wine, while pH below 3.5 eliminates most of the microbes and favors only a few of the microorganisms for fermentation. Specifically, the optimum pH for most microorganisms is near the neutral point (pH 7.0). Molds and yeasts are usually low pH tolerant and are therefore associated with the spoilage of foods with low pH. Yeasts can grow in a pH range of 4–4.5 and molds can grow from pH 2–8.5 but favor low pH.[50] A solution pH is the measure of hydrogen ions ($H^+$), concentration of an acid solution such as pineapple and grape juice or wine, or conversely, the concentration of hydroxyl ions ($OH^-$) in alkaline solution such as lye. As the numerical value of the hydrogen ions ($H^+$) concentration is often extremely small fraction ($1 \times 10^{-7}$), the pH unit was used to express this concentration. A pH unit has been expressed as the negative logarithm of the hydrogen ion ($H^+$) concentration, and it was determined by a pH meter.[67]

From the pH scale, the lower the pH value, the higher the concentration of $H^+$ ions, the higher the degree of acidity, thus there is an inverse relationship between decreasing pH value and increasing $H^+$ ions concentration. For example, a wine at a pH of 3.0 is 10 times more acidic than a wine at a pH of 4.0, thus there is a ten-fold change in acidity.[68]

The traditional process of fermentation involves extracting fruits juice and adjusting the pH to 4.0 using sodium bicarbonate and adding yeast nutrient (ammonium phosphate) at 0.14 g/l.[59] For example, during fermentation of fruit juice, reductions of soluble solids are possible from pH between 7.4 and 3.5 to 4.0 in worm fermentation.[22] A pH level of 4.0 may be conducive for the development of unwanted microbes like *Leuconostoc oenos,* and this can be prevented by controlling the pH by reducing the wine pH to below 3.2.[48] According to Rotter,[69] most fining and clearing agents such as Earths: Bentonite and Kaolin; Proteins: Gelatine, Isinglass, Casein, Pasteurized milk, Albumen, and Yeast; Polysaccharides: Alginate, Gum arabic and Carbons; Synthetic polymers: PVPP, Silica gel and Tannins; and Others: Metal chelators, Blue fining

and Enzymes are more effective in clearing the wine when the pH was below 3.5.

The pH plays an important role in aging, clarifying, or fining. As the strength of the relative charge of suspended particles decreases in the wine, the pH of the wine increases. At high pH, organic protein fining agents may possess a positive charge insufficient to bind to the negatively charged particulates, thus potentially increasing the turbidity of the wine. This phenomenon is called "over fining."[70]

## Effect of Sugar Content on Fermentation

Sugar is the main substrate for fermentation of fruits juice into alcohol.[44] Although other food nutrients such as protein and fats can be broken down by some microorganism in some cases where sugar is limited, as long as sugar is present, yeast cells will continue the process of fermentation until other factors that affect the growth of yeast become unfavorable.[7] According to Hui *et al*.,[71] sugars are the most common substrate of fermentation to produce ethanol, lactic acid, and carbon dioxide.

Although sugar is an important substrate of fermentation, higher sugar concentration inhibits the growth of microorganisms.[72] For example, during fermentation of the juices of the plant (*Agave americana*), the soluble solids should be at the optimum and should be reduced from between 25% and 30% to 6%; the sucrose content falls from 15% to 1%.[59] However, yeasts are fairly tolerant of high concentrations of sugar and grow well in solutions containing 40% sugar. At concentrations higher than this, only a certain group of yeasts - the Osmophilic type - can survive. There are only a few yeasts that can tolerate sugar concentrations of 65–70% and these grow very slowly in these conditions.[73] A winemaker who wishes to make a wine with high levels of residual sugar (like a dessert wine) may stop fermentation early either by dropping the temperature of the must to stun the yeast or by adding a high level of alcohol (like brandy) to the must to kill off the yeast and create a fortified wine.[74]

## Effect of Microorganisms on Fermentation

For many traditional fermented products, the microorganisms responsible for the fermentation are unknown to scientists. However, there have been several researches to identify the microorganisms involved in fruits fermentation. For example, the microorganism responsible for banana beer production is *S. cerevisiae,* which is the same organism involved in the production of grape and other fruit wine. These organisms vary according to the region of production.[75]

Yeast is a unicellular fungus which reproduces asexually by budding or division, especially the genus *Saccharomyces* which is important in food fermentations has the ability to reproduce much faster.[43] Yeasts and yeast-like fungi are widely distributed in nature. They are present in orchards and vineyards, in the air, the soil, and the intestinal tract of animals. Like bacteria and molds, they can have beneficial and non-beneficial effects in foods. Most yeast strains are larger than most bacteria. The most well-known examples of yeast fermentation are in the production of alcoholic drinks and the leavening of bread. For their participation in these two processes, yeasts are of major importance in the food industry. Some yeast strains are chromogenic and produce a variety of pigments, including green, yellow, and black. Others are capable of synthesizing essential B group vitamins.[76] Although there is a large diversity of yeasts and yeast-like fungi (about 500 species), only a few are commonly associated with the production of fermented foods. They are all either ascomycetous yeasts or members of the genus *Candida*. Varieties of the *S. cerevisiae* genus are the most common yeasts in fermented foods and beverages based on fruit and vegetables. All strains of this genus ferment glucose and many ferment other plant-derived carbohydrates such as sucrose, maltose, and raffinose.

In the tropics, *Saccharomyces pombe* is the dominant yeast in the production of traditional fermented beverages, especially those derived from maize and millet.[77] Brewer's yeast, *S. cerevisiae* var *ellipsoideus* and *Saccharomyces uvarum* are very common in the brewery and the wine industry. These yeasts are the microorganisms that are responsible for fermentation in beer and wine.[44] Yeast metabolizes the sugars extracted from grains and fruits, which produces alcohol and carbon dioxide, and thereby turns wort into beer and fruits into wine, respectively. In addition to fermenting the beer and wine, yeasts influence the character and flavor.[78] The dominant types of yeast used in fermenting alcoholic beverages are the *Saccharomyces* sp. For example, to make beer, the ale yeast (*S. cerevisiae*) and lager yeast (*Saccharomyces uvarum*) are used, while in wine, *S. cerevisiae* var *ellipsoideus* and *S. cerevisiae* may be used.[44] Other microorganisms used in fermentation wine and beer may include: *Brettanomyces* species for lambics,[6] and *Torulaspora delbrueckii* for Bavarian Weissbier.[71] Before the role of yeast in fermentation was understood, fermentation involved wild or airborne yeasts. A few styles such as lambics rely on this method today, but most modern fermentation adds pure yeast.[18]

The most common genera of wild yeasts found in winemaking include *Candida* sp., *Hanseniaspora* sp., *Metschnikowiaceae* sp., *Pichia* sp., and *Zygosaccharomyces* sp. Wild yeasts can produce high quality, unique flavored wines; however, they are often unpredictable and may introduce less desirable traits to the wine and can even contribute to spoilage.[44] Traditional winemakers, particularly in Europe, advocate the use of ambient yeast as a characteristic of the region's terroir; nevertheless, many winemakers prefer to control

fermentation with predictable cultured yeast. The cultured yeasts most commonly used in winemaking belong to the *S. cerevisiae* (also known as "sugar yeast") species. Within this, species are several hundred different strains of yeast that can be used during fermentation to affect the heat or vigor of the process and enhance or suppress certain flavor characteristics of the wine. The uses of different strains of yeasts are a major contributor to the diversity of wine, even among the same grape variety.[18] According to Saranraj and Stella[10] mixture of yeast thus dual culture (*Torulaspora delbrueckii* and *S. cerevisiae*) can be used to produce a complex fruit wine from pineapple.

Yeast, in general, has a natural protein removal effect during fining or clearing. It is also sometimes used in the dried (and dead) form to remove copper sulfate, ethyl acetate, browning, oxidation, and excess oak that may be associated with cloudy wine.[69] Doses commonly recommended are 240–1000 mg/L. It is important to rack the wine soon after yeast fining to avoid reductive aromas.[69] According to Madigan and Martinko,[79] homolactic fermentation can occur in some kinds of bacteria (such as *Lactobacilli*) and some fungi. It is this type of bacteria that converts lactose into lactic acid in yoghurt, giving it its sour taste. These lactic acid bacteria can be classed as homofermentative, where the end product is mostly lactate or heterofermentative, where some lactate is further metabolized and results in carbon dioxide, acetate, or other metabolic products.[21,80]

Bacteria may not always be bad in fermentation; this is because to clarify the wine, the fermented juice maybe transferred into a settling vat, or if made on a smaller scale, into a demijohn.[81] In these, suspended yeast cells, cream of tartar and particles of skin and pulp settle to the bottom of the container. As the yeast cells break down within the precipitate, they stimulate the growth of *Lactobacillus* sp. that converts the wine's malic acid into lactic acid. This process is, especially, important in wines made from highly acidic grapes because lactic acid was a weaker acid than malic acid (bacteria decarboxylate malic acid, thus removing the acidic carboxyl group), and therefore, it mellows the wine's taste.[82]

### Effect of Acid on Fermentation

Acid is said to directly affect wine quality, but wine owes its acid composition to citric acid, tartaric acid, and some traces of other acids like lactic acid which replaces malic acid during malolactic fermentation. These acids in fruits juice or wine can be determined by titration.[31,83] Fruit acids are weak acids compared to strong mineral acids such as sulfuric and hydrochloric. In solution, strong acids tend to yield their hydrogen ion ($H^+$) component nearly completely; weak acids dissociate only about 1% of their hydrogen ion. Thus, such acid solutions like fruit wine have more hydrogen ions ($H^+$) than hydroxyl ions ($OH^-$). As hydrogen ion concentration increases, the solution becomes more unfavorable for most microorganisms associated with spoilage of wine and acidic foods. However, some molds and yeasts which are needed in the fermentation of fruit juice into wine are usually acid tolerant, and therefore, they are very important in the production of dry wine (wine with a very low or no sugar).[50]

Wines produced from grapes grown in colder climates tend to have a higher concentration of malic acid and a lower pH (3.0–3.5) and the taste benefits from this slight decrease in acidity. Wines produced from grapes in warmer climates tend to be less acidic (pH > 3.5) and a further reduction in acidity may have adverse effects on the quality of the wine. Decreasing the acidity also increases the pH to values which can allow spoilage organisms like *Leuconostoc oenos* to multiply to embark on malolactic fermentation.[84] During fermentation of palm sap, within 24 h, pH can be reduced from 7.4 to 6.8 to 5.5 and the alcohol content ranges from 1.5% to 2.1%. Within 72 h, the alcohol level increases from 4.5% to 5.2% and the pH = 4.0. Organic acids present are lactic acid, acetic acid, and tartaric acid.[85]

During fermentation, the pH of the wine reaches a value of 3.5–3.8, suggesting that an acidic fermentation takes place at the same time as the alcoholic fermentation. Final alcohol content was about 7–8% within a fortnight.[51] Fruit juices often have all that yeast needs all by themselves. Notably, grape juice is a favorite, as it has the acids, tannins, and sugars needed. Apple juice stands on its own quite well too. Other juices may need acids (not only for the yeast but also for flavor), and many commonly need tannins to be added. Yeasts are very hardy microorganisms that will get by with most fruits sugar and juices in fermentation. They can even work on plain white sugar so far as the right acid and nutrient blend are available, although this is difficult to do by most microorganisms. Acids present in wine enhance the taste, aroma, and preservative properties of the wine.

## INDIAN WINE MARKET

### Wine Production

In India, the three major wine producing regions are Maharashtra, Karnataka, and Himachal Pradesh. Of these, Maharashtra is the largest producer and consumer of wine. After a decade of steady growth from 2000 to 2010, India's wine production dropped from 13.0 million liters (ML) in 2010 to 11.0 ML in 2011 and improved slightly in 2012 to 11.5 ML (1.3 million cases).[86,87] FAS Mumbai forecasted the availability of Indian wine production at a record 17.3 ML in 2014 and excluding fortified wine; the production was recorded as 14.2 ML. The wine production estimates of Maharashtra and Karnataka is 14.2 ML (1.58 million cases) in 2014, as cooler temperatures during February and March improved grape yields and quality. The expanded production of key wineries has steadily raised the production of Karnataka

and was estimated at 5 ML (555,000 cases), a jump of 1.3 ML (145,000 cases) from the previously.[88]

The decrease in wine production was mainly due to growers switching to table grapes and other crops, change in consumers drinking habit, drop in tourism, high land cost and state level land ceiling, wine policies, and rupee devaluation. Even with all these obstacles, the governments of Maharashtra and Karnataka have supported domestic wine industries by relaxing excise duties on local wines, easing distribution restrictions and providing fiscal incentives to establish wineries and vineyards, and imposing excise taxes on imported and wines from other states. Especially, Maharashtra has eased the license requirements and regulations for establishing wineries and wine retail outlets and established two wine industrial parks to facilitate investment in the industry.[89]

## Wine Consumption

India ranks 77$^{th}$ in terms of world wine consumption. The per capita consumption in India is only 0.07 L/person/year. The country accounts for 0.8% of the total wine consumed in Asia. In India, 80% of wine consumption is confined to major cities such as Mumbai (39%), Delhi (23%), Bengaluru (9%), and Goa (9%).[90] Major factors adding to the higher wine consumption are growing population, higher disposable incomes, relaxation on government regulation, and policies. Red wine is the most popular type of wine consumed in India, followed by white and rose wines. The consumption pattern of wine varieties is as follows: Red wine accounting for 45% of consumption, followed by white wine at 40%, sparkling wine at 10–15%, and rosé at 1–5%. There was an increase of 16.3% wine consumption between 2012 and 2013. More than 61% of wine consumption is of red category and is expected to grow by 71.6% between 2013 and 2017. In 2013, it was reported that 0.93 million cases of Indian wines were consumed as against to 0.28 million cases of imported wines.[91] Wine consumption appeared to be nil from 2000 to 2002 and improved slightly in a progressive manner from 2003, dropped in 2009, and slightly improved in 2010, and then, the consumption levels reached gradually to 15 ML in 2014.[92]

According to the reports of All India Wine Associations, Indian wine consumption is expected to rise at a CAGR of around 18% during 2014–2015. The forecast of Vinexpo survey reveals that consumption of wine in India is expected to reach 2.1 million cases by 2017, an increase of 73% from 2013. Indians will consume 1.15 million cases of red wine, 0.63 million cases of white wine, and 0.10 million cases of rose wine by 2017. According to the IWSR, wine consumption in India is expected to grow gradually and could reach 2.4 million cases by 2020.[93] Wine tourism will play a pivotal role in changing the market trends of Indian wine industry in the near future. In India, wine tourism has emerged as the latest trend as is gaining significant momentum in creating economic opportunities in rural communities and the government should provide favorable government policies to make wine tourism a populous one.

## Wine Exports

Cabernet Sauvignon, Sauvignon Blanc, and Chenin Blanc are the export quality wines to raise the stature of Indian wine in the global market. China, Singapore, Japan, Nepal, and Bhutan are the potential markets for Indian wines and are gaining greater acceptance in US and France also. At present, Indian wines are largely being imported by Malaysia, UAE, Bhutan, Germany, UK, Sri Lanka, Maldives, and New Zealand. There was a modest rebound of 2.6 ML in Indian wine exports during 2010 and had reached 739,000 L (2100 cases) in 2012. The country's wine export was accounted for about Rs. 80–100 crores and is expected to increase by Rs. 500 crores in the next 5 years.[94] India has the potential to become one of the major exporters of wine not only in Asia but also the world because of innovativeness in wine quality and marketing. According to the data of Ministry of Commerce, wine exports in 2013 were approximately 1.8 ML valued at nearly US $7 million. In the first 7 months of 2014, exports have increased by 20%, especially for sweeter wines to Bhutan and Vietnam, and export sales have grown by almost 40% by value compared to 2013 and have reached nearly US $ 4.4 million.[88]

## Wine Imports

Current Indian reported trade data suggest that the top three wine suppliers to India are France, Australia, and Italy and wine imports from "New World" wine countries are growing, especially for Australian, American, South African, and New Zealand products, while imports from France and Italy have fallen.[54] After the setbacks of 2001 and 2008 due to the ban on imported wines and Mumbai terror attacks, there was a huge drop in Indian wine imports. Sales of imported wine are through hospitality (63%) and retail (30%) sectors, the two major marketing segments.[95] There was an increase in wine imports since 2009 and reaching a high of 44,000 hL in 2011 and are on pace to match that level in 2012.[61] The Indian Ministry of Commerce reports the wine imports in 2013 equaled nearly 4 ML and totaled almost US $25 million. In the 1$^{st}$ 7 months of 2014, imports were just over 1.7 ML and have totaled just over US $10 million. In comparison with the first 7 months of 2013, import volumes and values were down by over 27% and 28%, respectively. Lower domestic production and persistent promotion efforts appear to be yielding results for imported wines.[5]

# CONCLUSION

Fruits both in fresh as well as in processed form not only improve the quality of our diet but also provide essential ingredients such as vitamins, minerals, and carbohydrates.

Fruit wines are undistilled alcoholic beverages usually made from grapes or other fruits such as peaches, plums, or apricots, banana, elderberry, or black current which are nutritive, more tasty, and mild stimulants. Being fruit-based fermented and undistilled product, wine contains most of the nutrients present in the original fruit juice. The nutritive value of wine is increased due to the release of amino acids and other nutrients from yeast during fermentation.

Today, wines can be made from any fruit other than grape, and the present review is a compilation of studies on wine preparation from assorted fruits. Research reports surveyed, in this review, demonstrated that wine could be prepared from nutritionally diverse, highly perishable, underutilized tropical, subtropical, or temperate fruits, thereby helping efforts to increase shelf life by reducing post-harvest and production losses, improve nutritional value of fruits, increase consumption and export, increase cultivation and commercialization of fruits as well as to generate profits to growers and the existing wine industry. Although during the last few years, remarkable progress has been made in wine biotechnology, particularly in wine yeast improvement, development of genetically modified yeast, and lowering alcohol concentration in wine, most studies have been carried out on grape wine rather than on non-grape fruit wines. However, progress made to date and anticipated advances toward improving aroma volatiles using improved yeast strains, detailed chemometric analysis, reduction in alcohol content, *in vitro* and *in vivo* evaluation of bioactive compounds offering health benefits, and sensory evaluation should lead to wider commercialization of non-grape fruit wines, thus contributing more to the economy of the wine industry.

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